IMPACT BEHAVIOUR OF COCONUT SHELL REINFORCED POLYMER COMPOSITES

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A report submitted
in fulfillment of the requirements for the degree of
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DECLARATION

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

Signature :..................................

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Date : 25th June 2019

APPROVAL

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

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Date : 25th June 2019

DEDICATION

To my beloved family

ABSTRACT

To date, there is a large body of knowledge in the literature on the development of natural composites. Nonetheless, some of the main limitation is the brittleness of the natural composites when using Polyester resin as a matrix can lead to poor mechanical performance of natural composites. Thus, the main objectives of this project are i) to fabricated Coconut Shell Reinforced Polymer Composite and ii) to study the impact behavior of Coconut Shell Reinforced Polymer Composite. In this project, the coconut shells were started by reinforcing coconut shell particle using a blender. The size of coconut shell was sieved at 500µm size using vibratory sieve shaker. The coconut shell composites were prepared from 0 wt% Coconut Shell Powder (CSP) following 10 wt% of CSP and 25 wt% of CSP. Open moulding method was used in this project by mixing the Unsaturated Polyester (USP) Resin and CSP using a stirrer machine. This project following Standard Test Method for Measuring the Damage Resistance of Fiber Reinforced Polymer Matrix Composite to a drop Weight Impact Loading (ASTM D7136). The impact behavior of the Coconut Shell Polymer Composites were investigated under drop weight impact test. The experimental began with 0 wt% CSP following 10 wt% and 25 wt% CSP at 1 m/s, 2 m/s and 3 m/s velocities. The result obtained was determined by collecting data from energy absorbed, force and displacement. This project shows as increase the impact velocity, the energy absorbed by the specimen also increase. 0 wt% CSP gives the highest energy absorbed which is 6.071 J. This test suggests 25 wt% specimen for material application due to lowest energy absorbed which is 0.684 J. The presence of 10 wt% CSP gives larger damage area compared to 25 wt% CSP. It shown the 25 wt% CSP gives better impact performance than 0 wt% CSP and 10 wt% CSP at 1 m/s low velocity impact or impact energy.

ABSTRAK

Sehingga kini, terdapat banyak pengetahuan dalam kesusasteraan mengenai perkembangan komposit semulajadi. Walau bagaimanapun, beberapa batasan utama adalah keruntuhan komposit semulajadi apabila menggunakan resin poliester sebagai matriks boleh menyebabkan prestasi mekanikal komposit semulajadi yang tidak baik. Oleh itu, matlamat utama projek ini adalah i) untuk fabrikasi Komposit Polimer Bertetulang Tempurung Kelapa dan ii) untuk mengkaji tingkah laku kesan Komposit Polimer Diperbuat daripada Tempurung Kelapa. Dalam projek ini, cangkang kelapa dimulakan dengan menguatkan zarah kelapa menggunakan pengisar. Saiz tempurung kelapa dipancarkan pada saiz 500μm menggunakan ayak penggetar. Kompos komposit kelapa telah disediakan dari 0 wt% Powder Shell Coconut (CSP) berikut 10% berat CSP dan 25% berat CSP. Kaedah pembukaan terbuka digunakan dalam projek ini dengan mencampurkan Resin Poliester Tidak Teratur (USP) dan CSP menggunakan mesin pengaduk. Projek ini mengikuti Kaedah Ujian Piawaian untuk Mengukur Rintangan Kerosakan Komposit Matriks Polimer Diperkuat Gentian ke penurunan Pengaruh Berat Berat (ASTM D7136). Tingkah laku kesan Polimer Komposit Polimer Kelapa telah disiasat di bawah ujian kesan penurunan berat badan. Eksperimen bermula dengan 0% berat CSP berikut 10% berat dan 25% berat CSP pada 1 m / s, 2 m / s dan 3 m / s halaju. Hasil yang diperoleh ditentukan dengan mengumpulkan data dari tenaga yang diserap, daya dan perpindahan. Projek ini menunjukkan sebagai meningkatkan kelajuan impak, tenaga yang diserap oleh spesimen juga meningkat. 0 wt% CSP memberikan tenaga tertinggi yang diserap iaitu 6.071 J. Ujian ini mencadangkan spesimen 25 wt% untuk aplikasi material kerana tenaga terendah yang diserap iaitu 0.684 J. Kehadiran 10 wt% CSP memberikan kawasan kerosakan yang lebih besar berbanding dengan 25% CSP. Ia menunjukkan bahawa 25% berat CSP memberikan prestasi impak yang lebih baik daripada 0% berat CSP dan 10% berat CSP pada kesan kelajuan rendah atau kesan impak rendah 1 m / s.

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LIST OF ABBEREVATIONS

CS	Coconut Shell
CCS	Crushed Coconut Shell
USP	Unsaturated Polyester
FRC	Fiber Reinforcing Composite
PMC	Polymer Matrix Composite
MMC	Metal Matrix Composites
CMC	Ceramic Matrix Composites
CSP	Coconut Shell Powder

CHAPTER 1

INTRODUCTION

1.1 Background

The interest in utilizing natural fibre as reinforcement has incremented dramatically during the last few years. Natural fibres can be divided into three subgroups, plant, animal and mineral fibres. Plant fibres such as flax, cotton and hemp are short or at least discontinuous and based generally on cellulose. Mineral fibres such as asbestos are also short, being rarely longer than a few centimetres and their fully crystalline structure places them apart from the others. Animal fibres which are based on animal protein can be discontinuous as in the case of wool or they can be virtually continuous as with silk. Coconut shell is one of the most important natural fillers engendered in tropical countries like Malaysia, Thailand, Indonesia, India and Sri Lanka. Fibre reinforced polymer matrix got considerable attention in numerous applications because of the good properties and superior advantages. The advantages of natural fillers are their low cost, high toughness, corrosion resistance, low density, good specific strength properties, low cellulose content, recyclable and biodegrable. (Kim, 2010)

A composite material is a cumulating of two or more distinct constituents all of which are present in plausible proportions and have different properties so that the composite property is conspicuous different from that of each other of the constituents. Composites are widely used in both military and civilian industries. They are used in the manufacture of a variety of products ranging from aircraft, spacecraft, satellites, missiles and rockets, marine equipment's and automobile components. Composite can be designed and fabricated to obtain various properties that suit specific applications. The polymer used as matrix materials can be divided in two primary families, the natures of which depend on their molecular structures. These are thermoplastic and thermosetting resins.

When resins are reinforced the composite which is formed has properties which depend on both the resin properties and those of the fibres and their arrangements. Polyester resins are most widely used in general purpose composites but epoxy resins represent the most important group of resin systems used in high performance composites. (Renard and Bunsell, 2005)

1.2 Problem Statement

The application of natural fibre reinforced polymer composite is increasing rapidly. This is especially related to certain problems concerning the utilization of synthetic fibre reinforced composites. As far as synthetic polymer composites ae concerned, waste disposal and recycling are major issues. Landfill disposal being increasingly excluded around the world due to growing environmentally sensitivity. It need to cover factors such as efficient cost effective and environmentally friendly recovery of raw materials, carbon dioxide thermal utilization or bio degradation in certain circumstances. Consequently, the fibres are usually strong polar materials and exhibit significant hydrophilicity. Most polymer matrices tend to be a polar and hydrophobic. As a result, there are significant problems of compatibility between fibre and matrix, leading to poor dispersion, a weak interface and ultimately inferior quality composites. Such compatibility problems have to be tackled with use appropriate methods to improve adhesion between fibre and matrix. This has possible general strategy to achieve this goal which is modify the matrix properties. The addition of natural fibres can influence processing thus some negative effects such as corrosion or abrasion of screw, barrel and mould can appear. It is important to consider that in some cases selected processing parameters need to be changed. A single drop weight test can produce several different damage modes simultaneously. In fibre reinforced polymer composite the damages can marginally detect so it is important to identify the factor that contributes to the damages and characteristics of impact test for fibre reinforced polymer composites.

1.3 Objective

The objectives of projects are:

1. To fabricate coconut shell reinforced polymer composite.
2. To investigate the impact behaviour of coconut shell reinforced polymer composite under impact loading.

1.4 Scope of Project

The scopes of projects are:

1. Type of fibre reinforced material used in natural fibre plant which is coconut shell.
2. Use of unsaturated polyester resin as a thermosetting polymer. Variation in the basic components of the polyester chain an in the ratio of the saturated and unsaturated components allows a wide range of resins to be produced to meet different performance requirements. It is also low cost other than resin.
3. Type of process used for coconut shell fibre reinforced polymer is open moulding.
4. Types of experiment which is drop weight test that include ratio of coconut shell powder and velocity parameters.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Composites

Composite material is a combination of two or more different materials to create unique and superior materials. There are several composite of classifications. The most common is Polymer Matrix Composite (PMC) or Fibre Reinforced Polymers (FRP). For this classification, polymer is used as the matrix and natural fibre as reinforcement. The fibres are usually glass, carbon and natural fibre. For the polymers that commonly used are polypropylene, polyethylene (thermoplastics) and epoxy, polyester (thermosets). Classification of matrix can be made based on the matrix material composite. They are Polymer Matrix Composites, Metal Matrix Composites and Ceramic Metal Composites. Figure 2.1 below shows the classification of matrix.

