

Study of Musa Acuminata Fibre Reinforced Composite- A Review

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Abstract

In recent years the natural particulate and natural fibre composites have attracted substantial importance as a potential structural material. The attractive features of natural particulates and fibres like jute, sisal, coir, banana and bagasse have been their low cost, light weights, renewable and biodegradability. These composites are gaining importance due to their non-carcinogenic and bio-degradable nature. Observing the tremendous advantages and opportunity of particulate and fibres there is a need to further explore the possibility of new natural particulate to be used as reinforcement in composites for mechanical applications. Musa Acuminata, locally called as "BANANA" is one such natural resource found abundantly in many parts of India, whose potential as reinforcement in composite has not been explored much till date. Musa Acuminata contains different percentage of cellulose, hemicellulose, and lignin, which are a necessary in making a reinforced composite. Literature indicates that no significant work will be done on this plant's stem (other than local and non-scientifically traditional or devotional works), but the leaves are good raw material in textile industries. Hence in this present work an attempt will be made to prepare and study the mechanical and environmental behaviour of Musa Acuminata reinforced epoxy composite (by bast fibres).

Keeping this in view the present work will be undertaken to study the development of a polymer matrix composite (epoxy resin) using Musa Acuminata fibres as reinforcement and further to manufacture and study its mechanical properties and environmental performance. The composites manufacture requires different volume fraction of Musa Acuminata fibres. After conduction of several experiments on the composite under laboratory conditions, the effects of different environment such as steam, subzero, saline water and natural conditions on the mechanical properties of the composites can be found out.

Keywords- banana bast fibre; epoxy; composite.

1. INTRODUCTION

1.1 OVERVIEW

The attraction in utilizing natural fibre, for example, distinctive wood fibre and plant fibre as support in plastics has expanded drastically throughout last few years. Concerning the ecological viewpoints if natural fibres might be utilized rather than glass fibres as fortification in some structural provisions it might be extremely intriguing. Natural fibres have numerous points of interest contrasted with glass fibre, for instance they have low thickness, and they are biodegradable and recyclable. Also they are renewable crude materials and have generally great strength and stiffness.

Natural fibres are classified on the basis of the origin of source, into three types:

1. Plant Fibres
2. Mineral Fibres

3. Animal Fibres

1. *Plant Fibres*: Plant fibres are usually consists of cellulose: examples cotton, jute, bamboo, flax, ramie, hemp, coir, banana and sisal. Cellulose fibres are used in various applications. The category of these fibres is as following: Seed fibres are those which obtain from the seed e.g. Kapok and cotton. These fibres have superior tensile properties than the other fibres. Because of these reasons these fibres are used in many applications such as packaging, paper and fabric. Fruit fibres are the fibres generally are obtained from the fruit of the plant, e.g. coconut fibre. Similarly, stalk fibre are the fibres which are obtain from the stalks (rice straws, bamboo, wheat and barley). Leaf fibres are the fibres those are obtained from the leaves (banana and sisal). Skin fibres are those fibres which are obtained from the bast or skin surrounding the stem of the plant (jute, banana etc.).

2. *Mineral Fibres*: Mineral fibres are those which are obtained from minerals. These are naturally obtained fibre or somewhat changed fibre. It has different classifications they are taking after: Asbestos is the main characteristically happening mineral fibre. The Variations in mineral fibre are the serpentine, amphiboles and anthophyllite. The Ceramic filaments are glass fibre, aluminium oxide and boron carbide. Metal filaments incorporate aluminium strands.

3. *Animal Fibres*: Animal fibre by and large comprises of proteins; cases, silk, alpaca, mohair, downy. Animal hairs are the strands got from creatures e.g. Sheep's downy, goat hair, horse hair, alpaca hair, and so forth. Silk fibre is the filaments gathered from dry saliva of bugs or crawling creatures throughout the time of planning of cocoons. Avian strands are the fibre from fowls [1].

