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Tumakuru-572103, Karnataka India

MINI PROJECT WORK REPORT ON
"ORGANIC POLYMER COMPOSITES
-CASE STUDY"

In partial fulfilment of the requirements for the VI Semester of Bachelor of Engineering

In Mechanical Engineering

Submitted By:

Saharsh Utkarsh 1SI18ME096

Shashank Raj 1SI18ME111

Kumar Aman 1SI18ME046

Deepak Kumar 1SI18ME026

Under the Guidance Of:

Dr. Prashanth S,

Assistant professor

Department of Mechanical Engineering

Siddaganga Institute of Technology Tumakuru

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Department of Mechanical Engineering

CERTIFICATE

This is to certify that the Mini Project work report entitled **"Organic Polymer Composites"** is prepared and presented by **Saharsh Utkarsh-1SI18ME096, Kumar Aman-1SI18ME046, Deepak Kumar-1SI18ME026, Shashank Raj-1SI18ME111** in partial fulfilment of the requirements for the Third year of Bachelor of Engineering in Mechanical Engineering at Siddaganga Institute of Technology-Tumakuru, during the academic year 2020-21. The report has been approved as it satisfies the academic requirements for the Bachelor of Engineering Degree.

Signature of the Guide:

Dr. Prashanth S,

Assistant professor

Department of Mechanical Engineering

Siddaganga Institute of Technology

Signature of the HOD:

Dr. HR Purushottam

Head of Department

Mechanical Engineering

Siddaganga Institute of Technology

Name and signature of the Examiners

1.
2.

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Saharsh Utkarsh
Shashank Raj
Kumar Aman
Deepak Kumar

ABSTRACT

Nowadays a lot of polymers have been manufactured, both organic and inorganic. The polymers are fairly strong. The inorganic polymers have a fair share of disadvantages over the organic polymers. The development of high-performance engineering products made from natural resources is increasing work wide, due to renewable and environmental issues. Natural fibre reinforced polymer composites have many advantages like availability, inexpensive, renewable, minimal health hazards, relatively high specific strength and modulus, lightweight and biodegradable. However, the physical properties of natural fibre had large variation according to plant originality, plant maturity, location in plant, retting and treatment technique and composite processing technique. Natural fibers are emerging as cost effective and apparently ecologically superior substitutes to glass fibers in composites. Therefore, this paper presents an over view of the developments made in the area of plant fibre reinforced polymer matrix composites in terms of their market, manufacturing methods, and overall properties. These include plant fiber preparation, composite fabrication technique, and composite material. Plant fibers have become a highly sought-after material in the recent days as a result of raising environmental awareness and the realization of harmful effects imposed by synthetic fibers. It can be seen that the physical and thermal properties as well as flexural strength of the composites are highly dependent on the interfacial adhesion condition. . Natural plant fibers have been widely used as fillers in fabricating plant-fibers-reinforced polymer composites. However, owing to the completely opposite nature of the plant fibers and polymer matrix, treatment is often required to enhance the compatibility between these two materials. Interfacial adhesion mechanisms are among the most influential yet seldom discussed factors
that affect the physical, mechanical, and thermal properties of the plant-fibers-reinforced polymer composites. Therefore, this paper even expounds the importance of interfacial adhesion condition on the properties of plant-fiber-reinforced polymer composites. The advantages and disadvantages
of natural plant fibers are discussed. Four important interface mechanism, namely interdiffusion, electrostatic adhesion, chemical adhesion, and mechanical interlocking are highlighted. In addition, quantifying and analysis techniques of interfacial adhesion condition is demonstrated. Lastly, the importance of interfacial adhesion condition on the performances of the plant fiber polymer composites performances is discussed.

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Chapter 1

Introduction

Every year, hundreds of studies regarding plant-fiber-reinforced polymer composites were published in various journals and the trend has been increased exponentially. Polymer matrix composites are mostly commercially produced composite in which resin is used as matrix with different reinforcing materials. Polymer (resin) is classified into two types- thermo plastics and thermo sets which reinforces different types of fibers natural and man-made fiber for different applications. The application of plant fibers in polymer composites have drawn attention of many industry manufacturers. Urgent call for ameliorating environmental impacts by reducing energy consumption and embedding biodegradability but retaining reasonable performances are the major driving forces for the development of plant-fiber-reinforced polymer composites. Due to increase in population, natural resources are being exploited substantially as an alternative to synthetic materials. Natural fibers present many advantages compared to synthetic fibers which make them useful as reinforcements in composite materials. They come from abundant and renewable resources, which ensures a continuous fiber supply and a significant material cost saving to the plastics industry. Unlike brittle fibers, such as glass and carbon fibers, cellulose fibers are flexible and will not fracture when processed over sharp curvatures. Now a days, various types of natural fibers have been investigated for use in composites including flax, hemp, jute straw, wood, rice husk, wheat, barley, oats, rye, cane (Sugar and bamboo), grass, reads, kenaf, ramie, oil palm, sisal, coir, water hyacinth, pennywort, kapok, paper mulberry, banana fiber, pineapple leaf fiber and papyrus.

For these reasons synthetic fiber reinforced polymers have emerged as a major class of structural materials and are widely used as substitution for metals in many weights critical components in air craft, aerospace, automotive, marine and other industries. The interest encompasses a wide variety of shapes and materials ranging from synthetic to natural, in order to fulfill the demands of producing composites with desired properties. There will be improvements in the composites which will be associated with economic advantages such as low production cost and resin consumptions In this paper, the overall characteristics of the natural plant reinforced composites, in terms of mechanical properties, thermal properties as well as water absorption properties will be reviewed and the manufacturing process will be discussed.