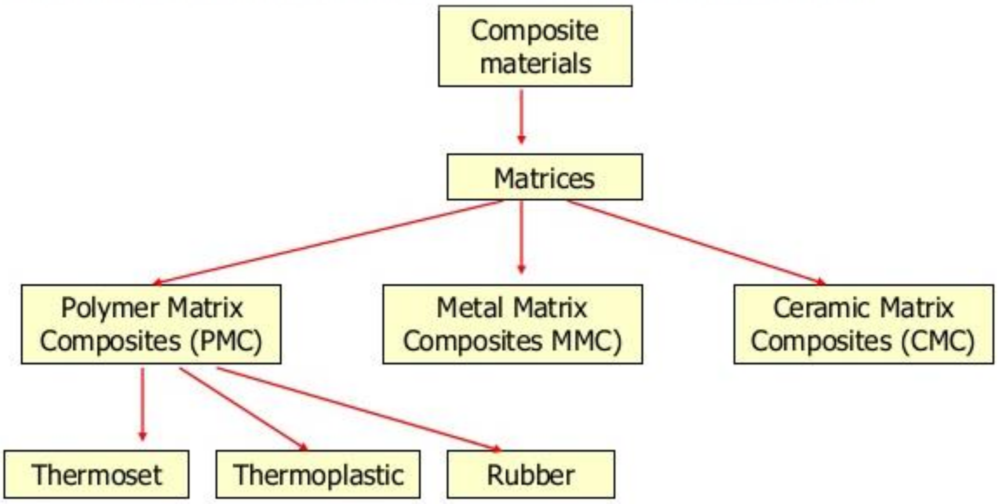


Figure 2.1: Classification of matrices (Nagappa, 2015)

Polymer Matrix Composites (PMCs) are advanced materials used in a variety of engineering applications because of their desirable-specific properties such as high strength and weight ratios that are not fully exploited yet (Anthony Waas, 2008). Most of the polymer matrix composites are filled with different inorganic fillers such as silicon carbide, aluminium oxide, silica, magnesium hydroxide, zinc oxide to achieve the desired mechanical properties. (Kiran, 2017). High-temperature polymer matrix composites comprising high temperature thermosetting polyimide resins reinforced with carbon fibres have emerged as an important class of aerospace materials that offer light weight combined with damage tolerance. Polymer matrix composites (PMCs) with advanced polyimide matrices that offer improved high-temperature capability are currently being considered for applications at temperatures previously limited to metals. (Ruggles-Wrenn and Noomen, 2018)

(Krishan Chawla, 2013) presented that Metal Matrix Composites consist of a metal or an alloy as the continuous matrix and a reinforcement that can be particle, short fibre or continuous fibre. They are three kinds of MMCs:

- Particle reinforced MMCs

- Short fibre reinforced MMCs
- Continuous fibre reinforced MMCs

Ceramic Matrix Composites(CMCs) have a very attractive package of properties which is high strength and high stiffness at very high temperatures. They are also having flaw properties because they are prone to catastrophic failures easily at surface or internal. They are extremely susceptible to thermal shock and easily damaged during fabrication. (Krishnan Chawla, 2013)

Based on the studies by (Lopresto et al, 2016) has mentioned that composite materials are made of two or more different materials to create properties that cannot be obtained from any one material component alone. In the composite, one of the materials is performed as matrix while the other one is performed as reinforcement. The properties of composite material are depending on the nature reinforcement and matrix. However, the composite can be telling they are combination between two materials but they do not dissolve or blend into each other easily, the materials need to undergoes several process before it become a new composite material.

2.1.1 Definition of Composites

Polymer composites are multi-phase materials produced by combining polymer matrix with fillers and reinforcing fibre to produce a bulk material with properties better than those of the individual base materials. The matrix can be thermoplastics, polyvinyl chloride or thermosetting. Fibres are used to reinforce the polymer and improve mechanical properties such as elasticity, strength, hardness and ductility. High strength fibres of glass, aramid and carbon are used as the primary means of carrying load, while the polymer matrix protects the surface of fibre and binds them into a cohesive structural unit. These are commonly called fibre-reinforced polymer composite materials. (Subrata Chandra Das, 2014)

2.1.2 Characteristic of Composites

Fibre and reinforcements generally increase the load carrying capacity and strength and reduce the extent of interaction of the polymer with the counter face. Fibres are wear resistant and wear preferentially to the matrix. The performance of fibre reinforced polymers depends on the type of fibre and matrix, concentration, distribution, aspect ratio, alignment and its adhesion to the matrix. (Fahim, 2008)

Natural fibre reinforced composites there is a lack of good interfacial adhesion between cellulose fibres and the hydrophobic resins due to their inherent incompatibility. The presence of waxy substances on the fibre surface contributes immensely to ineffective fibre to resin bonding and poor surface wetting. Similarly, the presence of free water and hydroxyl groups, especially in the amorphous regions, worsens the ability of plant fibres to develop adhesive characteristic with most binder materials. High water and moisture absorption of the cellulose fibres causes swelling and a plasticizing effect resulting in dimensional instability and poor mechanical properties. Fibres with high cellulose content have also been found to contain a high crystalline content. These are the aggregates pf cellulose blocks held together closely by the strong intermolecular hydrogen bonds which large molecules. (Fahim and Chand, 2008)

2.1.3 Applications of Composites

The main application of the natural fibre reinforced composites is in the automotive industry area, which has developed various new components based on natural-fibre composites. Natural fibre reinforcement in blended thermoplastics or resonated thermoset compression mouldings is now generally accepted for applications as door liners, parcel shelves and boot liners. The automotive components with natural fibre reinforced composites can be expected to increase steadily with increased model penetration. But the new invention is that, nowadays, natural fibre composites are used also in the exterior components of an automotive.

Recent research and development (Aková, 2013) shown that composite materials are increasingly used in the automotive and construction industries. The composite materials are chemically treated to highly cross linked or three dimensional network structure which is highly solvent resistant, tough and creep resistant. Thermoplastics are more advantageous than thermoset because it has low processing cost, ease of moulding complex parts, flexible, tough and show good mechanical properties.

Natural fibre composites are commonly used for manufacturing many components in the automotive sector. This is because the characteristic of natural composite fibre composites are highly ultimate breaking force and higher impact strength. Plant fibres are mainly used in this manufacture because of its reduction in weight about 10%, energy production of 80% and 5% cost reduction. (Aková, 2013). For example, the recent appliances using natural fibres over the world as presented in Figure 2.2.

Figure 2.2: Fibre Reinforced Polymer Composites Applications (Daniel Gay, 2014)

2.1.4 Polymer Matrix Composites

(Udhayasankar, 2015) represented that polymer matrix composites can be classified according to whether the matrix is a thermosets or a thermoplastic polymer. Thermosets are solidified by irreversible chemical reactions, in which the molecules in the polymer form connected chains. The most thermosetting matrix materials for high performance composites used in the aerospace industry are the epoxies.

Thermoplastic matrix composites are currently the focus of rapid development and even though the manufacturing technologies for thermoplastic are normally not as well developed as those for thermoset. The thermoplastic provides several advantages, such as low manufacturing cost, high toughness, good hot and wet properties, high environmental tolerance and good corrosion resistance. The main disadvantages of thermoplastic-matrix are high processing temperature, high viscosities, high coefficient of thermal expansion and they generally do not resist heat as well as thermosets.

However, improvements are being made in developing thermoplastics with a higher melting temperature. Fibrous polymer matrix composites can be classified according to whether the fibrous are short or continuous. The continuous fibres are more efficient at resisting loads than short ones, but it is more difficult to fabricate complex shapes from materials containing continuous fibres than from short fibre or particle reinforced material. This is because of the relatively low processing temperature required to fabricate polymer-matrix composites. For thermosets such as epoxy, phenolic polyester, vinyl ester, cyanate ester and polyamides, the processing temperature typically ranges from room temperature to about 2000°C. Thermoplastic polymer such as polypropylene, poly vinyl chloride, poly sulfone, poly ether either ketone, polyamide, nylon, polycarbonate and polyphenylene sulfide, the processing temperature typically ranges from 3000°C to 4000°C. The moulding methods are those conventionally used for polymer by themselves.