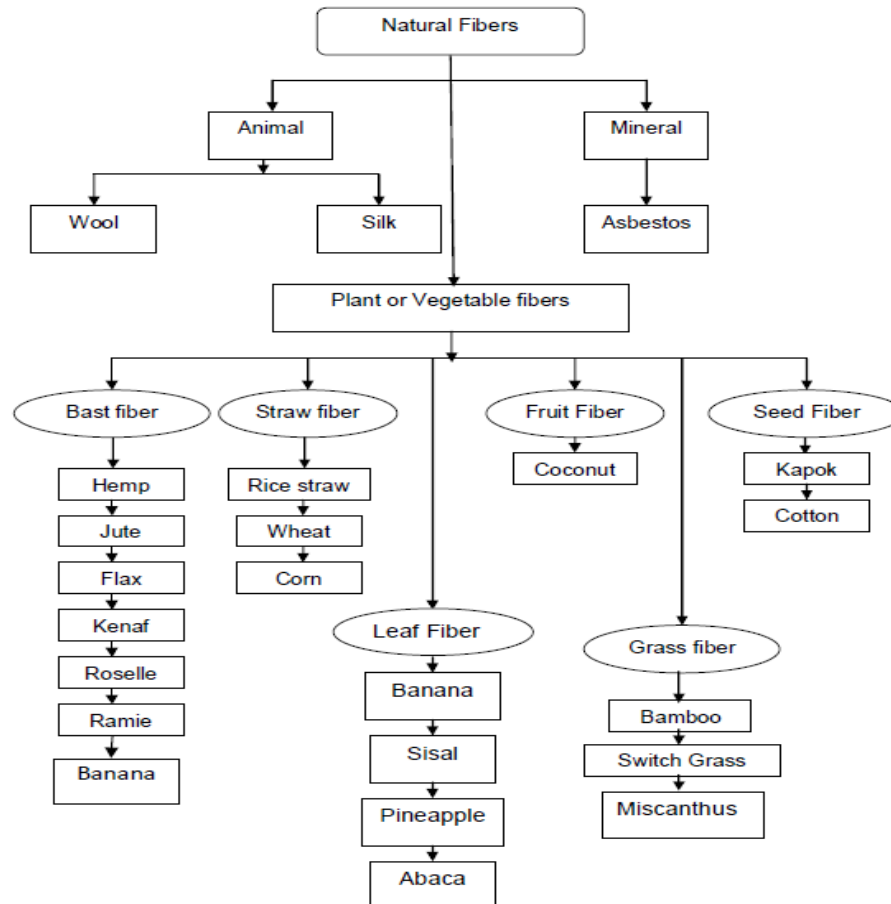


Figure 1.1 Classification of natural fibres

Composites of natural fibre used for drives of structural, but typically with synthetic thermoset matrix which of course bound the environmental benefits. Nowadays natural fibre composites applications are usually found in building and automotive industry and the place where dimensional constancy under moist and high thermal conditions and load bearing capacity are of importance. Natural fibres like cotton, sisal, jute, abaca, pineapple and coir have already been studied like a reinforcement and filler in composites. Among various natural fibres, banana fibre is considered as a potential reinforced in composites due to its many advantages such as easy availability, low cost, comparable strength properties etc. Generally, natural fibres consist of cellulose, lignin, pectin etc. The detail composition of few commonly used natural fibres are shown further.

Table 1.2 Annual Production of natural fibres & sources

Fiber type	Origin	World Production 10 ³ Tons
Coir	Fruit	100
Banana	Stem	200
Bamboo	Stem	10,000
Jute	Stem	2,500
Hemp	Stem	215
Flax	Stem	810
Abaca	Leaf	70
Kenaf	Stem	770
Roselle	Stem	250
Ramie	Stem	100
Sisal	Leaf	380
Sun Hemp	Stem	70
Cotton Lint	Fruit	18,500
Wood	Stem	1, 750,000

1.2 DEFINITION OF COMPOSITE

The most widely used meaning is the following one, which will be stated by Jartz [1] “Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form”.

The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should give it which distinguishes it from other very banal, meaningless mixtures.

Kelly [2] very clearly stresses that the composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them.

Van Suchetclan [4] explains composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

Beghezan [3] defines as “The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their shortcomings”, in order to obtain improved materials.

