HYBRIDIZATION OF NATURAL FIBRE POLYMER COMPOSITE

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DECLARATION

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LIST OF ABBREVIATIONS

NFPC	Natural Fibre Polymer Composite
NaOH	Sodium Hydroxide
UV	Ultraviolet
PP	Polypropylene
PLA	Polylactic Acid
PE	Polyethylene
ROM	Rule of Mixture
OPN	Oil Palm Nano-filler
MMT	Montmorillonite
OMMT	Organically Modified Montmorillonite
CNT	Carbon Nanotube
CNC	Cellulose Nanocrystal
RTM	Resin Transfer Molding
SMC	Sheet Moulding Compound
VARTM	Vacuum-assisted Resin Transfer Moulding
ASTM	American Society for Testing and Materials
USM	University Science Malaysia

ABSTRAK

Serat sintetik seperti karbon, kaca, dan kevlar digunakan sebagai penguat dan terbukti yang terbaik berkenaan dengan sifat, keupayaan penguat dan aplikasinya. Walau bagaimanapun, serat semula jadi seperti sabut, rami, sisal, rami, rami, kenaf dan banyak lagi kini banyak digunakan sebagai penguat, kerana sifatnya yang setara dengan serat sintetik. Oleh itu, projek ini memberi tumpuan kepada hibridisasi serat semula jadi dan komposit polimer. Penyelidikan projek ini tertumpu pada penilaian sifat mekanik komposit hibridisasi sabut dan epoksi. Untuk tujuan penyelidikan, sampel komposit disediakan menggunakan dua panjang serat sabut yang berbeza. Sampel pertama menggunakan panjang semula jadi dan sampel kedua menggunakan serat yang telah dipotong pendek. Kerja eksperimen merangkumi rawatan serat yang melibatkan rawatan alkali dan fabrikasi komposit yang melibatkan proses meletakkan tangan yang diikuti oleh proses pembungkusan vakum. Proses rawatan dan fabrikasi adalah sama untuk kedua-dua sampel komposit yang disediakan. Walau bagaimanapun, rancangan awal adalah untuk melaksanakan partikel nano seperti Nanotube Karbon dan mengkaji kesannya terhadap sifat mekanik komposit. Malangnya, kerana pandemik, kerja eksperimen saya tidak mengikut perancangan awal kerana peluang untuk akses makmal adalah terhad. Spesimen kemudian melakukan ujian tegangan dan ujian lenturan untuk menentukan kekuatan tegangan dan kekuatan lenturan komposit. Bagi hasilnya, panjang gentian pasti mempengaruhi modulus tegangan dan modulus lenturan komposit sabut / epoksi yang disediakan. Rawatan kimia pada serat sabut juga menunjukkan peningkatan pada sifat mekanik komposit tersebut.

ABSTRACT

Synthetic fibers such as carbon, glass, and kevlar are used as reinforcements and are proven to be the best in respect to the properties, reinforcing ability and application. However, natural fibers such as coir, jute, sisal, flax, hemp, kenaf and more are nowadays widely used as reinforcements, as they are on par with the properties of synthetic fibers. Hence, this project focused on the hybridization of natural fibre and polymer composite. This project research is focus on evaluation the mechanical properties of the composite of hybridization of coir and epoxy. For research purposes, the composite sample is prepared using two different length of coir fibre. First sample is using natural length and second sample is using fibre that have been cut shortly. The experimental works including the treatment of the fibre which involving alkaline treatment and the fabrication of the composite which involving hand lay-up process following by vacuum bagging process. The treatment and fabrication process were same for both composite samples prepared. However, the initial plan is to implement nano particles such as Carbon Nanotubes and study its effected to mechanical properties of the composite. Unfortunately, due to pandemic my experimental work does not followed the initial planned as the access to lab is limited. The specimens were then having tensile test and flexural test to determine the tensile strength and flexural strength of the composite. As for the result, the length of the fibre sure affected the tensile modulus and flexural modulus of the coir/epoxy composite prepared. The chemical treatment on the coir fibre also shows improvement on the mechanical properties of the composite.

CHAPTER 1

INTRODUCTION

1.1 Project Overview

Hybridization of natural fibre polymer composite (NFPC) provides a new way to broaden the application of composite materials, particularly in advanced applications. There are three main criteria that have a considerable impact on the qualities of the hybrid composite product that results. First are the materials used matrix and filler, which depend mostly on the intended application. Following that is the process of preparation, which is frequently based on the filler and the matrix under research. Finally, is the interaction between filler and the matrix [2]. Therefore, to design a new product, there are certain specifications that must be met, such as the condition outdoors or indoors in which that product will be used, balance between the sustainability and performance of the product to accommodate both the consumer and the environment. Several factors influence the mechanical characteristics of hybrid polymer composites. As example, dispersion and distribution of fibre in the chosen polymer matrix, interfacial adhesion between polymer and natural fibre, surface area, weight percent of natural fibre, mechanical properties of natural fibre and resin, surface modification, fibre dimension and orientation are some of these factors to consider. In this project, the parameter that affects the quality level of natural fibre polymer composite are being studied. These parameters include, properties of fibres and polymer resin, composition of the composite, the process involved, chemical treatment and implementation of Nano filler.

1.2 Problem Statement

Natural fibre reinforced polymer composites (NFPC) have a number of drawbacks, including low heat stability, high flammability, high moisture absorption, and mechanical property fluctuation, mostly in advanced or technical applications. The major drawback of natural fibres polymers composites is the incompatibility between the hydrophilic natural fibres and the hydrophobic thermoplastic matrices[1]. The voids

produced at the interphase between the matrix and fibre will lead to poor mechanical properties of composites prepared using natural fibre [2]. Therefore, fabrication techniques, suitable treatment and process involve need to be consider for improving the quality of natural fibre polymer composites.

1.3 Objectives

1. To study about the parameter that affects the quality of the natural fibre polymer composite such as composition of the composite, orientation of the fibre, the process involved, physical and chemical treatment and implementation of nano-filler.