For thermoplastic methods include injection moulding, extrusion, calendaring and thermoforming. For thermosets methods include compression moulding or matched die moulding. Depending on the application and on the type of load to be applied to the composite part, the reinforcement can be random, unidirectional multidirectional. If the load is uniaxial, the fibres are all aligned in the load direction to gain maximum benefit of their stiffness and strength. However, for multidirectional loading, the fibres must be oriented in a variety of directions. This is often accomplished by stacking layers of continuous-fibre systems.

2.2 Matrices of Composites

The polymers used as matrix materials can be divided into two primary families, the natures of which depend on their molecular structures. These are thermosetting and thermoplastic resins.

2.2.1 Thermoplastic

(Bunsell and Renard, 2005) carried out that thermoplastics are polymers which undergo dramatic changes to their mechanical properties when they are heated above their glass transition temperature but these changes are reversed on lowering the temperature and no structural modification at the molecular level occurs. Unlike the thermosetting resins the macromolecules making up the thermoplastics possess no reactive lateral bonds which can link them strongly with other molecules. Lateral bonding is through secondary forces such as hydrogen and van der Waals bonds and entanglement of the molecules. The effect of heating above the transition temperature is to supply enough energy to the polymer to liberate the molecules from these boundary bonds and allow free movement of the linear molecule structure. This is exploited in the forming of such thermoplastics, which can be rapid as it requires only heating the material to a high enough temperature.

Thermoplastic materials such as polyamide, thermoplastic polyester and polypropylene have become widely used as matrix materials for short fibre reinforced composites made by injection moulding and more recently are increasingly being considered for long or continuous fibre reinforced materials. Thermoplastics in and principle can be recycled and the final form of a structure can be modified by reheating and further forming. Processing times depend on the time to melt the thermoplastic and can be extremely rapid. Fibber impregnation is not as easy as with thermosets and is usually the responsibility of specialist material suppliers as the thermoplastic has be molten and fibre matrix adhesion controlled. (Bunsell and Renard, 2005)

2.2.2 Thermosetting

Thermosetting resins have been used the longest as matrices for composites and are materials which undergo and transformation of their molecular structure during the manufacture of the composite material. This is because the long macromolecules which make up thermosetting resins possess reactive bonds which can be opened by a hardener to form strong covalent lateral links with other molecules.

At room temperature, the resin starts as a viscous liquid, which in the presence of the hardener to initiate the crosslinking reaction and usually heating, changes to a rigid solid possessing a three-dimensional molecular network. Cooling to is original temperature reveals a completely modified material which is solid. The reactions are therefore irreversible. (Abhishek Dwivedi and Prem Kumar Bharti, 2015)

2.2.3 Polyester Resin as Matrix of Composite

This is the commercially most important resin system used with composite materials. It is not considered to be a high performance matrix system and so is not found in advanced composites, but it is very widely used for general purpose composite applications. Variation in the basic components of the polyester chain and in the ratio of the saturated and unsaturated components allows a wide range of resins to be produced to meet different performance requirements. Reactions generally occur quickly, but in a controllable manner to give a cross linked thermoset structure.

2.3 Natural Fibre Reinforcement

Natural fibre composites mostly consist fibres of jute, cotton, hemp and nonconventional fibres such as coir and many empty fruit bunches (Verma et al., 2013). All these fibres are growth in agricultural plants in various parts of the world and are commonly used for making ropes, carpet backing, bags, and so on. The components of natural fibres are cellulose micro fibrils dispersed in an amorphous matrix of lignin and hemicellulose.

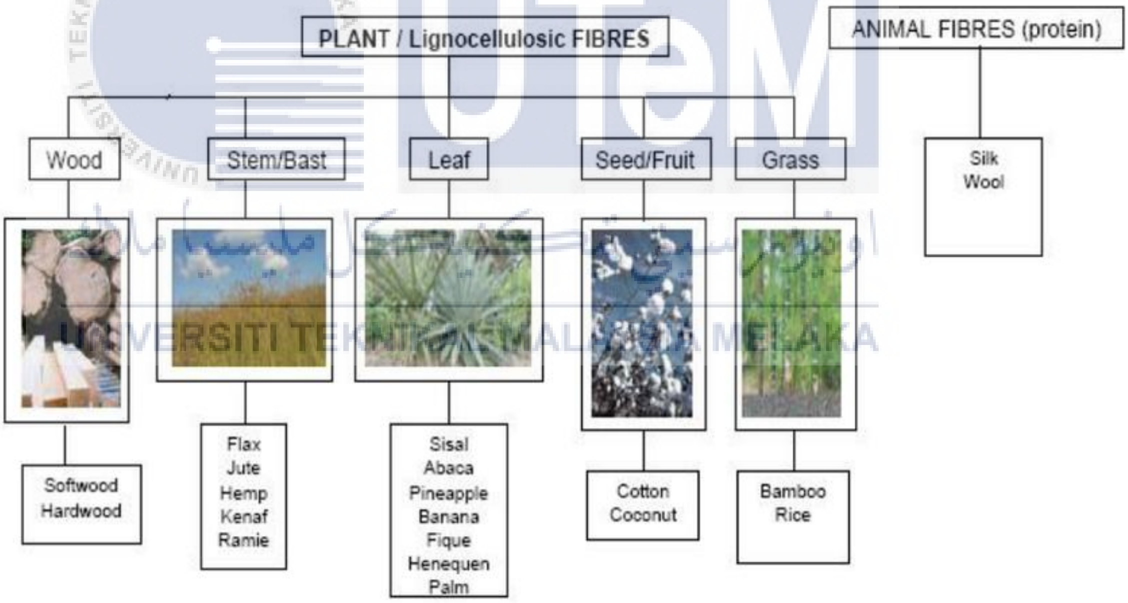


Figure 2.3: Classification of natural fibres (Chandramohan and Marimuthu, 2011)

2.3.1 Coconut Shell as Reinforcing Material

Based on the (Udhayasankar, 2015) carried out that coconut is a member of the palm family, which is one of the food crops in the world. It generates large amounts of waste material, namely coconut shell (CS). CS is non-food part of coconut which is one of the hard lignocellulosic agro wastes. Agro waste products such as CS is an annual increase every year and is available in abundant volume throughout the world10. Particularly CS is one of the most significant natural fillers produced in tropical countries like India, Malaysia, Indonesia, Thailand and Srilanka. Several workers have been dedicated to use of other natural fibre in composite in the latest post and CS fibre is a potential candidate for the improvement of new composites because of their high strength and modulus properties. Composite fibre can be used in, the board range of application such as, building material, furniture and fishnets. Coconut fibre is important reinforcement material in fabrication of various types of polymer based composites, due to cost effectiveness, high strength, etc11. Presently 90% CS was disposed as waste and either burned in the open air or left Seattle in waste ponds. This way the coconut processing industries waste according to him contributed significantly to CO_2 and methane emissions. Based on economic as well as environmental related issues, this effort should be directed worldwide towards coconut management issues i.e. of utilization, storage and disposal. Different avenues of CS utilization are more or less known, but none of them have so far proved to be economically viable or commercially feasible.

The CS agro waste lignocellulosic filler exhibits some admirable properties compared to mineral filler (e.g. Calcium carbonate, kaolin, mica and talc) such as low cost, renewable, high specific strength-to-weight ratio, minimal health hazard, low density, less abrasion to machine, certainly biodegradability and environmental friendly. However, due to the presence of strong polarized hydroxyl groups on the surface of lignocellulosic fillers, the formation of a strong interfacial bonding with Anon polar polymer matrix becomes complex as the hydrogen bonds tend to prevent the wetting of the filler surfaces. As a result, lignocellulosic fillers show poor mechanical properties in polymer composites due to the lack of interfacial adhesion. Alternatively, the interfacial adhesion among filler and matrix can be enhanced by surface modification of filler. Currently there are many methods to promote the interfacial adhesion between the lignocelluloses filler and polymer matrix, such as alkaline treatment, esterification, silane treatment, using compatibilizers and treatment with other chemical compound, when appropriate modifications and production procedures applied. CS displays improved mechanical properties such as tensile strength, flexural strength, flexural modulus, hardness and impact strength.

The low density, high cellulose content, and plenty of CS fibre, make them popular in Southeast Asia and other areas for a number of rope, fibre, and textile applications. Other benefits using the fibres of coconut coir include its toughness, low density, low cost and biodegradability. Several different types of biocomposites are already existing, including those composed of biodegradable plant-based or animal-based natural fibres, such as flax, jute, silk, or wool. When this biocomposite material was tested for dimensional stability, it exhibited very low water absorption rates of less than three percent and low thickness swelling of less than one percent. These results have shown that plant-based fibres may be used as reinforcement in a composite system to improve the properties and performance of polymer matrix resins. The better strength and stiffness, in addition to the lower weight of natural fibres can make the composite tiles useful in vehicle plates, some industrial applications and for walls and floors in construction. (Karthikeyan, 2015)

CHAPTER 3

METHODOLOGY

3.1 Introduction

The project starts with the study of literature review from the various sources, specimen preparation and impact test to study behaviour of coconut shell reinforced polymer composites. The raw materials used in this project are coconut shell, unsaturated polyester and hardener. Figure 3.1 shows the flowchart of the project.