1.3 CHARACTERISTICS OF THE COMPOSITES

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is harder and stronger than the continuous phase and is called the ‘Reinforcement’, whereas the continuous phase is called the ‘Matrix’.

Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (size, shape, and distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties.

The shape of the discontinuous phase (which may be spherical, cylindrical, or rectangular cross-sanctioned prisms or platelets), the size and size distribution (which controls the texture of the material) and volume fraction determine the interfacial area, which plays an important role in determining the extent of the interaction between the reinforcement and the matrix.

Concentration, usually measured as volume or weight fraction, determines the contribution of a single constituent to the overall properties of the composites. It is not only the single most important parameter influencing the properties of the composites, but also an easily controllable manufacturing variable used to alter its properties.

1.4 COMPONENTS OF A COMPOSITE MATERIAL

In its most basic form a composite material is one, which is composed of at least two elements working together to produce new material properties that are different to the properties of those elements on their own. In practice, most composites consist of a bulk material (the 'matrix'), and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix. Matrices are more ductile and less hard and these are generally either inorganic or natural. The constituents of composite materials have their own properties, however when they are consolidated together, they give a blend of properties that a singular can't have the capacity to give.

1.4.1 Role of matrix in a composite

The matrix isolates the reinforcement from one another in order to prevent abrasion and formation of new surface flaws and acts as a bridge to hold the reinforcement in place. A good matrix should possess ability to deform easily under applied load, transfer the load onto the reinforcement and evenly distributive stress concentration.

(1) Bulk Phases

Generally, composite materials are arranged on the basis of matrix materials as:

1. Metal Matrix Composites
2. Polymer Matrix Composites
3. Ceramic Matrix Composites

Metal matrix composite: Composites consisting of metal matrix such as Mg, Al, Fe are called metal matrix composites. The interest in metal matrix composites is due to many reasons such as their engineering properties. They exhibit good stiffness, light weight, and low specific weight as compared to other metal alloys and metals. Although it has many advantages, low cost remains a major point of interest for many applications.

Metal matrix composites possess some attractive properties, when compared with organic matrices. These include

- (i) Strength retention at higher temperatures.
- (ii) Higher transverse strength,
- (iii) Better electrical conductivity,
- (iv) Superior thermal conductivity,
- (v) Higher erosion resistance etc.

However, the major disadvantage of metal matrix composites is their higher densities and consequently lower specific mechanical properties compared to polymer matrix composites. Another notable difficulty is the high-energy requirement for fabrication of such composites.

Polymer matrix composite: Polymer matrix composites are recognized to be a more conspicuous class of composites when contrasted with artistic or metal lattice composites once in business requisitions. It includes a

matrix from thermoplastic (polystyrene, nylon) or thermosetting (epoxy, unsaturated polyester) or an inserted steel, glass carbon, or Kevlar strands.

A very large number of polymeric materials, both thermosetting and thermoplastic, are used as matrix materials for the composites. Generally speaking, the resinous binders (polymer matrices) are selected on the basis of adhesive strength, fatigue resistance, heat resistance, chemical and moisture resistance etc. The resin must have mechanical strength commensurate with that of the reinforcement. It must be easy to use in the fabrication process selected and also stand up to the service conditions. Apart from these properties, the resin matrix must be capable of wetting and penetrating into the bundles of fibres which provide the reinforcement, replacing the dead air spaces therein and offering those physical characteristics capable of enhancing the performance of fibres.

Ceramic matrix composite: The composite which is consisting of a ceramics combined with a ceramic dispersed phase. Because of availability of new technologies, the demand for high performance products and processing methods, the growth of advanced ceramic products is improved, but brittleness of ceramics still retain a major disadvantage. Ceramic fibres, such as alumina and SiC (Silicon Carbide) are advantageous in very high temperature applications, and also where environment attack is an issue. Since ceramics have poor properties in tension and shear, most applications as reinforcement are in the particulate form (e.g. zinc and calcium phosphate). Ceramic Matrix Composites (CMCs) used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibres, or whiskers such as those made from silicon carbide and boron nitride.