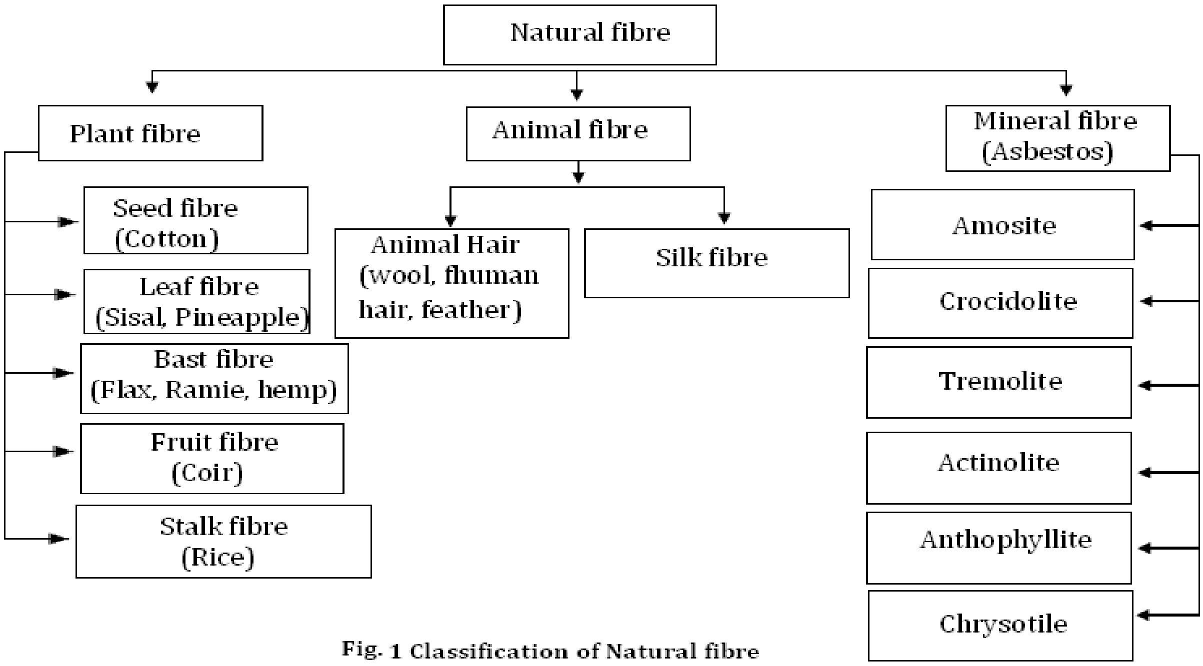

Fig. 1 Classification of Natural fibre

Chapter 2

Literature Survey

2.1. Plant/Natural Fibers

➔ Natural Fibre

Natural fiber is not a strange term in the current decade. It has been advertised as an alternative material to non-degradable materials by the companies supporting green materials, to fight global warming and supporting local social economic. This has contributed to the discovery of more renewable natural resources and join the competitive natural fiber markets.

➔ Plant fibre

Among the big families of natural fibers, plant fibers are the most extensively developed. The plant fibers are categorized by location where the fiber was obtained like stem, leaf, seed, and grass. Plant fibers are generally inexpensive byproducts, bestowed with high strength-to-weight ratio, volume-to-weight ratio, and excellent biodegradability. Detailed advantages and disadvantages of plant fibers are listed in Table 1. These gifted properties made them comparable to synthetic fibers. However, drawbacks of plant fibers were found and reported by previous reviews and studies. The most unfavored characteristic of plant fibers is their hydrophilic nature, which made them incompatible with hydrophobic polymer. Poor interface adhesion is usually observed in the micrographs of plant-fibers-reinforced polymer composites and followed by weakened properties.

The properties and adhesion ability of the plant fibers are attributed by its chemical compositions. There are three main chemical constituents in plant fibers, namely cellulose, hemicellulose, and lignin components. Cellulose is responsible for strength tolerator, its hydroxyl groups form strong molecular bonding with polymer at interface layer, regulating superior load transfer mechanism. Hemicellulose component dominant on thermal degradation, moisture absorption, and biodegradation of the fiber as it shows the least resistance. On the other hand, lignin is thermally stable and is greatly accountable for the UV degradation. Table 2 shows the chemical compositions of the frequently used plant fibers. Fiber treatments are commonly applied to modify fiber chemical compositions in order to achieve better interface adhesion.

Table 1: Advantages and disadvantages of Plant Fibers

Advantage	Disadvantage
Less Expensive	Lower Mechanical Properties.
Lower Weight.	Higher moisture absorption.
Renewable	Poor fire resistance
Bio degradable	Variation in quality
Good Thermal and sound insulation	Restricted maximum processing temperature.
Eco friendly	Poor microbial resistance
Non toxic	Low thermal Resistance

2.2. Natural fiber composites

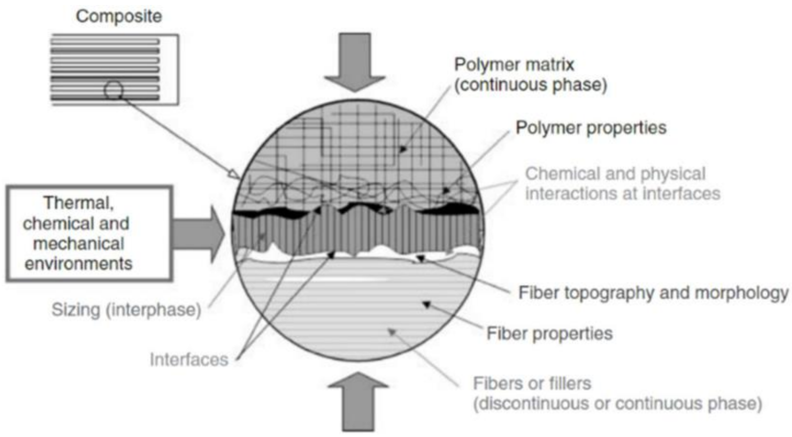

Figure 2. Schematic illustration interface of fiber/matrix composite.