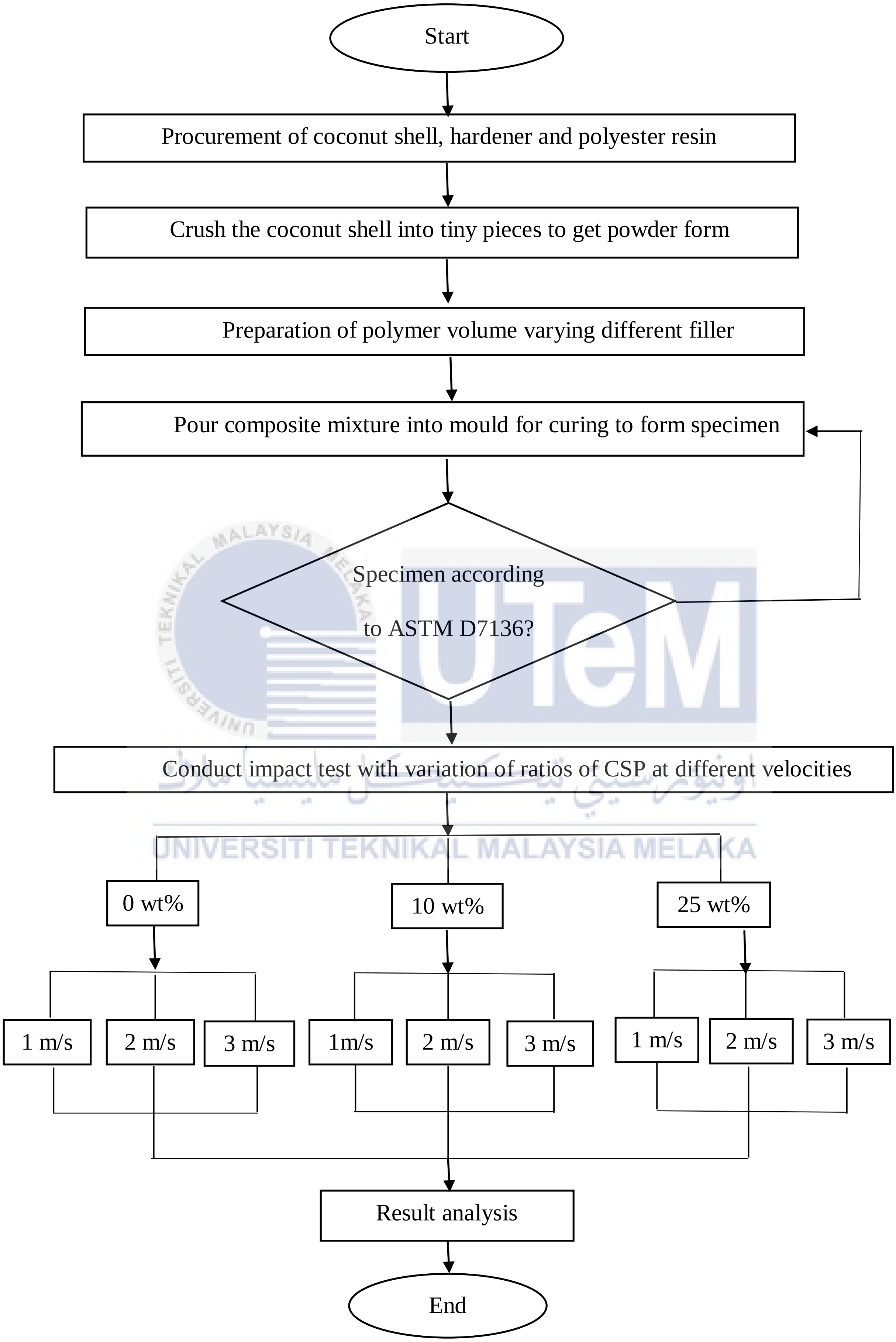


Figure 3.1: Flowchart of project

3.2 Specimen Preparation

The density of the composite was determined to find all overall weight of the composite. It can be done by applying the Law of Mixture. Then, volume of the specimen was acquired by using formula Length X Width X Thickness. Next, the data will be inserted into the Law of Mixture.

Density of coconut shell, $\rho_f = 1.6\ g/cm^3$

Density of polyester resin, $\rho_m = 1.23\ g/cm^3$

Volume of specimen mould = Length x Width X Thickness

$= 100mm \times 100mm \times 2.5mm$

$= 25\ cm^3$

Density of composite, $\rho_c = \rho_m\ (V_f/V_c) + \rho_m\ (V_m/V_c)$

$= \rho_f V_f + \rho_m V_m$

$= (1.6 \times 0.1) + (1.23 \times 0.9)$

$= 1.267\ g/cm^3$

Total weight of specimen wt% = $\rho c \times v$

$= 1.267\ g/cm^3 \times 25cm^3$

$= 31.7\ g$

Table 3.1: Weight percentage of reinforcement

	0 wt%	10 wt%	25 wt%
fibre(g)	0	3.17	7.93
Matrix(g)	31.7	28.6	23.77

The outer coat of the coconut was removed using a machete until it reaches the inner shell. The Coconut Shell (CS) was dried in open air for 24 hours as in to remove the coconut milk and coir easily. Next, the CS was broken with hammer to clean the CS easily. The coconut milk and coir the CS was clean using coir brush and sandpaper. Then, rinse the CS with distilled water to remove dust and foreign particles on the CS and dry it at room temperature again for 24 hours as in Figure 3.2. After that, the CS was ground into by using crushing machine as in Figure 3.3 to produce tiny coconut shell pieces as in Figure 3.4. Then the Crushed Coconut Shell (CCS) was blended using blender as in Figure 3.5 to produce CCS in powder form as in Figure 3.6. Coconut shell was put in the sieve at 500 µm size. Coconut shell powder was sieved by using Vibratory Sieve Shaker as in Figure 3.7 to separate larger coconut shell tiny pieces from powder to reduce weak fibre dispersion and distribution.

Figure 3.2: Broken coconut shells dry at room temperature

Figure 3.3: Crusher machine

Figure 3.4: Coconut shell pieces

Figure 3.5: Blender

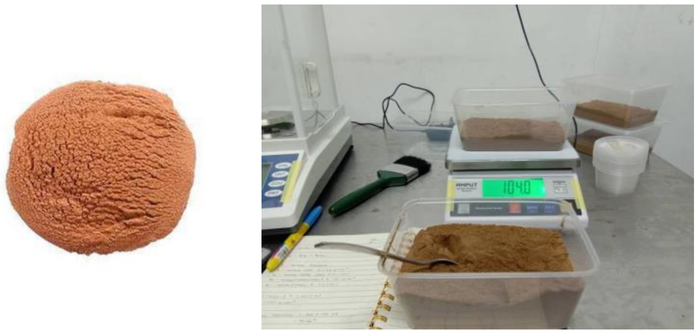


Figure 3.6: Coconut shell powder (500 µm size particles)

Figure 3.7: Vibratory Sieve Shaker

3.2.1 Mixing of Polyester resin and reinforcing material

The percentage of the coconut shell powder in the matrix were varied at 10 wt% CSP and 25 wt% CSP. The resin that used is polyester resin. The Unsaturated Polyester (USP) resin were weight at 0 wt% CSP as matrix which is 31.7 g. This polyester resin is the simplest, most economical resin systems that are easy to prepare and show good performance.

The USP resin was being weighted using an electronic weighing machine as in Figure 3.8 with the use of the beaker placed on the petty dish. The polyester resin was added gradually into the beaker until the weight indication observe is equal to the require polyester amount needed for that particular mixture with reinforcement particulates. The same process was repeated for other polyester amount needed for the other particulate mixture. With the help of a syringe, the quantity of the hardener needed was taken at 1g and pour by drops into the beaker containing the reinforcement-matrix mixture. Next, crush coconut shell will be mix with unsaturated polyester resin as the matrix using a stirrer machine as in Figure 3.9 until it is homogeneously mix.

Figure 3.8: Electronic weighing balance

Figure 3.9: Stirrer machine

3.2.2 Mould Preparation

For the best results the mould surface was completely free from dust traces from the previous cast, failure to completely clean the whole mould surface runs the risk of coating failing for the next cast which can result in sticking castings and or defective casting surfaces.