Among these all types of composites, polymer matrix composite is most commonly used composites, because of its advantages such as high strength, low cost, simple manufacturing procedure. The requirement of polymer material in this modern dynamic world is increasing day by day because it has wide range of advantages over traditional material in terms of high strength to weight ratio, cost, high toughness, high tensile strength and high creep resistance at increase in temperatures. Polymer matrix composites have three types of polymers which have been used as matrix. These are thermoplastics, thermosetting polymers and elastomers.

Thermoplastic polymer is that polymer which are over and again diminished and transformed by heating. A few illustrations of thermoplastics are PVC, PP, PS, LDPE and HDPE. Thermoplastic materials are shaped when they are in softened or melted. Thermoplastics have numerous properties, for example, light weight, low thicknesses, which rely on science they could be similar to elastics, and strong as aluminium.

Thermosetting polymer is the polymer which has hard and firm cross-interfaced materials. They are not moldable when at room temperature and soften when they are warmed. Epoxy is the most normally utilized thermosetting polymer. They have numerous advantages, for example, better grip to different materials, great mechanical properties, and great electrical protection.

Elastomer is a kind of polymer which is determined from flexible polymer, is frequently utilized reciprocally with the term elastic, despite the fact that the last is favored when alluding to vulcanizes. Elastomers have numerous properties which having low density and high disappointment strain compare with other materials. The other sort of constituents of composites is reinforcements. Reinforcements are generally used to upgrade general mechanical properties of matrix and offer quality to composites. The reinforcements in composites are either fibrous or non-fibrous. Again fibrous composites are either natural fibre reinforced or synthetic fibre reinforced composites. There are many factors affecting the properties of fibre reinforced polymer composites such as fibre parameters, fibre-matrix, interfacial bonding etc. A great deal of work will be done on the different kinds of natural fibre based polymer composites [5].

(2) Reinforcement

The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the neat resin system. All of the different reinforcement used in composites have

different properties and so affect the properties of the composite in different ways. For most of the applications, the fibres need to be arranged into some form of sheet, known as a fabric, to make handling possible. Different way of assembling fibres into sheets and the variety of fibre orientations make possible to achieve different characteristics.

(3) Interface

It has characteristics that are not depicted by any of the component in isolation. The interface is a bounding surface or zone where a discontinuity occurs, whether physical, mechanical, chemical etc. The matrix material must “wet” the reinforcement (fibre or particulate). Coupling agents are frequently used to improve wet ability. Well “wetted” fibre or particulates increase the interface surfaces area. To obtain desirable properties in a composite, the applied load should be effectively transferred from the matrix to the reinforcement via the interface. This means that the interface must be large and exhibit strong adhesion between reinforcement and matrix. Failure at the interface (called deboning) may or may not be desirable.

1.5 TYPES OF COMPOSITE MATERIALS

1.5.1 Fibre-reinforced composites

Reinforced-composites are popularly being used in many industrial applications because of their inherent high specific strength and stiffness. Due to their excellent structural performance, the composites are gaining potential also in tribological applications. In this type composite the second phase is in the form of fibres dispersed in the matrix which could be either plastic or metal. The volume fraction (V_f) varies from a few percentage to as high as 70%. Usually the fibre reinforcement is done to obtain high strength and high modulus. Hence it is necessary for the fibres to possess higher modulus than the matrix material, so that the load is transferred to the fibre from the matrix more effectively.

1.5.2 Particulate composite

A particulate is characterized by its size. The dimensions of the reinforcement determine its capability of contributing its properties to the composite. Particulates are very effective in improving the tensile and flexural strength of the matrix since a reinforcement having a fine size discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to failure, particularly with brittle matrices. Also these materials possess improved high temperature strength and creep resistance.

