



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**A MECHANICAL STUDY ON COCOA HUSK – GLASS FIBRE/
POLYPROPYLENE (PP) HYBRID COMPOSITE**

Thesis submitted in accordance with the requirements of the Universiti Teknikal
Malaysia Melaka for the Degree of Bachelor of Engineering (Honours)
Manufacturing (Engineering Material)

By

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ABSTRACT

This research presents the ‘Mechanical Study on Cocoa husk – glass fiber/ polypropylene (PP) hybrid composite. The purposes of doing this research are to determine the effect of various fiber loading and fiber sizes of cocoa husk into mechanical properties of cocoa husk- glass fiber / polypropylene hybrid composite and to analyze the morphology behaviour of the hybrid composite in relation to their mechanical properties. In this project, the cocoa husk particles, E-glass fiber with the length of 3mm and polypropylene pellet are used to form hybrid composite with the weight ratio 88.33/5/6.67, 86.66/6.67/6.67, and 85/8.33/6.67. The size of cocoa husk particles was characterized by using Laser Particle analysis. The specimens were fabricated by using the Internal Mixer, crusher and compression-moulding machine to form the composite sheet. The composite sheets were then cut into the dimension as required by ASTM standard. The specimens were divided two categories; one was subjected to mechanical testing and another one was subjected to water absorption testing. The effects of cocoa husk fiber loading and size fiber on the tensile properties, flexural properties and impact properties of the specimen were observed. The dry specimens were then further analyzed with the morphology analysis on the microstructure surface of the specimen by using the SEM. The results showed that the cocoa husk fiber filled composite had increased the tensile strength and tensile modulus as the cocoa husk fiber increased. The optimal flexural properties of the PP/E-glass/cocoa husk hybrid composite were found at the weight ratio of 88.33/5/6.67 with the size of 250 μ m. the morphology behaviours showed that the bonding between E-glass and matrix are poor and the structure of cocoa husk that embedded with composite are not see clearly. It shows that the bonding between cocoa particle and matrix are stronger than E-glass. To solve the problems and to increase the bonding of fiber and matrix, the coupling agent is need to be use for cocoa husk and E-glass. The fabrications of sample were giving an effect to the final results. From the observation, it shows that defects

such as bubbles, impurity and unmelted material were decreased the ability of the composite materials.

ABSTRAK

Kertas kerja ini menerangkan mengenai projek bertajuk ‘Kajian mekanikal pada komposit hibrid pada gentian koko- kaca-E/polipropelene (PP)’. Tujuan menjalankan kajian ini adalah untuk menentukan kesan perbezaan sifat mekanikal pada PP/kaca-E komposit jika serbuk koko ditambah dengan peratus pengisian yang berbeza dan mengkaji sifat morfologi pada PP/kaca-E/ koko komposit hibrid pada nisbah berat ; 88.33/5/6.67, 86.66/6.67/6.67, dan 85/8.33/6.67. Saiz pada serbuk koko ditentukan melalui analisis laser mikroskop. Komposit hibrid dibentuk ke dalam kepingan dengan menggunakan mesin pencampur dalaman, penghancur dan pemampat. Kepingan komposit yang dihasilkan seterusnya dipotong berdasarkan dimensi yang ditetapkan dalam ASTM. Sampel yang dihasilkan telah dibahagikan kepada dua kumpulan iaitu ujian mekanikal dan ujian penyerapan air. Kesan-kesan setiap pengisian koko pada sifat mekanikal seperti sifat ketegangan, sifat kelenturan dan sifat tahan kejutan pada sampel ditentukan melalui ujian-ujian mekanikal. Kemudian, sifat morfologi menunjukkan penambahan pengisian serbuk koko ke dalam komposit meningkatkan sifat ketegangan. Sifat kelenturan pada komposit hibrid didapati paling optima pada nisbah berat 88.33/5/6.67 pada saiz pengisi, 250 μ m. sifat morfologi didapati mempunyai ikatan yang lemah diantara kaca-E dengan matrik dan pada ikatan koko tidak kelihatan pada permukaan komposit. Untuk mengatasi masalah ini, bahan kimia digunakan untuk menguatkan lagi ikatan diantara kaca-E dengan matrik. Penghasilan sampel boleh mempengaruhi kekuatan komposit. Kebanyakan daripada sampel didapati mempunyai kecacatan seperti rongga udara, bendasing dan bahan tidak melebur sepenuhnya. Dengan wujudnya kecacatan ini, ia akan mengurangkan kekuatan ikatan pada komposit .

DECLARATION

I hereby declare that this report entitled “**A MECHANICAL STUDY ON COCOA HUSK-GLASS FIBER/ POLYPROYLENE (PP) HYBRID COMPOSITE**” is the result of my own research except as cited in the references.


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LIST OF ABBREVIATIONS, SYMBOLS, NOMENCLATURES

PP	-	Polypropylene
SEM	-	Scanning Electron Microscope
ASTM		American Society of Testing Materials

CHAPTER 1

INTRODUCTION

1.1 Research Background

A characteristic feature of today's modern technology and market-oriented economy is the excessive and exponentially increasing usage of polymer composites in all fields of industry. The reason for this phenomenon can be explained by the favourable price/weight ratio. The automotive industry is developing most dynamically since a serious weight decrease can be achieved by using polymer composites and hence fuel can be saved and damage to the environment decreases. It is possible to make completely new types of composite materials by combining different resources.

The objective will be to combine two or more materials in such a way that a synergism between the components results in a new material that is better than the individual components. One of the big new areas of development is in combining natural fibres with thermoplastics. Since prices for plastics have risen sharply over the past few years, adding a natural powder or fibre to plastics provides a cost reduction to the plastic industry and in some cases increases performance as well, but to the lignocelluloses- based industry, this represents an increased value for the lignocelluloses-based component (Rowell *et al*, 1999).

Any substance such as natural fibre and other plant that contains both cellulose and lignin is lignocelluloses. In general, wood is also in type of other lignocelluloses even though they may differ in chemical composition and matrix morphology. The main of composite development is to produce a new product with excellent

performance in characteristics that combine the positive attributes of each constituent component. Like other lignocelluloses material, nature fibre is strong, lightweight, abundant, nonhazardous and relatively inexpensive. Any lignocelluloses can be chemically modified to enhance properties such as dimensional stability and resistance to bio-deterioration. This provides a new improvement in cost and performance of value-added from different raw materials (Gilbert *et al*, 1994).

The main limitation by using the lignocelluloses fibres is the lower processing temperature permissible due to the possibility of fibre degradation and/or the possibility of volatile emissions that could affect composite properties. The processing temperatures are thus limited to about 200°C, although it is possible to use higher temperatures for short periods. This processing factor limits the type of thermo-plastics that can be used with lignocelluloses fibres; to commodity thermoplastics such as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC) and poly-styrene (PS). However, it is important to note that these lower-priced plastics constitute about 70% of the total thermoplastic consumed by the plastics industry, and consequently the use of fillers/reinforcement presently used in these plastics far out-weigh the use in other more expensive plastics. In the way to make a better mix with the hydrophore (plastic) in the hydrophil (lignocelluloses), there are two basic area; one in which no attempt is made to compatibilize the two dissimilar resources and, a second in which a compatibilizer. In the first case, the lignocelluloses fibre is added as relatively of low cost filler and in the second, the lignocelluloses fibre is added as reinforce filler. Both of these types of materials are usually referred to as natural fibre/thermoplastic blends (Rowell *et al*, 1999).

Several million metric tons of fillers and reinforcements are used annually by the plastics industry. The use of these additives in plastics is likely to grow with the introduction of improved compounding technology, and new coupling and compatibilizing agents that permit the use of high filler/reinforcement content. As suggested by Katz *et al*. (1987), fillings up to 75 parts per hundred (pph) could be common in the future. This level of filler could have a tremendous impact in lowering the usage of petroleum-based plastics. It would also be particularly beneficial; both in terms of the environment and also in socioeconomic terms, if a

significant amount of the fillers were obtained from a renewable agricultural source (Anand, R. *et al*, 1997).

1.2 Problem Statement

In worldwide, the usage of any substance of natural fibre such as wood agricultural crops, like jute or kenaf; agricultural residues, such as bagasse or corn stullus; grasses; and other plant substances are getting increase to produce new products. From the wasted materials, it becomes a useful product to replace the old materials. In manufacturing sector especially in healthy and food, the natural fibre is most popular material usage in producing cosmetic and food for animal. Many sectors have been use cocoa husk as the addition of ingredient. In manufacturing food products, the cocoa husk was suggested as an ingredient in foods (Bonuchi J.S. *et al*, 1999).Today, the natural fibre is mostly use as addition materials for produce a product such as cotton, recycles paper, cabinet and so on. In general, the mechanical and physical properties of natural fibre reinforced plastic only conditionally reach the characteristic values of glass-fibre reinforced system. By hybrid composites, in using of natural fibre and carbon fibre/ glass fibre as the reinforcement is adding with the polymer (Polypropylene) as a matrix the properties of natural fibre reinforced composite.

A wasted materials are rarely use in manufacturing. Some other can be used and a less is wasted. Cocoa husk pod is category of wasted material use in food manufacturing cocoa. Cocoa husks, when properly processed, serve as animal feeds and can be burnt to produce potash for making soft soap (Owolarafe, O.K, *et.al*, 2007).

But, now, some of researcher uses the cocoa husk for produce cosmetic and preparation food animal. In this research, cocoa husk will use to combine the synthetic fibre and matrix polymer to reveal the properties in mechanical and physical. In this research, the cocoa pod husk as natural fibre will adds with glass-fibre/polypropylene to get new mixture materials. Hence, the testing and analysis will be done to investigate the strength of hybrid composite in mechanical and

physical properties. From that, the characteristics of hybrid composite can be use for producing products that due to economic today.

1.3 Objectives

- a) To investigate the effect of various fiber loading and fiber sizes of cocoa husk into mechanical properties of cocoa husk-glass fiber/polypropylene hybrid composite.
- b) To analyze the effect of water absorption of cocoa husk-glassfiber/ polypropylene hybrid composite.
- c) To investigate the morphology of cocoa husk-glassfiber/ polypropylene hybrid composite.

1.4 Scopes

- a) To prepare the sizes of cocoa husk in three types; 45 μ m, 250 μ m and 500 μ m.
- b) To fabricate the specimen of cocoa husk-glassfiber/ polypropylene hybrid composite.
- c) To identify the feasibility of cocoa husk (wasted material) reinforced glass fiber/polypropylene hybrid composite on impact resistance.
- d) To find the strength of mechanical and physical properties on cocoa husk-glassfiber/ polypropylene hybrid composite.
- e) To identify the ability of water absorption on cocoa husk-glassfiber/ polypropylene hybrid composite.
- f) To analyze the morphology of the particular composite by using Scanning electron microscope (SEM)

CHAPTER 2

LITERATURE REVIEW

2.1 Composite

2.1.1 Introduction

Nowadays, the request and needs of high performances materials such as composite are increase due to the rapid development in manufacturing. Despite the fact that composites are generally more expensive in comparison to traditional construction materials, and therefore not as widely used in many constructive and building activities, they have the advantage of being lightweight, more corrosion resistant and stronger. The fibre reinforcements provide good damping characteristics and high resistance to fatigue. Over the last thirty years composite materials, plastics, and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials has grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market.

Composite is define as a combination of two or more materials (reinforcing elements, fillers, and composite matrix binder), differing in form or composition on a macro scale. The constituents retain their identities, that is, they do not dissolve or merge completely into one another although they act in concert. Normally, the components can be physically identified and exhibit an interface between one another. Examples are cermets and metal-matrix composites. Composite materials are constantly being

adapted to the way that they are used. As a result, there are a wide variety of composites to choose from, thanks to the ever-changing technological advances that make it possible to apply Composite Engineering. As a result, each type of composite brings its own performance characteristics that are typically suited for specific applications. In modern materials of engineering, the term of composite is usually refers to a matrix material that is reinforced with fibers. For instance, the term FRP (Fiber Reinforced Plastic) usually indicates a thermosetting polyester matrix containing glass fibers (Roylance, 2000).

2.1.2 Matrix

2.1.2.1 Introduction

Most basic form a composite material is one, which is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. In practice, 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. This reinforcement is usually in fibre form. Today, the most common man-made composites can be divided into three main groups (Callister, 2003).

(a) Polymer Matrix Composites (PMC's)

PMC that consists of glass, carbon and aramid in a thermoset or thermoplastic are provided strong, stiff and corrosion resistant. It also known as FRP Fibre Reinforced Polymers or Plastics that use as polymer-based resin in the matrix (Anonymous 1, 2001).

(b) Metal Matrix Composites (MMC's)

MMC is a continuous metallic phase (matrix) where is combined with another phase (reinforcement). Increasingly found in the automotive industry, these materials use a metal such as aluminium as the matrix, and reinforce it with fibres such as silicon carbide. Most of MMC exhibited such as lower density, increased specific strength

and stiffness, increase high temperature performance limits and improved wear abrasion resistance (Anonymous 2, 2009).

(c) Ceramic Matrix Composites (CMC's)

CMC is combinations of reinforcing ceramic phases with a ceramic matrix to create materials. This material is produced a new properties in structural part such as rocket and jet engines. The characteristic of CMC are including high temperature, stability, high thermal shock resistance, high hardness, and high corrosion resistance and so on. Anyway, it used in very high temperature environments where 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 (Naslain, 2009).

2.1.2.2 Thermoset/ Thermosetting

Thermosetting plastics (thermosets) are polymer materials that irreversibly cure to a stronger form. The cure may be done through heat (generally above 200 degrees Celsius), through a chemical reaction (two-part epoxy, for example), or irradiation such as electron beam processing. Thermoset materials are usually liquid or malleable prior to curing and designed to be molded into their final form, or used as adhesives. Others are solids like that of the molding compound used in semiconductors and integrated circuits (IC's).

Thermosetting polymers become permanently hard when heat is applied and do not soften upon subsequent heating. During the initial heat treatment, covalent crosslink are formed between adjacent molecular chains; these bonds anchor the chains together to resist the vibration and rotational chain motions at high temperature. Crosslinking is usually extensive, in that 10% to 50% of the chain mer units are crosslinked. Only heating to excessive temperature will cause severance of these crosslink bonds and polymer degradation. Thermoset polymer is generally harder and stronger than thermoplastics and has better dimensional stability. Thermoset may contain filler materials such as powder or fiber to provide improved strength and stiffness (Anonymous 3, 2009).

2.1.2.3 Thermoplastic

Thermoplastics soften when heated 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 so that the relative movement of adjacent chains is facilitated when a stress is applied. Irreversible degradation results when the temperature of a molten thermoplastic polymer is raised to the point at which molecular vibrations become violent enough to break the primary covalent bonds. In addition, thermoplastic are relatively soft. Most linear polymers and those having some branches structures with flexible chains are thermoplastic. These materials are normally fabricated by the simultaneous application of heat and pressure (Callister, 2003).

2.1.3 Reinforcement

2.1.3.1 Introduction

The characteristics of reinforcement are usually stronger and stiffer than the matrix. The matrix holds the reinforcements in an orderly pattern. Because the reinforcements are usually discontinuous, the matrix also helps to transfer load among the reinforcements. Reinforcements basically come in three forms: particulate, discontinuous fiber, and continuous fiber. Thus, the composite properties cannot come close to the reinforcement properties. Composite properties are much higher, and continuous fibers are therefore used in most high performance components, be they aerospace structures or sporting goods. An important characteristic of most materials, especially brittle ones, is that a small diameter fibre is much stronger than the bulk materials. The fibre phase or reinforcement is strengthening of a relatively weak material by embedding a strong fibre phase within the weak matrix materials. These reinforcements are often in the shape of fibre because fibres can be made very stiff primarily in their long direction. When the fibre long, the applied load tend to transmitted along the fibre. If short and the volume fibre low, the mechanical properties composite is equal (Anonymous 4, 2009).

There are three different classification; whiskers, fibre and wires. Whiskers have very thin single crystal structure. It also has a high length to diameter ratio. If small size of whiskers, it have a high degree of crystalline perfection and are virtually flaw free and high strength. Whiskers are an expensive and impractical to incorporate whiskers into matrix. Example of whisker are; graphite, silicon carbide, aluminium oxide, etc. Materials that are classified as fibres are either polycrystalline or amorphous and have small diameter; fibrous materials are generally either polymers or ceramic (e.g., the polymer aramids, glass, carbon, boron, aluminium oxide and silicon carbide). Fines wires have relatively large diameters; typical materials include steel, molybdenum and tungsten. Wires are utilized as a radial steel reinforcement in automobile tires, in filament wound rocket casings, and in wire wound high pressure hoses .

2.1.4 Synthetic Fibre

The types of synthetics fibre are; glass fibre, boron fibre, fumed silica, fused silica and etc. There are two types of synthetic fibre products, the semisynthetics, or celluloses (viscose rayon and cellulose acetate), and the true synthetics, or noncellulosics (polyester, nylon, acrylic and modacrylic, and polyolefin). Semisynthetics are formed from natural polymeric materials such as cellulose. True synthetics are products of the polymerization of smaller chemical units into long-chain molecular polymers

2.1.4.1 Natural Fibre

A fibre obtained from a plant, animal, or mineral. The commercially important natural fibres are those cellulose fibres obtained from the seed hairs, stems, and leaves of plants; protein fibres obtained from the hair, fur, or cocoons of animals; and the crystalline mineral asbestos. Until the advent of the manufactured fibres near the beginning of the twentieth century, the chief fibres for apparel and home furnishings were linen and wool in the temperate climates and cotton in the tropical climates. However, with the invention of the cotton gin in 1798, cheap cotton products began

to replace the more expensive linen and wool until by 1950 cotton accounted for about 70% of the world's fibre production. Despite the development of new fibres based on fossil fuels, cotton has managed to maintain its position as the fibre with the largest production volume in the industries.

The natural fibres may be classified by their origin as cellulose (from plants), protein (from animals), and mineral. The plant fibres may be further ordered as seed hairs, such as cotton; bast (stem) fibres, such as linen from the flax plant; hard (leaf) fibres, such as sisal; and husk fibres, such as coconut. The animal fibres are grouped under the categories of hair, such as wool; fur, such as angora; or secretions, such as silk. The only important mineral fibre is asbestos, which because of its carcinogenic nature has been banned from consumer textiles. The most used natural fibres are cotton, flax and hemp, although sisal, jute, kenaf, and coconut are also widely used. Hemp fibres are mainly used for ropes and aerofoils because of their high suppleness and resistance within an aggressive environment. Hemp fibres are, for example, currently used as a seal within the heating and sanitary industries.