Over the past few decades there has been a growing interest in the use of natural fibers in composite applications. These types of composites present many advantages compare to synthetic fibers such as low tool wear, low density, cheaper cost, availability and biodegradability. The most common natural plant used in applications is bast fibers such as hemp, jute, flax, kenaf and Ramie.

Natural fibers are subdivided based on their origins i.e., whether they are derived from plant, animals, or minerals, as shown in fig. According to study groups, plant fibers are the most popular of the natural fibers, used as reinforcement in fiber reinforced composites. Plant fibers include bast (or stem, soft, or sclerenchyma) fibers, leaf or hard fibers, seed, fruit, wood, cereal straw, and other grass fibers. Plant fibers are composite materials designed by nature. The fibers are basically comprised of a rigid, crystalline cellulose micro fibril reinforced amorphous lignin, and/or hemicelluloses matrix. Most plant fibers, except for cotton, are composed of cellulose, hemicelluloses, lignin, waxes, and several water-soluble compounds; where cellulose, hemicelluloses, and lignin are the major constituents.

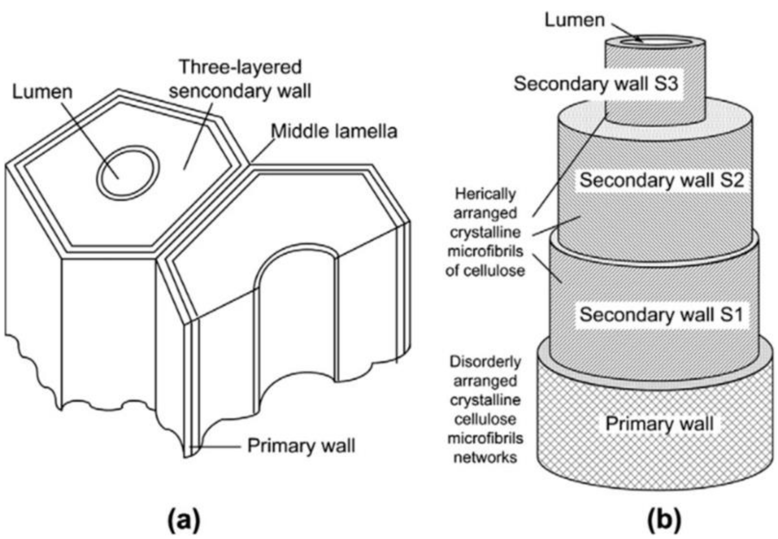

Figure 3. (a) Cross section cell arrangements and (b) structural of single fiber.

2.3. Properties of Plant fibers and Plant fibre composites

2.3.1. Mechanical Properties

The mechanical properties and physical properties of natural fibers vary considerably depending on the chemical and structural composition, fiber type and growth conditions. Some of the mechanical properties of plant fiber reinforced composites are: Ultimate strength, fracture strain, flexural modulus and impact strength.

Mechanical structure of plant fibers is much lower when compared to those of the most widely used competing reinforcing glass fibers. However, their Strength and stiffness of plant fibers are comparable to the values of glass fibers. Tensile strength of synthetic fibers is more compared to natural fibers but in natural fibers, bast fibers have more tensile strength when compared to leaf fiber and seed fiber. Fruit fibers has very low tensile strength and higher in elongation at break. Meanwhile these bast fibers have a higher modulus than seed fiber, leaf fiber, fruit fiber and less value than synthetic fibers.

It has been seen through various experiments that mechanical properties are enhanced by plasma treatment to a certain extent after which it starts affecting the crystalline structure of cellulose and makes the fiber weaker.

2.3.2. Thermal Properties

Thermal Analysis needs to be considered to fully distinguish the overall behavior of plant fiber reinforced composite.

Thermal degradation started with thermal energy absorption to break the bonding.Hence, higher thermal decomposition temperature is recorded for plant fiber composites, having good interfacial bonding. However, agglomeration of fiber reduces the fiber adhesion intensity, thereby reducing the thermal stability of the composite.

2.3.3. Water Absorption properties

For a given composite system, the water absorption characteristic depends on the content of the fibre, fiber orientation, temperature, area of the exposed surface, permeability of fibers, void content, and the hydrophilicity of the individual components.

2.3.4. Physical Properties

The insertion of natural fibers in PLA composites have induced a non-negligible pro- degradative effect on PLA molten state. The higher pace of hydrolysis and biodegradation of PLA polymer was found with increased fiber contents, thereby reducing complex viscosity of molten state. Fortunately, better interfacial bonding adhesion between fiber/matrix minimizes this drawback and retains the viscosity close to pure PLA. This unchanged viscosity value allows plant-fiber-reinforced polymer composites to fabricate with similar processing parameters as pure polymer. Manufacturers may introduce plant fiber into polymer products without varying the processing setting.

The fiber/matrix adhesion condition is an important criterion in determining the water absorption behavior. The main constituents of natural fiber are cellulose and hemicellulose, which was dominated by hydroxyl and carboxyl groups. Owing to its easy attachment to water molecules via hydrogen bonding, these functional groups are hydrophilic in nature. Mildly alkaline sodium bicarbonate treatment has reported good reduction of hemicellulose and lignin contents in natural fibers. However, it activates and worsens the propagation of damage phenomena, resulting in higher water absorption.

Alkaline treatment has helped in improving the mechanical interlocking and chemical bonding between fibers and matrix, resulting in superior properties. Kenaf fibers have relatively higher non-cellulosic components than hemp fibers. This made the removal of impurities for kenaf fibers effective, indicating higher bulk density changes and performance improvement.