1.6 NATURAL FIBRES

Natural fibres can be obtained from natural resources such as plants, animals or minerals. With the increase of global crisis and ecological risk, the unique advantages of plant fibres such as abundant, non-toxic, non-irritation of skin, eyes or respiratory system, non-corrosive property, plant-fibre reinforced polymer composites has lately received increasing attention both from academia and by industries. It can be brought to notice that compared to most synthetic fibres, natural fibres are has emerged to be more environment- friendly and appeared realistic alternative for the following reasons:

- (1) Natural fibre production has consumed of non-renewable energy lesser than synthetic fibre and thus lesser pollution emissions.
- (2) The higher volume fraction of natural fibre than synthetic fibre for equivalent performance has decreased the volume and weight of basic synthetic polymer matrix, which decreases the energy use and emissions in production of polymer.
- (3) The lower weight (20-30 wt.%) and higher volume of natural fibre compared to synthetic fibre has improved the fuel efficiency and reduced emission in the use phase (automatic applications).

1.6.1. Chemical composition of natural fibres

The proportions of constituents of any natural fibre vary with origin, area of production, variety and maturation of plant.

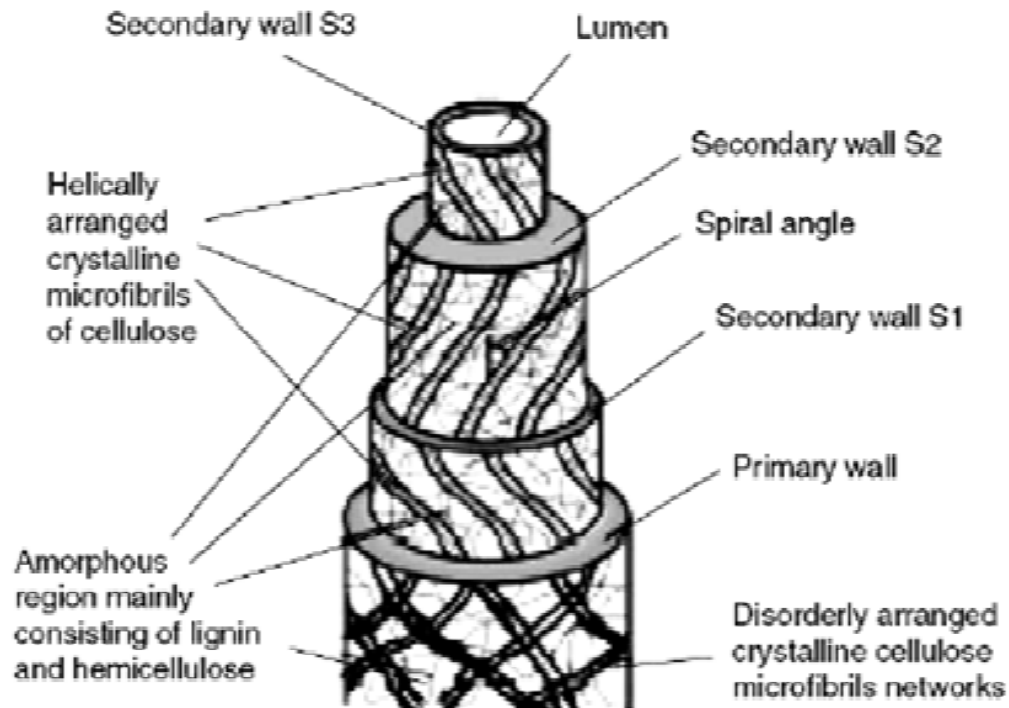


Fig 1.2 Structure of plant fibre

The major constituent of a fully developed natural fibre cell walls are cellulose, hemicellulose, lignin and pectin. These hydroxyl-containing polymers are distributed throughout the fibre wall.

a) Cellulose

The long thin crystalline micro-fibrils in the secondary cell wall are made of cellulose. It is the reinforcing material and is responsible for the high mechanical strength of fibres. It consists of a linear polymer of D-anhydrous glucose units where two adjacent glucose units are linked together by β -1, 4-glycosidic linkages with elimination of one water molecule between their -OH groups at carbon atoms (1 & 4).