1.4 Project Scope

This project used Coir fibre as the reinforcement and Epoxy as the resin. The project research is focus on evaluation the mechanical properties of the composite of hybridization of coir and epoxy. For research purposes, the composite sample is prepared using two different length of coir fibre. First sample is using natural length and second sample is using the fibre which is cut into 25-40mm long approximately. The experimental works conducted were the treatment of the fibre which involving Sodium Hydroxide (NaOH) and the fabrication of the composite which involving hand lay-up process following by vacuum bagging process. The treatment and fabrication process were same for both composite samples prepared. The specimens were then having tensile test to determine the tensile strength, yield strength, ultimate strength, elastic limit, and the elastic modulus of the sample. After that the specimen is having flexural test to determine flexural strength and flexural modulus that can be used to evaluate the composite ability to withstand flexure or bending forces. Finally, the result of these tests was compared to published work and verify its capability to applied in Engineering Industry.

CHAPTER 2

LITERATURE REVIEW

This chapter provides relevant and latest research in this area of study. It begins with an introduction on the characteristic of the natural fibre and its pros and cons as a reinforcement. Next, an overview on the critical factor that affected the quality of the NFPC such as fibre orientation, matric resin, fabrication process and composite composition. Then, a review of the used of NFPC in current product available in the market. Then, the data on the review will be compared to the data obtained from the project.

2.1 Natural Fibre

Natural fibres are classified according to their origins, such as whether they come from plants, animals, or minerals. According to study groups, plant fibres are the most popular of the natural fibres used as reinforcement in fibre reinforced composites[2].

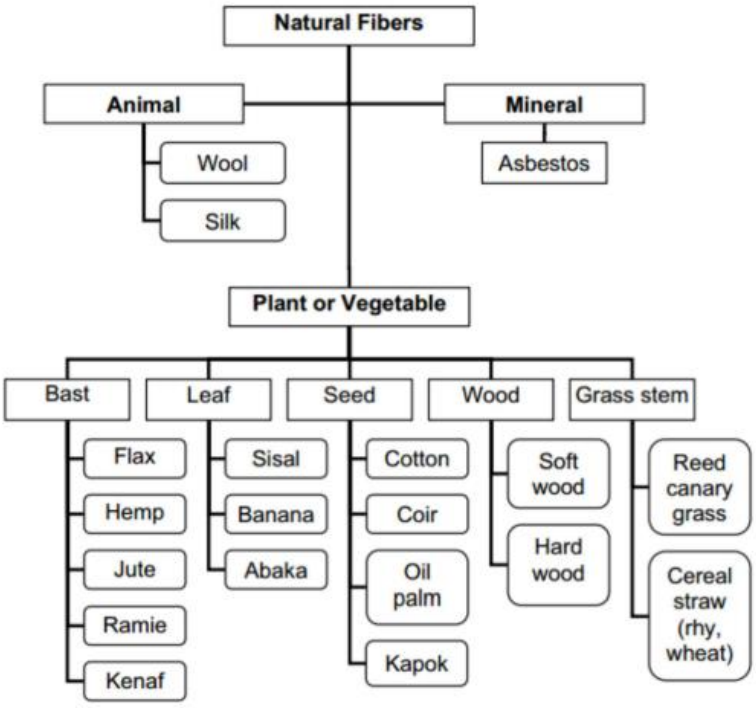

Figure 2-1 Classification of natural fibre [3].

However, there are some important characteristics of natural fibre that can influence properties of NFPC. Natural fibre performance highly depends on geometrical, mechanical, chemical, and physical properties of the fibre. Geometrical properties are length, diameter, cross-section, surface shape and structure, Mechanical properties are single fibre strength/modulus, fibre bundle strength/modulus, poison's ratio, flexural properties, elastic modulus, yield strength, elongation, and fatigue properties.

Fibers	Density (g cm^3)	Diameter (μm)	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)
Flax	1.5	40–600	345–1500	27.6	2.7–3.2
Hemp	1.47	25–500	690	70	1.6
Jute	1.3–1.49	25–200	393–800	13–26.5	1.16–1.5
Kenaf			930	53	1.6
Ramie	1.55		400–938	61.4–128	1.2–3.8
Nettle			650	38	1.7
Sisal	1.45	50–200	468–700	9.4–22	3–7
Henequen					
PALF		20–80	413–1627	34.5–82.5	1.6
Abaca			430–760		
Oil palm EFB	0.7–1.55	150–500	248	3.2	25
Oil palm mesocarp			80	0.5	17
Cotton	1.5–1.6	12–38	287–800	5.5–12.6	7–8
Coir	1.15–1.46	100–460	131–220	4–6	15–40
E-glass	2.55	<17	3400	73	2.5
Kevlar	1.44		3000	60	2.5–3.7
Carbon	1.78	5–7	3400[a]–4800[b]	240[b]–425[a]	1.4–1.8

Figure 2-2 Characteristic values for the density, diameter, and mechanical properties of natural and synthetic fibre [2].

Chemical properties are concentration of different constituents such as lignin, cellulose and hemi cellulose, impurities due to processing and cultivation, degree of polymerization. Physical properties are density, texture, coefficient of thermal expansion, thermal conductivity, degree of crystallinity, micro fibril angle and wettability [4].

Type of fiber	Cellulose (%)	Hemi cellulose (%)	Lignin (%)	Pectin (%)	Wax (%)	Ash (%)	Moisture (%)
Cotton	82.7	5.7	28.2	5.7	0.6	ND	10.0
Jute	64.4	12.0	0.2	11.8	0.5	0.5-2.1	10.0
Flax	64.1	16.7	2.0	1.8	1.5	13.1	10.0
Sisal	65.8	12.0	9.9	0.8	0.3	4.2	10.0
Bamboo	48.2-73.8	12.5-73.3	10.2-21.4	0.37	ND	2.3	11.7
Hemp	55-80.2	12-22.4	2.6-13	0.9-3.0	0.2	0.5-0.8	6.5
Kenaf	37-49	18-24	15-21	8.9	0.5	2.4-5.1	ND
Abaca	56-63	15-17	7-9	0.3	0.1	3.2	ND
Sugarcane Bagasse	28.3-55	20-36.3	21.2-24	ND	ND	ND	ND
Coir	19.9-36.7	11.9-15.4	32.7-53.3	4.7-7.0	ND	ND	0.2-0.5
Banana	48-60	10.2-15.9	14.4-21.6	2.1-4.1	3-5	2.1	2-3
Pineapple	57.5-74.3	80.7	4.4-10.1	1.1	3.3	0.9-4.7	ND

Figure 2-3 Chemical compositions of natural fibres [3].