Fibers	Cellulose (wt%)	Hemicellulose (wt%)	Lignin (wt%)	Waxes (wt%)
Bagasse	55.2	16.8	25.3	-
Bamboo	26–43	30	21–31	-
Flax	71	18.6–20.6	2.2	1.5
Kenaf	72	20.3	9	-
Jute	61–71	14–20	12–13	0.5
Hemp	68	15	10	0.8
Ramie	68.6–76.2	13–16	0.6–0.7	0.3
Abaca	56–63	20–25	7–9	3
Sisal	65	12	9.9	2
Coir	32–43	0.15–0.25	40–45	-
Oil palm	65	-	29	-
Pineapple	81	-	12.7	-
Curaua	73.6	9.9	7.5	-
Wheat straw	38–45	15–31	12–20	-
Rice husk	35–45	19–25	20	-
Rice straw	41–57	33	8–19	8–38

Table 2: Chemical composition of frequently used plant fibers.

Chapter 3

Design and Fabrication

3.1. Fibre Treatment

- **Alkali Treatment**

Three samples are taken and washed with sodium hydroxide (NaOH) to lose some amount of lignin so that certain active sites (hydroxyl groups) could be formed at the surface, which would facilitate water absorption. Fibers will be immersed in NaOH solution at different concentrations (0.5, 2, and 5%) for half, one and two hours. Later they are washed several times using cold tap water. These fibers are then dried in an air oven at 60^{o}C for 24 hrs.

- **Acetylation**

Untreated fibers are immersed in 18% aqueous NaOH solution at 28^{o}C for 1 hr. These fibers are washed several times with cold water finally with acidified water (0.1 N HCL). These fibers are dried in an air oven and then soaked on glacial acidic acid for 1 hr at the same temperature.

- **Permanganate Treatment**

The alkali treated fibers are soaked with $KMnO_4$ solution in acetone for 1 minute. This is decanted and the fibers are dried in air.

- **Heat Treatment**

Fibers are heated at 150 deg C in an air circulating oven for 4 hrs. The weight loss is measured when the fiber is cooled down to room temperature.

3.2. Composite Fabrication

There are several methods for making of natural fiber composites. Most of the techniques commonly used for making glass fiber composites are applicable for making natural fiber composites. However, the well-known method for composites making are as follows:

3.2.1. Hand lay-up/Spray-up method

Hand Lay – up/Spray up is one of the cheapest and most common processes for making fiber composite products. In this process, the mold is waxed and sprayed with gel coal and cured in a heated oven. In spray up process, catalyzed resin is sprayed into the mold, with chopped fiber where secondary spray up layer imbeds the core between the laminates resulting a composite. In hand layup processing, both continuous fiber strand mat and fabrics are manually placed in the mold. Each ply is sprayed with catalyzed resin and with required pressure compact laminate is made.

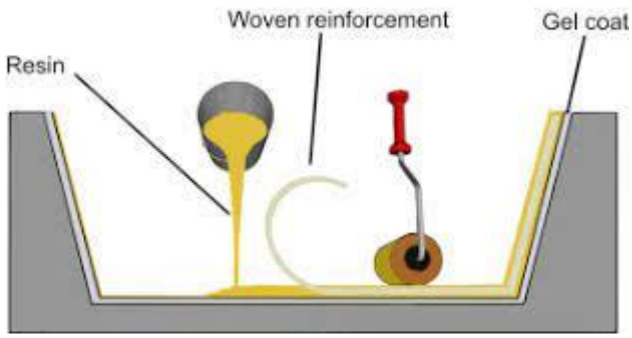

Figure 4. Schematic representation of Hand layup method

3.2.2. Resin Transfer Moulding (RTM)

In a Resin Transfer Moulding (RTM) the glass mat is first heated and pressed into a mould to create a preform. Resin is then injected or transferred into the mould to create the composite component. As the glass mat is pressed into the mould the arrangement of the fibers may be distorted from that originally designed. RTM provides high quality finished surface on both the sides of composite with a relatively low energy makes perfect shapes. The fabricator generally gel coats the mold halves, then lays continuous or chopped strand mat and closes the mold. Resin transfers into mold through injection pressure, vacuum pressure, or both. Cure temperature depends on the resin system.

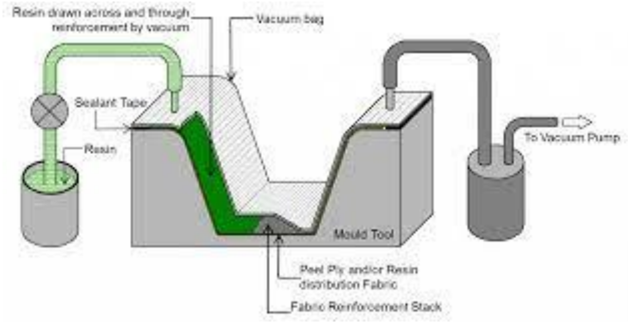

Figure 5. Schematic representation of Resin Transfer Moulding

3.2.3. Compression moulding

Compression molding is a molding technique for making composite materials with low unit cost with faster cycle times. Components may be manufactured from a compression moulded composite material such as Glass Mat Thermoplastic (GMT) or Sheet Moulding Compounds (SMC). GMT usually consists of continuous random glass fibers in a polypropylene matrix, whilst SMC usually consists of 25mm long random glass fiber in a polyester matrix with calcium carbonate filler. Sheet Molding Compounds (SMC) is a sheet that sandwiches fiber between two layers of resin paste. Fiber/Fabric drop onto the paste and a second film carrier faces with another layer of resin. When the SMC is ready for molding, the mold is closed, clamped, and between 500 to 1,200 psi pressure is applied. After curing, mold is opened and the sheets were removed manually or through an injector system and ready for use.