Chemically, cellulose is defined as a highly crystalline segment alternating with regions of non-crystalline or amorphous cellulose [6]. The glucose monomers in cellulose form hydrogen bonds both within its own chain (intra molecular) forming fibrils and with neighbouring chains (intermolecular), forming micro fibrils. These hydrogen bonds lead to formation of a linear crystalline structure with high rigidity and strength. The amorphous cellulose regions have a lower frequency of intermolecular hydrogen bonding, thus exposing reactive intermolecular -OH groups to be bonded with water molecules. Amorphous cellulose can therefore be considered as hydrophilic in nature due to their tendency to bond with water. On the other hand, very few accessible intermolecular -OH are available in crystalline cellulose and it is far less hydrophilic than amorphous cellulose. Crystalline micro-fibrils have tightly packed cellulose chains within the fibrils, with accessible -OH groups present on the surface of the structure. Only very strong acids and alkalis can penetrate and modify the crystalline lattice of cellulose.

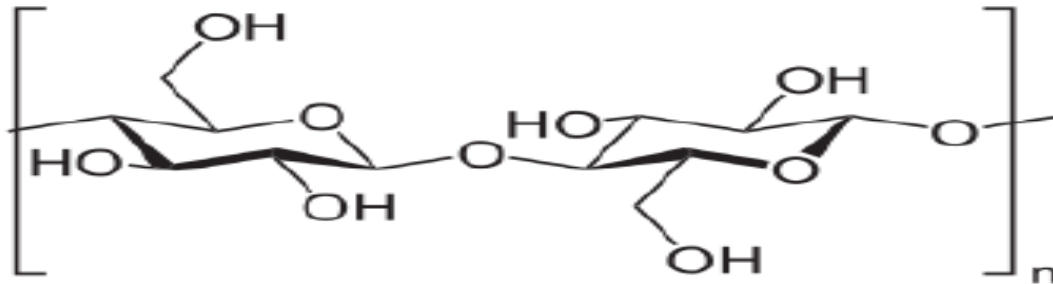


Fig 1.3 Structure of cellulose

b) Hemicelluloses

Hemicelluloses differ from cellulose in three different ways. Firstly, unlike cellulose (containing only 1, 4- β -D-glucopyranose units) they contain several different sugar units. Secondly, they exhibit a considerable degree of chain branching, whereas cellulose is a linear polymer. Thirdly, the degree of polymerization of native cellulose is ten to hundred times higher than that of hemicelluloses. Unlike cellulose, the constituents of hemicelluloses differ from plant to plant. Hemicelluloses contain substituents like acetyl (-COCH₃) groups and glucuronic acid. By attaching ferulic acid and p-coumaric residues, hemicelluloses can form covalent bonds to lignin [4]. Due to this linking ability of hemicelluloses, degradation of it leads to disintegration of the fibres into cellulose micro-fibrils resulting in lower fibre bundle strength [5].

c) Lignin

Lignin increases the compression strength of plant fibres by gluing the fibres together to form a stiff structure, making it possible for trees of 100 meters to remain upright. Lignin is essentially a disordered, polyaromatic, and cross-linked polymer arising from the free radical polymerizations of two or three monomers structurally related to phenyl-propane [6]. Free radical coupling of the lignin monomers gives rise to a very condensed, reticulated, and cross-linked structure. The lignin matrix is therefore analogous to a thermoset polymer in conventional polymer terminology. The dissolution of lignin using chemicals aids fibre separation. When exposed to ultraviolet light, lignin undergoes photochemical degradation. The lignin seems to act like a matrix material within the fibres, making stress transfer on a micro-fibril scale and single fibre scale possible. Studies of fibre composition and morphology reveals that cellulose content and micro fibril angle tend to control the mechanical properties of celluloid fibres.

