A Review on Natural Fibre Polymer Composites

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ABSTRACT
Natural fibre are readily available in abundant within our surrounding. It is cheap, easy to harvest and environmental friendly. With environmental issue arising from problem of disposing synthetics fibre, natural fibre are starting taking its place in composite product development. Unlike its synthetic rival, natural fibre are potentially biodegradable and poses less threat to the environment. Natural fibre may be a good substitution to synthetic fibre should the proper treatment and manufacturing method applied. This review aim to provide overview of natural fibre composites, its characteristic, why natural fibre composite are used in order to improve material properties to blend with matrix, their mechanical properties and applications. Particular attention being made on kenaf due to its abundance availability and making it a good fibre source in Malaysia. Kenaf is also having similar properties of jute and carry many possibilities to be utilized commercially provided its weakness is addressed properly.

Keywords *– Natural Fibre Polymer Composites (NFPC), Kenaf fibre, Tensile properties, Compression properties.*

I. INTRODUCTION

A composite material is a material made of two or more material which aims to obtain properties advantage of each material involved. Composite materials consist of matrix and fibre which contribute to the physical properties of the composite. They did not undergo chemical reaction, making it possible to separate the fibres and matrix physically. Composite are normally used to increase material strength, getting a lighter component, corrosion resistivity, and cost advantage (as cheaper material substitution)[1].

Evidence of composite popularity can be seen by increasing application in the automotive, aerospace, marine as well as sporting goods [1].

In automotive the composite material is initially used by racing car to reduce its weight. As cost and technology advance, it is getting cheaper to apply composite technology and now days we can see various composite parts being used to gain weight saving. Car bonnet, spoiler are some of the examples of parts made of composite. For marine, a traditional vessel made of wood are now replaced by fibreglass boat. It offer a much lighter parts and cheaper to when compare to wood or metallic structures [2].

In sports application, example of composite material can be found in golfing as well as badminton. Golf clubs are using carbon fibre material to reduce weight and also increase strength. Badminton racket frame are now made of composite to gain weight advantage as well as other mechanical properties such as strength and flexibility.

Previously synthetics fibre such as carbon fibre and glass fibre are used for the composite making. Glass fibre for example offers a lightweight material substitution for automotive parts. This enables a more efficient vehicle with less emission due to lightweight characteristic of vehicle using carbon or glass fibre [3]. However a new issue arises, with regard to disposal of non biodegrable composites. These composite does not decay naturally and poses harm to the environment. It is reported that some non biodegradeable materials may take up to few hundred years to decay. Even worst, some materials like glass and polystyrene might never biodegrade.

Accumulation of the materials over years have started another pollution issue. Trash of non-biodegradable materials are flooding seas, harming sea creatures. It was reported creature like turtle are death due to suffocating with polystyrene. On land, these material pollute land, started to clogged drain, as well as create air pollution when burned in the air.

Due to these issues, natural fibre composite are gaining popularity in the recent years. They are biodegradable which means environmentally friendly and easy to

source. They are also relatively cheaper when compare to the non-natural composite material cost. For example hemp is naturally available and does not need to undergo any complicated process before can be used as component in composite [2].

There are however limitation for application of natural fibre composite. For example, incompatibility with matrix, risk of degradation due to moisture absorption properties of natural fibre, physical properties of the fibre itself which prevent good bonding with matrix [4].

There have been a case where natural fibre found to be incompatible with matrix, due to less bonding between two, composite degradation due to natural fibre absorbing water than it should do as well as inconsistency of the fibre geometry that make it difficult to produce a uniform composite quality.

In order to overcome these limitation, there have been many studies to improve the quality of natural fibre composite. For example Changlei Xia [5] do perform a preparation of the natural fibre material through Calcium carbonate inorganic nanoparticle to improve mechanical properties as well as water resistance of kenaf fibre/polyester composite. The nano particle improve tensile strength of kenaf/polymer composite about 20% when compared with kenaf/polymer composite without nano particle impregnation.

The aim of this paper is to review about composite material development using natural fibre as well as improvement done so far to achieve a better natural fibre composite properties.

II. NATURAL FIBRE

Natural fibre are fibre that is derived from natural resources. We can classify natural fibre into three categories; consist of plant, animal or mineral fibre. [6]. The literature study however will focused on natural fiber from plant. According to A.K. Bledzki [1], stem, bark, seed and leafs are among plant parts that can be utilized as natural fiber material. They are naturally available at our surrounding making it an abundance source as well as cost economic as it is readily available.