The use of natural fibres at the industrial level improves the environmental sustainability of the parts being constructed, especially within the automotive market. Within the building industry, the interest in natural fibres is mostly economical and technical; natural fibres allow insulation properties higher than current materials. Natural fibres are rapidly emerging in composites applications that glass fibres (predominantly E-glass) have been traditionally used. This is particularly true within the automotive and construction industries. These natural fibres provide several benefits: low cost, “green” availability, lower densities, and recyclable, biodegradable, moderate mechanical properties, abundant. Their uses have found entry into both the thermoset and thermoplastic composites market places. Industries are rapidly learning to analysis effectively process these natural resources and use them in numerous composites applications.

Typically they are used with well-recognized thermoset resin families: polyesters, vinyl esters and epoxies. Thermoplastics resin matrices also are those commonly seen within the commercial markets: polypropylene, low density polyethylene (LDPE), high density polyethylene (HDPE), polystyrene, Nylon 6 and Nylon 6,6 systems. Soy based resin systems also are coming into vogue in some applications as been learn more about its chemistry and

processing. Natural fibres systems tend to fall into several categories as noted in Table 2.1, with the most commonly used ones noted in bold type. From the table below is shown that cocoa husk is type of fruit fibre categories (Beckwith, 2008).

Table 2.1: Types of Natural fiber and general families (Sources: Beckwith, (2008).

Plant and Cellulose Fiber Types	
Bast Fibers	Flax, Hemp, Kenaf, Jute , Mesta, Ramie , Urena, Roselle
Leaf Fibers	Pineapple, Banana, Sisal , Srew Pine, Abaca , Curaua, Agaves, Cabuja, Henequen, Date Palm, African Palm
Seed Fibers	Cotton , Kapok
Fruit Fibers	Coconut, Coir
Wood Fibers	Hardwoods, Softwoods – many numerous types (~10,000 varieties)
Grasses and Reeds	Wheat, Oat, Barley, Rice, Bamboo, Bagasse, Reed, Corn, Rape, Rye, Esparto, Elephant Grass, Canary Grass

2.1.5 Polymer Matrix Composite

Polymer matrix composites consist of glass, carbon, or other high strength fibres in a thermoset or thermoplastic resin. The resulting materials are strong, stiff, and corrosion resistant. PMCs adopt flat, gently curved, or sharply sculpted contours with ease, providing manufacturers with design flexibility. In addition, composites offer the opportunity for parts consolidation and lower assembly costs. Polymer-matrix composites provide a stiff, lightweight alternative to steel, aluminium, and traditional materials such as wood. Currently, composites find use in a broad range of applications. In the aerospace, automotive, rail, and bus sectors, their light weight leads to lower fuel consumption. Their resistance to corrosion enables their use in marine, construction, and infrastructure applications, including piping and storage tanks. Composites' lightweight strength and vibration-damping properties protect athletes from tennis elbow and allow fisherman to cast with increased accuracy.

In addition, polymer-matrix composites are the material of choice for wind-turbine blades. Composites continue to make steady progress in new as well as established applications. In the aerospace industry, the current emphasis on fuel efficiency favours the use of PMCs instead of aluminium; in addition, a new class of aircraft micro jets makes extensive use of lightweight composites. In the automotive

industry, manufacturers are recognizing the advantages of weight reduction, parts consolidation, and design freedom that PMCs afford. In the energy sector, the growing use of wind energy has led to increased demand for PMC turbine blades (Anonymous 1, 2001).

2.1.6 Hybrid Composite

A relatively new fibre-reinforced composite is the hybrid, which is obtained by using two or more different kinds of fibres in a single matrix; hybrids have a better all-round combination of properties than composites containing only a single fibre type. A variety of fibre combinations and matrix materials are used, but in the most common system, both carbon and glass fibre are incorporated into a polymeric resin. Hybrids contain a range of particle sizes ranging from 0.6 to 1 micrometer. Developed in the late 1980's, these composites achieve between 70 to 75 percent by weight of filler particles. The first generation hybrids achieved excellent wear characteristics which made them acceptable as posterior filling materials. They also had fair polishability. The second generation of hybrids achieved greater polishability and superior colour optics by using uniformly cut small filler particles between the larger particles, as well as resin hardeners which help to maintain a surface polish during prolonged function.

Hybrids also have unique colour reflecting characteristics which gives them a chameleon-like appearance. In other words, these materials are able to emit their own colour as well as absorb colour from the surrounding and underlying tooth structure. Hybrid composites are today the workhorse of the modern dentist. They are used in nearly all anterior restorations, and are becoming commonplace in posterior restorations as well (Anonymous 5, 2009).

2.2 Cocoa Husk Fibre

2.2.1 Introduction

The Malaysian Cocoa Board (MCB) is a federal statutory research and development agency under the Ministry of Plantation Industries and Commodities (previously called Ministry of Primary Industries Malaysia). It was established under the Act of Parliament 343 (incorporation) in 1988 and has been in operation since 1989. The main objective is to develop the cocoa industry in Malaysia to be well integrated and competitive in the global market. Emphasis is given to increasing productivity and efficiency in cocoa bean production and increasing downstream activities.

Cocoa, the nectar of the gods and even the cocoa tree's botanical name, 'Theobroma cacao' translated from the Greek means "food of the gods" has a history rooted in the mists of time as far back as 1662. In the early days, the native belief that cocoa tree was of divine origin and resulted in a holy ritual being performed whenever cocoa trees were planted. The cocoa tree can grow to between 12 to 15 m high in the wild, and up to 4 to 5 m in cultivated form. It bears fruit or pods that contain cocoa beans, which when fermented and dried, provide valuable material for all chocolate-based products ranging from beverages and confectionaries to cosmetics.

Cocoa has successfully conquered all countries and continents of the world in just over 500 years since its first discovery in the ancient civilization of the Mayas and Aztecs in South America. In Malaysia, the first cocoa planted area was found in Malacca in 1778. Subsequently, the cocoa planting was started in a plotted area at Serdang Agriculture Station and Silam Agriculture Research Centre, Sabah. The earliest cocoa commercialization started from 1853 to 1959 where cocoa types Amelonado was first planted at Jerangau, Terengganu. The planted area was 403 hectares. Cocoa trial was further undertaken at Serdang, Cheras, Kuala Lipis and Temerloh from 1936 to 1940. However, cocoa was only actively planted after World War II. Cocoa officially came to Quoin Hill, Tawau, Sabah in 1960. From then on, there was no turning back to cocoa fever (Anonymous 6, 2004).

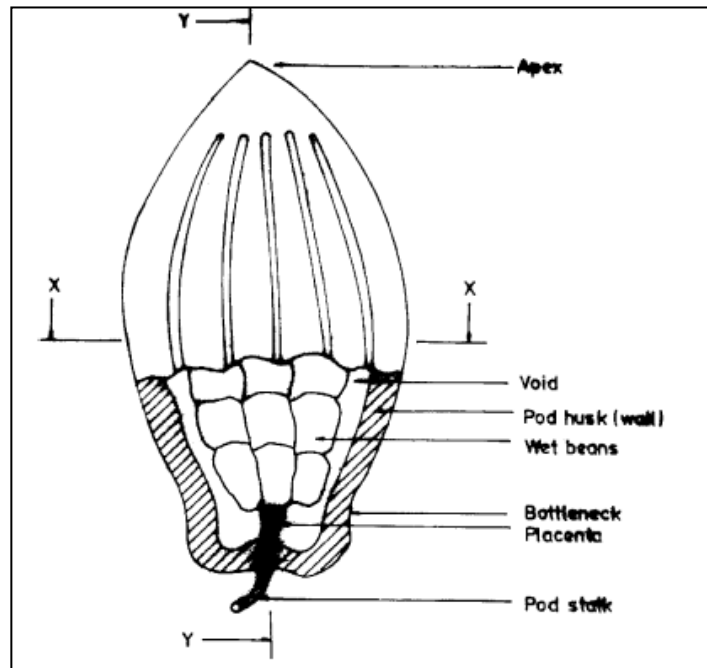


Figure 2.1: Longitudinal section of a cocoa pod showing the physical features (section y-y)
(Source: Owolarafel *et.al*, 1997)

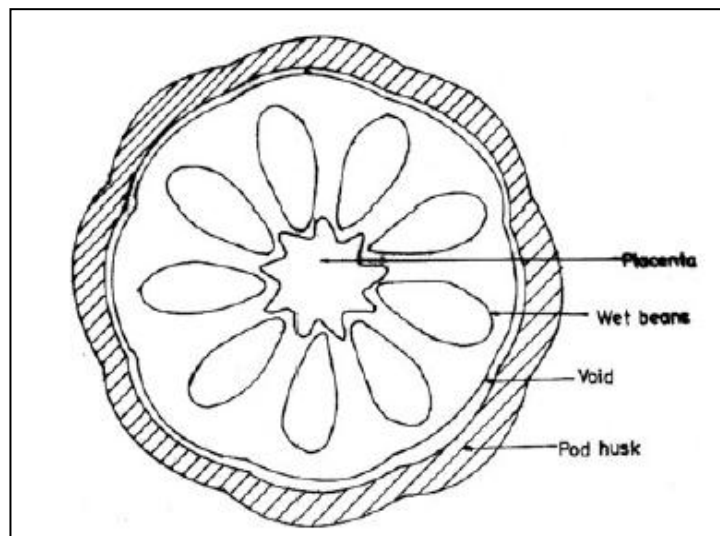


Figure 2.2: Transverse section of a cocoa pod showing the physical features (section x-x)
(Source: Owolarafel *et.al*, 1997)

The physical structure of a longitudinally and transversely sectioned cocoa pod is shown in figure 2.1 and figure 2.2 (Owolarafe1, 1997). A cocoa pod is approximately 20 cm long and 10 cm wide. A section through the pod shows a rough leathery rind about 3 cm thick, filled with sweet (although not edible), slimy and pinkish pulp, enclosing from 30 to 50 large, soft, pink or purple almond-like seeds or beans. Among most commercial crops, cocoa is known to provide very high economic

returns because of the wide range of domestic and industrial uses of the beans. Cocoa pulp juice is used in the production of soft drinks and alcohol. Cocoa husks, when properly processed, serve as animal feeds and can be burnt to produce potash for making soft soap (Owolarafe *et al*, 2007).

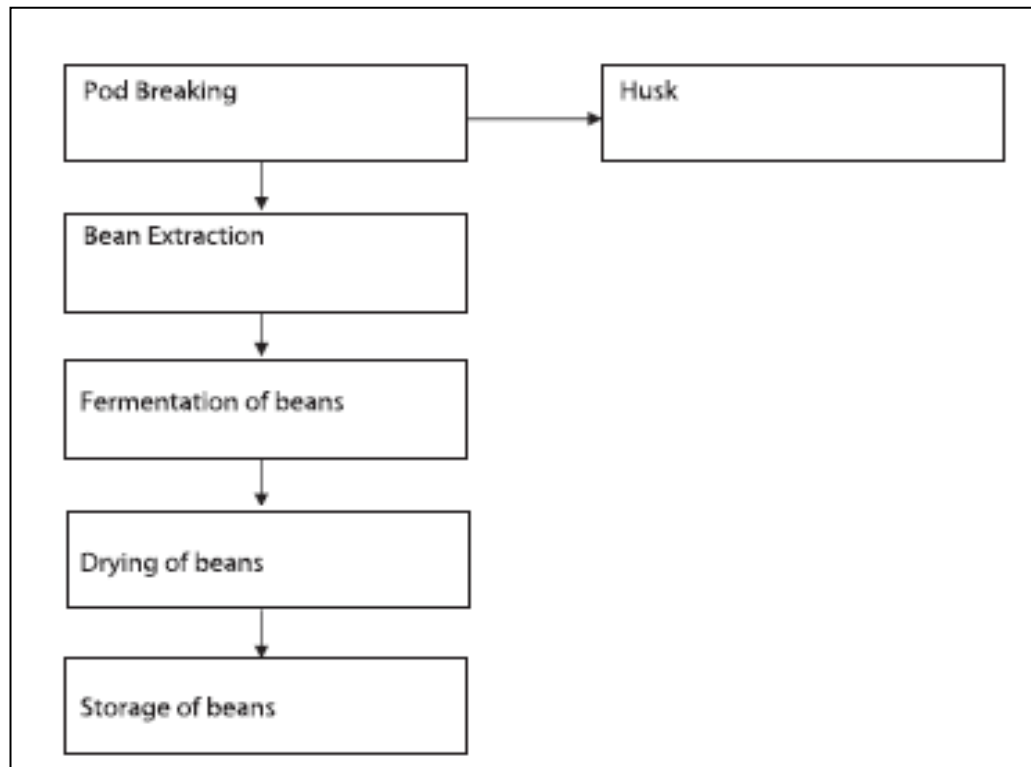


Figure 2.3: Flowchart of cocoa processing. (Source: Owolarafel *et.al*, 1997).

In most places, especially in Africa, harvesting is done manually with go-to-hell and is therefore a labor-intensive operation. Cocoa bean extraction (i.e., breaking the pods and separating the wet beans from the husks) is the first step in cocoa pod processing (see Figure 2.3) which is traditionally manual. Pods are broken with objects such as wooden clubs, cutlasses and knives to hit or strike the pods or by knocking two pods against each other laterally.

2.2.2 Characteristic Of Cocoa Husk

2.2.2.1 Chemical composition

Table 2.2: Composition of Chemical between untreated maize cob and cocoa pod husk (Source: Tuah *et al*, 2009).

	Chemical constituent (g/100 g DM)								
	DM(%)	Ash	ADF	NDF	Lignin	Cellulose	Hemicellulose	Nitrogen	Cell content
Maize cob	93.27	1.96	47.61	93.96	9.60	38.01	46.35	0.50	6.04
Cocoa cob Husk	89.50	10.02	50.62	59.34	26.38	24.24	8.72	1.12	40.64

Where:-

DM = dry matter.

ADF = acid-detergent fibre.

NDF = neutral-detergent fibre

A cocoa pod husks contained a higher level of lignin (26.38%). Table 2.2 contains the chemical composition of the untreated maize cobs and cocoa pod husks (Table 2.2). When these products were treated with ammonia, the nitrogen contents increased from 0.50 to 1.29% for maize cobs and from 1.12 to 3.53% for cocoa pod husks (Tuah *et al*, 2009). The hemicellulose content of the maize cobs was very high (46.4%) compared to that of cocoa pod husk (8.7%). Hemicellulose is more closely associated with lignin than any other polysaccharide fraction and is believed to be bonded to phenolic constituents. The cell wall of cocoa pod husk is relatively rich in pectin (about 11% of whole product on DM basis), which is totally digestible in the digestive tract of the sheep and low in hemicellulose. Adomako, (1975) reported that cocoa pod husk has very short fibres. It is therefore interesting to note that it has high lignin content. It is possibly not totally lignin but also same amounts of condensed tannins. Further work to characterise this "lignin" will be pursued (Tuah *et.al*, 2009).

2.2.2.2 Mechanical and Physical Of Cocoa Husk

Table 2.3: A few typical mechanical and physical properties of natural fibres compared to their commercial and aerospace counterparts (Source: Beckwith, 1997).

<i>Fiber</i>	<i>Density (gm/cm²)</i>	<i>Tensile Strength (ksi)</i>	<i>Tensile Modulus (msi)</i>	<i>Range of Elongation (%)</i>
Flax	1.50	75 – 215	4	2.7 – 3.2
Hemp	1.47	100	10	2.0 – 4.0
Kenaf	1.45	135	7.7	1.6
Jute	1.30	55 – 110	3.8	1.5 – 1.8
Ramie	1.50	60 – 135	8.9 – 18.6	3.6 – 3.8
Sisal	1.50	75 – 90	1.4 – 3.2	2.0 – 2.5
Coir	1.20	85	0.6 – 0.9	~30
Cotton	1.55	60	0.8 – 1.8	3 – 10
E-Glass	2.56	290 – 350	10	3.0
S-Glass	2.57	665	12.5	2.8
Aramid (Commercial)	1.44	435 – 455	9 – 10	3.3 – 3.7
Carbon (PAN Std. Mod.)	1.67	580	33 – 35	1.4 – 1.8

Table 2.3 presents a number of the critical mechanical and physical properties of common natural fibres compared to E-glass, S-glass, commercial Aramid and standard modulus PAN-based carbon fibres materials. While the strength properties, and often the stiffness properties, are not on comparable levels to S-glass, Aramid and carbon fibres, the natural fibres do provide a wide range of workable strength and stiffness properties when compared with E-glass fibres. Natural fibres are very typically about 30-50 percent lower in density when compared to E-glass fibres, and roughly the same as the Aramid commercial grade systems.

This advantage has made natural fibres quite attractive to use within the automotive industry across a wide range of applications with both thermoset and thermoplastic resin matrices. In fact the stiffness of some of these natural fibres can be higher than or equivalent to that of E-glass (see, for example, Hemp and Ramie). Flax, Sisal and Kenaf fibres also tend toward a higher stiffness. Hence, for stiffness driven designs, these fibres are reasonable options. Their abundance, and a growing understanding of their processibility, makes them attractive to engineers (Beckwith, 2008).

2.3 Glass fibre

2.3.1 Introduction

Fiberglass or glass fibre is material made from extremely fine fibers of glass. It is used as a reinforcing agent for many polymer products; the resulting composite material, properly known as fiber-reinforced polymer (FRP) or glass-reinforced plastic (GRP), is called "fiberglass" in popular usage. Glass fiber is formed when thin strands of silica-based or other formulation glass is extruded into many fibers with small diameters suitable for textile processing. Glass, even as a fiber, has little crystalline structure.

The properties of the structure of glass in its softened stage are very much like its properties when spun into fiber. One definition of glass is "an inorganic substance in a condition which is continuous with, and analogous to the liquid state of that substance, but which, as a result of a reversible change in viscosity during cooling, has attained so high a degree of viscosity as to be for all practical purposes rigid" (Anonymous 7, 2007).

In this research, E-glass is used as reinforcement in hybrid composite materials. Commonly, E-glass is familiar use as the reinforcement material in polymer matrix composites. Their properties such optimal strength is gained when straight, continuous fibres are aligned parallel in a single direction. To promote strength in other directions, laminate structures can be constructed, with continuous fibres aligned in other directions.

2.3.2 Characteristic Of Glass fibre

Glass fibers are useful because of their high ratio of surface area to weight. However, the increased surface area makes them much more susceptible to chemical attack. By trapping air within them, blocks of glass fiber make good thermal insulation, with a thermal conductivity on the order of 0.05 W/(mK).

Glass strengths are usually tested and reported for "virgin" fibers: those which have just been manufactured. The freshest, thinnest fibers are the strongest because the

thinner fibers are more ductile. The more the surface is scratched, the less the resulting tenacity. Because glass has an amorphous structure, its properties are the same along the fiber and across the fiber. Humidity is an important factor in the tensile strength. Moisture is easily adsorbed, and can worsen microscopic cracks and surface defects, and lessen tenacity.

In contrast to carbon fiber, glass can undergo more elongation before it breaks. There is a correlation between bending diameter of the filament and the filament diameter. The viscosity of the molten glass is very important for manufacturing success. During drawing (pulling of the glass to reduce fiber circumference) the viscosity should be relatively low. If it is too high the fiber will break during drawing, however if it is too low the glass will form droplets rather than drawing out into fiber (Callister, 2003).