Natural fibre reinforcement can either be in the form of fibre or particle. Commonly loose fibre, nonwoven mats, aligned yarns, and woven fabrics are possible forms of natural fibre for composites, with aligned variants offering the best mechanical properties [5]. A woven fabric is characterized by continuous interlacing of perpendicular yarns, in a regular pattern. Yarns are constructions made up of several interwoven fibres. The mat or woven can either be composed of continuous or chopped unidirectional fibres, randomly chopped fibres, or suspended particles, and the non-woven arrangement is a flat structure without interwoven strands, consisting of a mat directionally or randomly oriented and placed together using heat, chemicals, pressure, or a combination of these as an adhesion promoter, the mat or woven can either be composed of continuous or chopped unidirectional fibres, randomly chopped fibres, or suspended particles. [2][6].

Next, the hydrophilic characteristic of natural fibres drives moisture absorption in composite materials. This is due to the fact that natural fibres contain several hydroxyl groups (–OH) found in hemicellulose and cellulose, although not all of the ingredients contribute to moisture absorption. Direct penetration of water molecules into micro gaps between polymer chains, transport of water molecules through micro cracks in the matrix caused by swelling of fibres, and finally capillary transport of water molecules into flaws and gaps at the interface between the fibres and the polymer due to poor impregnation and capillary transport of water molecules into flaws and gaps at the interface between the fibres and the polymer [7][8]. Figure 2-4 below demonstrate the effect of water absorption on fibre matrix interface stage by stage.

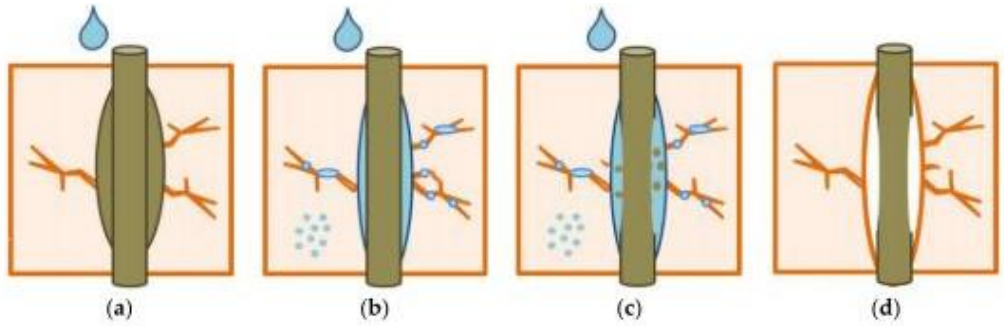

Figure 2-4 Effect of water absorption on fibre matrix interface (a) Formation of micro-cracks due fibre swelling (b) penetration and transport of water molecules through micro-cracks (c) water soluble substance leaching; and (d) debonding of fibre matrix interface [9].

Natural fibres are known to be sensitive to deterioration, depending on particular constituents. For example, lignin is mostly responsible for UV and fire degradation, whereas hemicelluloses are primarily responsible for biological, thermal, and high moisture absorption degradation. The information based on these parameters is of significance to achieve their full potential. Table 2-1 below exhibits the summary of studied on influence of constituents on the properties of fibre.

Degradation Type	**Plant constituent that plays major role in ascending order**
Strength	Lignin < Hemicellulose < non-Crystalline cellulose < Crystalline
Thermal degradation	Lignin < Cellulose < Hemicellulose
Biological degradation	Lignin < Crystalline cellulose < non-Crystalline cellulose
Moisture absorption	Crystalline cellulose < Lignin < non-Crystalline cellulose < Hemicellulose
UV degradation	Crystalline cellulose < non-Crystalline cellulose < Hemicellulose < Lignin

Table 2-1 Plant constituent that plays major role in ascending order [7].

2.2 Fibre treatment

Treatment of the fibres or the application of a coupling agent, particularly for natural fibres, to improve the interfacial adhesion between these components would improve the hybrid product's overall qualities.

2.2.1 Chemical treatment

Chemical treatments can improve the interface adhesion between the fibre and the matrix while also lowering fibre water absorption. As a result, chemical treatments can be used to alter the qualities of natural fibres.[10]. Alkaline, silane, acetylation, benzoylation, acylation, and acrylonitrile grafting, maleate coupling, permanganate, peroxide, and isocyanate treatments are known to increase adhesion by chemically attaching the adhesive to the substance. [6][3]. The effect of chemical treatments on the functional properties of natural fibre are summarized and listed in Table 2-2 below: -

Treatment process	Major Effect
Alkali	Reduce the lignin content. Improve fibre-matrix adhesion, thermal stability, and heat resistivity.
Acetylation	Improve tensile and flexural strength
Benzoylation	Improve hydrophobicity.
Enzyme	Reduce the lignin content.
Grafting	Improve UV-protective properties, hydrophobicity, and mechanical properties.
Isocyanate	Surface modification
Mercerization	Reduce the moisture regain and improve the mechanical properties.
Methacrylate	Improve tensile and flexural strength
Sodium chlorite	Improve tensile strength, young’s modulus, and elongation at break.
Peroxide	Reduce the moisture regain.

Table 2-2 The effect of chemical treatments on the functional properties of natural fibre [7].