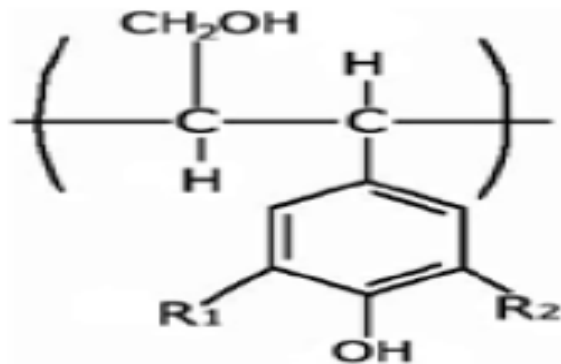


Fig 1.4 Structure of Lignin

Table 1.3 Chemical compositions of natural fibres

Fiber type	Cellulose (wt %)	Hemicellulose (wt %)	Lignin (wt %)	Pectin (wt %)	Moisture content (wt %)	Waxes (wt %)	Micro fibrillar angle (Degree)
Flax	71	18.6-20.6	2.2	2.3	8-12	1.7	5-10
Hemp	70-74	17.9-22.4	3.7-5.7	0.9	6.2-12	0.8	2-6
Jute	61.1-71.5	13.6 -20.4	12-13	0.2	12.5-13.7	0.5	8
Kenaf	45-57	21.5	8-13	3-5	--	--	--
Ramie	68.6-76.2	13.1-16.7	0.6-0.7	1.9	7.5-17	0.3	7.5
Nettle	86	--	--	--	11-17	--	--
Sisal	66-78	10-14	10-14	10	10-22	2	10-22
PALF	70-82		5-12.7		11.8	--	14
Banana	63-64	10	5		10-12	--	--
Abaca	56-63	--	12-13	1	5-10	--	--
Cotton	85-90	5.7		0-1	7.85-8.5	0.6	--
Coir	32-43	0.15-0.25	40-45	3-4	8		30-49

2. LITERATURE SURVEY

2.1 BACKGROUND

Composite structures have shown universally a savings of at least 20% over metal counterparts and a lower operational and maintenance cost [7]. As the data on the service life of composite structures is becoming available, it can be safely said that they are durable, resist fatigue loading, maintain dimensional integrity and are easily maintainable and repairable.

From mechanical point of view, in natural fibres, the enhanced mechanical properties of polymers with some considerations can give improvement to the surface characteristics natural fibres. There are several factors related to the natural fibres which influence the performance of the composites such as the orientation, interfacial adhesion, the strength, physical properties, etc. The mechanical properties of the fibre reinforced polymer composites depends on the fibre–matrix interface and the ability to transfer stress from the matrix to reinforcement as reported by many researchers [8-12]. For automotive applications utmost impact strength is required in order to implement a maximum of passenger safety by good crash behavior. H. Mueller [13] describes the effects of several material parameters such as fibre fineness or fleece composition as well as the impact of the process conditions on this important composite characteristic. Composite of chopped sun hemp and polyester composite were examined by Navin Chand and P. K. Rohtagi [13] and they reported that the impact strength increases with the increase in volume fraction of fibre because the fibres help in arresting and diverting cracks.

2.2 LITERATURE ON MUSA ACUMINATA

Banana is in Musa family. Banana plant is a large perennial herb with leaf sheaths that form pseudo stem. Its height can be 10-40 feet (3.0-12.2 meters) surrounding with 8-12 large leaves. The leaves are up to 9 feet long and 2 feet wide (2.7 meters and 0.61 meter). Its fruits are approximately 4-12 inches (10.2-30.5 centimeters). Different parts of banana trees serve different needs, including fruits as food sources, leaves as food wrapping, and stems for fibre and paper pulp. It is available throughout Thailand and Southeast Asia, India, Indonesia, Malaysia, Philippines, Hawaii, and some Pacific islands. This source of fibres provides great strength, used generally in particular products, such as tea bags and Japanese yen notes. Typically, banana plants are grown in 3 types; (1) food source, (2) decorative plants, and (3) starch and fibres sources (abaca). Abaca fibre has a long history as a leading cordage fibre of the world, known as Manila hemp. Abaca is one kind of banana plants. The fibre is obtained from outer layers from the stalks of the abaca plant. It is light, strong, and durable. After extraction and dry, it provides a white lustrous colour fibre. One particular characteristic of the abaca fibre over all other fibres of its class is the great strength and resistance to the action of water, therefore its particular adaptability for marine ropes. However, abaca's fruit is not human food source. It is specifically grown for fibre cultivation. Instead of growing banana tree only for fruit consumption and discard the trunks, the use of banana fibres after the fruits are harvested should be explored. Therefore, the focuses of this research is on banana fruit plant.