2.3.3 Composition of Glass fibre

Such structures are used in storage tanks and the like S-Glass has a typical nominal composition of SiO₂ 65wt%, Al₂O₃ 25wt%, MgO 10wt%. E-Glass or electrical grade glass was originally developed for stand off insulators for electrical wiring. It was later found to have excellent fibre forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as fibreglass. E-Glass is a low alkali glass with a typical nominal composition of SiO₂ 54wt%, Al₂O₃ 14wt%, CaO+MgO 22wt%, B₂O₃ 10wt% and Na₂O+K₂O less than 2wt%. Some other materials may also be present at impurity levels. Table 2.4 below are shown the mechanical of glass fibre comparing other of materials.

Table 2.4: Characteristic of fiber glass with some common fibres (Source :Anonymous 7, 2007).

Materials	Density (g/cm ³)	Tensile Strength (MPa)	Young modulus (GPa)
E-Glass	2.55	2000	80
S-Glass	2.49	4750	89
Alumina (Saffil)	3.28	1950	297
Carbon	2.00	2900	525
Kevlar 29	1.44	2860	64
Kevlar 49	1.44	3750	136

2.4 Polypropylene (PP)

2.4.1 Introduction

Polypropylene (PP) is one of the most widely used plastics for packaging applications. Polypropylene or polypropene (PP) is a thermoplastic polymer, made by the chemical industry and used in a wide variety of applications, including food packaging, ropes, textiles, stationary, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. In a continuously increasing part of this market, especially in the pharmaceutical area, but also in food packaging and especially in medical applications (syringes, pouches, tubes etc.), the material is sterilized in one or the other way.

The use of either heat (steam), radiation (β / electrons or γ) or chemicals (mostly ethylene oxide) affects the mechanical and optical properties, but sometimes also the organoleptics of the material significantly. From the literature it becomes clear that the changes are quite different. Radiation, where mostly the effect of γ -rays has been investigated in the past, induces chain scission and degradation effects, resulting in a reduced melt viscosity and severe embrittlement. Parallel to that oxidized phenolic antioxidants results in discoloration; the material becomes yellow.

2.4.2 Characteristic of Polypropylene

Polypropylene has an intermediate level of crystalline and Young's modulus between that of low density polyethylene (LDPE) and high density polyethylene (HDPE). However, Polypropylene has less tough than HDPE and less flexible than LDPE, it much less brittle than HDPE. From this feature can make Polypropylene be used in replacement for engineering plastic such as ABS. Polypropylene is rugged, stiffer than some other plastics and reasonably economical. Polypropylene also can be made translucent when uncoloured but not perfect as polystyrene, acrylic or certain other plastics can be made. It can also be made opaque and sometime have many kinds of colours. Polypropylene has excellent in resistance to fatigue, this reason allows most

plastic living hinges such as those on flip-top bottles are made from Polypropylene. In certain high performance pulse and low loss RF capacitors, Polypropylene is used as a dielectric in size very thin of sheets (Anonymous 8, 2009).

Again, also optical disturbances are possible in the form of significantly increased haze of transparent articles. The post-sterilization changes are significant, but less dramatic than in the irradiation case. While it is rather clear that chemical sterilizing agents like ethylene oxide have a rather limited effect on PP, little experience exists so far in public about modern alternative sterilization processes like electron (β) irradiation, UV irradiation and the application of ozone.

2.4.3 Mechanical and Physical of Polypropylene

All of these three methods are capable of forming radicals in the polymer, resulting in similar degradation effects as the γ -radiation. In thermoplastic, polypropylene is types of semi-crystalline structure. Semi-crystalline materials such as polyamides do not exhibit a clear Tg or 'rubbery' region, although one is often quoted as the amorphous parts of the structure will undergo some transition. Some chain rotation in the amorphous regions will occur below Tm, giving some impact resistance at these temperatures. Values of Tg and Tm for a number of polymers are given in Table 2.5. From the table below is shown the Tg and Tm for Polypropylene is -10°C and 176°C (Callister, 2003).

Table 2.5: Values of Tg and Tm for selected polymers (Source: Callister, 2003).

Polymer	Tg (°C)	Tm (°C)
High density polyethylene (HDPE)	-	135
Polyp ropylene (PP)	-10	175
Polystyrene (PS)	100	-
Polymethylmethacrylate (PMMA)	105	-
Polyvinylchloride (PVC)	65	-
Natural rubber (NR)	-75	25
Polydimethyl siloxane (PDMS)	-125	-55
Polyoxymethylene (POM)	125	175
Polycarbonate (PC)	150	-
Polyethylene terephthalate (PET)	70	265
Polyether ether ketone (PEEK)	145	335
Nylon 6 (PA6)	50	215
Polyamide imide (PAI)	295	-
Polysulphone (PSul)	195	-
Polyphenylene sulphide (PPS)	90	285
Polyethersulphone (PES)	230	-
Polyetherimide (PEI)	218	-
Polytetrafluoroethylene (PTFE)	20	325
Liquid crystal polymer (LCP)	-	420

2.5 Natural Glass fibre Reinforced Polymer Material

2.5.1 Fibre Surface Modification

In mechanical properties and delaminating of reduction in natural fibre, the problems associated with the use of natural fibre are in their high moisture sensitivity. It is may be due to poor interfacial bonding between resin matrices and fibres. It is therefore necessary to modify the fibre surface to render it more hydrophobic and also more compatible with resin matrices. An effective method of chemical modification of natural fibres is graft copolymerisation. The resulting co-polymer displays the characteristic properties of both fibrous cellulose and grafted polymer. One of the most explored chemical modifications is the acetylation esterification of cellulose-OH, by reaction with acetic anhydride. This reaction reduces hydrophilicity and swelling of lignocelluloses and their composites.

The effect by using sodium- alginate and sodium hydroxide as a chemical treatment for natural fibre such as coir, banana, and sisal fibre has been increase in adhesion bonding and thus improve ultimate tensile strength up to 30% .According to researcher, Saira *et al*, 2007 have reported that treatment of jute with polycondensates such as phenol-formaldehyde, melamine-formaldehyde and cashew nut shell with liquid-formaldehyde improves the wetability of jute fibres and reduces water regain properties. The chemical modification of pineapple leaf fibres using alkali treatment, diazo coupling with aniline and cross-linking with formaldehyde. These chemical treatments result in signified cant improvements in mechanical properties; chemical resistance and reduced moisture regain. Finally, the influence of chemical treatment with sodium hydroxide, isocyanate and peroxide on the properties of sisal/polyethylene composites has investigated by Saira *et al*, 2007.

The observed enhancement in properties of the composites and attributed to this the strong bonding between sisal and polyethylene matrix. In an effort to improve the mechanical properties of recycled HDPE/wood fibre composites, the use of several additives with possible effect on the fibre/matrix adhesion or fibre dispersion into the matrix has been found that malefic anhydride modified polypropylene appears especially promising, since its use at a concentration of 5% in composites with 30% wood fibre results in an increase in tensile strength and elongation at break (Saira *et al*,2007).

Similar results have been obtained by Dalvag *et.al*, 1985, who has reported that the composite's elastic modulus remains unchanged. Some coupling agents, namely trichloro-striazineand di-methylol melamine can produce covalent bonds between celluloses materials and polymer matrices, leading to modified performance and reduced sensitivity to water. This approach has been further explored by Maldas and Kokta , who used phthalic anhydride as coupling agent for wood fibre/polystyrene composites. In addition to the chemical affinity of the benzene rings of phthalic anhydride with those of polystyrene, the anhydride group can directly attack the OH group of cellulose. Furthermore, Razi *et.al*,1999) found that the treatment of wood with sodium hydroxide followed by drying with vinyltrimethoxysilance is superior, for obtaining maximum bonding strength at the wood/polymer interface that yields improved mechanical properties (Saira *et al*, 2007).

2.5.2 Coupling Agent Addition

Many other coupling agents have also been investigated, namely anhydrides, maleated polymer, isocyanates, and alkoxy-silanes. Among these different reagents, maleated polypropylene (MaPP) or polyethylene (MaPE) gives significant enhancement in tensile and flexural strength, ranging from 40 up to 80%, when they are blended with cellulose fibres before mixing with matrix (Saira *et al.*, 2007).

Silane chemical coupling presents three main advantages:

- a) They are commercially available in large scale,
- b) At one end, they bear alkoxy-silane groups capable of reacting with OH-rich surface, and
- c) At the second end, they have a large number of functional groups which can be tailored as a function of the matrix to be used.

The last feature ensures, at least, a good compatibility between the reinforcing element and the polymer matrix or even covalent bonds between them. The reaction of silane coupling agents with lignocellulose fibres (mainly: cellulose and lignin) has been found to be quite different in comparison with that observed between them and glass surface, in the sense that with cellulose macromolecules, only prehydrolyzed silanes undergo the reaction with cellulose surface. Besides the chemical bonding theory, other theories such as the interpenetrating networks theory have also been proposed. This theory states that the matrix diffuses inside the silane interphase to form an entangled network. A number of attempts have been carried out to understand the silane-cellulose system. Thus, the interaction of silane coupling agents with cellulosic fibres and the effect of some parameters, such as pH, the initial amount of silane with respect to cellulose and the adsorption contact time, on their anchoring capability onto the fibre surface have been ascertained (Saira *et al.*, 2007).

2.6 Mechanical Properties

2.6.1 Introduction

Mechanical responses of this type of composite depend on several factors to include the stress-strain behaviors of fibre and matrix phases, the phase volume fractions, and in addition, the direction in which the stress or load is applied. Furthermore, the properties of a composite having its fibres aligned are highly anisotropic, that is dependent on the direction in which they are measured. The mechanical characteristic of a fibre-reinforced composite depend not only on the properties of the fibre, but also on the degree to which an applied load is transmitted to the fibres by the matrix phase. Under an applied stress, this fibre matrix bond ceases at the fibre ends, yielding a matrix deformation pattern. Some critical fibre length is necessary for effective strengthening and stiffening of the composite materials.

2.6.2 Tensile Strength

The ability of a material to resist breaking under tensile stress is one of the most important and widely measured properties of materials used in structural applications. The force per unit area (MPa or psi) required to break a material in such a manner is the ultimate tensile strength or tensile strength at break. The rate at which a sample is pulled apart in the test can range from 0.2 to 20 inches per minute and will influence the results. Figure 2.4 shows the UTM machine that use for tensile testing for composite Tensile strength σ_{UTS} , or S_U is the stress at which a material breaks or permanently deforms. Tensile strength is an intensive property and, consequently, does not depend on the size of the test specimen. However, it is dependent on the preparation of the specimen and the temperature of the test environment and material. Tensile strength, along with elastic modulus and corrosion resistance, is an important parameter of engineering materials that are used in structures and mechanical devices. It is specified for materials such as alloys, composite materials, ceramics, plastics and wood.



Figure 2.4: Tensile Testing

2.6.3 Impact test Charpy and Izod

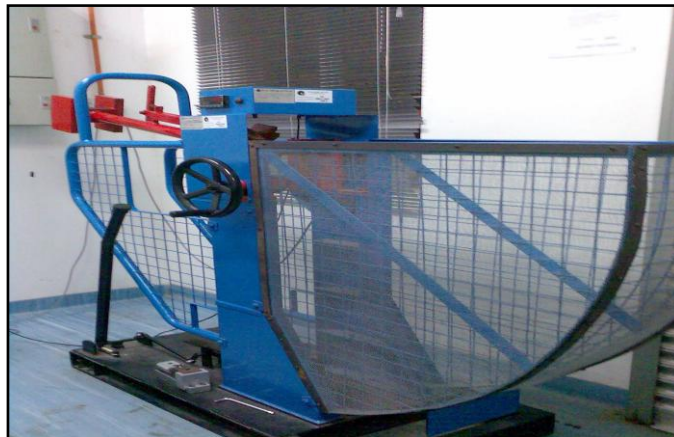


Figure 2.5: Impact test Charpy and Izod machine

The impact properties of the polymeric materials are directly related to the overall toughness of the material. Toughness is defined as the ability of the polymer to absorb applied energy. Most polymers, when subjected to the impact loading, seen to fracture in a characteristic fashion. The crack is initiated on a polymer surface due to the impact loading. The energy to initiate such a crack is called the crack initiation energy. If the load exceeds the crack initiation energy, the crack continues to propagate. A complete failure occurs when the load has exceeded the crack

propagation energy. Thus, both crack initiation and crack propagation contribute to the measured impact energy. Impact testing is divided by two method; Charpy test and Izod test. The Charpy impact test, also known as the Charpy v-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. But a major disadvantage is that all results are only comparative. Notched Izod Impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Izod impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. Izod specimens are notched to prevent deformation of the specimen upon impact. This test can be used as a quick and easy quality control check to determine if a material meets specific impact properties or to compare materials for general toughness (Anonymous 9, 2007).

2.6.4 Flexural Test



Figure 2.6: Flexural Test machine

The Flexural test measures the force required to bend a beam under 3 point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material's stiffness when flexed. Since the physical properties of many materials (especially thermoplastics) can vary depending on ambient temperature, it is sometimes

appropriate to test materials at temperatures that simulate the intended end use environment. The three points bending flexural test provides values for the modulus of elasticity in bending E_B , flexural stress σ_f , flexural strain ε_f and the flexural stress-strain response of the material. The main advantage of a three point flexural test is the ease of the specimen preparation and testing. However, this method has also some disadvantages: the results of the testing method are sensitive to specimen and loading geometry and strain rate.

In engineering mechanics, bending (also known as flexure) characterizes the behavior of a structural element subjected to an external load applied perpendicular to the axis of the element. A structural element subjected to bending is known as a beam. A closet rod sagging under the weight of clothes on clothes hangers is an example of a beam experiencing bending (Anonymous 10, 2007).

2.7 Physical Properties of Composite

2.7.1 Water Absorption Properties

All polymer composites absorb moisture in humid atmosphere and when immersed in water. The effect of absorption of moisture leads to the degradation of fibre matrix interface region to creating poor stress transfer efficiencies resulting in a reduction of mechanical and dimensional properties. One of the main concerns for the use of natural fibre reinforced composite materials is their susceptibility to moisture absorption and the effect on physical, mechanical and thermal properties. It is important therefore that this problem is addressed in order that natural fibre may be considered as a viable reinforcement in composite materials. Several studies in the use of natural fibre reinforced polymeric composites have shown that the sensitivity of certain mechanical and thermal properties to moisture uptake can be reduced by the use of coupling agents and fibre surface treatments. Moisture diffusion in polymeric composites has shown to be governed by three different mechanisms. The first involves diffusion of water molecules inside the micro gaps between polymer chains. The second involves capillary transport into the gaps and flaws at the interfaces between fibre and the matrix. This is a result of poor wetting and

impregnation during the initial manufacturing stage. The third involves transport of microcracks in the matrix arising from the swelling of fibres (particularly in the case of natural fibre composites). Generally, based on these mechanisms, diffusion behavior of polymeric composites can further be classified according to the relative mobility of the penetrate and of the polymer segments, which is related to either Fickian, non-Fickian or anomalous, and an intermediate behavior between Fickian and non-Fickian . In general moisture diffusion in a composite depends on factors such as volume fraction of fibre, voids, viscosity of matrix, humidity and temperature (Saira *et al*, 2007).

2.8 Morphology Properties of Composite

2.8.1 Morphology of Fibre

Figure 2.7 (a) has been taken of unmodified (standard) coir with modified coir fibers, hardly any difference in the surface structure between the fibers can be observed at low magnification (magnification factor 3250). The coir fibers display many pinholes on the surface ('rotten wood'-like appearance). The diameters of natural fibers (coir as well as sisal) vary considerably. The SEM micrograph of untreated (standard) coir Figure 2.7 (a) clearly demonstrates the presence of longitudinally orientated unit cells with more or less parallel orientations. The intercellular space is filled up by the binder lignin and fatty substances, which hold the unit cells firmly in a fibre (Bismarck *et al*, 2001).

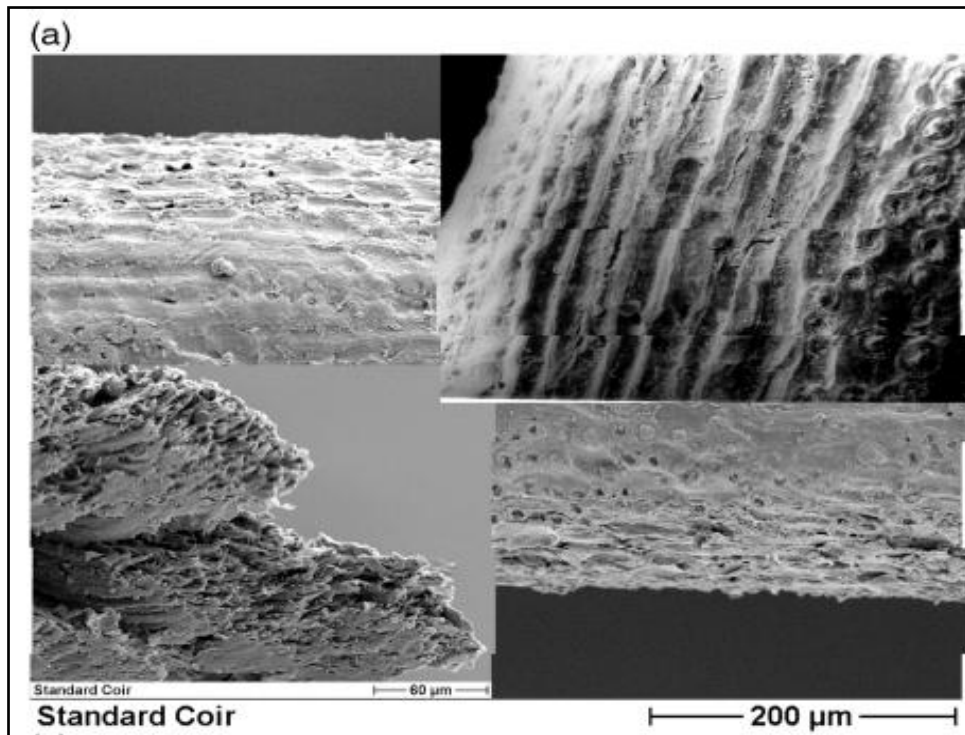


Figure 2.7: Standard Coir (Source: Bismarck *et al*, 2001).

2.8.2 Morphology of Effect of the Fiber Loading On the Composite

Examination of the fracture surfaces of the composites by scanning electron microscope gave information about how impact modifiers and MAPP affect the morphology of the composite. The rubber particle sizes and the interracial region between the PP matrix and the wood filler were investigated. Figure 2.8 shows the microstructure of the composite without impact modifier and compatibilizer (blend 1) showing a wood particle embedded in the polymer matrix. The wood particle is not broken and there are voids around the particle indicating poor interaction between the wood surface and the PP matrix. The WF particles were well dispersed on the PP matrix (Bismarck *et al*, 2001).