The size of mould was chosen according ASTM D7136 Standard. The dimension of the mould is 100mm x 100mm x 2.5mm as Figure 3.10. The mixture of unsaturated polyester resin, hardener and the crush coconut shell was poured into an open mould and left to harden at certain times. During pouring care was being taken to avoid formation of air bubbles and also while applying the pressure some polymer comes out of the mould so care should be taken while pouring. Next, the sample was removed from the mould for impact test as can be seen in Figure 3.11.

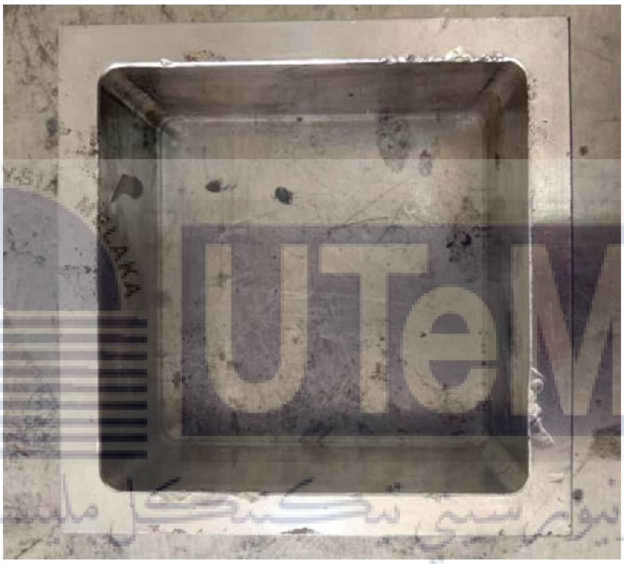


Figure 3.10: Open mould

Figure 3.11: Specimens for drop weight test

3.3 Drop Weight Test

The machine was used for impact test is Instron Ceast 9340 as in Figure 3.12. Drop weight impact testing is another type of low velocity testing, and it is the most common test for composite materials. Before the test start, the specimen was marked ‘X’ to get the central point. After that, the specimens were placed on two supported stage and load were applied as illustrated in Figure 3.14. The impactor was adjusted to impact the specimen at centre point that has being marked early and the velocity was set in the software. The hemispherical steel tube indenter is 12.5 in diameter as shown in the Figure 3.13 and a constant mass of 3.121 kg. Lastly, the experiment was started at 0 wt%, 10 wt% and 25 wt% of fibre with velocities 1m/s, 2m/s and 3m/s according to ASTM D7136. The impact load, energy absorbed and impact time were determined from 3 specimens per batch. Table 3.2 shows the calculated impact energy by using simple kinetic energy formula, the impact energy at 1m/s, 2m/s and 3m/s as given in Equation 3.1 below:

$$E_k = \tfrac{1}{2} m v^2 \quad (3.1)$$

Where,

m = mass (kg)

v = velocity (m/s)

Table 3.2: Impact Energy

Impact Velocity (m/s)	Impact Energy (J)
1	1.56
2	6.2
3	14.04

Figure 3.12: Instron Ceast 9340 Machine

Figure 3.13: Round indentor (diameter size: 12.5 in)

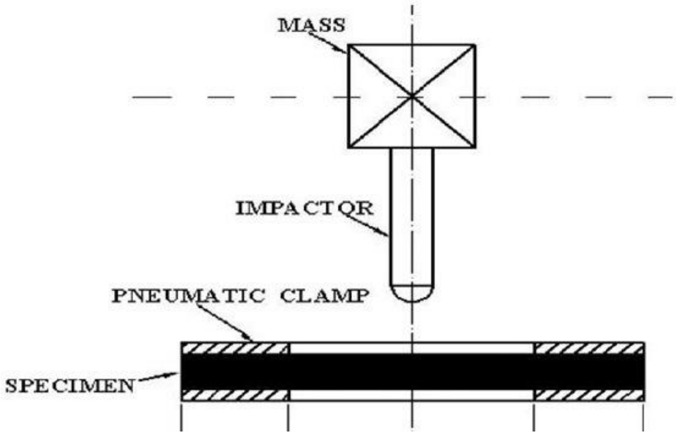


Figure 3.14: Illustration of dynamic impact testing (Yougashwar, 2011)

3.4 Morphological Study

The cross section of fractured specimen surface of Coconut Shell Reinforced Polymer Composite was studied via JEOLJSM-6010/LV Scanning Electron Microscope (SEM) as shown in Figure 3.15. The specimen was cut for 10 mm x 5 mm x 2.5 mm. Prior to the test were platinum coated using JEOLJEC-3000FC as shown in Figure 3.16.

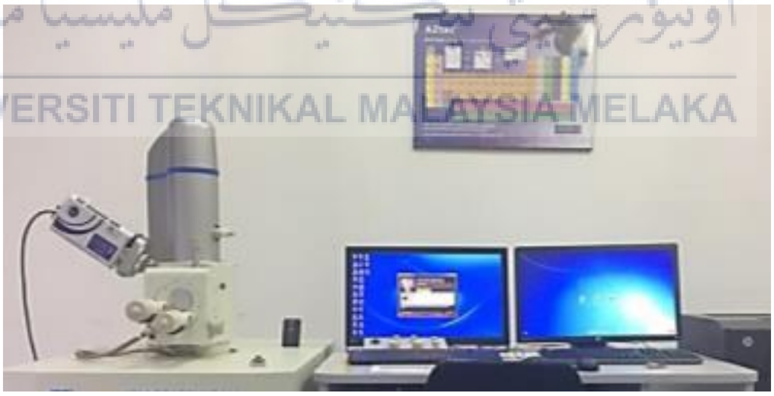


Figure 3.15: Scanning Electron Microscope (SEM)

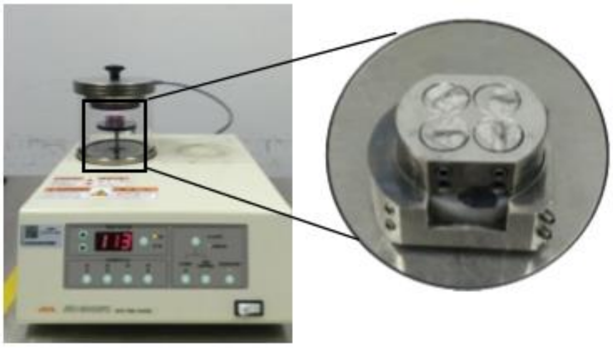


Figure 3.16: A photograph image showing the coating process using a JEOL JEC-3000FC prior to SEM analysis

CHAPTER 4

RESULT AND DISCUSSION

4.1 Drop Weight Impact Testing

Specimens with dimension of 100 mm x 100 mm x 2.5 mm were subjected to drop weight impact testing with impact velocities of 1m/s, 2m/s and 3m/s at 0 wt%, 10 wt% and 25 wt% of CSP. For each testing speed, a minimum three specimens were tested. All test specimens were simply supported using a steel hemispherical indenter having 12.5 in diameter, in which the specimens were centrally impacted.

The experimental results following the different weight percentage of ratio at impact velocities are discussed in terms of impact force, energy absorbed, impact time and damage patterns observed to evaluate the impact response of CS Reinforced Polymer Composite. The average results from a minimum three repeated specimens of drop weight impact testing for different weight percentage of CSP. Table 4.1 shows the main experimental result data for 0 wt%, 10 wt% and 25 wt% of CSP under drop weight test.

Table 4.1: Experimental data following drop weight impact test on 0 wt%, 10 wt% and 25 wt% Coconut shell reinforced polymer composites

Velocity [m/s]	Specimen ID	**0 wt% Coconut Shell Powder**		**10 wt% Coconut Shell Powder**		**25 wt% Coconut Shell Powder**	
		Peak Force [N]	Peak Energy [J]	Peak Force [N]	Peak Energy [J]	Peak Force [N]	Peak Energy [J]
1 m/s	1	104.43	0.214	208.053	0.691	205.402	-0.371
	2	297.63	0.141	208.053	0.726	225.390	0.587
	3	259.965	0.353	254.586	0.839	236.949	1.107
Average		**220.675**	**0.236**	**223.464**	**0.752**	**244.758**	**0.441**
2 m/s	1	355.61	0.404	468.118	1.753	381.430	1.899
	2	204.30	0.517	433.443	2.018	468.118	0.276
	3	440.419	1.128	398.767	0.729	508.573	1.260
Average		**333.443**	**0.683**	**433.443**	**1.500**	**452.707**	**1.145**
3 m/s	1	510.28	1.361	537.469	2.076	456.560	4.066
	2	379.19	2.039	479.677	1.399	618.378	0.690
	3	480.19	1.316	549.028	2.599	595.261	1.675
Average		**456.733**	**1.572**	**522.058**	**2.025**	**556.733**	**2.124**