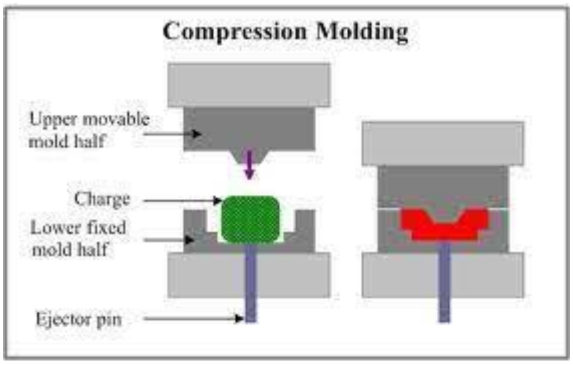

Figure 6. Schematic representation of Compression Moulding

3.2.4. Injection Moulding

Injection moulding refers to a process that generally involves forcing or injecting a fluid plastic material into a closed mould. Injection molding is a fast, high volume, low pressure, and closed process. Injection speeds are typically 1-5 s and nearly 2,000 small parts can be produced per hour. A ram or screw type plunger forces a material shot through the machine's heated barrel and injects it into a closed, heated mold. Heat build-up is carefully controlled to minimize curing time. After cure and injection, parts need only minimally finishing. Filament winding is an automated, high volume process that is ideal for manufacturing pipe, tank, shafts and tubing, pressure vessels, and other cylindrical shapes. The winding machine pulls dry fibers form supply racks through a resin bath and winds the wet fiber around a mandrel. This method a normally used for high-volume and low-cost component manufacturing. The disadvantage of the method is that it is limited to materials with very short lengths. Also, since there is large amount flow during the process, material non-uniformities do exist.

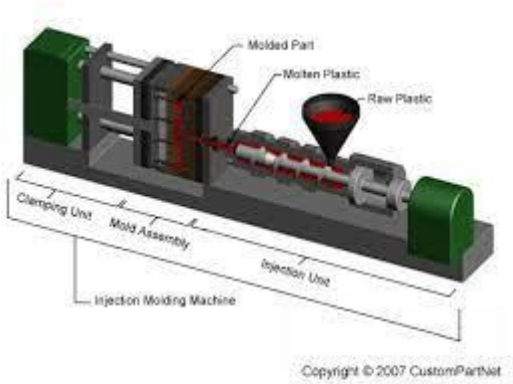

Figure 7. Schematic representation of Injection Moulding

3.2.5. Pultrusion

Evolution of manufacturing processes of polymer composites has introduced the unique technique of the pultrusion process. Recently, this technology has been and, given all of the available evidence, is likely to remain a very attractive application and growth sector of the whole polymer composites industry. Moreover, pultruded profiles are already recognized as a high-quality industrial product, capable of satisfying a wide range of high performance and structural element requirements. Pultrusion is the continuous, automated closed- molding process that is cost effective for high volume production of constant cross-sectional parts. Pultruded custom profiles include standard shapes such as channels, angles, beams rods, bars, tubing and sheets

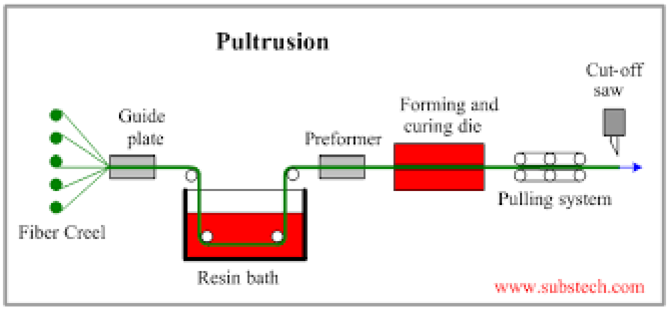

Figure 8. Schematic representation of Pultrusion

Chapter 4

Study on Interfacial Adhesion

Matrixes are generally a homogeneous and monolithic material in which fiber and/or fillers system of a composite is embedded. It is completely continuous and provides a medium for binding and holding reinforcements together into a solid structure. The main purpose of matrixes is to offer protection and transfer loads to the reinforcement fillers. On the other hand, plant fibers are held in place by the matrix resin, sustaining under high strength and enhancing performances of composites with almost zero cost. However, cooperation between plant fibers and matrix in a composite system relies on its interface conditions.

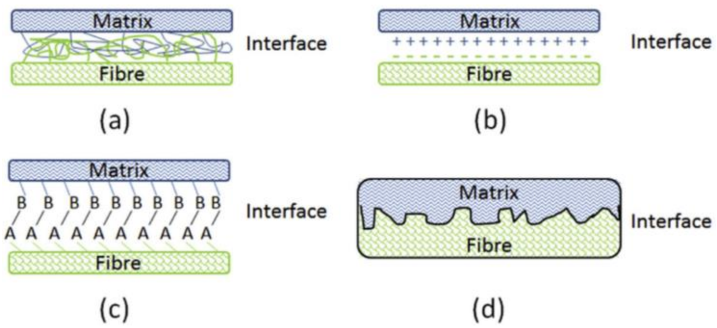

Figure 9. Schematic figure of fibers/matrix interfacial bonding mechanisms with the methods of (a) interdiffusion, (b) electrostatic adhesion, (c) chemical bonding, and (d) mechanical interlocking.

Interface conditions are the prime factor of determining the properties of plant fiber polymer composites. This region experiences different thermal expansion during thermal processing and it acts as a barrier between the two distinct materials that are differed in terms of physical and chemical properties. A composite with bad interface may find significant deterioration in mechanical and thermal properties. To increase the adhesiveness, alkaline treatment is the most widely used treatment on plant fiber composites because of its high cost-effectiveness. It removes non-cellulosic components on the fiber surface and offering a clean but rough surface for better interfacial adhesion. Coupling agents and compatibilizers are deployed to promote more functional groups to enhance interfacial adhesion between fiber/matrix. Through the above mentioned material modifications, researchers could improve conditions of interfacial bonding between the fiber/matrix's interface, as illustrated in Figure.