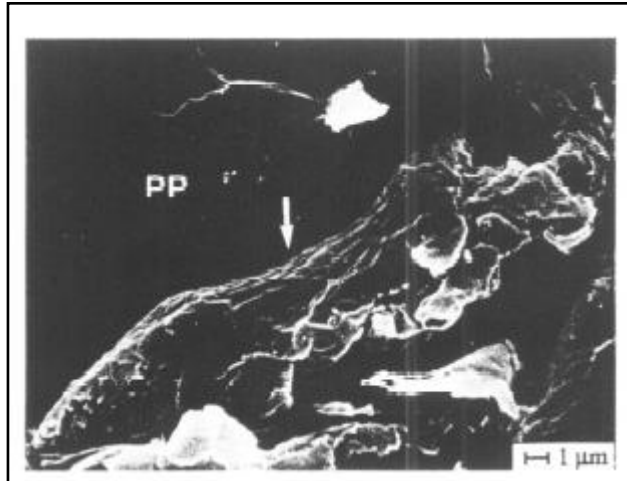


Figure 2.8: SEM micrograph of room temperature fractured specimen. Interface/ interphase region between the wood filler and the PP matrix (Source: Bismarck *et al*, 2001).

2.8.3 Morphology of Surface Fracture of the Composite

Comparing the coir fibers with sisal fibers (Figure 2.9 (a)–(d), magnification factor 3400) it is seen that coir fibers are much larger in diameter and they look smoother. Again only the unmodified sisal fiber (Figure 2.9 (a)) seems to be a little bit rougher compared to the surface modified sisal fibers (Figure 2.9 (b)–(d)) containing small particles (possibly waxes and fats) attached to the fiber surface. These particles thus appear to be removed by the applied modification procedures (dewaxing, treatment with NaOH). All sisal fibers display a grain-like surface structure (Bismarck *et al*, 2001).

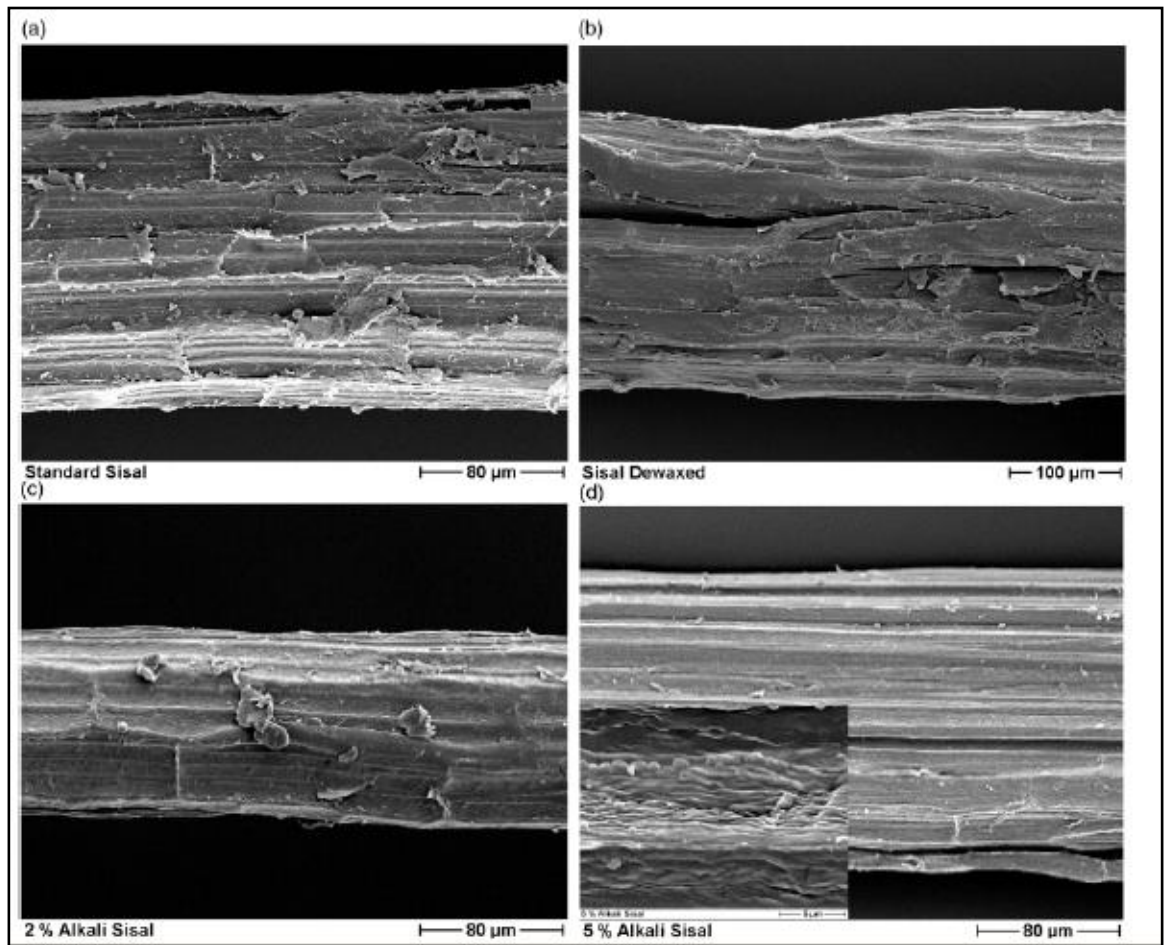


Figure 2.9 : (a) Original, untreated (standard) sisal fiber, plane view. (b) Dewaxed sisal fiber, plane view. (c) Sisal fiber treated with 2% NaOH, plane view. (d) Sisal fiber treated with 5% NaOH, plane view and magnified section of the outer fiber surface (Source: Bismarck *et al.*, 2001).

CHAPTER 3

MATERIALS & METHODOLOGY

3.1 Materials

3.1.1 Introduction

In this research, the hybrid composite method is used in several materials as a matrix and reinforcement to get new properties of composite. Natural fibre such as cocoa pod husk is the main of this research following by fibre glass (E-glass) as filler and Polypropylene as matrix.

3.1.2 Preparation of Cocoa Pod Husk



Figure 3.1: Cocoa Bean with surrounding by Cocoa Husk (Source: Anonymous 6, 2004).

Figure 3.1 shows the cocoa fruit is surrounded by cocoa pod husk. Cocoa husk is obtained from the cocoa fruit processing plant near Jekebu, Negeri Sembilan (Tiara Cocoa Manufacturing Sdn.Bhd). Figure 3.2 shows the flow chart of processing of preparation of cocoa husk. The process of getting cocoa husk is started from breaking the pods or separating the wet beans from the husks which is traditionally manual. Pods are broken with knives to hit the pods against each other laterally. The cocoa husk is cleaned and immersed into water for 7 days. Later, the cocoa husk is dried at sunlight to remove the moisture in 2 weeks. The dried husk is crushed into desired sizes: 45 μ m, 250 μ m and 500 μ m as in figure 3.3.

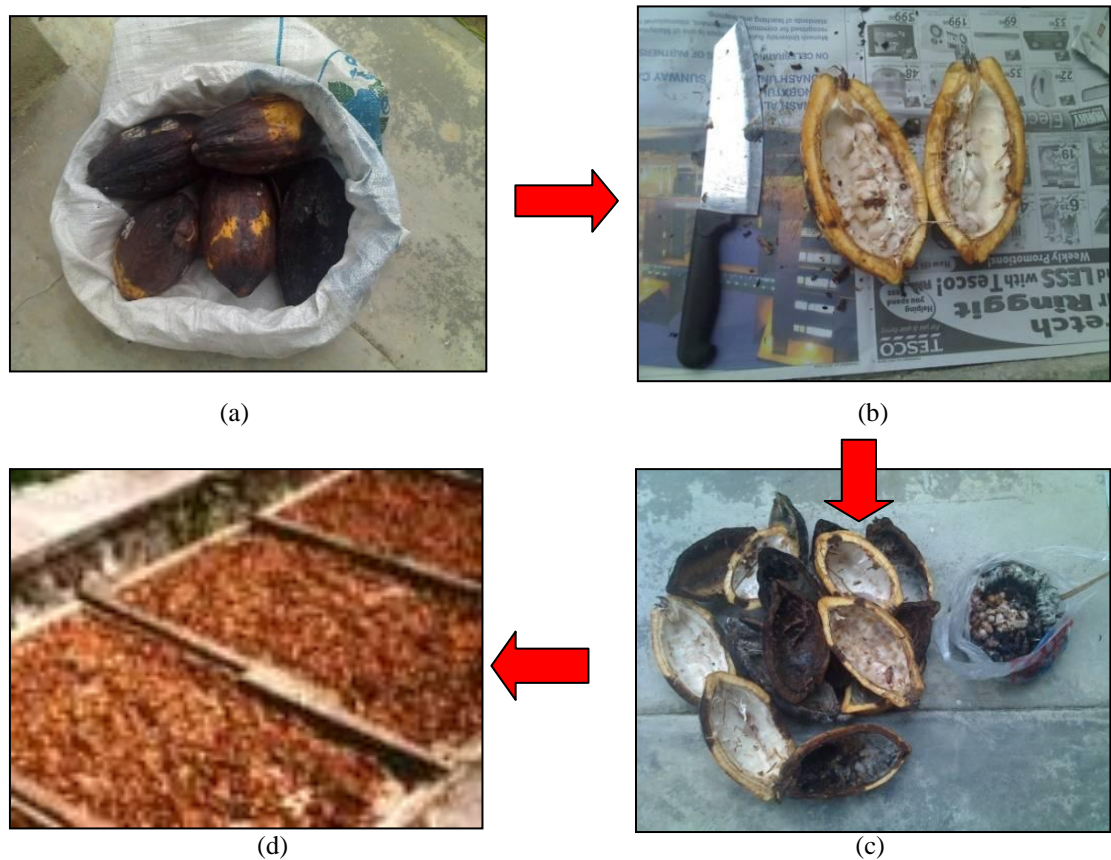


Figure 3.2: Flow Step of Processing Cocoa Husk ; (a) cocoa fruit has been taken from tree, (b) and (c) cocoa fruit has been separated from cocoa beans using a knife and (d) cocoa husk is drying at sunlight.



(a) Fineness particle, 45 μm



(b) Large particle, 250 μm



(c) Coarse particle, 500 μm

Figure 3.3: (a), (b) and (c) Particle size of cocoa husk

3.1.3 Polypropylene (PP)

Polypropylene (PP) with density of 0.905gcm^{-3} is supplied by Laboratory Polymer, UTeM T PP is used as the matrix and received in form of pellets (Figure 3.4).



Figure 3.4: Pellets of Polypropylene

3.1.4 E-glass (Fibre glass)

E-glass fibres that type of synthetic fibres that used as reinforcing agent for this project. The type of E-glass is available in mat shapes. In this project, E-glass fibers (Polymer Laboratory, UTEM) in diameter of 12 μm was manually cut into average fiber length of 3 mm as shown in the Figure 3.5. into short fibre by using scissors .



Figure 3.5: E-fibre glass

3.2 Methodology

3.2.1 Introduction

The preparation of raw materials has been done on the cocoa husk and E-glass fiber. The cocoa fiber was dried in oven (Universal Ovens, UNB 100-500) for 24 h at 105 C to a moisture content of 1-2 % (based on dry weight) before processing. Then, the cocoa fiber is crushed and into powder with different range of sizes; 45µm, 250µm and 500µm. The E-glass fiber length was manually cut into average fiber length of 3mm. Plastic granulates; polypropylene, cocoa fiber and E-glass fiber was compounded using a co-rotating twin-screw extruder (Polylab Extruder, HAAKE Rheomix OS). The temperatures were between 180°C and 200 °C. The screw speed set at 50 rpm. Finally the mixed samples coming out in bulk form. The crushing machine is used to crush in particle form. The compound of hybrid composite is fabricated in 300mm x 300mm x 30mm of dimension of mold. The melting point is 200°C with pressure of 25 Ton for 10 min and the timer for hot is 10minutes and cold is 15minutes. Each of plate are cut into desired dimension for specimens testing The first testing was tensile test, followed by flexural test, impact test and finally the water absorption. And the last study made was the microstructure observation using the Scanning Electron Microscope (SEM). The schematic of the methodology process flow of the project can be review at Figure 3.6.

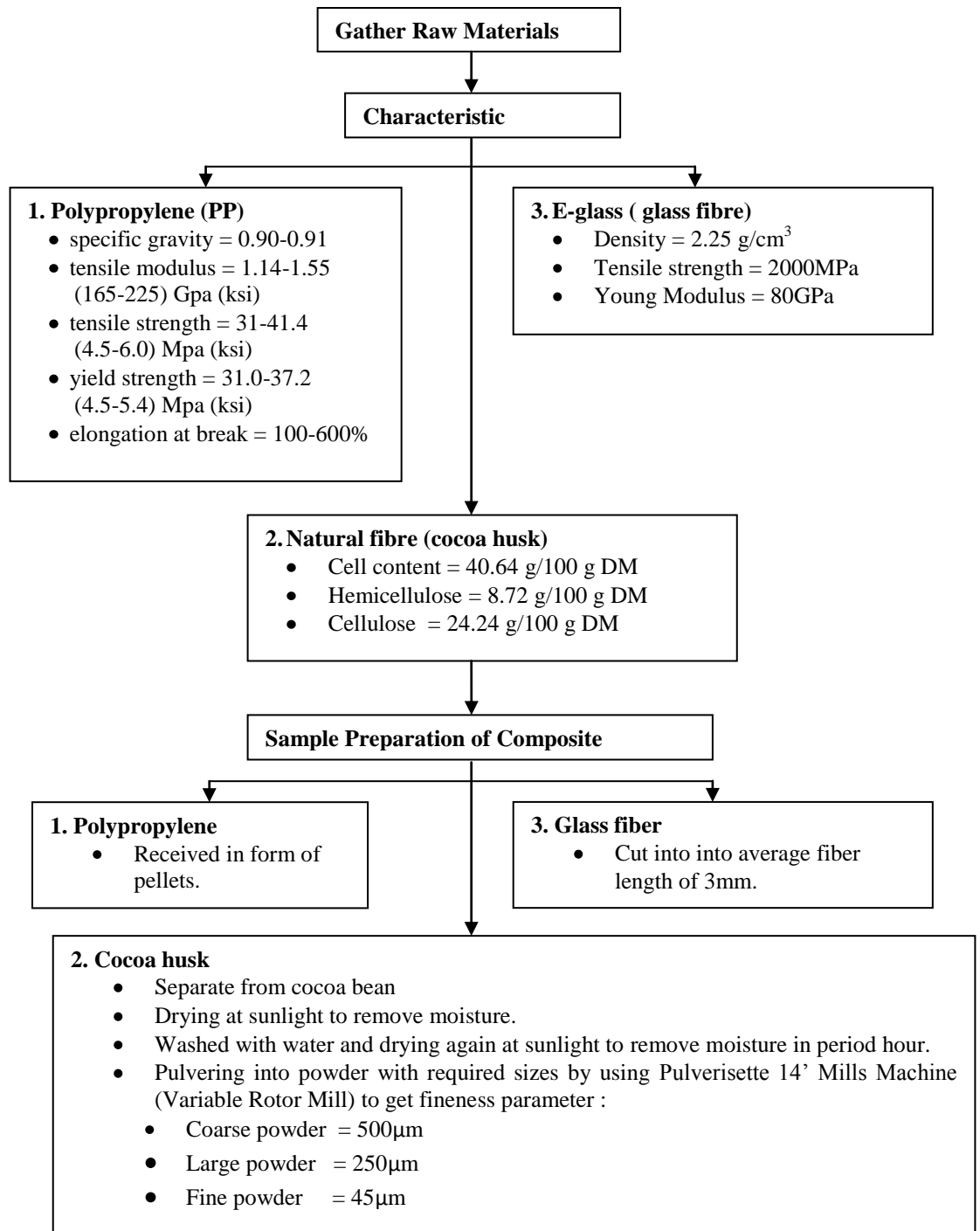


Figure 3.6: Manufacturing Process Flow Chart (continues)

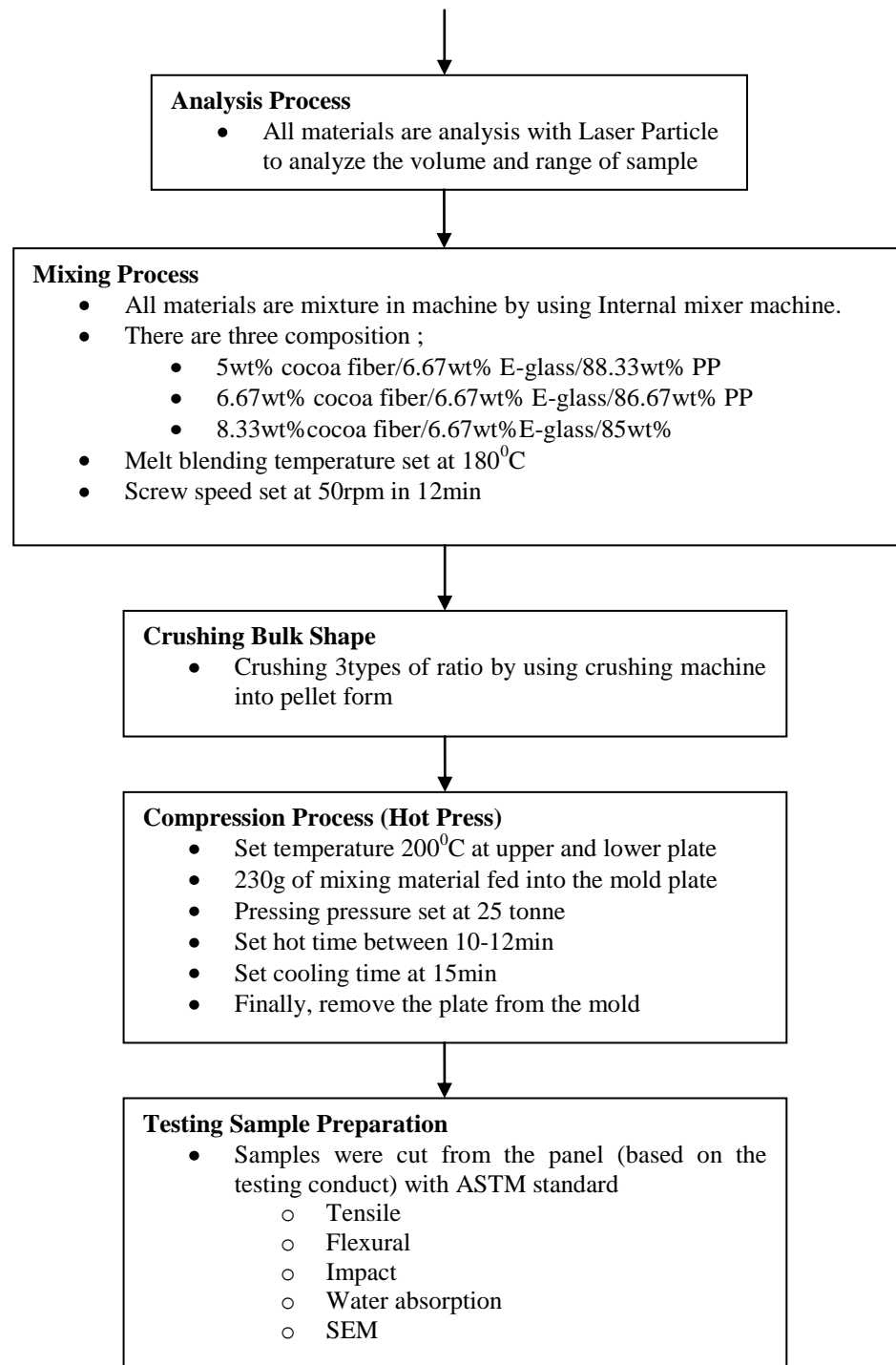


Figure 3.6: Manufacturing Process Flow Chart (continues)