2.2.2 Physical treatment

Physical treatment of natural fibres also improves mechanical adhesion between the natural fibre and the matrix by improving the interface without affecting the chemical properties of the fibres. Corona, plasma, ultraviolet (UV), fibre pounding, and heat therapy are examples of physical treatment methods. These methods are solely used to modify the surface qualities of natural fibres. That can be said, in natural fibre reinforced composites, modifications have been a hot issue in order to increase interfacial adhesion and, as a result, the overall qualities of the composite product.[6].

2.3 Fibre Orientation

The natural fibres extracted from various sources are used in different ways like short fibres, medium fibres, long fibres, and particulates. They may also be in different orientations like 0°, +45°, −40°, and +90° or they may be in nonwoven or woven format. Among these forms, the usage of woven threads has piqued the interest of many researchers, as they are more competitive in many ways than artificial fibres. When weaving a natural fibre, the orientation of the fibres can be changed to improve the mechanical qualities. Hence, in recent research studies the fibre orientations in the alternate layers must be different and an orientation between 0° and 90° would be optimum range. However, in recent research studies, using the natural fibres in random orientation and dispersed randomly was proved that they are good in mechanical properties most of the times [11].

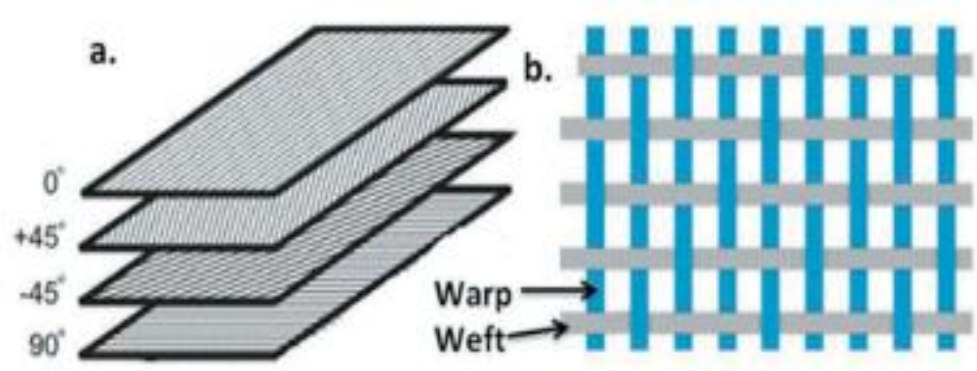

Figure 2-5 (a) Fibre orientations (b) weave form [11].

2.4 Polymer Matric Resin

The shape, surface appearance, environmental tolerance, and overall longevity of the hybrid composite product are all determined by the resin. The resins which is a polymer, thermoplastic, and thermoset, are frequently bonded with different fillers depending on the processing procedure.

2.4.1 Thermoplastics

Because of its inherent qualities, such as being lightweight, affordable, and easily moldable into diverse shapes, thermoplastics have been a focal point for reinforced composites materials. The main concern about these techniques is the heat involved, which may degrade the plant fibres, hence affecting their valuable properties. This had been one of the major parameters, which controls the selection of polymeric matrix, which must at least melt well below the thermal degradation of the plant fibres. Of interest, is the inclusion of high thermal stable synthetic fibre or flame retardant material as second filler can protect these fibres from thermal degradation during processing. Some of polyolefin such as Polyethylene (PE) and Polypropylene (PP) melt below 200°C, which makes them suitable candidates for the production of natural fibre based hybridized composites[8].

2.4.2 Thermosets

The processing temperatures of most of the thermoset is ranging from 25°C to above 100°C are good because it is below the degradation temperature of the plant fibres [8]. Epoxy resins, phenolic resins, polyurethanes, acrylics, polyimides, vinyl esters, and unsaturated polyesters are example of thermosets that cure to form three-dimensional cross-linked networks.

2.4.3 Polymer resin factor

The type of polymeric resins used and the length of time they are immersed in water are important factors in determining the equilibrium moisture content absorbed in the polymer matrix. In comparison to its synthetic equivalent, the biopolymer matrix has a stronger tendency to absorb moisture. The main effect of moisture absorption on the polymer is saponification, plasticization, hydrolysis, and other degradation

mechanisms, which result in both irreversible and reversible changes in the polymer's structure[9].

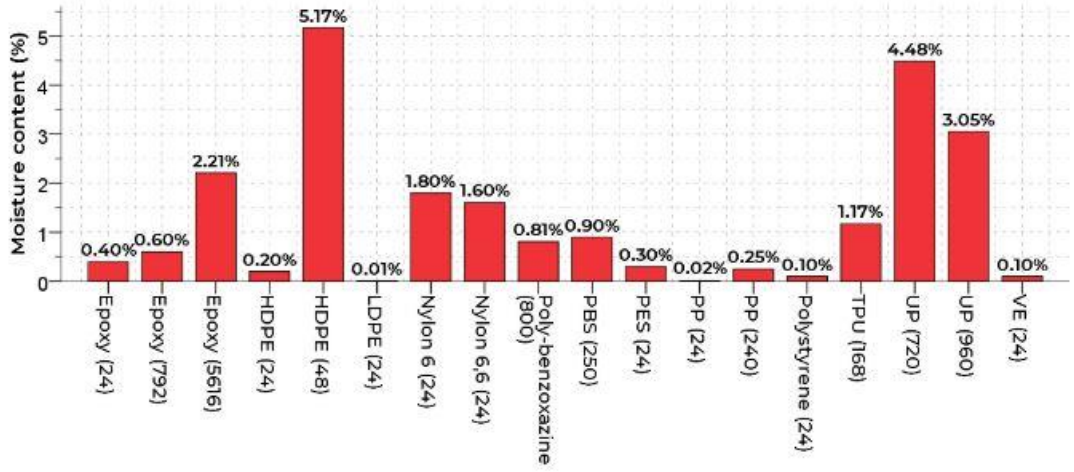

Figure 2-6 Moisture content (%) of selected polymer [9].

2.5 Nano-Filler Implementation

Nanotechnology can be implemented to improve the moisture absorption properties of natural fibres composites through using Nano fillers and nanotechnology-based coatings. When compared to other types of matting and short fibres, the particle morphologies of particular types of natural fibres can significantly reduce the water uptake behaviour of natural composites[9]. Aside from that, flame retardants and nanoparticles can be included into the polymeric material to improve the flame resistance of the resulting hybrid goods, making them suitable for use in areas where fire safety is critical.