4.1. Interface Mechanisms

For the plant fiber polymer composites, properties are dominant by reinforcing plant fibers, matrix, and most importantly interface conditions. The interface was considered as an intermediate layer, formed by bonding matrix and fibers, in the thickness of one atom to micron thickness. A good interlayer forms strong linkages and enable maximum stress transmission between fibers and matrix, without disruption and, hence showing superior properties. Therefore, the conditions of interface are worth investigating in depth. Interface mechanism include interdiffusion, electrostatic adhesion, chemical adhesion, and mechanical interlocking.

4.1.1. Physical Adhesion

Physical adhesion interface is referred to as the interdiffusion bonding mechanism. Good wettability has governed the condition of this interface, which relied on surface energies and polarities, of both plant fibers and matrix. The surface energy and polarity can be analyzed by the contact angle measurements of solid–liquid interactions, which is further discussed . Non-polar waxes found on the fiber surface have relatively lower surface tension than polar components like lignin and fats. Fiber surface treatments or malleated coupling agents can be used to regulate the surface energies and polarities to create better wettability. Once good wetting occurs, permanent adhesion is developed through molecular attractions such as Van der Waals, covalent, and electrostatic. Tran et al. found in their study that alkaline-treated coir fibers have lower surface energies but higher polarity. It is more compatible and has better wettability with polymer that has similar surface energy and resulted in higher work of adhesion. The higher the work of adhesion, the better the composite's mechanical properties.

4.1.2. Electrostatic Adhesion

The opposite charges because of which contacting surfaces on plant fibers and polymer matrix are attracted and adhered together are known as electrostatic adhesion. Both anionic and cationic bodies formed an interface, which accounts for the adhesion of the two constituents of composite. In the chemical and physical interactions, adhesion property of surfaces is a consequence of interatomic and intermolecular surface forces including electrostatic forces. Atomic force microscope was used to create 3D images of composite topography and investigate its electrostatic adhesion conditions. However, authors in this review paper failed to identify any electrostatic adhesion study on plant-fiber- reinforced polymer composites, and only mentioned briefly the physical adhesion. This may be due to the fact that plant fibers are difficult or not preferred to be processed into a more ionic state. Some studies have reported the integrating electrostatic adhesion to composite structures reinforced with synthetic fibers (carbon or glass fibers) to strengthen the interface. Electrostatic discharge treatment on polymer fibers or electrostatic fibers by electrospinning process could incorporate electrostatic adhesion to its interface and consequently could provide significant value-added functionality to the composites.

4.1.3. Chemical Adhesion

Chemical bonded interface is the most widely discussed in plant fiber polymer composites. Chemical modifications could be done on both fiber and matrix in order to gain higher intensity of chemical bonding sites. Improved hydrophobicity of fibers could increase the adhesive compatibility with hydrophobic matrix and this could be done by removing fiber's hydroxyl groups and substitutes with hydrophobic chemical bonding. Figure shows the chemical modification treatments on the fiber's surface. The details of the chemical reactions have been reviewed. The destruction of hydroxyl groups on fibers prohibits the attraction of water moisture. Hence, improved fiber hydrophobicity and minimized phenomena of swelling-to-crack could be observed. Cracked composite receives lower loads since load transferring mechanism is forced to end and concentrates on the cracking spots .

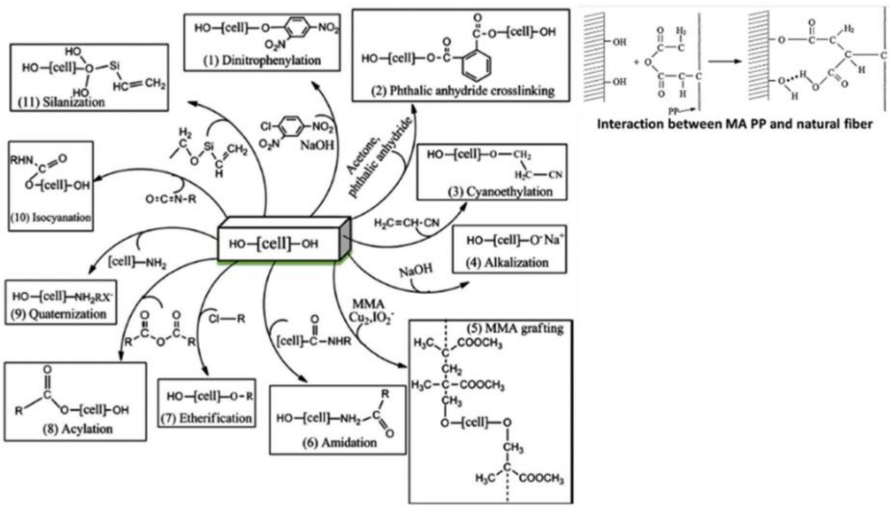

Figure 10. Chemical modification treatments on fiber's surface.

4.1.4. Mechanical Interlocking:

Penetration of molten polymer into micron-diameter holes and adhering to irregular, rough fiber surface has created mechanical interlocking support system. This adhesive mechanism does not rely on any chemical bonding or electrostatic forces, but the polymer acts like multiple hooks anchored on fiber surface. Rougher fiber surface provides more spots to anchor. Alkaline treatment is one of most frequently used methods to remove non-cellulosic components from the fiber surfaces, offering a clean and rough fiber topography, other than reducing the hydrophilicity for better chemical adhesion mechanism. On the other hand, flow of the polymer resin filled into lumens, open pores, and free volumes within the cell wall has restricted shrinking and swelling of fibers, and thereby better dimensional integrity of composites. The wettability as discussed in the above section (physical adhesion) is the crucial factor for flowability of resin on/into the plant fibers. Hence, the mechanical interlocking often provides extra load-bearing capabilities to the interface.