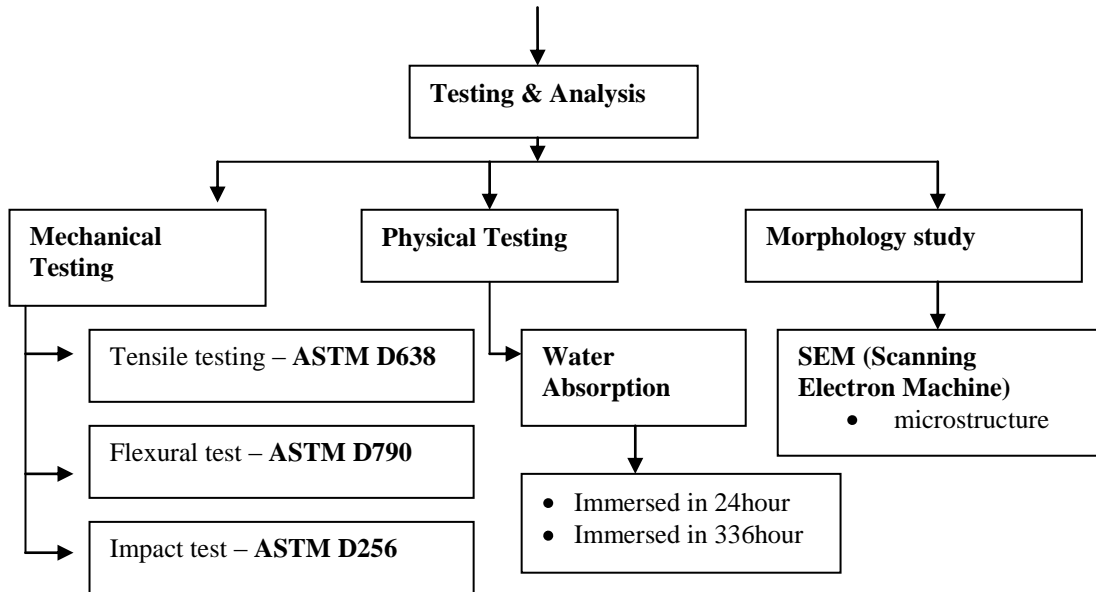


Figure 3.6: Manufacturing Process Flow Chart

3.2.2 Raw materials Preparation

Pulverizing process has been done on the cocoa husk that dried. There were sieved using Variables Speed Rotor Mill at 300 μ m to 500 μ m aperture sizes based on the optimum tensile results (Anuar *et.al*, 2005). Figure 3.7 shows the Variables Speed Rotor Mill that was used is the Pulverisette 14 from FRITSCH which is available in Laboratory Material FKP. The machine is run between 12 to 14 rpm depend on the size of cocoa pod husk the run time is set for 3 minutes to prevent the machine from overheated.



Figure 3.7: Pulverisette 14 with 12-ribs-rotor and Sieve Ring (Source; Fritsch GmbH)

With a feed size of $< 10\text{mm}$, a final fineness of up to $40\mu\text{m}$ can be achieved. The throughput depends on the material and lies between 0.05 and 5 l per hour. The operation of principles is a high-speed rotor with shaped ribs crushes the sample by impact force. In addition, the sharp-edged teeth and the sieve insert reduce the sample by shearing. The sample is placed under stress in the last milling stage by friction between the rotor and the sieve insert. Ground material is collected in a stainless collection pan. All the particles cocoa husk were shakes into desired sizes: $45\mu\text{m}$, $250\mu\text{m}$ and $500\mu\text{m}$; by using Shaker machine.

3.2.3 Hybrid Composite Fabrication

3.2.3.1 Internal Mixing Process

The next process is mixing method using Internal Mixing machine. The figure 3.8 is show the model of this machine is Thermal Haake PolyLab OS RheoDrive 16 that stated at Laboratory Polymer FKP, UTeM. This machine is used twin-screw to disperse fibre into Polypropylene homogeneous. The commingled of PP pellet and fibre is firstly pre-mixed manually in a bowl based on the weight proportion of PP, natural fibre and glass fibre. Then, poured into the hopper of the extruder. The mixture of cocoa husk, glass fibre and PP at required ratio was used in this work. This process was rotate in 12 times to produce 1 samples in 60gram per weight The blending was carried out at $180\text{-}200\text{ }^{\circ}\text{C}$ and $40\text{-}60\text{ rpm}$ speed of twin screw for 12 min. The figure 3.9 is showing the basic parameter setting on machine software. The table 3.1 is shown the parameter of composition of mixture for Internal Mixer machine.

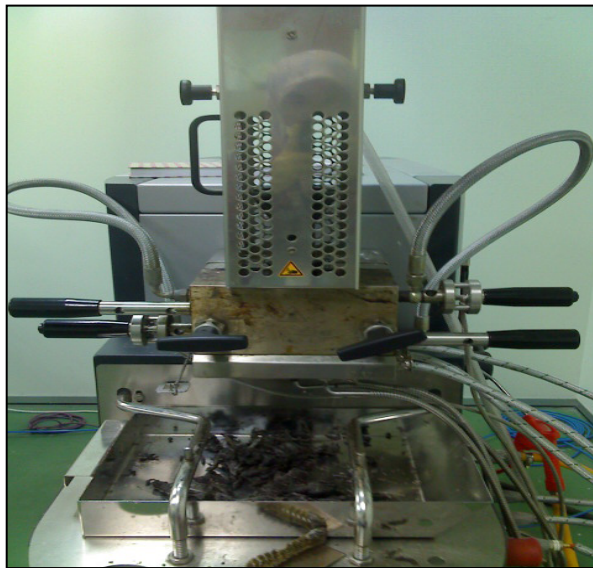


Figure 3.8: The Thermal Haake Internal Mixer machine

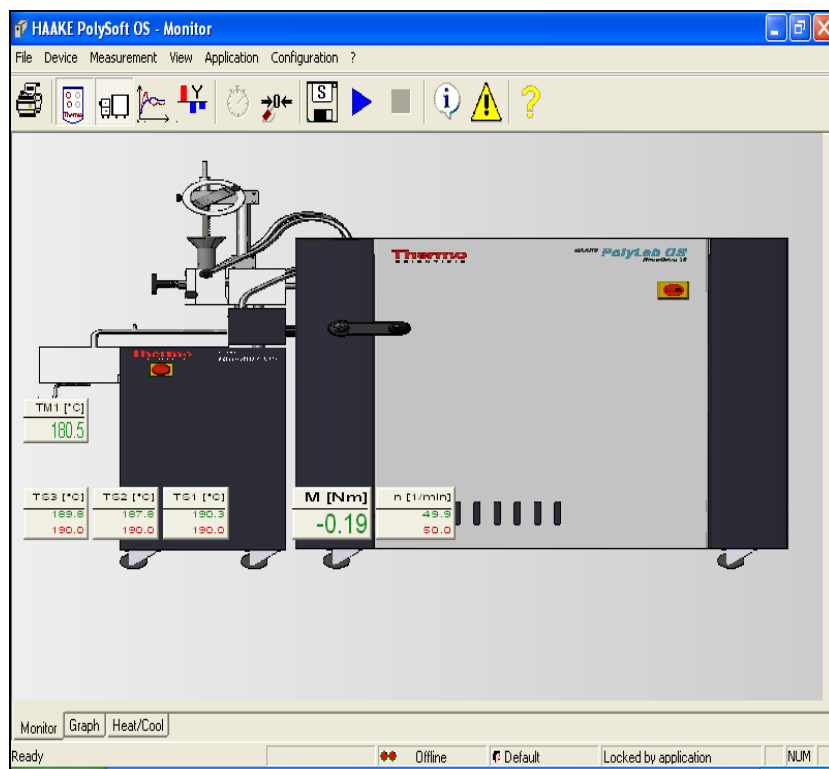


Figure 3.9: General setting on Thermal Haake Internal Mixer machine

Table 3.1: The Ratio Parameter for Mixture Machine

Sample No	Matrix (PP) %	Reinforcement 1 (Glass Fibre) wt%	Reinforcement 2 (Cocoa husk) wt%
1	88.33	6.67	5
2	86.67	6.67	6.67
3	85	6.67	8.33

3.2.3.2 Crushing Process



Figure 3.10: Crusher Machine

Figure 3.10 shows a crusher machine, model TW-SC-400F which that designed to reduce large solid material objects into a smaller volume, or smaller pieces (figure 3.11). Crushers may be used to reduce the size, or change the form, of waste materials so they can be more easily disposed of or recycled, or to reduce the size of a solid mix of raw materials (as in rock ore), so that pieces of different composition can be differentiated.

Crushing is the process of transferring a force amplified by mechanical advantage through a material made of molecules that bond together more strongly, and resist deformation more, than those in the material being crushed do. Crushing devices hold material between two parallel or tangent solid surfaces, and apply sufficient force to bring the surfaces together to generate enough energy within the material being crushed so that its molecules separate from (fracturing), or change alignment in

relation to (deformation).The sample form internal mixer has been crushes with require sizes (figure 3.12).



Figure 3.11: Bulk Shape of Hybrid Composite



Figure 3.12: Blend Material after crushing (particle form)

3.2.3.3 Hot Press Process



Figure 3.13: Hydraulic Moulding Test Press Machine

Figure 3.13 shows the Hydraulic Moulding Test Press machine, model GoTech is stated at Laboratory Polymer FKP, UTeM. The sample is transfer to Hot press machine to melt into the mold with require sizes. The hot press machine were melt the sample with pressure applied is 20tones with temperature 160°C for a period of 600seconds. The composite then were cooled down by cold press in 900 seconds to harden it. Five samples are prepared for each of the composite for every testing. Figure 3.14 is show the component of Hot Press machine. There are two side of mold; female and male. For melting process, the male mold is used and for cooling process, the female mold.

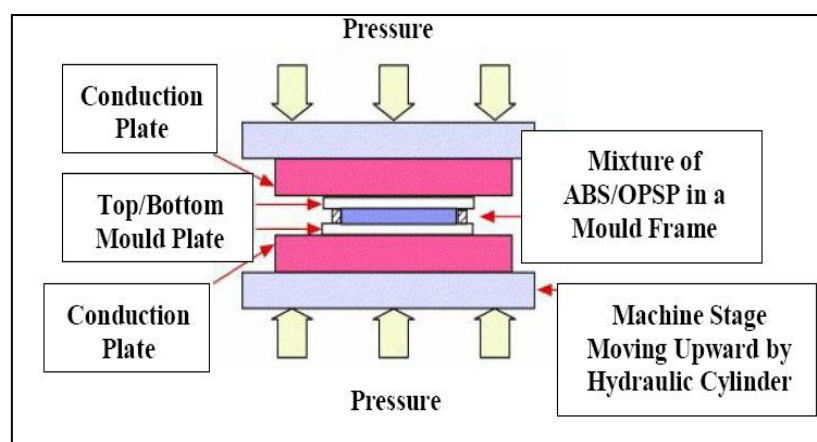


Figure 3.14: The Component of Hot Press Machine

3.2.3.4 Specimen Cutting Process

The sheet materials were cut into the required sizes of the tensile sample and flexural sample as indicated in their ASTM by using the Hacksaw and Hardness Plastic Specimen Cutting GT-7016-H (GoTech Testing Machine Inc., Taiwan) as shown in figure 3.15.



Figure 3.15: Cutting Process of Tensile Specimen

3.3 Preparation of Sample for Testing

3.3.1 Introduction

The samples from the hot press are to produce identical shape and dimension suitable for tensile, impact and flexural tests. The entire sample was cut with hacksaw to get the size with standard size ASTM.

3.3.1.1 Tensile Test – ASTM D638-01

This test method covers the determination of the tensile properties of unreinforced and reinforced plastics in the form of standard dumbbell-shaped test specimens. This test method can be used for testing materials of any thickness up to 14mm (0.15in). Figure 3.16 is shown specimen dimension for thickness tensile test. Refer to the table 3.2 is shown the type of specimen in 1 until 5. Each types of specimen have different dimension especially in thickness (Anonymous 11, 2001).

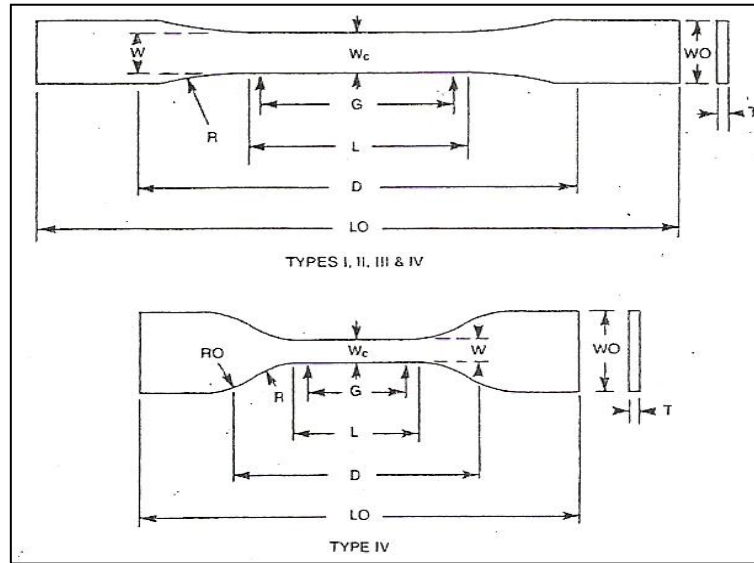


Figure 3.16: Specimen Dimension for Thickness, T, mm (Source: Anonymous 11, 2001).

Table 3.2: Standard Dimension for Rigid and Semirigid Plastics, ASTM D638. (Source: Anonymous 11, 2001).

Part (See Drawing)	Dimension (mm)
W- Width of narrow section	13
L- Length of narrow section	57
WO- Width Overall, min	19
LO- Length Overall, min	165
G- Gage Length	50
D- Distance between grips	115
R- Radius of fillet	76

For tensile test, the samples are aligned properly to prevent bending moment occur during test. According to ASTM D638-01, at cross-head speed of 5mm/min was measured. The gauge length was 40mm (figure 3.17). Three samples were tested for each compositions and a mean of these samples were taken for Young modulus, yield strength, tensile strength and elongation calculations. Extensometer is used to monitor the sample elongation and stress versus strain is plotted automatically.

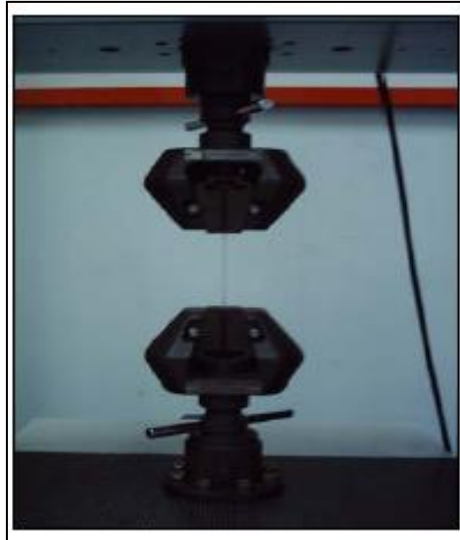


Figure 3.17: Tensile Testing (Universal Testing Machine)

(a) Procedures

1. The width and thickness of specimen is measured with a suitable micrometer to the nearest 0.025mm (0.001in) at several points along their narrow sections.
2. The specimen is placed in the grips of the testing machine, taking care to align the long axis of the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine.
3. The extension indicator is attached.
4. The speed of testing is set at the proper rate and the machine is started.
5. The load-extension is recorded the curve of the specimen.
6. The load and extension is recorded at the yield point and the load and extension at the moment of rupture.

3.3.1.2 Izod Pendulum Impact – ASTM D256-00

For impact test, Izod test method is used to study the impact behavior of the samples. It is one of an ASTM D256-00 standard method of determining impact strength and the amount of energy absorbed by a material during fracture. Specimens for Izod tests were sawed on manual band saw equipment to dimensions of 55 x 10 x 3.0-mm (figure 3.18). The sample is notched and placed vertically (Izod) in a vice with the notch positioned central to the top of the vice, facing the swing patch of the pendulum. The pendulum, having a known energy, strikes the sample and the swing height of the pendulum after breaking the sample is measured and subtracted from the calibrated swing height. The result is the energy absorbed to break the sample. All the data from table were converted to the graph to show the line of impact strength of each of sizes as seen in Result section.

The relationship between the hammer weight and the velocity of the swing to determine the impact energy;

$$\text{Impact energy} = 0.5 \times \text{Hammer Weight (kg)} \times \text{Velocity}^2 \text{ (m/s)}$$

$$\text{Impact strength} = \frac{\text{Impact value}}{\text{Width} \times \text{thickness} (10^{-6} \mu\text{m})} \quad (\text{K J/m}^2)$$

These test methods cover the determination of the resistance of plastic to ‘standardized’ pendulum type hammers, mounted in ‘standardized’ machine, in breaking standard specimens with one pendulum swing (Anonymous 11, 2001).

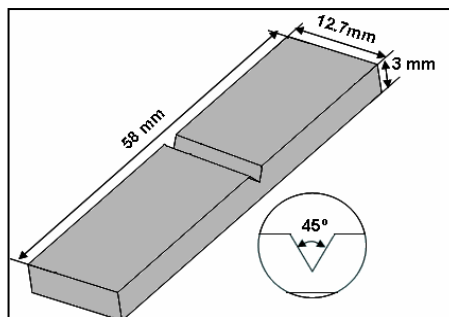


Figure 3.18: Izod V-Notch Specimen (Source: Anonymous 12, 2001).