When secondary Nano-fillers are used in conjunction with chemical or physical treatments, their role is magical, as these fillers perform multiple tasks at the interface, including strengthening mechanical interlocking by increasing the surface roughness of natural fibres, alleviating the damaging effect of delamination caused by moisture absorption through the pinning mechanism, and reducing the damaging effect of delamination caused by moisture absorption through the pinning mechanism[9]. List of Nano Particles include Oil Palm Nano-filler (OPN), Montmorillonite (MMT),

Organically Modified Montmorillonite (OMMT), Carbon nanotubes (CNT), Cellulose nanocrystals (CNC) and Nano-clay and Nano silica carbide [9][8].

2.5.1 Carbon Nanotube

A carbon nanotube (CNT) is a good nanomaterial for changing the surface of natural fibres by enhancing the compatibility between the biofiber and the matrix polymer. Furthermore, to be suitable for the space or automobile industries, the polymeric materials utilised in BC materials must have great resistance to damage from mechanical deformation, thermal instability, and chemical change. CNT could be an excellent choice in this case, as it requires relatively little loading as a significant nanofiller. Because of its exceptional thermal and mechanical capabilities, CNT is an excellent candidate for improving the interfacial mechanical strength of the NFPC.

2.6 Composite Fabrication

In general, thermoplastics are processed by melting the polymer into a viscous state, which allows for fibre impregnation. Melt mixers, single/twin screw extruders, and compression moulding are example of process which often used by industry. These processes can be employed alone or in combination.

Resin transfer moulding (RTM), sheet moulding compound (SMC), pultrusion, vacuum-assisted resin transfer moulding (VARTM), and manual lay-up (Figure 2-7) are all popular processing processes for thermoset-based composites. One of the most common processing procedures for the preparation of thermoset hybrid composites is hand layup followed by minor compression during curing. This is due to the fact that they are less expensive and easier to apply on a laboratory size.

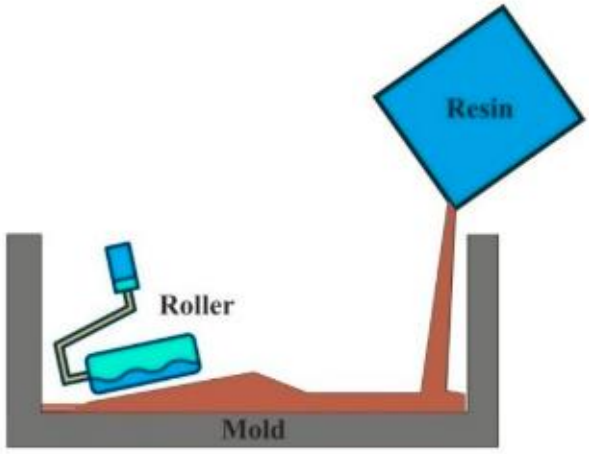

Figure 2-7 Example of hand-layup process [12].

2.7 Current Product Review

Natural fibre reinforced polymer composite use is importance in numerous applications including the automotive, building and construction industries, sports, aerospace, and others. Several automotive components and construction materials are already produced with natural fibres composites with various polymers. The most common polymers used for the applications are polyester or polypropylene, and the natural fibres are flax, hemp, and sisal. As example, (kenaf reinforced PLA is applied to mobile phone casing), (Flax, Balsa, Wood are applied on summer and winter sports equipment), (flax and hemp reinforced epoxy applied to racing bicycle), (flax and kapok reinforced plastics (PP and PLA) applied to cases of musical instrument) and many more [5]. Figure 2-8 below shown the summarize of application of NFPC and its related manufacturing process.

Materials Used		Application	Manufacturing Techniques
Fiber Reinforcement	Matrix/Binder Material		
Carbon	PP, metals, ceramics, epoxy resin, Polyether ether ketone (PEEK)	Lightweight automotive products, fuel cells, satellite components, armor, sports.	Injection molding, filament winding, resin transfer molding (RTM)
Graphene	Polystyrene (PS), epoxy, Polyaniline (PANI)	Wind turbines, Gas tanks, aircraft/automotive parts.	CVD, pultrusion, hand/spray up method
Sisal	PP, PS, epoxy resin	Automobile body parts, roofing sheets	Hand lay-up, compression molding
Hemp	PE, PP, PU	Furniture, automotive.	RTM, compression molding
Kenaf	PLA, PP, epoxy resin	Tooling, bearings, automotive parts.	Compression molding, pultrusion
Flax	PP, polyester, epoxy	Structural, textile.	Compression molding RTM, spray/hand lay-up, vacuum infusion
Ramie	PP, Polyolefin, PLA	Bulletproof vests, socket prosthesis, civil.	Extrusion with injection molding
Rice Husk	PU, PE	Window/door frames, automotive structure.	Compression/injection molding
Jute	Polyester, PP	Ropes, roofing, door panels.	Hand lay-up, compression/ injection molding
Coir	PP, epoxy resin, PE	Automobile structural components, building boards, roofing sheets, insulation boards.	Extrusion, injection molding

Figure 2-8 Example of application of NFPC and its manufacturing technique[5].

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Experimental flow process

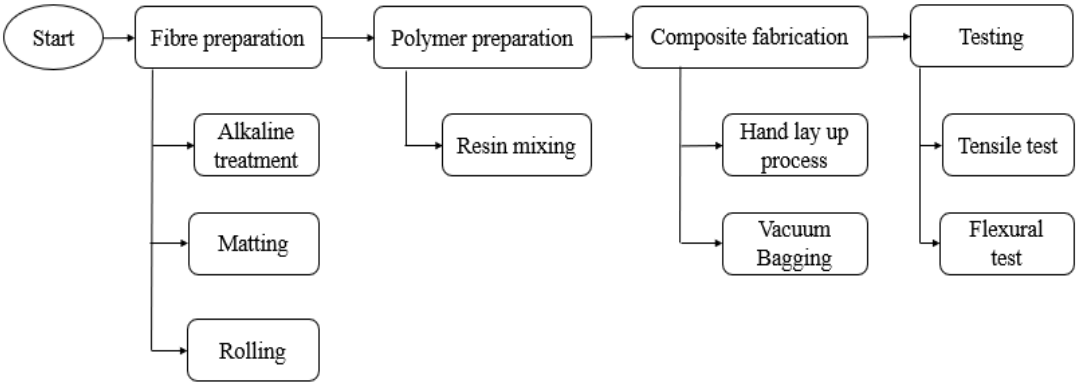

Figure 3-1 Flow process of the experimental work.