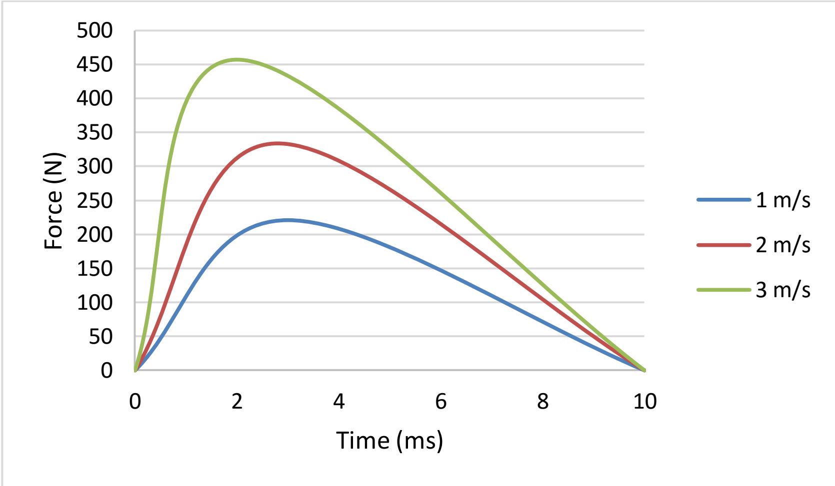
4.1.1 Impact Force Analysis

The comparison of the force time traces under different weight percentage of CSP with velocities 1 m/s, 2 m/s and 3 m/s are shown in Figure 4.1. The force-time curves are used to characterize the capability of the coconut shell composites to sustain forces until reaching a maximum limit (maximum force, P_{max}) followed by a drastic decline in forces. P_{max} is a point where the composites lose their stiffness and continued to carry impact load.

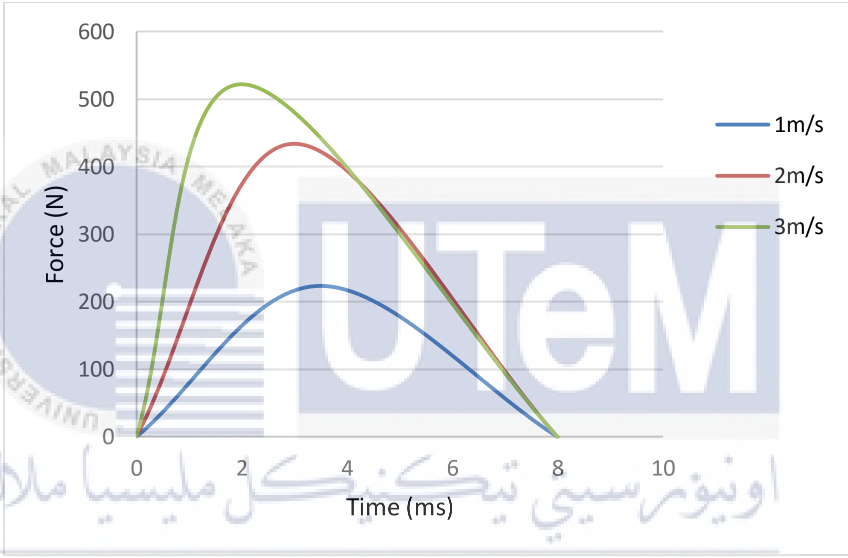
Figures 4.1 shows the comparison between the experiment data of 0 wt%, 10% and 25 wt% CSP FRP at 1m/s, 2m/s and 3m/s velocities. There a difference in the load-time due to differences with different of impact velocity. From the experiments, the impact velocity of 3 m/s sustain more load compared to 2 m/s and 1 m/s velocity. As the increase the impact velocity from 1m/s to 3 m/s, then the peak force is increase. It is also observed that with increasing of impact velocity, the time taken undergoing failure also decrease. This could be attributed to the fact that high speed breaks the specimen shortly.

From Figure 4.2, it is also observed that the average of impact force is follow the same increasing trend with respect to impact velocity regardless of the weight percentage of CSP and USP. The force is dependent on the impact velocity or impact energy. Hence, as increasing of impact velocity, the impact force also increases. As the stiffness increase, impact force increase. This is because more forces are required to initiate damage on the specimens. The impact forces generated on the 25 wt% CSP is the largest compared to 0 wt% and 10 wt% CSP due to the high stiffness of 25 wt% CSP.

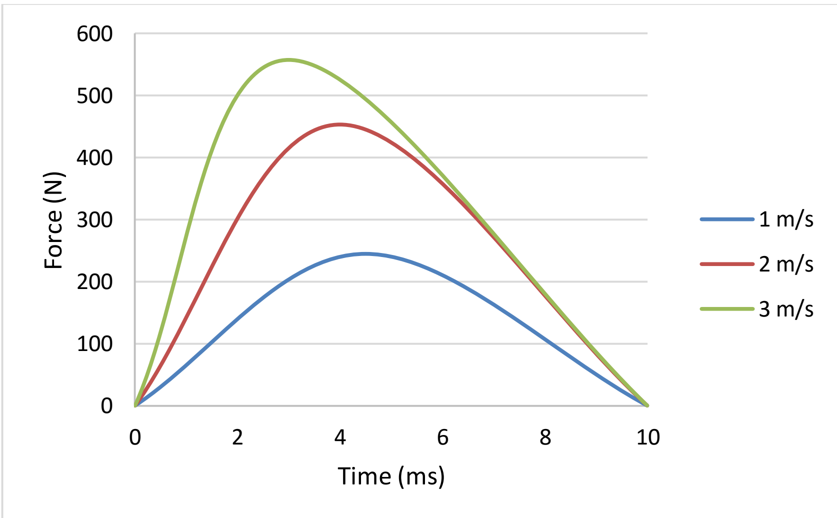
Besides the experimental result obtained from the series of test suggest that the 25 wt% of CSP exhibit higher ability to deform than 10 wt% of CSP. This probably due to higher stiffness with higher of CSP based natural composites. The CSP FRP are good reinforcing of 25 wt% materials to reduce the consumption of resin as well as utilizing waste natural material with maintaining properties required for structural application.



(a)



(b)



(c)

Figure 4.1: Force-time traces following drop weight impact with 1m/s, 2m/s and 3m/s velocities on (a): 0 wt%, (b):10 wt% and (c): 25 wt% CSP.

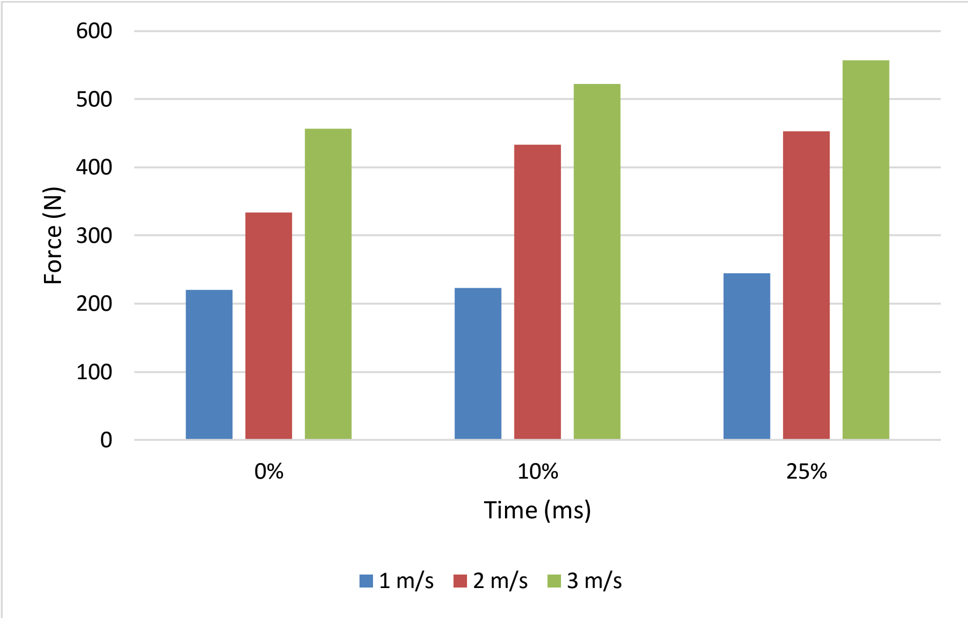
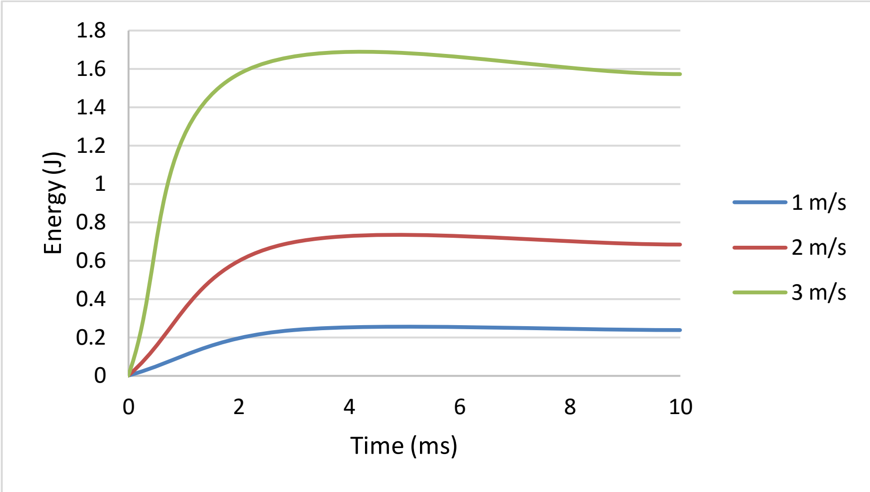


Figure 4.2: Maximum force following drop weight impact with varying velocities on 0 wt%, 10 wt% and 25 wt% CSP.