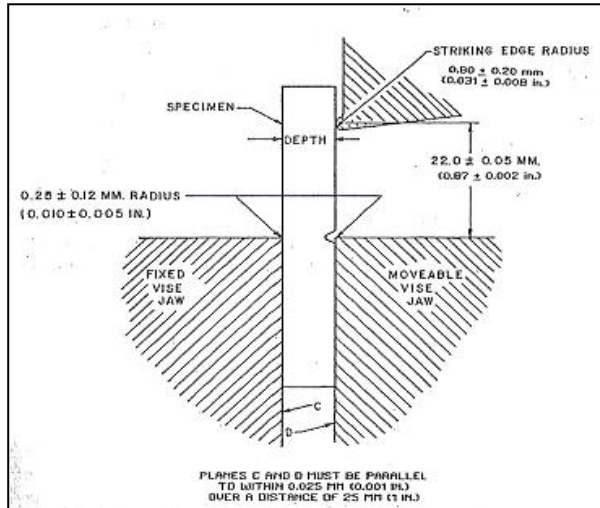


Figure 3.19: Relationship of Vise, Specimen and Striking Edge to each other for Izod Test Methods A and C (Source: Anonymous 12, 2001).

Figure 3.19 shows the relationship of Vise, Specimen and Striking Edge to each other for Izod Test Methods A and C. In Test Method A, the specimen is held as a vertical cantilever beam and is broken by a single swing of the pendulum. The line of initial contact is at a fixed distance from the specimen clamp and from the centerline of the notch and on the same face as the notch. Test Method C is similar to Test Method A, except for the addition of a procedure for determining the energy expended in tossing a portion of the specimen.

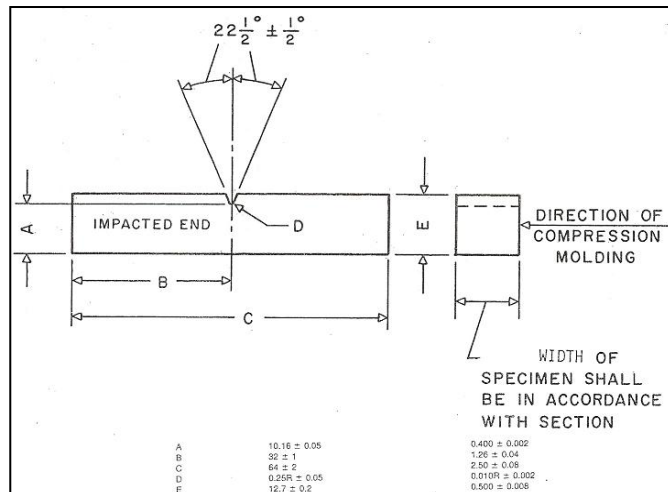


Figure 3.20: Dimensions of Izod- Type Test Specimen (Source: Anonymous 12, 2001).

Refer to figure 3.20 shows the test specimens with dimension that use for Izod Test. It shall conform to the dimensions and geometry. To ensure the correct contour and conditions of the specified notch, all specimens shall be notched.

(a) Procedures

1. At least five and preferably ten or more individual determinations of impact resistance must be made on each sample to be tested under the conditions.
2. Estimate the breaking energy for the specimen and select a pendulum of suitable energy.
3. The specimen is measured the length, height and width.
4. The software of impact is setup up, the data of specimen is recorded in table.
5. The specimen is set at the vice on the impact machine.
6. The machine is started, the swing is released.
7. The data of energy is recorded in the table.

3.3.1.3 Flexural Test – ASTM D790-00

These test methods cover the determination of flexural properties of unreinforced and reinforced plastics, including high-modulus composites and electrical insulating materials in the form of rectangular bars molded directly or cut from sheets, plates or molded shapes. These test methods are generally applicable to both rigid and semirigid materials. These test methods utilize a three-point loading system applied to a simply supported beam (Anonymous 13, 2001). For flexural test; the samples are aligned properly to prevent error measurement during test. According to ASTM D790, at cross-head speed of 5mm/min was measured. The gauge length was 40mm (figure 3.21). Three samples were tested for each compositions and a mean of these samples were taken for stress and strain calculations.

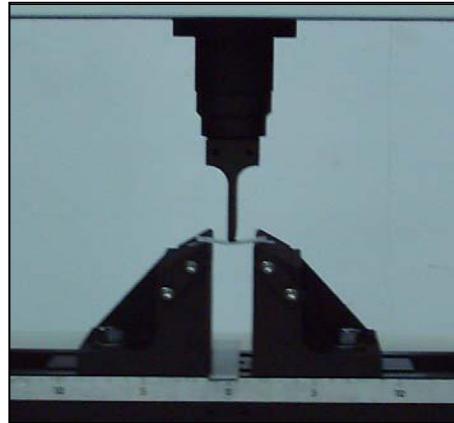


Figure 3.21: Flexural Test Method

(a) Procedures

1. An untested specimen for each measurement is used in this testing. The width and depth of the specimen is measured to the nearest 0.03 mm (0.001in) at the center of the support span.
2. The support span is determined to be used and the support span is set to within 1% of the determined value.
3. For flexural fixtures that have continuously adjustable spans, the span is measured accurately to the nearest 0.1mm (0.004in) for spans less than 63mm (2.5in) and to the nearest 0.3mm (0.012in) for span greater than or equal to 63 mm (2.5in).
4. The rate of crosshead motion is calculated as follows and the machine is set for the rate of crosshead motion.
5. The loading nose is aligned and supports so that the axes of the cylindrical surfaces are parallel and the loading nose is midway between the supports.
6. The load is applied to the specimen at the specified crosshead rate.
7. The test is terminated when the maximum strain in the outer surface of the test specimen.

3.3.1.4 Water absorption - ASTM D570

This study of water absorption was referring to ASTM D570 standard. This method is to determine the amount of water absorbed under specified conditions. Specimens for water absorption tests were sawed on manual band saw equipment to dimensions of 10 x 10 x 3.0-mm. Before immersion, the specimens were dried in an air conditioned oven at 100 °C until the moisture is removed properly. Specimens are removed, patted dry with a lint free cloth, and weighed by using Mettler Balance tool as shown in Figure 3.22. The weight of sample is taken as references. (Anonymous 14, 2001).



Figure 3.22: Mettler Balance Equipment

3.4 Preparation for Analysis

3.4.1 Morphology Investigation

The fracture surfaces from both tests are observed using scanning electron microscope (SEM). This is very important to study micro-toughening occurred and the interaction between fibers and matrix. Prior to the observation, the fracture surfaces are gold-coated to avoid electron charging that can be interrupted the observations.

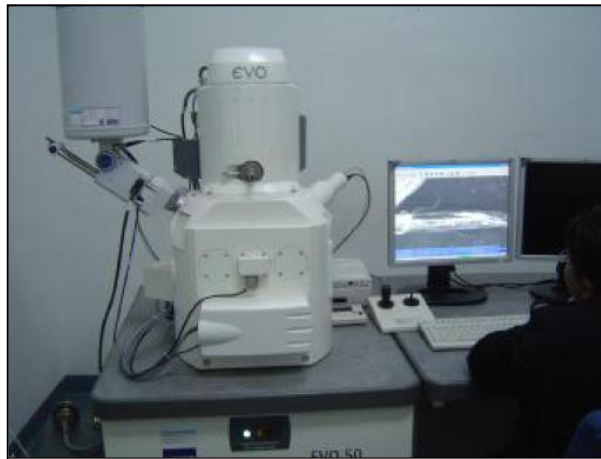


Figure 3.23: SEM equipment



Figure 3.24: Examples of specimen that mounted on SEM Stubs

Figure 3.23 is shown the SEM analysis that stated at Laboratory Material,FKP,UTeM. The SEM is an instrument that produces a largely magnified image by using electrons instead of light to form an image. A beam of electrons is produced at the top of the microscope by an electron gun. The electron beam follows a vertical path through the microscope, which is held within a vacuum. The beam travels through electromagnetic fields and lenses, which focus the beam down toward the sample. Once the beam hits the sample, electrons and X-rays are ejected from the sample. The SEM has allowed researchers to examine a much bigger variety of specimens. The researcher has much more control in the degree of magnification because the SEM uses electromagnets rather than lenses. The scanning electron microscope has many advantages over traditional microscopes. The SEM has a large depth of field, which allows more of a specimen to be in focus at one time. The SEM also has much higher resolution, so closely spaced specimens can be magnified at much higher levels. The specimen is cut into small piece around 5mm and mounted onto SEM stubs as shown in the Figure 3.24.

(a) Procedures

1. All water must be removed from the samples because the water would vaporize in the vacuum.
2. All metals are conductive and require no preparation before being used. All non-metals need to be made conductive by covering the sample with a thin layer of conductive material. This is done by using a device called a "sputter coater." which is used uses an electric field and argon gas.
3. The sample is placed in a small chamber that is at a vacuum.
4. Argon gas and an electric field cause an electron to be removed from the argon, making the atoms positively charged.
5. The argon ions then become attracted to a negatively charged gold foil.
6. The argon ions knock gold atoms from the surface of the gold foil. These gold atoms fall and settle onto the surface of the sample producing a thin gold coating.

3.4.2 Laser Particle Analysis



Figure 3.25: Laser Particle Analysis

Figure 3.25 shows the Laser Particle Analysis that used to analysis size of particle of specimens. In a laser-based instrument, due to the near-parallel nature of the laser beam, light scattering from the unimpeded laser beam is minimal because it is focused into a beam stop until a particle passes through the instrument. As the laser strikes the particle, light scatters and hits the photocell. Just like a white light instrument, the change in voltage across the photocell is directly related to the size of the particle. In the laser-based instrument, one looks at an increased signal against what should be a zero background (in theory). Laser optical particle counters are generally considered to be slightly more accurate and sensitive than white light instruments. This machine is used to check the particle of cocoa powder to ensure the size is acceptable in this research.

(a) Procedures

1. Make sure the sample is taken from the correct location using the correct sampling procedure. Take steps to minimize sample contamination during sample collection and be sure to leave headspace in the bottle.
2. Ensure the sample bottle is at least 2 ISO range codes cleaner than the desired lowest levels of ISO fluid cleanliness.
3. Dilute viscous fluids and heavily contaminated samples using prefiltered reagent grade kerosene prior to particle counting (remember to recalculate the original particle count concentrations using the appropriate dilution factor). Prefilter the diluent if its cleanliness is in question.
4. Test for free and emulsified water using a crackle test or other moisture screening method. If water is present, the water may be vacuum dehydrated or treated by mixing the oil 50:50 with a tonic comprised of three parts toluene and one part isopropyl alcohol.
5. If more than a few minutes pass between sampling and testing, resuspend the particles by agitating the sample for five minutes (longer for viscous fluids) in a paint shaker.
6. Ensure that the effects due to air bubbles are negated by using vacuum ultrasonic bath and/or a vacuum de-greasing - preferably both, starting with the ultrasonic bath (optical particle counters).

7. Don't leave onsite particle counter idle on the shelf make the most of this valuable asset each and every day.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Data Analysis

4.1.1 Introduction

The purpose of carrying out this mechanical testing is, to do a study on the specimen's mechanical properties such as Tensile properties, Flexural properties and Impact energy absorption of a specimen. The analyses have been done on fracture surface morphology and micrograph under Scanning Electron Microscope (SEM).

4.1.1.1 Tensile Testing

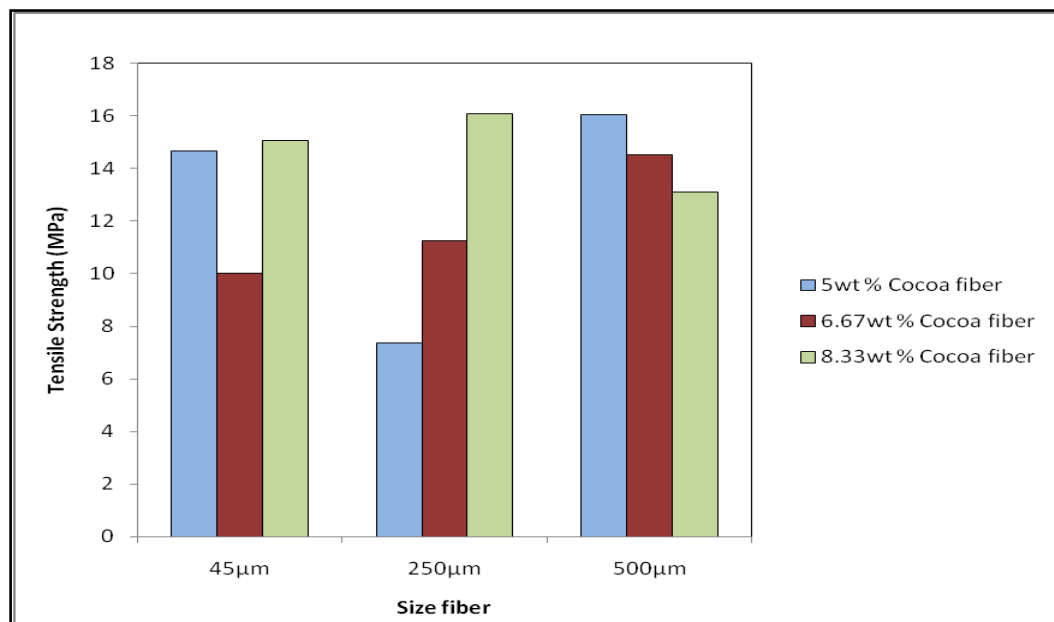


Figure 4.1: Tensile Strength versus Size Fiber of Hybrid Composite

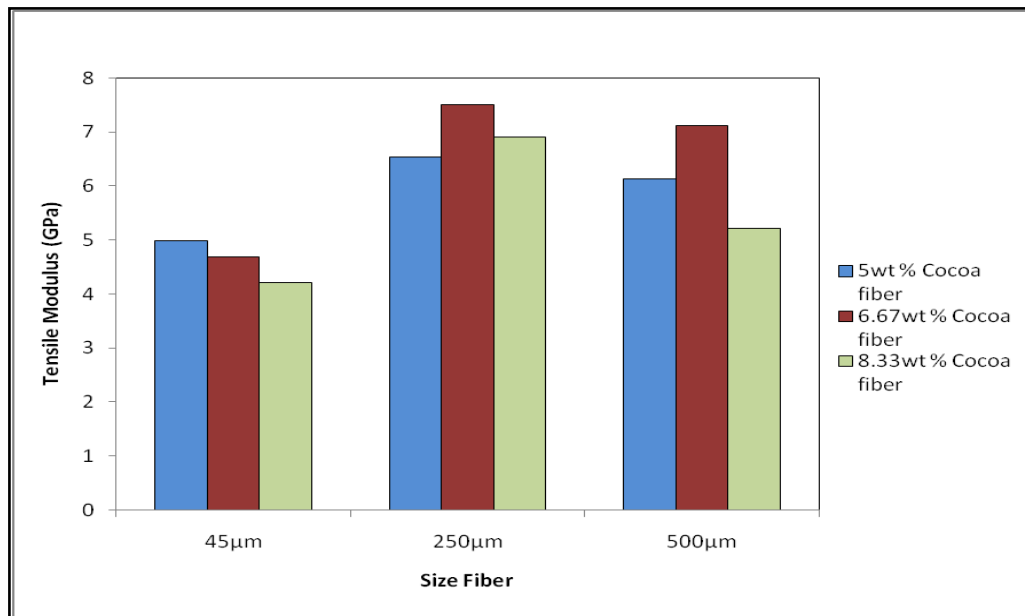


Figure 4.2: Tensile Modulus versus Size Fiber of Hybrid Composite

The tensile strength and tensile modulus versus size fiber results for cocoa fiber-E-glass reinforced polypropylene are shown in Figure 4.1 and Figure 4.2. The tensile strength and modulus of the hybrid composite reinforced composites increased as increasing fibers loading has been investigated by Ismail *et.al*,(2008). Figure 4.1 shows the tensile strength for 250µm size fiber has increase with an increase in fiber content but decrease its tensile modulus since it shows lowest tensile strenght when compared to 500 µm size fiber. Theoretical, when fiber loading is increased, the strength must be increase. From the experimental value, it shows that the graph of 500µm fiber size is opposite compare to the theoretical. But, when compare to the effect of analysis of size fiber, it shows that 500µm has been right in theory. The effects of fiber size on the tensile strength and modulus for the hybrid composite samples are summarized in Figure 4.1 and 4.2. The tensile strength was not significantly affected by changing the cocoa fiber size from 45µm,250µm to 500µm in the hybrid whereas the tensile modulus of 250µm size fiber has increased by 51% compare to those with 45µm size fiber. This condition is due to increasing the size fiber because larger fibers are carrying more tensile loads as a result of increased transfer size. Futher increased in cocoa fiber in 500µm did not result in an increase in tensile modulus, a slight drop in tensile modulus on the opposite. According to Thwe

et al.(2003) stated that larger size of fiber may lead to poorer compatibility with the matrix.

