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A Review on Characteristic of Polymer Composites with Natural Fiber Used as a Reinforcement Material

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Abstract: Natural fiber-reinforced polymer composite materials are quickly growing both in terms of their industrial applications and primary research as they are renewable, low, completely or partially recyclable and eco-friendly. In order to produce cost effective polymer reinforced composites and to reduce the destruction of ecosystem, researchers have come up with new manufacturing trends for composite using natural fibers which are partially biodegradable, for which plants such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, banana, wood etc., used from time immemorial as a rich source of lignocellulosic fibers are more often applied as the reinforcement of composites. The chemically treated natural fibre shows better improvement in properties than untreated fibres. The chemically treated natural fibre has improved interfacial adhesion between fibre surface and polymer matrix. Natural fibre reinforcements have shown better results in impact toughness and fatigue strength. This review aims at explaining about the research and development in the improvement in properties of natural fibre reinforced polymer composites along with its application.
Keywords: Natural fibers, Composites, Polymer, Reinforcement, Mechanical properties

I. INTRODUCTION

Basically, when two or more than two chemically distinct materials are combined, produces synergistic effect, with a distinct separating interface of component. Due to this the component gets aggregate properties different from the component by which it is formed. The main components cannot compete with the composites in terms of properties [2]. The component materials can be metal, ceramic or polymer etc. [3].The use of natural or plant fibre reinforced composite [4] is increasing with time. This is due to its advantages like low cost, ease of availability, light weight etc. The important and exclusive properties of natural composite are its renewability and biodegradability. These properties with low cost fulfil the economic interest of industries [5]. These materials are eco-friendly and use of green materials in these composites also provides an alternative way to deal with agricultural residue [1]. Natural fibers already have been used the first time 3000 years ago in composite systems in the ancient Egypt, where straw and clay were mixed together to build walls. Over the last decade, polymer composites reinforced with natural fibers have received ever increasing attention, both from the academic world and from various industries. The interest in natural fiber reinforced polymer composite material is growing day by day [1, 2, 3]. There are a wide variety of different natural fibers which can be applied as reinforcement or fillers. The most important types of natural fibers used in composite materials are flax, hemp, jute, kenaf, and sisal due to their properties and easy availability. Further environmental suitability can be achieved by using post-consumer recycled plastic in place of virgin polymer matrices. The major problem identified with natural fibers is the incompatibility between the hydrophilic natural fibers and the hydrophilic thermoplastic matrices during incorporation, which leads to undesirable properties of the resulting composites. It is therefore necessary to alleviate this problem by various fiber-polymer interface modification to improve the adhesion between fiber and matrix, which results in an improvement of performance of the resulting composite [3, 6]. Considering the ecological aspects in material selection, replacing synthetic fibers with natural ones is only a first step. Restricting the emission of greenhouse effect caused by gases such as CO_2 into the atmosphere and an increasing awareness of the finiteness of fossil energy resources are leading to develop new materials that are entirely based on renewable resources.
The word natural implies a particular substance which exists naturally and not manmade. The word fiber is defined as a hair-like or thread like structure which has high aspect ratio. Fibers are a class of hair like materials that are continuous filaments are in discrete elongated pieces, similar to pieces of thread. They can be spun into filaments, thread or rope and can be used as a component of composites materials. It can also be matted into sheets to make products such as paper or felt [7]. According to study, plant fibers are the most popular natural fibers, used as reinforcement in fiber reinforced composites, includes bast (or stem, soft, or sclerenchyma) fibers, leaf or hard fibers, leaf or hard fibers, seed, fruit, wood, cereal straw [9].

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A. Reinforcing Fibers

An increasing awareness of non-renewable resources becoming scarce and our inevitable dependence on renewable resources has arisen. This century could be called the cellulosic century, because more renewable plant resources for products are being discovered. The living plants are renewable and sustainable from which the natural fibers are taken, but not the fibers themselves.

B. Source

The plants, which produce natural fibers, are classified as primary and secondary depending on their utilization. Primary plants are those grown for their fiber content while secondary plants are plants in which the fibers are produced as a by-product. Jute, hemp, kenaf, and sisal are examples of primary plants. Pineapple, oil palm and coir are examples of secondary plants. Table I shows the fibers used commercially in composites which are now produced throughout the world

Table I
Commercially major fiber sources [10]

Fiber source	World production (ton)
Bamboo	30,000
Jute	2300
Kenaf	970
Flax	830
Sisal	378
Hemp	214
Coir	100
Abaca	70
Sugar cane bagasse	75,000
Grass	700

C. Classification of Natural Fibre

Natural fibre can be classified into two major categories:

1) Animal fibre (silk, wool, feathers etc.)
2) Plant fibre

D. Plant fibres are Further Classified as

1) Primary plant fibre (form plant which are grown for fibres)
2) Secondary plant fibre (form the waste product of plant)

Mainly, there are six types of plant fibres named as; bast fibre (flax, hemp#, kenaf#, jute, etc.), leaf fibre (sisal, banana), fruit fibre (cotton, coir), grass fibre (bamboo, indiangrass), straw fibre (corn, rice) and other like wood pulp and roots [3].