3.2 Fibre preparation

Initially the raw fibre is washed using water to remove dust and impurities inside the fibre. Then, the fibre is sun dried for 6-8hours.

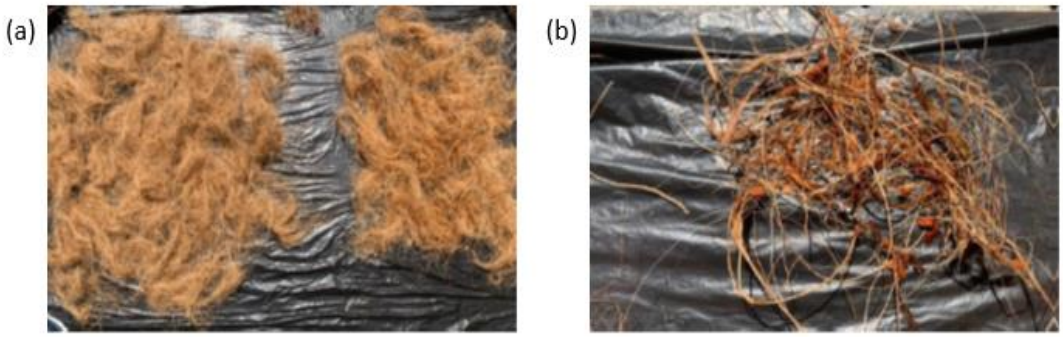

Figure 3-2 Sample of the coir fibre (a) sun drying after washed; (b) example of impurities removed.

Before performing the treatment process, the fibre initial weight is taken and then the fibre is oven dried at 100℃ for 3hour. Temperature of 105℃ is used because 100℃ is boiling point for water. The temperature can be increased until 180℃ but if the fibre is overheated, the different between humidity of room temperature and inside

then oven will make the fibre to absorb the moisture in the air. The weight of the fibre after oven dried is noted and the moisture percent reduction is calculated. The oven used is available on Nano Manufacturing Lab in Mechanical School and Composite Lab in Aerospace School, USM.

$$moisture\ \%\ reduction = \frac{initial\ weight\ (g) - final\ weight\ (g)}{initial\ weight\ (g)}$$

$$= \frac{73.9g - 62.6g}{73.9g}$$

$$= 15.3\%$$

	Initial weight (g)	Final weight (g)	Moisture reduction (%)
1st batch	66.4	57.8	12.9
2nd batch	72.1	63.6	11.9
3rd batch	73.9	62.6	15.3

Table 3-1 Moisture reduction of the coir fibre after dry by batch

Figure 3-3 Batch of coir fibre is dry using the oven.

3.2.1 Alkaline Treatment

For the treatment process, Alkaline treatment is involved where 5% sodium Hydroxide (NaOH) solution is used. The solution is prepared in a 2litre beaker available in Nano Manufacturing Lab in Mechanical School, USM. 100g of sodium hydroxide powder is added into a 2litre solution of deionised water. The fibre is immersed and left in the beaker for 24-28 hours at room temperature. Based on recent studies, this concentration and duration is the best to increase the mechanical properties of the fibre [13]. The treated fibre is then wash with deionised water to remove the absorbed sodium hydroxide solution. The solution is only can be used once, hence the used or excess sodium hydroxide solution is carefully disposed by pouring on soil. During handle the NaOH solution, proper equipment such as rubber glove, face mask, google or face shield must be worn to avoid from unwanted accident. Direct contact to skin or direct inhaled will harm and damage to human body. The treated fibre is sun dried for 6-8hours. These steps are repeated until total of 200g treated fibre is achieved.

Figure 3-4 Example of Alkaline treatment process

3.2.2 Fibre matting

For the fibre preparation process, an adhesive spray is used which acted as a binder for the fibre. Initially 100g of the fibre is cut into 25-40mm using scissor. The fibre is then poured one by one randomly on Teflon paper sheet until a layer is finished. Then the adhesive is sprayed on the surface on the layer. These steps are repeated until

thickness of 3cm is achieved. The steps are repeated for another treated fibre until all the treated fibre is used up.

Figure 3-5 Example of coir fibre in mat form

3.3 Composite fabrication

For the composite fabrication process, hand layup process is used followed by vacuum bagging method. This process is fully performed on Composite lab in Aerospace School, USM.

3.3.1 Rolling

Initially the mat formed fibre is then rolled using the Bending Roller machine (Figure3-5). This is to reduce cavity and air trap inside the fibre for easier to do hand layup process. In addition, the vacuum bagging method required the fibre to rolled beforehand because the load applied on the composite just 100N.

Figure 3-6 Bending Roller Machine available at workshop in school of Mechanical Engineering, USM.

Next, the rolled fibre is oven dried for 1 hour at 105℃ to remove the moisture trap in the fibre and to make sure the fibre is totally dry. High air humidity maybe affected the dryness of the fibre, so it is suggested that the drying process need to do just before the hand layup process. After that, the weight of each dried rolled coir mat is tabulated and the weight percent reduction can be observed in Table 3-2 below.