4.2. Importance of quantifying and analysis of interfacial adhesion

Quantifying and analysis of interfacial adhesion properties is very important to compare or predict the properties of plant-fiber-reinforced polymer composites. Treatment may improve the interface conditions. However, excessive treatment is not beneficial to interface adhesion, and deteriorated performances. One study discovered that the presence of moisture on the interface can affect interfacial adhesion thereby reducing the mechanical performances. Most of the time, delamination happens on poor interface composites. The topography of fiber and matrix decides the condition of the interface. Figure shows the simple schematic view of the fiber/matrix interface

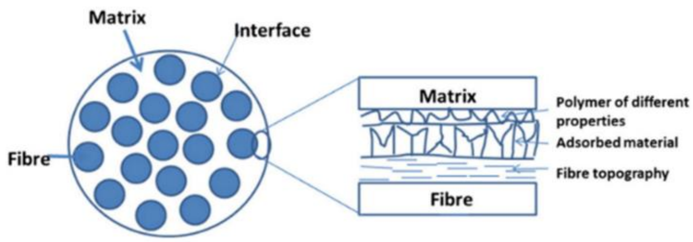

Figure 11. Simple schematic of plant fiber/matrix interface

Stress concentrated at the interface because of **two reasons**:

- ➔ Different thermal expansion coefficients for fiber and matrix when subjected to thermal processing.
- ➔ Different strength properties of both materials. When a low-interfacial adhesive's composite is subjected to loads, microcracks begin to form at the interface and are propagated to the matrix.

Good interface ensures effective load transmitting from the matrix to the fibers, which helps reduce stress concentrations and subsequently improves the overall mechanical properties. Nano-scale plant fibers, or known as nanocellulose fillers, are getting more and more attention because of its superior reinforcement effects. The high surface area-to- volume ratio of nanocellulose provides a great contact surface between the nanocellulose and the matrix. This created intense interactions at the interface. However, aggregation of nanofillers reversed the strengthening effect. In the well-dispersed nanocomposites,numerous interfacial bonding could be located everywhere inside the matrix even at low filler concentrations. Even distribution of load transmitting among these interfaces in turn yields higher load capability of nanocomposite. Interface characterizations could be identified by four methods according to Jose namely:-

- **Thermodynamic methods** (contact angle analysis and gas chromatography.)

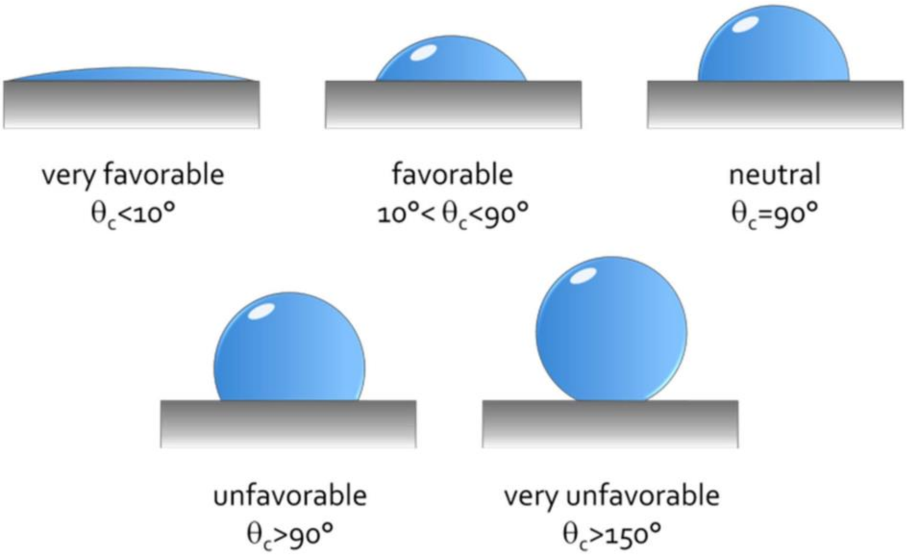

Figure 12. Thermodynamic methods illustration

- **Microstructural analysis consisting of SEM, TEM and AFM:**

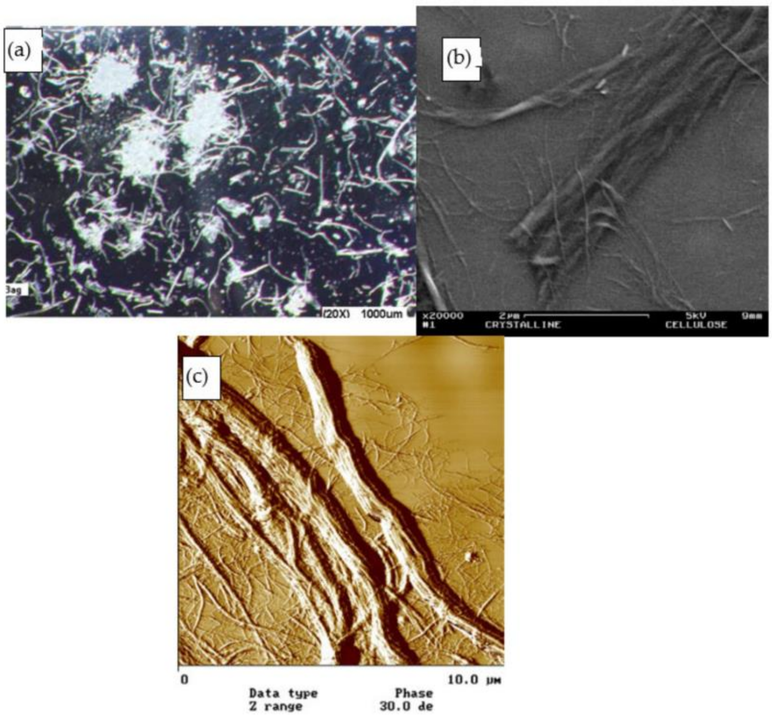

Figure 13- SEM, TEM and AFM structures as viewed from an electron microscope

- **Spectroscopic techniques** (chemical analysis and X-ray diffraction)