4.1.1.2 Flexural Testing

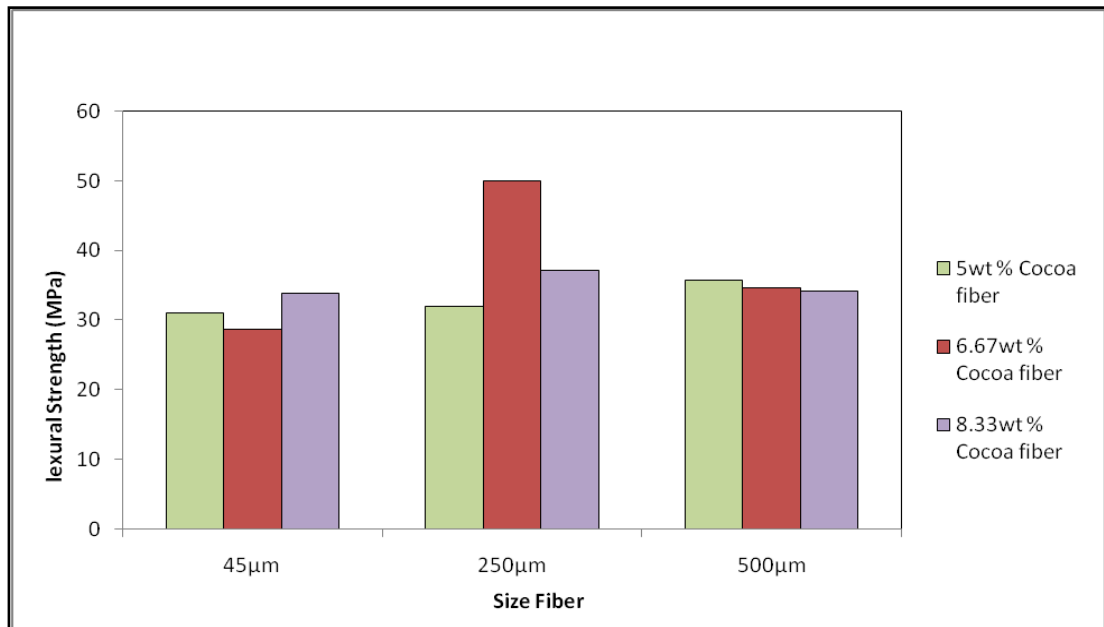


Figure 4.3: Flexural Strength versus Size Fiber of Hybrid Composite

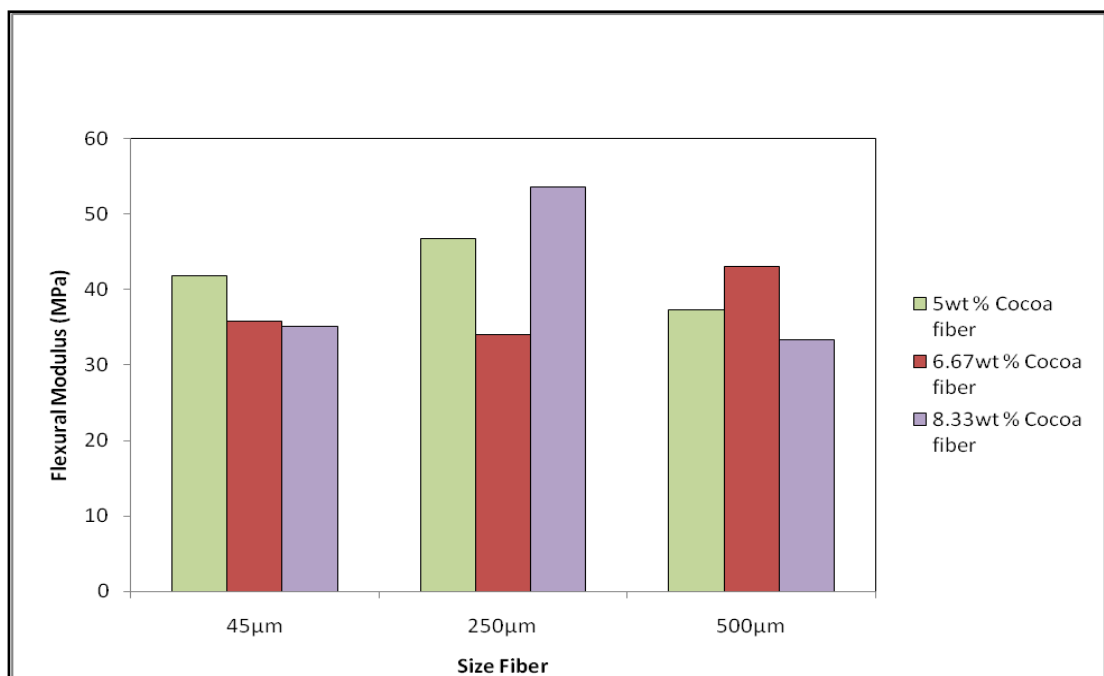


Figure 4.4: Flexural Modulus versus Size Fiber of Hybrid Composite

Figure 4.3 and Figure 4.4 are shown the effect of hybrid composite with different size and content of fiber in flexural strength and modulus. According to the graph of flexural strength (Figure 4.3), it clearly shown that the strength value was increase when the fiber content increases but it is not for all ratios. The strength value for 250 μ m size fiber content 5wt% cocoa fiber is 31.949 MPa and the value is increase to 49.933 MPa when the fiber content is 6.67wt%. Theoretically when the fiber content is increase to 8.33wt%, the strength value must be increase, but the experimental value was shown that it decrease to 37.078 MPa. When making some observation to the specimens, most probably the material not bind property when the mixing. There are some defects such as pores, voids, impurity and unmelted plastics. All these defects are influences to the strength of specimens. The graph was decrease with existing of pores and impurity in the specimens. The same problem is occurred on the sample of 45 μ m size fiber where the strength is decrease to 28.598 MPa in 6.67wt% of fiber content before going increase to 33.916 MPa in 8.33wt% of fiber content.

According to the graph of flexural modulus (Figure 4.4), the experimental values are opposite to theoretical value but it is not for all values. The value of flexural modulus of 45 μ m size fiber is shown decrease by increasing of fiber loading. The size fiber of 250 μ m shows the fiber content of 6.67wt% was decrease in 34.07 MPa before going to increase to 53.63 MPa by increasing fiber content in 8.33wt%. This condition happens when the fabrications of specimen are not property well. From the observation, it shows that most probably specimen have large void and pores produced during the fabrication of specimens. The same problem is occurred on the sample of 500 μ m size fiber where the strength is increase to 43.02 MPa in 6.67wt% of fiber content before going decrease to 33.29 MPa in 8.33wt% of fiber content.

Suppose the modulus value of specimens must be high by increasing of fiber content. The flexural modulus of the natural fiber composites showed significant improvements with the addition of the fiber as compared to PP alone. These statements are well agreed with Rozman *et al*, (1997). However, the experimental values are shown the different of theoretical value for flexural strength and flexural modulus.

4.1.1.3 Impact Testing

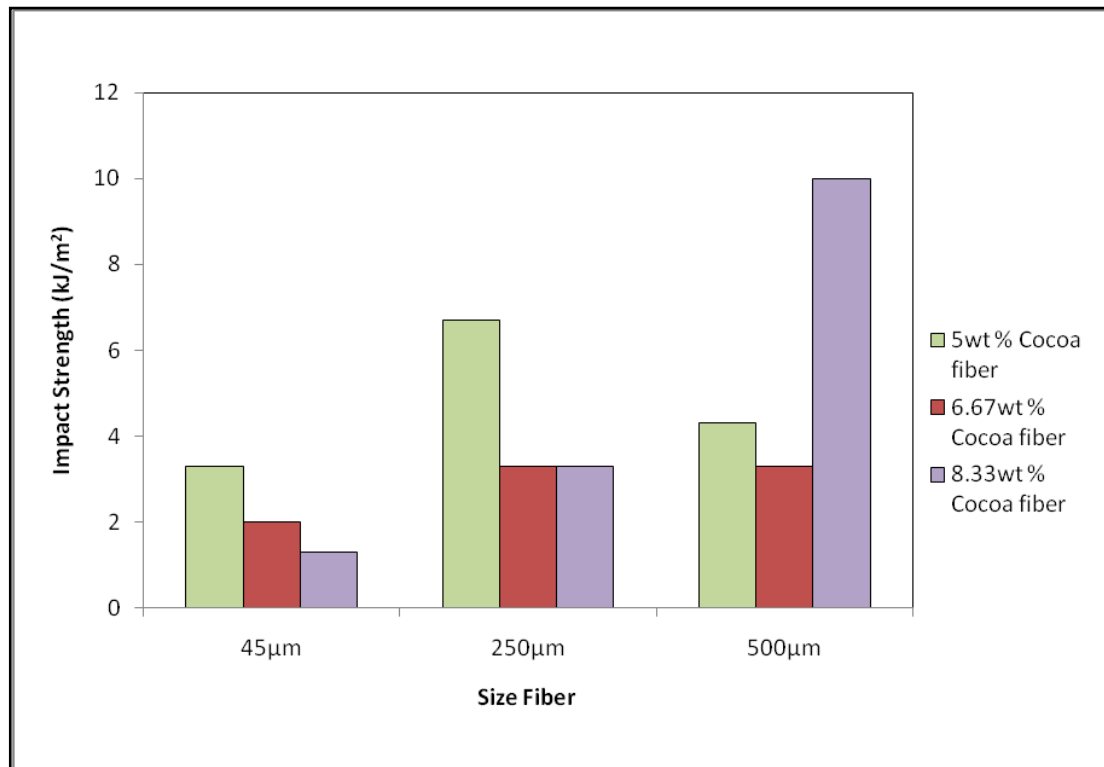


Figure 4.5: Impact Strength versus Size Fiber of Hybrid Composite

The effect of hybrid composite fibers loading on the impact strength is shown in Figure 4.5. The graph of 500µm of size fiber, it shows that the highest value compare to others. Theoretical, the largest size fiber will reduced the strength of specimens and the bonding of fiber and matrix is poor. But, the experimental shows that the largerst size is increase compare to others sizes. From the observation on the samples of 500µm, it shows that there are no bubbles and impurity compare to others samples. From the good fabrication of this sample that make the good impact resistance. The strength value for 45µm size fiber content 5wt% cocoa fiber is 3.3kJ/m² and the value is decrease to 2kJ/m² when the fiber loading is increase to 6.67wt%. The strength of impact was slightly dropped when the filler content is high to 8.33wt%.

From observation, it shows that most probably the material not bind property when the mixing. There are some defects such as pores, voids, impurity and unmelted plastics. All these defects are influences to the strength of specimens. The graph in Figure 4.5 was decrease with existing of pores and impurity in the specimens. The

same problem is occurred on the sample of 250 μm size fiber where the strength is decrease to 4.3kJ/m² to 3.3kJ/m² in 6.67wt% and 8.33wt% of fiber content before going increase to 10kJ/m² in 8.33wt% of fiber content.

Based to the mechanical properties, when fiber ratio is increase, the impact strength increases (William *et al*, (2008)). When the matrix content is high, the energy use for brake the specimen is high compared to fiber content specimen. It is because the normally composite content with the fiber is more brittle. When the energy is applied it's easy to break. This is caused in impact energy; the fiber decreased the properties of composite. As mention at tensile and flexural properties, the size and shape of fiber content is very important. Using the coarse particle of cocoa fiber, the composite break easily compared with the using fine particles. Fine particle is mix or blend well with matrix and the strength is high.

4.1.1.4 Water Absorption

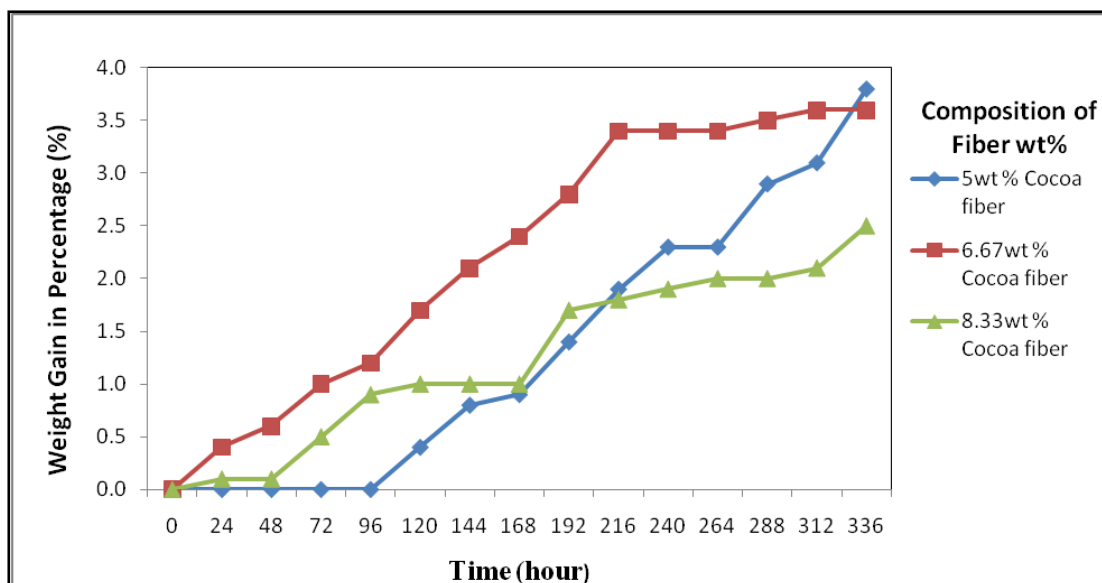


Figure 4.6: Weight Gain in Percentages versus Time for Hybrid Composite with 45 μm size fiber.

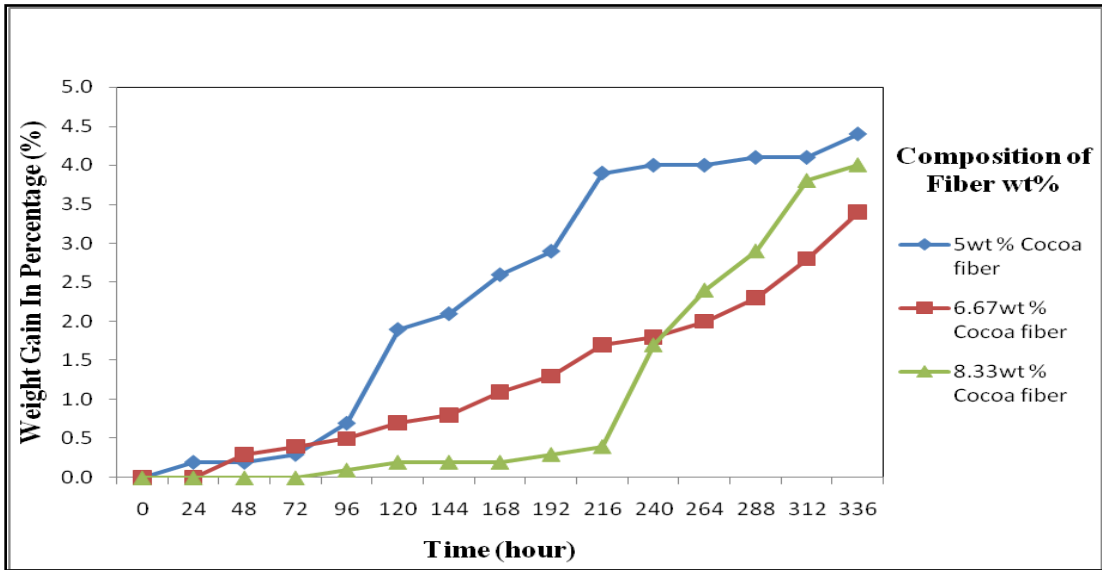


Figure 4.7: Weight Gain in Percentages versus Time for Hybrid Composite with 250 size fiber.

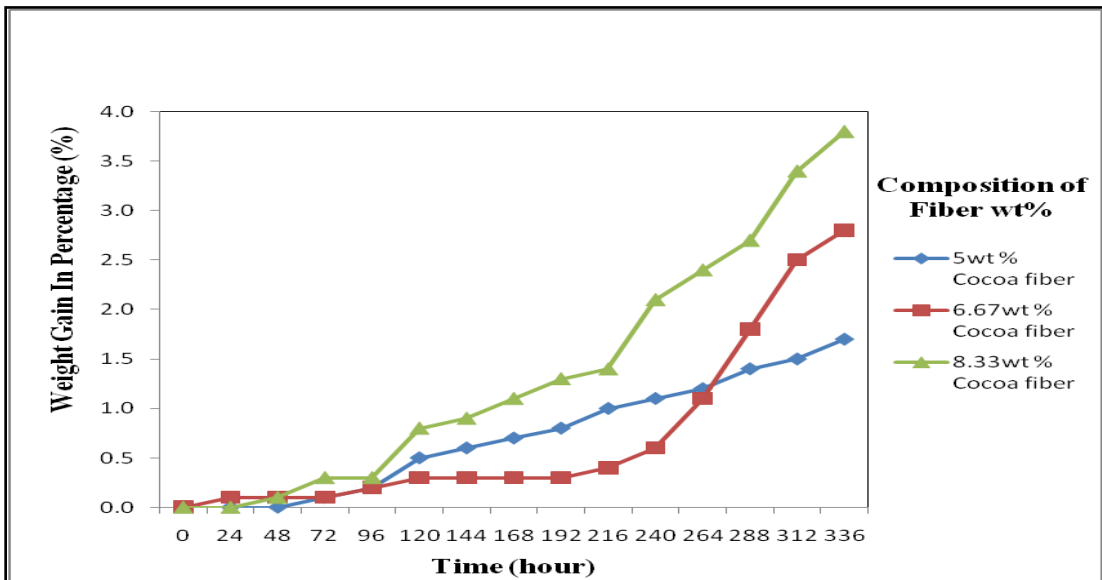


Figure 4.8: Weight Gain in Percentages versus Time for Hybrid Composite with 500µm size fiber.

Figure 4.6 shows the percentage of weight gain of 45µm size fiber and different fiber content on hybrid composite. With the addition of E-glass fiber and cocoa fiber, the weight of specimens increase after immersed in the water for 336 hour in 14days. The percentages increase in weight for specimen is proportional to the addition of the cocoa fiber and E-glass fiber, but it is not for all ratios. The highest absorption was in the specimen containing 5 wt% cocoa fiber whereas the specimen containing 8.33wt% cocoa fiber absorbs minimum amount of water. Theoretically when the

fiber content is increase to 8.33wt%, the absorb value must be increase. But the experimental value was shown that it decrease to 2.5%. When making some observation to the specimens, most probably the material not bind property when the mixing. There are some defects such as pores, voids, impurity and unmelted plastics.

The same problem is occurred on the sample of 250 μ m size fiber (Figure 4.7) where the percentage of absorption water is decrease to 4.0% in 8.33% of fiber content compare to less fiber content is increased to 4.3% in 5wt% of fiber content. According to the graph of 500 μ m (figure 4.8) shows the percentage weight of value was increase when the fiber content increases in 8.33wt% cocoa fiber. The less of fiber content was decrease to 1.7% weight gain.

4.2 Mechanical Properties of Size fiber

The size of fiber is really influence the tensile and flexural strength properties (figure 4.1 and 4.3). The size of the fiber is divided into coarse particles (around 500 μ m), large particle size (around 250 μ m) and fine particle size (around 45 μ m). The strength value was decrease in figure 4.1. After revise the tensile properties, the mechanical interlocking between cocoa fiber and matrix (PP), significantly affected the properties. When using the high percentage of cocoa fiber, it makes the composite content with micro-voids between matrix and fiber. It show that, when the micro-voids is increase the tensile modulus will increase, which indicate that finer cocoa particle structure increases the properties (Andrzej *et al.* (2006). When using the coarse particle and high quantity of cocoa fiber, its make air stored on that composite between the bonding areas. Finally this air became in micro-voids foam after the compacting process and content at bonding area. In the other hand, while using the coarse size cocoa fiber its make debonding with matrix .Some of cocoa particles is not bond proper with the molten thermoplastic and make some gap on area. So this type of defects makes the composite failure or decrease the strength. In analysis, when the larger particle size fiber is use, the strength was decrease and the modulus value was increases. Other hand, fine particle provides better flow of molten composite. In water absorption, when the fiber was added or bond with matrix (PP),

it's really tends to absorb the moisture. But in facts, E-glass does not absorb water. The more E-glass content in composite, the less of water can absorb.

4.3 Morphology Analysis

4.3.1 SEM Examination on Microstructure Surface

The microstructure surfaces from samples are observed using Scanning Electron Microscope (SEM). This is very important to study-micro-toughing occurred and the interaction between fibers and matrix. Microstructure surface of the sample of 45 μm , with 5% wt of cocoa fiber loading can be seen in Figure 4.9. The cocoa fiber cannot see clearly and the short rod is glass fiber as seen in figure 4.9. The amount of cocoa husk is less than the glass fiber. According to Hanafi Ismail *et al.*, (1997), stated that there are two distinct failure mechanisms of the fibers are observed, (i) for cocoa fiber, the particulates size have embedded into the matrix structure which is cannot be seen clearly in microscopic. It become brittle and can separate easier without showing the condition of structure of cocoa husk fiber. The composition of cocoa husk is less compare to the composition of matrix. It shows that the surface of matrix is base in the structure of hybrid composite and (ii) for glass fiber, all the fibers are nicely embedded in the matrix in random directions.