Rolled coir mat	Initial weight (g)	Final weight (g)	weight reduction (%)
1	28.8	26.0	9.72
2	33.1	30.1	9.06
3	32.2	28.9	10.25
4	31.5	28.3	10.16
5	30.7	27.9	10.09
6	29.9	27.1	9.36

Table 3-2 Observation on weight percent reduction

3.3.2 Polymer preparation

As for the polymer resin, 2:1 weight ratio of Epoxy resin is used. The resin and hardener required for the composite is estimated using the weight of the fibre.

$$Resin\ weight = Fibre\ weight\ \times 2$$

$$hardener\ weight = resin\ weight/2$$

Usually, the resin is mixed just following the weight percent ratio but don't take the total amount of resin needed into account[14][15]. As for that, this calculation method is suggested by the technician to avoid any waste in using the resin. The resin and hardener are then weighted to achieve the estimated weight. After that, the resin and hardener are then mixed in a plastic cup and stirred until fully mixed. Then the mixed solution is then put into a vacuum oven (Figure 3-7) for 5 minutes to remove the air trap (bubble) inside the resin solution.

Figure 3-7 Vacuum oven available at Composite Lab in school of Aerospace Engineering.

3.3.3 Layup process

Before mixing the resin, the vacuum bagging process need to set up beforehand. Double sided tape is applied rectangularly (40cm X 40 cm) on the table. The wax layer is applied on the surface of the table inside the tape applied. This wax acting as a mold release agent to avoid the cured composite stick to the table. As for the composite thickness, according to ASTM D638 and ASTM D790 the required thickness is 3mm. Hence, the number of sheets used to prepare a composite is 2 layers because the each of the layer thickness is around 1.5-2mm. As for the start, a sheet of rolled fibre is put on the table and the resin is applied starting from the centre of the fibre. The fibre is then flipped, and resin is applied again. These two steps are repeated until and the

surface of the fibre is fully applied with resin. The steps are repeated for the second layer and then both fibre sheets are stacked. Then, a metal plate is applied on top of the fibre acting as a load to press the fibre to remove air trap. Teflon sheet is put between them to avoid the cured composite to stick with the metal sheet.

3.3.4 Vacuum Bagging process

After that, poly foam sheet is applied to cover from the plastic to interact with the excess resin. A plastic sheet is applied and sealed with the tape around the composite workplace. Make sure the plastic is fully stitched to the tape to avoid air leakage. Then, the vacuum pump is turned on to remove the air inside the plastic. The pump is turned off if there is not having leakage on the plastic. Finally, the composite is leaved for 24 hours until the resin in fully cured. After that, the composite is cut and weight.

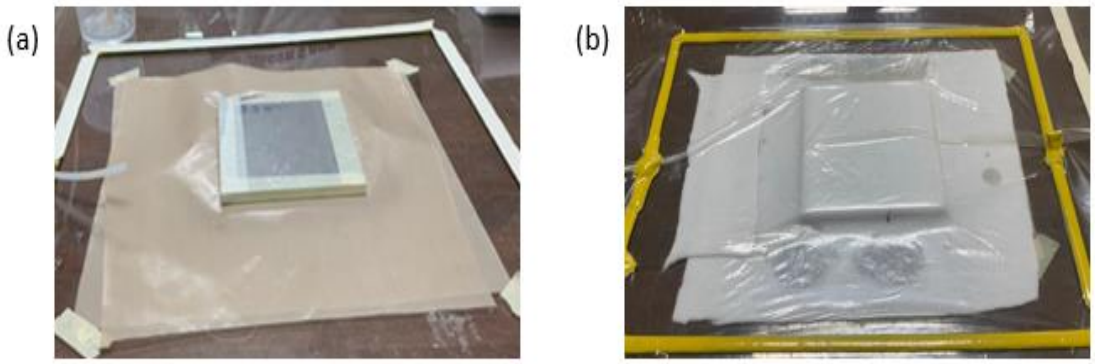

Figure 3-8 Vacuum Bagging process. (a) load applied on top of the fibre; (b) vacuum process

Weight percent and volume of the composite between the resin and the fibre is calculated.

$$wt\%\ resin = \frac{weight\ composite - weight\ fibre}{weight\ composite}$$

Weight (g)	Composite	Fibre	Resin	Composition coir/epoxy (wt%)
Short fibre	142.8	57.9	84.9	59.5/40.5
Natural fibre	147.2	58.5	88.7	60.3/39.8

Table 3.3-3 Composite weight percent composition

3.4 Sample testing

The composites are cut according to ASTM D638-01 for preparation of tensile test and ASTM D790-00 for preparation of flexural test.

Figure 3-9 Specimen for tensile and flexural test (a) long random fibre; (b) short fibre.

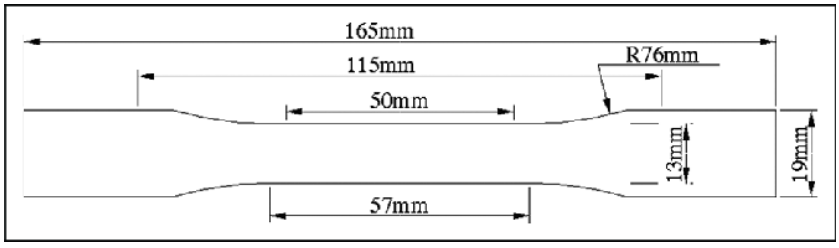

Figure 3-10 ASTM D638-01

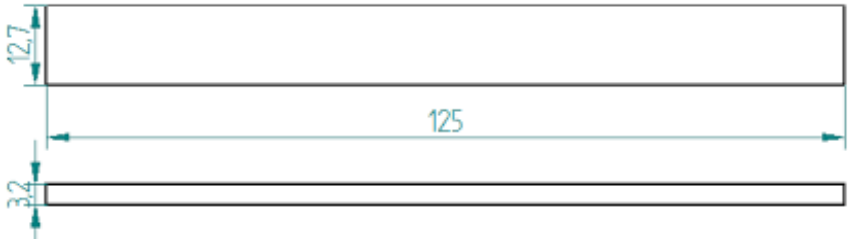

Figure 3-11 ASTM D790-00

In the beginning three point is marked on each sample using permanent marker and the thickness on each point is measured using vernier calliper. This is to calculate the average thickness of the samples as the thickness is vary and not constant. The thickness data is tabulated, and average thickness of each plate is calculated in Table 3-4 and Table 3-5.