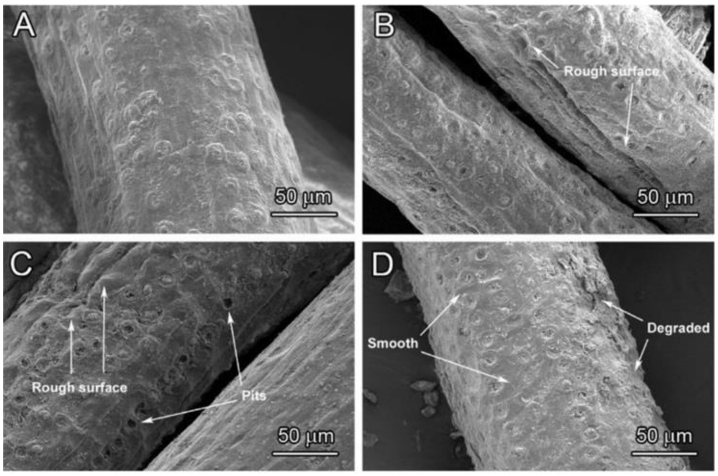

Figure 14. View of fibers under a microscope after spectroscopic techniques

4.3. Importance of Interfacial Adhesion Condition on PFCs

Interfacial adhesion of the fiber/matrix plays a vital role in determining the physical, mechanical, and thermal properties of its composites. Ideally, two materials with similar properties should be combined. For example, in order to create superior interfacial adhesion and strong bond, hydrophilic and hydrophilic materials should be used, and vice versa. Better dimensional stability could be attained when hydrophobic fillers and hydrophobic matrices are combined. Unfortunately, in the case of plant fiber polymer composites, the combination of hydrophilic plant fibers and hydrophobic polymer matrix can lead to inferior dimensional stability as a result of poor interfacial adhesion. However, enhancement could be done through treatment. Impurities removal through effective treatment has made fibers rearrange themselves in a more compact manner, creating stronger composites. This manner has changed the physical characteristics of plant fibers and its composites. Besides, the bonding strength at the interface regulates the proper load-transferring mechanism which in turn to bestow the composite with high toleration toward maximum load bearing. On the other hand, breaking a high interfacial bonding strength requires relatively higher amount of thermal energy, making it perform well under elevated temperatures.

Fiber treatments are often conducted to improve the interfacial adhesion. Optimum treatment parameters resulted in a higher resistance to the pull-out process. Better interfacial adhesion and penetration of molten polymer into rough fiber surface lead to a better mechanical interlocking. Contrarily, poor interface showing fiber debonding and fiber pull-out for under- and over-treated fibers, resulted in poor composite characteristics. Hence, interfacial adhesion condition on plant-fiber-reinforced polymer composite is a crucial factor to control its performances.

TABLE 3: Fiber Pull out stages

Steps	Fiber Pull-Out Stages
1	Initiation of interfacial microfailure at fiber tips due to tensile stress concentration in matrix around fiber tips: from about 50% of ultimate load
2	Separation at the interface, formation of a microvoid. Propagation of interfacial microfailures along fiber sides due to critical shear stress
3	concentration: from about 75% of ultimate load; a fringe pattern of shear mode and microcracks are observed in the matrix along fiber sides.
4	Occurrence of plastic deformation bands in the matrix due to stress concentration caused by the reduction of fiber load bearing capability; crack opening and slow crack propagation through plastic deformation bands (ductile crack propagation).
5	propagate along fiber sides and through the matrix, which leads to composite failure.

TABLE 4: Possible Pull out Condition

	Possible Pull Out Condition
Low Interfacial Bonding Strength	
Medium Interfacial Bonding Strength	
High Interfacial Bonding Strength	

Chapter 5
Discussion & Scope For Future Work

The use of plant fibers as reinforcement in composite materials is finding increasing interest in the automotive and building industry, and the properties of plant fiber composites have been addressed in numerous research studies. New composite materials based on plant fibers and polymers are being increasingly used in the building industry and in automotive industry. Plant fibers, such as sisal, jute, hemp, flax, palm etc can be used as Natural fiber composite materials are being used for manufacturing many components in the automotive sector. Like glass, the natural fibers combine readily with a thermoplastics or thermosetting matrix to produce commodity goods. Typical market specification natural fiber composites include ultimate breaking force and elongation, impact strength, flexural properties, acoustic absorption, fogging characteristics, flammability, and suitability for processing: temperature and dwell time, odor, water absorption, dimensional stability and crash behavior. Plant fibers are mainly used in the interior parts making of passenger cars and truck cabins.

It has prospects for the use of plant fiber in Automotive locomotive, aerospace, construction industry has long way to go to meet the societal area. In railways, the gear case, main doors, luggage racks, floor/roof panels, berths, chair backings, interior panels and partitions, interior furnishing and seating. Modular toilets and lightweight coaches are made from different natural fiber composites and their combinations. Composite materials offer some significant advantages to metals in many structural applications in railways to the effect that they are lightweight, cost-effective, corrosion resistant energy saving Development of biodegradable materials as an alternative to synthetic materials such as glass fiber-reinforced plastic and other synthetic plastics is the challenge for the present and future generations in the context of global climate change.

Chapter 6
Conclusion

To conclude this case study, we found that : -

- Large variation in fiber properties due to various types of plant fiber, plant maturity, plant originality, location in plant and retting process.
- Nature of plant fiber where their strong polar character creates incompact ability with most polymer matrices. Thus, the mechanical properties of natural fiber reinforced composite are influenced mainly by the adhesion between matrix and fiber.
- Natural fiber have good prospective as reinforcements in polymers (thermo plastics, thermosets and elastomers) composites. Due to the high specific properties and low density of natural fibers, composites based on these fibers may have good implications in industry.
- It has prospects for the use of plant fiber in Automotive locomotive, aerospace, construction industry has long way to go to meet the societal area. In railways, the gear case, main doors, luggage racks, floor/roof panels, berths, chair backings, interior panels and partitions, interior furnishing and seating.

Chapter 7

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