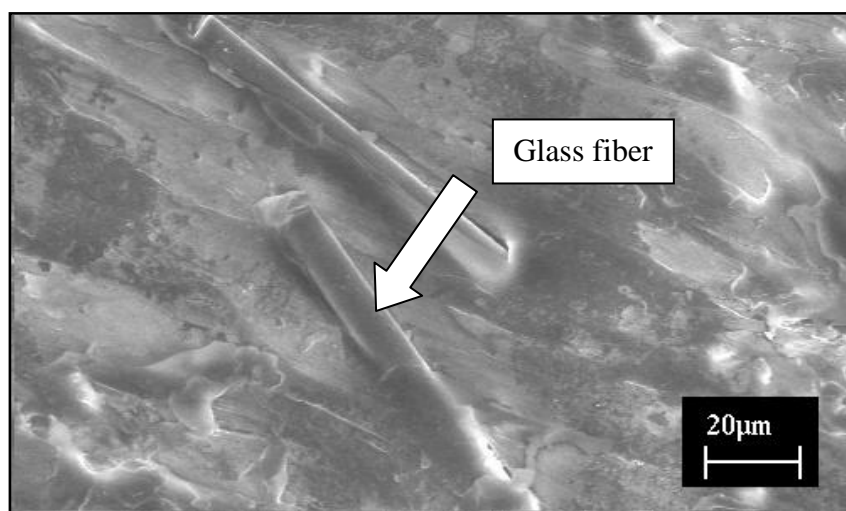


Figure 4.9: SEM micrograph of 5% wt of cocoa fiber loading hybrid composite (45 μm)

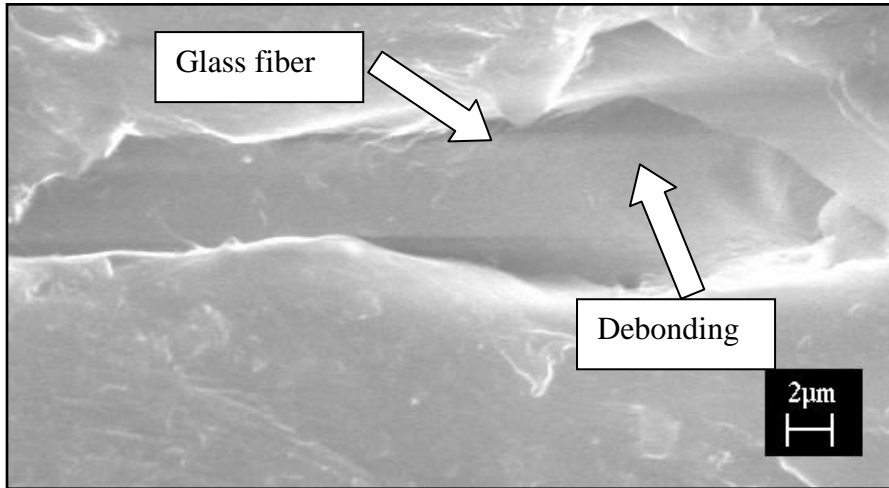


Figure 4.10: SEM micrograph of 85PP/6.67 GF/8.33CF (45µm)

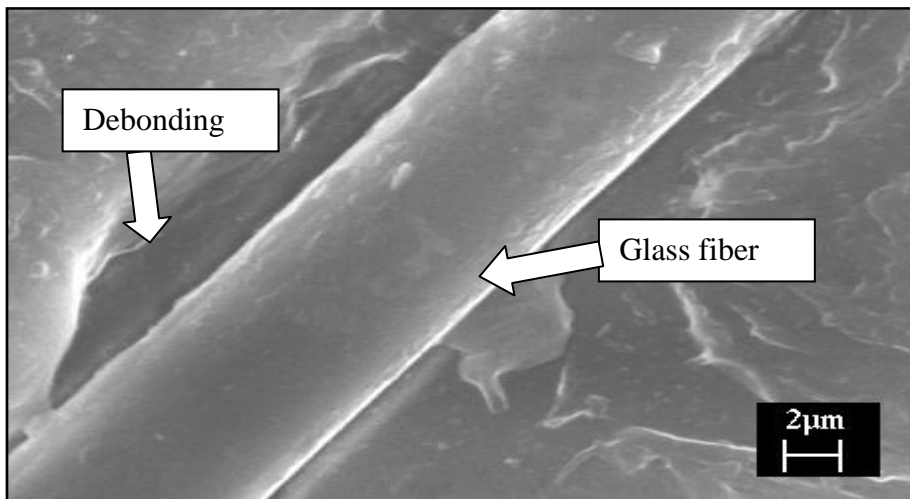


Figure 4.11: SEM micrograph of 86.67PP/6.67 GF/6.67CF (250µm)

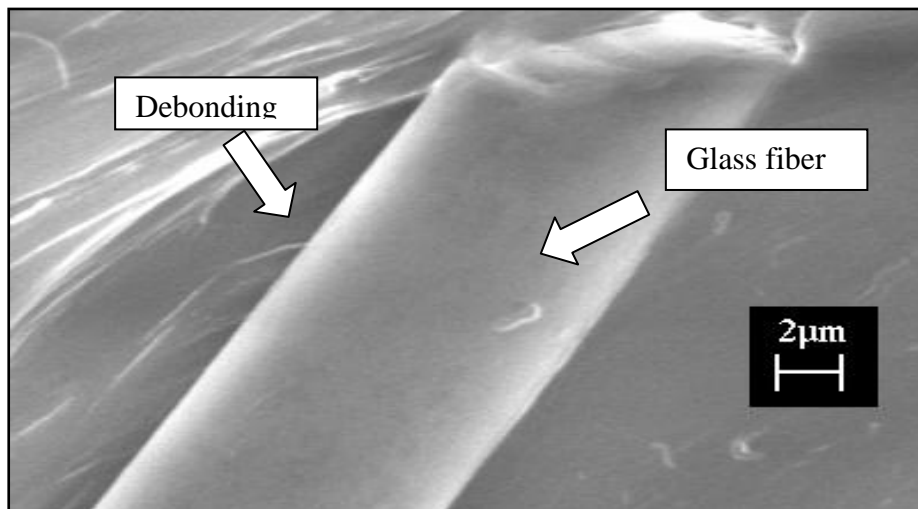


Figure 4.12: SEM micrograph of 88.337PP/6.67 GF/5CF (500µm)

From the SEM micrographs in Figure 4.10, it can be observed that glass fiber is embedded into the matrix phase. The cocoa husk fiber is not clear in this figure. The bonding of glass fiber and matrix is poor. But, the cocoa husk has good bonding with the matrix in composite. It influences with the size of fibers. The smallest size will be strong bonding to the matrix. Figure 4.11 are shown the micrograph of 86.67PP/6.67 GF/6.67CF which the size of cocoa fiber is 250 μ m. The bonding between the matrix and glass fiber are poor. This structure are not immerse with any coupling agents. The structure of cocoa husk bond with matrix is not clear. From the SEM micrographs in Figure 4.12, it can be observed that glass fiber has poor wetting debonding with matrix phase. These structures are not using any coupling agents. These failure happen that might be caused that denoted as reduction in strength. Unlike uniform synthetic fibers, irregularly shaped of fillers, their capability to support stress from matrix is rather poor. The micrographs also show that there are no interaction in between fibers and matrix. In evaluation, it shows that the cocoa fiber-glass fiber reinforced with matrix has poor bonding. It looks that, the glass fiber cannot be strong to bond with matrix and the cocoa particle can bond with matrix properly.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The effects of natural fiber reinforced hybrid composite have been investigated as a function of fiber loading, ratio and size fiber. The present work showed that the E-glass fiber reinforced composite showed a contradictory result in view of the fact that its mechanical properties should be greater than the PP alone. The decreasing of the mechanical properties was found attributed by incompatibility between the reinforcement and matrix. From water absorption observation, the highest amount of fibers will give higher absorption of water and the highest resistance of water will be effected through the same amount of fiber. The better sample is 5wt% fiber loading for 500 μ m size fiber. The comparison of size of fibers; it shows that the biggest size will absorb more water compared to the smallest sizes and the same amount of fiber will exhibit greater resistance to water entering. The defect of specimen can give an effect to water absorption. The effect of different sizes of cocoa husk fiber on the impact strength has been explained in 'Discussion' section. The combination of cocoa husk and E-glass in this present work improved the impact strength of the hybrid composites. The impact strength increased as increasing the fiber loading. The better sample is (10KJ/m²) for 500 μ m size fiber in 8.33wt% fiber loading.

This is because E-glass provided sufficient and better interfacial adhesion between fibers and matrix. This behavior strengthens the composites especially under impact loading. The impact strength of the hybrid composite depends on the amount of fiber and the type of testing. In case of notched samples, the impact strength increases with the amount of fibers added until a plateau is reached.

Generally, the mechanical properties of PP/E-glass composite can be improved by adding the natural fiber (cocoa husk) particle, except for the flexural modulus. The

better flexural strength is (49.933 MPa) for 250 μ m size fiber in 6.67wt% fiber loading and the better tensile strength is (16.07 MPa) for 250 μ m size fiber in 8.33wt% fiber loading.

The results showed that the natural fiber filled PP/E-glass hybrid composite had increased the tensile strength and tensile modulus as the loading of charcoal filler increased. Through study of morphology on the microstructure surface, it was found that the adhesion between the PP and E-glass fiber was poor. It is because this experiment is not using any coupling agents, but, other method is by using natural fiber also can solve this problem. For cocoa fiber, the particulates size have embedded into the matrix structure which is cannot be seen clearly in microscopic.

5.2 Recommendations

From this work, the following recommendations on the future work are:

- a) Do the treatment on the natural fiber before mix with others material between the PP and E-glass fiber in the E-glass fiber reinforced polypropylene specimen. The suggestions such as applying the coupling agent or the chemical modification that will develop strong bond between fiber and matrix of the PP matrix and can enhance their mechanical properties.
- b) The specimen should prepared by using various process parameters settings in order to study the effect of fiber loading on processing parameters.
 - a) - varies % of cocoa husk and glass fiber.
 - b) - minimize the size of cocoa husk and glass fiber.
- c) In future, from the investigation on cocoa husk-glassfiber/polypropylene hybrid composite, it can be use in producing product for the industries such as furniture and so on.

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APPENDIX A

Tensile testing

Table 1: Tensile Properties of Cocoa Husk fiber added with E-glass reinforced Polypropylene for Young modulus.

Composite Characteristic		Maximum stress, N/mm ² (MPa)	Maximum Strain, %	Young modulus, E (GPa)
45μm	Type A	17.4095	3.4905	4.9877
	Type B	11.9803	2.5596	4.6805
	Type C	17.6093	4.1878	4.2049
250μm	Type A	8.7929	1.3457	6.5341
	Type B	12.2143	1.6261	7.5114
	Type C	19.6954	2.8506	6.9092
500μm	Type A	20.3248	3.3169	6.1276
	Type B	16.7314	2.3511	7.1164
	Type C	15.08	2.8923	5.2138

Calculations of Testing test

1. The tensile strength or ultimate tensile strength (UTS) is the stress at the maximum on the engineering stress-strain curve. This corresponds to the maximum stress that can be sustained by a structure in tension. The formula of tensile strength in stress-stroke can be expressed:

$$f_v = \frac{F_{\max}}{b \cdot h}$$

where;

- f_v = tensile strength (MPa)
- F_{\max} = maximum load (N)
- b = width of specimen (mm)
- h = thickness of specimen (mm)

2. Young modulus is a measure of the stiffness of an isotropic elastic material. It allows the behavior of a bar made of an isotropic elastic material to be calculated under tensile or compressive loads. It is also determined from the slope of a stress-strain curve created during tensile tests conducted on a sample of the material.

Young's modulus, E , can be calculated by dividing the tensile stress by the tensile strain:

$$E = \frac{\text{tensile stress}}{\text{tensile strain}}$$

$$E = \frac{\sigma}{\epsilon}$$

Where,

E = Young's modulus (modulus of elasticity)

F = the force applied to the object;

A_0 = the original cross-sectional area through which the force is applied;

ΔL = the amount by which the length of the object changes;

L_0 = the original length of the object.

Water Absorption

WEIGHT OF SPECIMEN									
HOUR	45 μ m			250 μ m			500 μ m		
	A	B	C	A	B	C	A	B	C
WEIGHT	0.2697	0.2757	0.2570	0.2617	0.2623	0.2623	0.2647	0.2607	0.2590
24	0.2697	0.2767	0.2573	0.2621	0.2623	0.2623	0.2647	0.2609	0.2591
48	0.2698	0.2773	0.2573	0.2623	0.2630	0.2624	0.2648	0.2609	0.2593
72	0.2698	0.2784	0.2584	0.2624	0.2633	0.2624	0.2649	0.2610	0.2597
96	0.2698	0.2789	0.2593	0.2635	0.2635	0.2625	0.2651	0.2611	0.2599
120	0.2709	0.2803	0.2595	0.2666	0.2641	0.2627	0.2660	0.2615	0.2611
144	0.2719	0.2814	0.2595	0.2673	0.2645	0.2627	0.2663	0.2615	0.2613
168	0.2721	0.2824	0.2596	0.2685	0.2651	0.2629	0.2665	0.2616	0.2619
192	0.2735	0.2835	0.2613	0.2694	0.2656	0.2631	0.2669	0.2616	0.2623
216	0.2747	0.2850	0.2617	0.2720	0.2667	0.2633	0.2673	0.2617	0.2627
240	0.2758	0.2851	0.2619	0.2722	0.2617	0.2667	0.2675	0.2623	0.2644
264	0.2760	0.2851	0.2621	0.2722	0.2675	0.2687	0.2680	0.2635	0.2653
288	0.2775	0.2853	0.2621	0.2723	0.2683	0.2699	0.2685	0.2653	0.2660
312	0.2780	0.2855	0.2623	0.2723	0.2697	0.2723	0.2687	0.2673	0.2677
336	0.2797	0.2856	0.2633	0.2733	0.2711	0.2735	0.2693	0.2680	0.2689
360	0.2817	0.2857	0.2653	0.2743	0.2731	0.2745	0.2730	0.2703	0.2725
384	0.2833	0.2863	0.2683	0.2753	0.2740	0.2777	0.2740	0.2711	0.2737
408h	0.2834	0.2863	0.2686	0.2759	0.2753	0.2787	0.2745	0.2723	0.2744

Impact Test

WEIGHT OF SPECIMEN									
HOUR	45µm			250µm			500µm		
	A	B	C	A	B	C	A	B	C
WEIGHT	0.2697	0.2757	0.2570	0.2617	0.2623	0.2623	0.2647	0.2607	0.2590
24	0.2697	0.2767	0.2573	0.2621	0.2623	0.2623	0.2647	0.2609	0.2591
48	0.2698	0.2773	0.2573	0.2623	0.2630	0.2624	0.2648	0.2609	0.2593
72	0.2698	0.2784	0.2584	0.2624	0.2633	0.2624	0.2649	0.2610	0.2597
96	0.2698	0.2789	0.2593	0.2635	0.2635	0.2625	0.2651	0.2611	0.2599
120	0.2709	0.2803	0.2595	0.2666	0.2641	0.2627	0.2660	0.2615	0.2611
144	0.2719	0.2814	0.2595	0.2673	0.2645	0.2627	0.2663	0.2615	0.2613
168	0.2721	0.2824	0.2596	0.2685	0.2651	0.2629	0.2665	0.2616	0.2619
192	0.2735	0.2835	0.2613	0.2694	0.2656	0.2631	0.2669	0.2616	0.2623
216	0.2747	0.2850	0.2617	0.2720	0.2667	0.2633	0.2673	0.2617	0.2627
240	0.2758	0.2851	0.2619	0.2722	0.2617	0.2667	0.2675	0.2623	0.2644
264	0.2760	0.2851	0.2621	0.2722	0.2675	0.2687	0.2680	0.2635	0.2653
288	0.2775	0.2853	0.2621	0.2723	0.2683	0.2699	0.2685	0.2653	0.2660
312	0.2780	0.2855	0.2623	0.2723	0.2697	0.2723	0.2687	0.2673	0.2677
336	0.2797	0.2856	0.2633	0.2733	0.2711	0.2735	0.2693	0.2680	0.2689
360	0.2817	0.2857	0.2653	0.2743	0.2731	0.2745	0.2730	0.2703	0.2725
384	0.2833	0.2863	0.2683	0.2753	0.2740	0.2777	0.2740	0.2711	0.2737
408h	0.2834	0.2863	0.2686	0.2759	0.2753	0.2787	0.2745	0.2723	0.2744

Gantt Chart

Table 1: Gantt Chart for PSM I

PROJECT TITLE		A MECHANICAL STUDY ON COCOA HUSK – GLASS FIBER/ POLYPROPYLENE (PP) HYBRID COMPOSITE																	
NO	PROJECT TASK	STATUS		WEEK															
		Done	Progress	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	
1	Title selection	√	100%	→															
2	Research & analyze	√	100%		→	→	→	→	→	→									
3	Introduction	√	100%			→	→	→	→	→	→	→	→	→	→				
4	Literature review	√	100%					→	→	→	→	→	→	→	→	→			
5	Methodology	√	100%					→	→	→	→	→	→	→	→	→			
6	Expected result	√	100%							→	→	→	v		→	→			
7	Finalize report										→	→	→	→	→	→			
8	Report submission																→		
9	Preparation & finalize presentation																→	→	
10	Presentation																	→	
DESCRIPTION		Plan		Actual	→	Delay													

Table 2: Gantt Chart PSM II

PROJECT TITLE			A MECHANICAL STUDY ON COCOA HUSK – GLASS FIBER/ POLYPROPYLENE (PP) HYBRID COMPOSITE																
NO	PROJECT TASK		STATUS			WEEK													
			Done	Progress	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
1	Laboratory Training		√	100%	→														
2	Sample Preparation		√	100%		→	→	→	→	→	→								
3	Mechanical Testing		√	100%			→	→	→	→	→	→	→	→	→	→	→	→	→
4	Microstructure Inspection		√	100%					→	→	→	→	→	→	→	→	→	→	→
5	Writing for Results		√	100%					→	→	→	→	→	→	→	→	→	→	→
6	Writing for Discussions		√	100%							→	→	→	→	→	→	→	→	→
7	Writing for Conclusions		√								→	→	→	→	→	→	→	→	→
8	Compilation PSM II		√								→	→	→	→	→	→	→	→	→
9	Final check		√														→	→	→
10	Submission		√																→
DESCRIPTION		Plan	Actual	→	Delay														