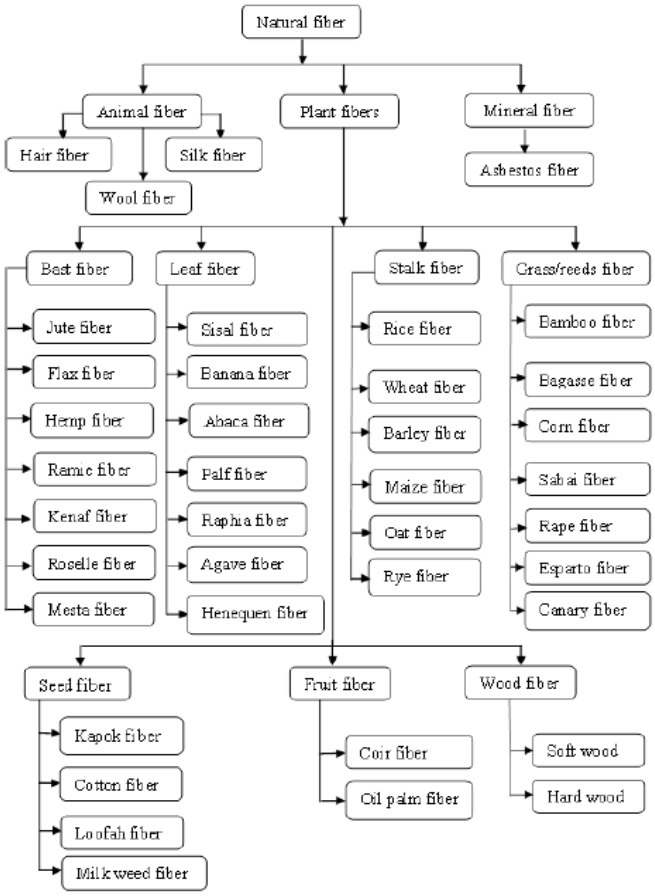

Figure 1: Natural Fibre classification [6]

Zoi N. Terzopoulou in his study did mentioned about few classification of natural fiber consist but not limited to bast, leaf , fruit, and grass, straw and wood pulp[2].

Natural fiber obtained from plant contain mainly cellulose and its structural vary for each plant. The different structural explain why they have different size and diameter. Due to this physical trait, the tensile strength and elongation of the each plants or part used will vary when subjected to the same force. It was found that a different natural fiber when applied to same matrix will produced different composite characteristic such as strength, rigidity, flexibility and impact resistivity.

Different fiber are also having different chemical composition. This composition may affect their characteristic beside physical properties described in Table 1 below.

TABLE 1: Chemical composition percentage of common natural fiber [7]

Name of Fiber	Cellulose (wt%)	Hemi-cellulose (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

Kenaf Fiber

Kenaf is natural fiber derived from bast of plant. The kenaf plant or Hibiscus Cannabinus is a plant originated from Africa and believed to be in existence for more than 4000 years. Beside supplying fiber for fiber glass substitution kenaf plant also being used in mattress and furniture production.

In Malaysia, Kenaf is consider as industrial crop. It is being planted commercially due to its suitability with Malaysian climate. Kenaf will require only four month to achieve its maturity for harvesting, making it fast returning investment.

Figure 2: Kenaf Trees being planted in Malaysian Soil.

Kenaf fibers are considered as long fibers. It is derived from outer fibrous bark of the bast. Due to its long fiber, it have potential to be used in various polymer composite product. Many studies have been conducted for kenaf composites in order to improve the features of the polymers. Kenaf, having a similar mechanical properties of existing materials which make it as potential substitution materials for composite applications [8].

III. POLYMER COMPOSITES

Polymer matrix

Polymer is an element form by chain of molecules side by side. This is achieved by polymerization process where it produces a long chain due to this bonding structure. Beside length of the chain molecular, distribution of mass will contribute to the structural of the polymer. Since they are made of monomer they shall pose chemical characteristic of its parent monomer. Polymer can be made of 1 or more type of monomer, which result a more complex structure. This is normally done in order to gain chemical advantage of both materials

Umar Nirmal [9], describe polymer types into three categories, namely thermoplastic, thermosetting and elastomeric.

Thermosetting polymer obtained when the heat is applied to the monomer and form a polymer. The process is irreversible. Thermosetting polymer are found to be stronger when compared to thermoplastic and potentially to be used in higher service temperature.
Thermoplastic polymer have tendency to melt at higher temperature and become hardened when cooled. This allow thermoplastic polymer to be reshaped when subject to heat. Thermoplastic properties are changeable by altering form and length of the individual chain of monomer it is made of. Polypropylene, polyvinyl chloride and polyethylene are example of thermoplastic polymer material [10].