Point no.	Tensile				Flexural			
	ST1	ST2	ST3	ST4	SF1	SF2	SF3	SF4
1	5.8	5.9	5.9	6.0	5.8	5.9	5.9	5.7
2	5.7	5.9	5.8	6.1	5.9	5.8	6.0	5.6
3	5.6	5.8	5.9	5.9	6.0	5.9	5.9	5.7
Avg	5.7	5.9	5.9	6.0	5.9	5.9	5.9	5.7

Table 3-4 Thickness data of sample composite from short fibre

Point no.	Tensile				Flexural			
	NT1	NT2	NT3	NT4	NF1	NF2	NF3	NF4
1	5.7	5.8	5.8	5.8	5.8	5.7	5.8	5.7
2	5.5	5.6	5.6	5.6	5.4	5.3	5.5	5.4
3	5.1	5.1	5.1	5.1	5.0	5.0	5.1	5.0
Avg	5.4	5.5	5.5	5.5	5.4	5.3	5.5	5.4

Table 3-5 Thickness data of sample composite from short fibre

Based on the data, observed that the average thickness of one specimen in each sample is different from the rest. This error probably occurred because the fibre is dispersed randomly during fibre preparation. In the end, only three specimen of each sample which the average thickness that having lower standard deviation is selected to

perform tensile and flexural test. The specimens that excluded from the testing are ST1, SF4, NT1 and NF2.

Next, all the specimen is labelled according to its group sample. All the selected sample that prepared for flexural test is having 3-point bending flexural test. The experiment is performed at a crosshead speed of 10 mm/min and at normal room temperature. For information, the specimens are placed manually and tested one by one. After that, the jig is change and has been setup for tensile test. The crosshead speed and test condition are same with flexural test. The experiments setup is as Figure 3-12 below.

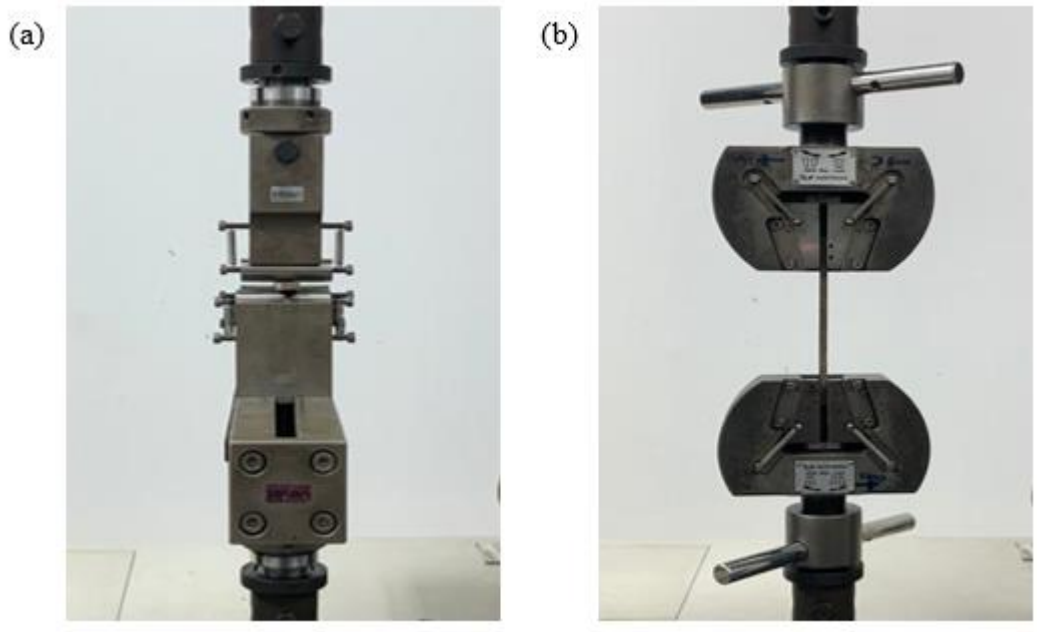

Figure 3-12 Universal Testing Machine available at Applied Mechanic Lab in school of Mechanical Engineering, USM (a) flexural test setup; (b) tensile test setup

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Tensile test

Specimen	Maximum Load (N)	Strain at max (%)	Stress at max (MPa)	Young 's Modulus (MPa)	Extension at maximum Load (mm)	Maximum Tensile strain (mm/mm)
NT1	2906.333	2.950	30.593	1895.378	2.950	0.030
NT2	2991.939	3.167	31.494	1889.858	3.167	0.032
NT3	2867.399	2.667	30.183	2052.412	2.667	0.027
	2921.890	2.928	30.757	1945.883	2.928	0.030

Table 4-1 Tensile properties of composite prepared with normal long fibre.

Specimen	Maximum Load (N)	Strain at max (%)	Stress at max (MPa)	Young's Modulus (MPa)	Extension at maximum Load (mm)	Maximum Tensile strain (mm/mm)
ST1	3366.567	2.233	35.438	2542.914	2.233	0.022
ST2	3400.868	2.667	35.799	2490.438	2.667	0.027
ST3	3353.841	2.517	35.304	2489.539	2.517	0.025
	3373.759	2.472	35.514	2507.630	2.472	0.025

Table 4-2 Tensile properties of composite prepared with short fibre.

Based on Table 4.1, the maximum tensile strength of natural long fibre is 30.593MPa, 31.494MPa, and 30.183MPa which give average 30.757MPa. Then, based on the Table 4-2, the maximum tensile strength of short fibre is 35.438MPa, 35.799 MPa, and 35.304 MPa which give average of 35.514MPa. The tensile strength mean difference is 4.757MPa. Hence, the maximum tensile strength of composite that prepared with long fibers is lower than the composite that prepared short fibre. Next, the maximum tensile strain of short fibre is 2.233%, 2.667%, and 2.517% which give the average of 2.472%. While the maximum tensile strain of long fibre is 2.950%,