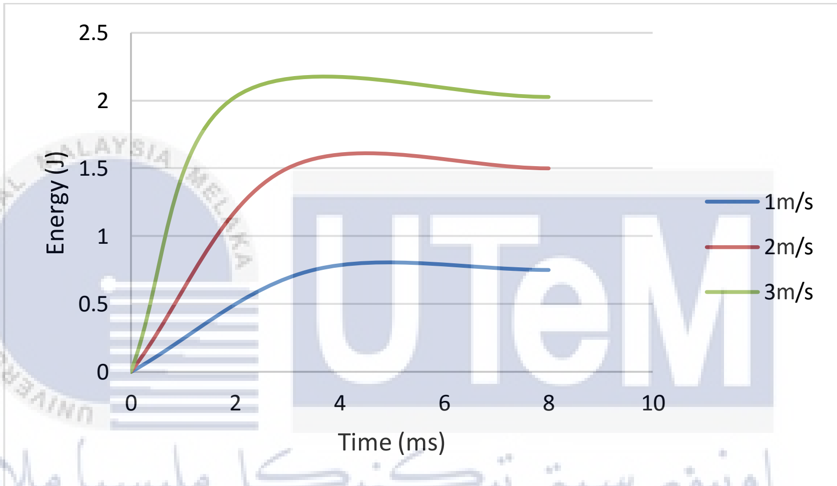
4.1.2 Energy absorbed analysis

Peak energy consists of the energy absorbed via the elastic deformation of the specimen and energy dissipated via damage initiation and propagation. Impact velocity or impact energy has a relationship with the absorbed energy. The absorb energy is defined as the total amount of the energy can be absorbed by the specimen and it was not transformed on the elastic energy. The energy absorbed can analysed from the energy-time curve. Figure 4.3 shows the peak energy for 0 wt%, 10 wt% CSP and 25 wt% CSP is increasing as the increasing of impact velocity. The highest energy absorbed by the specimen at 3 m/s impact velocity. The impact velocity at 1 m/s absorbed energy the lowest.

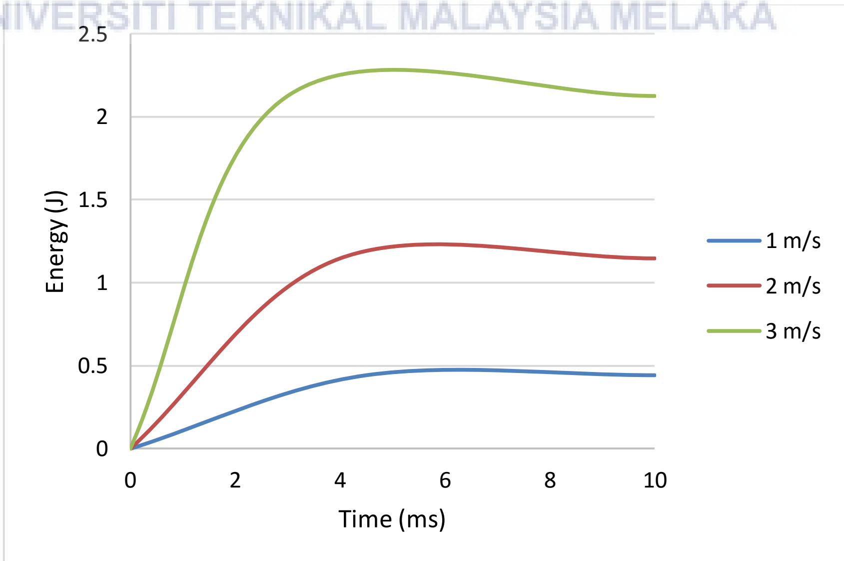
The influence of weight percentage of fibre on the energy absorption following different impact velocity is also important in this project. From the Figure 4.4 shows, the 25 wt% CSP have the highest energy absorption while the 0 wt% CSP have the lowest energy absorption. The specimen at 25 wt% need more energy to undergoing the failure. The lower energy absorption means that there is not much energy lost due to failure. It was notable that as the impact energy or impact velocity increase, the energy absorbed by the specimens increase because the Young Modulus of the CS Reinforced Polymer Composite increases. Young's modulus is a measure of the stiffness of an elastic material. Hence, the higher of elastic modulus means the material is stiffer (Somashekhar, 2018).



(a)



(b)



(c)

Figure 4.3: Energy-time traces following drop weight impact with 1m/s, 2m/s and 3m/s velocities on (a): 0 wt%, (b): 10 wt% and (c): 25 wt% CSP.

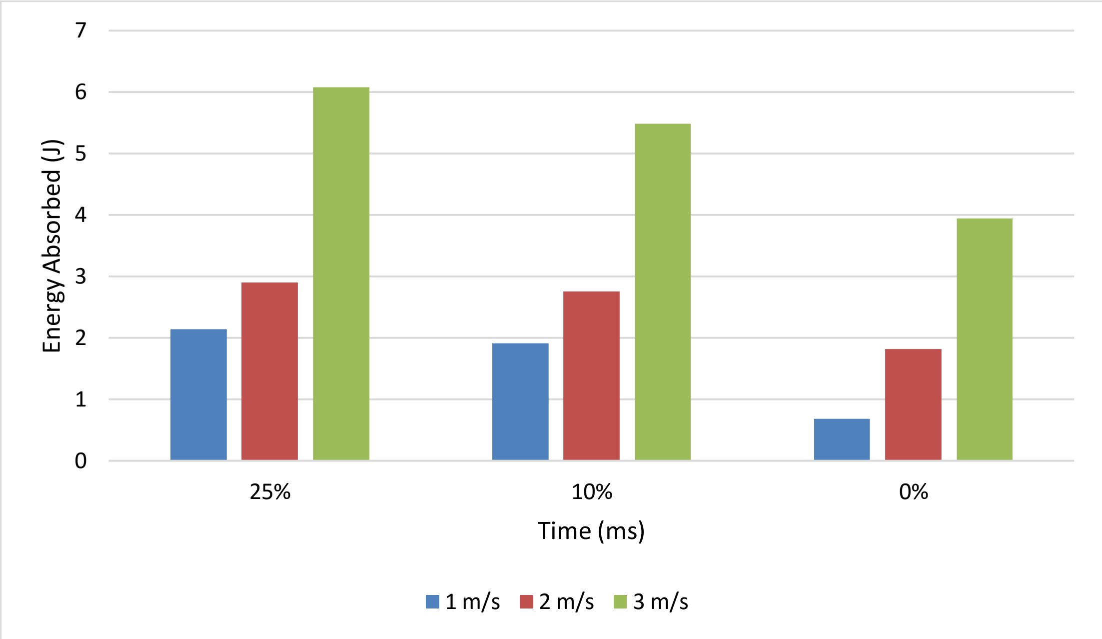


Figure 4.4: Total energy absorbed following drop weight impact with varying velocities on 0 wt%, 10 wt% and 25 wt% CSP.

4.1.3 Peak displacement analysis

Figure 4.5 shows that the peak displacement increases with increasing the impact velocity for the test 0 wt%, 10 wt% and 25 wt% CSP. Peak displacement indicates the maximum deflection of the specimen. It implies that there is a higher amount of damaged area specimens due to increase amount of impact velocity. Therefore, it can be concluded that 25 wt% of CSP has the better impact performance.