Elastomer polymers are form through cross linked reaction between monomer. The structural of monomer in the elastomeric are not in regular arrangement. They may be stretched to greater extend, which portray elastic properties and hence the name given, elastomer. Rubber is a good example of elastomeric polymer.

Polymer exist naturally and can also can be made available thru synthesis. Example of natural polymers

are wool, protein, DNA, and silk. For synthetic polymer, rubber produced as a result of vulcanization is a good example how this material can be man produced.

According to Sarah [11] polymer are available in various form such as packing materials, toys, clothing, shampoo as well as automobile application. Polymer have advantages such as light, lower production cost, long lasting and easy to be formed into shape. However polymer also has disadvantages. They tend to be flammable when subject to heat.

Polymer Composite

Polymer composite is the composite material with polymer material as the matrix. The function of the matrix is to hold the fiber together and also to provide supplementary advantage to the fiber. For example some fiber are very good at tension but failed under compression. Hence matrix help to hold them together and also provide compression resistance resulting a better overall composite properties. Apart of that matrix help protect fiber reinforced composite against environment (humidity), mechanical damage due to friction as well as transferring load to the next fibers [12]. Presently, there are two type of matrix that is commonly used in preparation of natural fiber composite, thermoplastic polymer and thermoset polymer such as epoxy.

Polymer composite are alternative to epoxy composite and have some advantage as well as advantages when compare to epoxy composite. Table 2 below summarize some comparison between polymer and epoxy composite based on the same fiber used. The different in characteristic is purely due to matrix (polymer/epoxy) properties that contribute to the different of composite characteristic. Obviously there are a lot of polymer weakness that may be studied in future.

TABLE 2: Comparison of composites based on polymer matrix [8],[13]

Criteria	Thermoplastic composite	Thermoset composite
Production cost	Cheaper	Expensive
Rate of production	Shorter period (shorter curing time)	Longer period (longer curing time)
Strength	Lower	Higher
Matrix-fiber bonding strength	Lower	Higher
Water resistivity	Lower	Higher
Tensile strength	Lower	Higher
Stiffness	Lower	Higher
Shrink volume	Higher	Volume

Natural Fiber Polymer Composite (NFPC)

Natural fiber composite is composite material consisting of polymer matrix and one or more natural substance as a fiber. Natural fiber composite are produced by mixing heated polymer resin with one or more natural fiber. The mixing solution must be allowed to cool over some period of time where it will solidify and hold the natural fibre at its place. NFPC's are gaining popularity due to lower production cost, easy to shape and reshape. Shape of NFPC may be easily amended by reheating the composite, re-melting the polymer above its activation temperature. Since composite material did not react chemically, the characteristic of the polymer matrix remain and theoretically may be reshape on unlimited basis without any degradation.

IV. MECHANICAL PROPERTIES

The characteristics of the composite are mainly determine by two factors namely fibre and matrix. The stronger the fibre the stronger the composite potentially be. Matrix help bond fibre together as well as supplementing fibre weaknesses. A good bonding between matrix to fibre will help to transfer load among fibres effectively [14]. Beside matrix helps to protect fibre itself from mechanical damage, humidity that potentially damage the natural fibre. It can be concluded a composite made of natural fibre exhibit better mechanical properties when compare to pure matrix itself [14]. Beside interrelation between fibre and matrix, fibre properties such as length, volume fraction, aspect ratio and orientation does also affect mechanical characteristic and becoming interesting topic of study [15].

Natural Fibre with common polymer matrix are explored for their compatibility. Hence, the dissimilarity will be purely contributed by the fibre used in the composite itself. One of the factor that distinguish each natural fibre composite is the mechanical properties of the natural fibre itself, which vary due to chemical composition, orientation of fibrils and also percentage of cellulose in each fibre. These factor does effect fibre strength individually. Bledzki [1] in his study concluded different alignment of cellulose microfbrills and also different fibre bundle orientation does explained why they have different mechanical properties.

Compressive Properties

Compressive properties of Natural Fibre Composite varied for different fibre used. A.W. Van Vuure[16] performed compressive test for three natural fibre composite (flax, bamboo and coir) according to ASTM

3039. Based on test sample of 230 x 12.7 x 2mm^3 and test span of 150mm, it was found that compressive properties of the three fibre tested to be between 60 to 80% of tensile properties. It was also concluded performance of natural fibre composite are less than glass fibre when subject to compression.