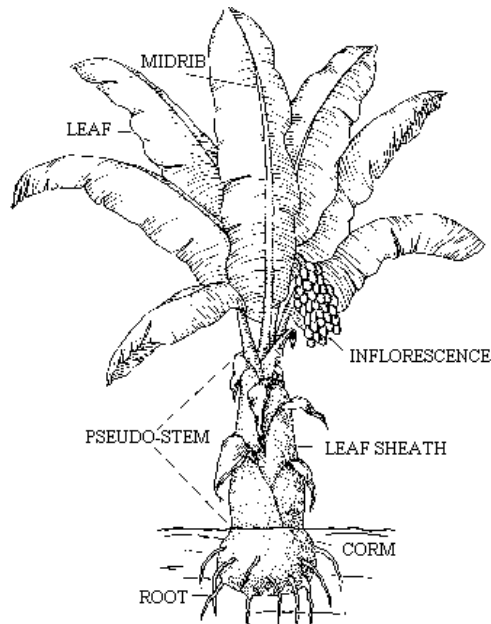


Image 2.1 Detailed Image of Banana Plant

The mechanical behavior of a natural fibre based polymer composite depends on numerous factors, for example, fibre length and quality, matrix, fibre-matrix adhesion bond quality and so forth. The strong interface bond between fibre and matrix is paramount to show signs of improvement mechanical properties of composites. Merlini et al. [13] have studied the effect surface treatment on the chemical properties of banana fibre and reported that treated banana fibre give higher shear interfacial stress and tensile strength when compared with the untreated fibre. Dhieb et al. [13] have studied about the surface and sub-surface degradation of unidirectional carbon fibre and have given many conclusions such as under sliding in demineralized water, the simplest degradation will be detected on sliding in anti-parallel direction. Shankar et al. [9] have studied and reported that the ultimate tensile strength value maximum at 15% and then decreases with increasing in fibre starting from 15% to 20%. They also reported that the flexural strength value decreasing from 5% to 10% (87.31 MPa) and after that the value increased from fibre.

The effects of this study uncovers that short zigzag/random oriented fibre composites with great rigidity and element mechanical properties might be effectively ready utilizing banana fibre as reinforcement in a polyurethane matrix inferred from castor oil. The treated banana fibre demonstrated higher shear stress and tensile strength when contrasted with the untreated fibre, showing a solid association between the treated strands and the polyurethane matrix. The hybridization of these reinforcements in the composite shows more terrific flexural quality when contrasted with singular kind of characteristic strands strengthened composites.

Maleque et al. [22] have studied the mechanical properties of banana fibre based epoxy composite and observed that the tensile strength is increased by 90% of the pseudo-stem banana fibre reinforced epoxy composite associated to virgin epoxy. In his results the impact strength of pseudo-stem banana fibre improved by approximately 40% compare to the impact strength of neat epoxy.

2.3 MOTIVATION FOR FIBRE REINFORCEMENT

Although thermoplastics provide a great alternative to the irreversibility of thermoset polymers and resulting low processing cost, the loss of mechanical strength is not insignificant. Especially as industries such as aerospace, require high strength-to-weight materials, there is a great need to increase product strength,

stiffness, and toughness. Fibre-reinforcement is an excellent method to improve these composites without radically affecting processing methods. Ranging from 20 to 60 percent of composite volume filled with fibre, product cost can often drop proportionally. The composition of lignocellulose fibres, such as banana fibres, does cause significant limitations in the fibres' interfacial compatibility. This interfacial compatibility plays a primary role in the mechanical performance of a composite, and must be addressed. Lignocellulose fibres are inherently polar and hydrophilic, meaning they readily absorb moisture. Since the majority of thermoplastic polymers are non-polar and hydrophobic, meaning polymers do not absorb or bond with water, the fibres and polymer are naturally incompatible and have inefficient fibre-matrix interfacial bonding. This poor adhesion effectively dilutes the composite matrix and causes the fibres to act as flaws in the composite, greatly reducing the mechanical strength.

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