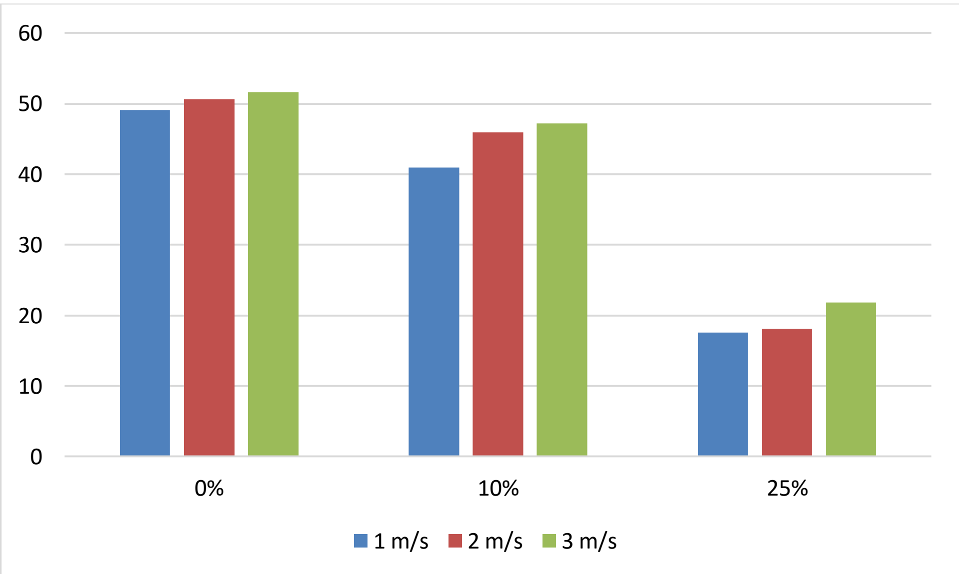


Figure 4.5: Peak displacment following drop weight impact with varying velocities on 0 wt%, 10 wt% and 25 wt% CSP.

4.2 Failure Behaviour of Coconut Shell Reinforced Polymer Composite

In this section, failure behaviour of Coconut Shell Reinforced Polymer Composite following different impact velocity via different weight of ratio are observed from visual inspection. Damage characteristic following different impact velocities at 1 m/s, 2 m/s and 3 m/s following 0 wt%, 10 wt% and 25 wt% CSP are shown in Figures 4.6, Figure 4.7 and Figure 4.8. From the visual inspection, visible damage at 1 m/s testing have the smallest damage area compared to 2 m/s and 3 m/s. It is because the specimen at 1 m/s impact velocity test was absorbed the smallest energy. At 3 m/s impact velocity testing result, it can be seen that the specimen has the largest damage area. It is because the specimen under 3 m/s impact velocity test was absorbed the highest energy. Hence, the area damage for the specimens increase as the increasing the impact velocities or impact energy. For the 25 wt% CSP experienced less damaged area for the compared to 10 wt% CSP at low velocity impact or impact energy. Thus, 25 wt% CSP is the highest in strength compared to 0 wt% CSP and 10% wt% CSP. The 0 wt% CSP experienced fully damaged. It is cleared that all the specimens impacted suffered fully penetration at 1m/s, 2 m/s and 3m/s. All the Coconut Shell Reinforced polymer composite under different impact velocities test suffered the damage due to brittle behaviour of unsaturated polyester resin and having poor resistance to crack propagation. (Kede Huang, 2016)

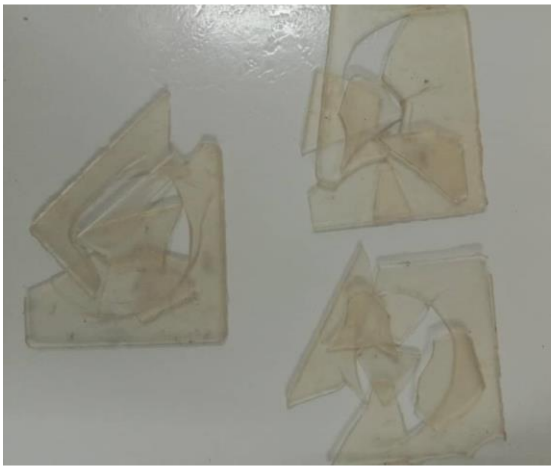


Figure 4.6: Failure mode observation on 0 wt% Coconut shell reinforced polymer composite.

Velocity	Specimen	Observations
1 m/s		Smallest damage area and have the cracks on circular damaged are.
2 m/s		Medium damage area.
3 m/s		Largest damage area.

Figure 4.7: Failure mode observation on 10 wt% Coconut shell reinforced polymer composite

Velocity	Specimen	Observations
1 m/s		Smallest damage area
2 m/s		Medium damage area
3 m/s		Largest damage area

Figure 4.8: Failure mode observation on 25% Coconut shell reinforced polymer composite

4.3 Morphological Study

A morphological study has been done to observed to observe the adhesion between matrix and fibre. Figure 4.9 shows the image of sample for 25 wt% of CSP Reinforced Polymer Composite under 3 m/s impact velocity. The magnification used for this image is 100x and 5000x. There some pores in the fibre that affect the adhesion of fibre and matrix. The presence of the pores had make the specimens undergoing failure under drop weight test.

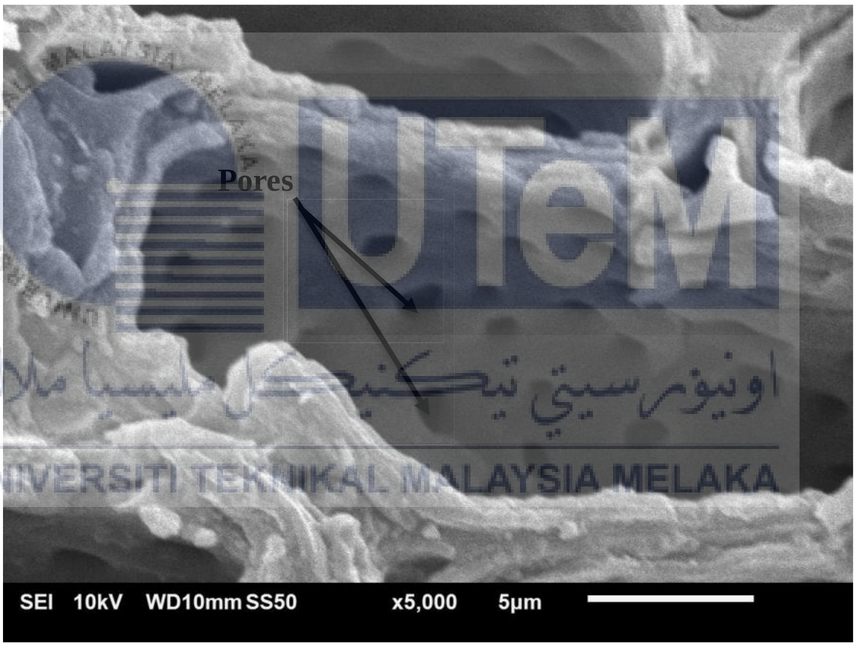


Figure 4.9: SEM image of failure surface of Coconut Shell Reinforced Polymer Composites.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Characterization of Coconut Shell Reinforced Polymer Composite

As a summary, coconut shell was processed to form a powder with diameter 500 µm as reinforcing material of the composite, while polyester resin as matrix was prepared to fabricate composite samples to undergo drop weight impact test and microstructure analysis according to ASTM D7136 respectively. The sample was fabricated using open-mould method and left to cured. The drop weight impact test had done on 1 m/s, 2 m/s and 3 m/s impact velocity with 0 wt%, 10 wt% and 25 wt% CSP specimens. The analysis of peak force and energy absorbed by the specimens of this composite was compared due to different of weight percentage of CSP and different impact velocity.

Understanding the impact behaviour of Coconut Shell Reinforced Polymer Composites is crucial in meeting specific requirement for any type of composite applications. In this study, the factor that affect the mechanical performance following impact behaviour of CS Reinforced Polymer Composites are attained with impact velocity on the different weight percentage of fibre.

Drop weight impact test were performed on 0 wt%, 10 wt% CSP and 25 wt% CSP specimens with different impact velocity or impact energy. From the result obtained, the peak impact force, the peak energy, the energy absorbed, the damage area and the peak displacement increase with an increase of impact velocity. The 0 wt% of CSP experienced fully damaged while the 10 wt% of CSP specimens exhibited more severe damage area than

25 wt% CSP specimen. It can be concluded that Coconut Shell Reinforced Polymer Composite in 25 wt% CSP is higher in the strength compared to 10 wt% CSP.

5.2 Recommendation for future works

An extension of work to further investigate the behaviour of Coconut Shell Reinforced Polymer Composite can be sought, with suggestion as follow:

i. To use the sieve size of 100 μm on Vibratory Sieve Shaker to form Coconut Shell Powder at 100 μm. As the smaller of particles fibres, the mechanical performance of the composite will improve.

ii. To fabricate the Coconut Shell Reinforced Polymer Composite using different of matrices because different type of matrix gives the different performance of the composite.

iii. To fabricate the Coconut Shell Reinforced Polymer Composite using different fabrication process technique for optimum impact properties of natural composites.

iv. To study the physical, thermal and chemical properties of Coconut Shell Reinforced Polymer Composite.

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