Allan C. Manalo [17] performed compression test on polyester bamboo composite and plot stress strain curves produced from the testing. He observed a linear elastic characteristic for the composite and demonstrates non liner when subject to higher compression. Allan [17] also observed reduction of composite strength when tested at elevated temperature 120^{0}C. The finding are in line with Sigley et al [18] observation on resin characteristic, ductile when subject to compression.

A study [19] provided suggestion of relationship between compression properties of composite and interfacial adhesion between fibre and matrix. It was suggested interfacial adhesion play a major role in determining compression properties, and may be a good subject for improvement.

Tensile Properties

Tensile properties are one of the main indications to gauge material strength. It is obtained by applying a load over the samples and measure the force required to achieve before the material failed (break). The test shall be conducted with dedicated testing machine in order to obtain an accurate data. Other parameter may be also monitored during the experiment such as material elongation prior to break. There is an international standard being practiced to performed tensile test. ASTM D638 provide guideline for testing the tensile strength and also method to calculate their mechanical properties resulting from the test. Specimens for ASTM D638 are dumbbell-shaped with either a 25 mm or 50 mm gauge length; a 50 mm gauge length is recommended.

Feldmann [20] in his experimental has observed increase of tensile properties for polyamide with 20% and 30% cellulose fibre compared to a pure polyamide. This provide evidence role of fibre in strengthened composite material compare to strength of pure resin alone. Method of manufacturing also affects tensile strength of composite material.

Zhen-Xiu Zhang [21] in his experimental work have discover different tensile values of composite materials when subject to different extruder screw speed. These facts indicate a variable factor of improvement that can be studied in the future.

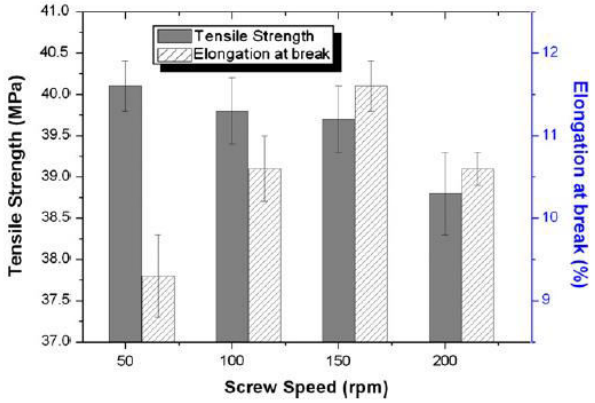

Figure 3: Tensile strength and elongation at break for different extruder screw speed [21].

V. APPLICATIONS OF NFPC

Polymer composite are used in (but not limited) various industry such as construction, automotives, machineries, aerospace and military. In construction, evidence of application can be found by construction materials such as Fibre Reinforced Plastic Gratings, composite decking and lately cement-polymer composite are being introduced to overcome weakness of traditional cement used. Polymer cement are found to be able to withstand deterioration as a result of water absorption. In automotives, NFP Care potentially to be used as material for car bumper, as a materials for bicycle frame, fishing boats. The aim of polymer composite application in this industry is driven by weight saving. Evidence of application of composite in the airplane can be seen by composite materials in the centre wing box's primary structure, wing ribs, and rear fuselage section**.** The development of natural fibre composite, addressing it weakness has open its potential to application that has never been imagine before. Low maintenance cost, high stress to weight ratio, easy installation are among factor it is being considered as replacement to conventional material such as metal, aluminum and FRP.

VI. CONCLUSION

This paper reviews about natural fibre, its application and composite materials. Current problem of non-natural materials used in composite materials are referred to, including issue of disposing these materials as they no longer required. The non-biodegradable item do not degrade and stay on earth. It became worst in time as people find it getting difficult to handle them as well as issue with wildlife life being threatened due to these

non-perish materials. Introduction to natural fibre, its type and source being discussed as well as kenaf as potential natural fibre material due to its abundance in Malaysia. There is a lot of room for natural fibre application should its weaknesses are mitigate. This include improving adhesion between fibre and matrix, a major factor affecting natural fibre strength and physical properties. When it comes to the fibre, potential study include influence of fibre properties such as length, volume fraction, aspect ratio and orientation to the overall composite properties. Natural Fibre composite becoming more practical as a result of its development. Evidence of natural fibre gaining popularity could be found in construction, automotive and aerospace.

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