E. Fiber Types

There are six basic types of natural fibers. They are classified as follows: bast fibers (jute, flax, hemp, ramie and kenaf), leaf fibers (abaca, sisal and pineapple) seed fibers Coir, cotton and kapok), core fibers (kenaf, hemp and jute), grass and reed fibers (wheat, corn and rice) and all other types (wood and roots).

F. Some Of The Important Natural Fibers Are As Follows

1) Flax Fiber: Flax is one of the oldest fiber crops in the world which is grown intemperate regions. Flax fiber-reinforced plastic composites have attracted increasing interest because of the advantages of the flax fibers, such as low density, relatively high toughness, high strength and stiffness, and biodegradability. Flax fibers have specific tensile properties greater than those of E glass fibers [11, 12, 13].

2) Kenaf Fiber: Kenaf is one of the natural (plant) fibers use as reinforcement in polymer Matrix Composite (PMCs). Kenaf (Hibiscus cannabinus, L.family Malvacea) has been found to be an important source of fiber for composites, other industrial applications [14]. Kenaf has been as a crop to produce twine, rope and sackcloth [15]. The kenaf plant is composed of many useful component (e.g. stalk, leaves and seeds and within each of these there are various usable portions e.g. fibers and fiber strands, proteins, oils and allopathic chemicalsThe yield and composition of these plant components can be affected by many factors, including cultivar, planting date, photosensitivity, length of growing season, plant populations and plant maturity [19]. Kenaf filaments consists of discrete individual fibers of generally 2-6 mm. Filaments and individual fiber properties can vary depending on sources, age, separating technique, and history of the fibers. The stem of kenaf plant is straight and unbranched and is composed of an outer layer bark and core [20]. The bark constitutes 30-40% of the stem dry weight and shows a rather dense structure. On the other hand, the core is wood like and makes up the remaining 60-70% of the stem [21].

3) *Hemp Fiber:* Another notable bast fiber crop is hemp, which belongs to the cannabis family. It is an annual plant that grows in temperate climates. Hemp is known to provide an excellent mechanical strength and young's modulus, consists of cellulose (55-72%), hemicelluloses (8-19%), lignin (2-5%), wax (<1%) and minerals (4%). It is estimated that in recent years China has become the world leader in hemp fiber production, nearly one third of total production [23].However, the application of hemp fiber is still mainly listed to the textile industry.
4) *Jute Fiber:* Jute is produced from plants of the genus *Corchorus*, which includes about 100 species. The fibers are extracted from the ribbon of the stem. Among all natural fibers, jute fibers are easily available in fabric and fiber forms with good mechanical and thermal properties [10]. Jute has wood-like characteristics as it is a bast fiber. Jute fiber has a high aspect ratio, high strength to weight ratio, good insulation properties. Jute fiber reinforced polymer composite has tested for door, window, furniture, floor tiles [24, 25].
5) *Ramie Fiber:* Ramie belongs to the family Utricacea*e* (Boehmeria), which includes about 100 species. The density is much less than that of synthetics fibers and the specific strength and specific modulus of natural fibers are comparable or even superior to E-glass fibers [26]. Ramie popularity as a textile fiber has been limited largely by regions of production and a chemical composition that has required more expensive pre-treatment than is required of the other commercially important bast fibers [27].
6) *Bamboo Fiber:* Bamboo (Bambusa Shreb) is a perennial plant, which grows up to 40 m in height in monsoon climates. A bamboo plant tends to reach its mature size in six to eight months with some variation between species [26]. The diversity of bamboo is itself reflected by its number of species, there are roughly 1000 species of bamboo found world wide. Bamboo grows very fast, rather it is better to say extremely fast growing grass. Since ancient times bamboo has been utilized in many Asian countries as well as South America for centuries. Bamboo can be considered an ecological viable substitute for takes almost more than 20 years [29].
7) *Sisal Fiber:* Sisal is an agave (Agave sisalana) and commercially produced in Brazil and East Africa. Sisal fiber is one of the most widely used natural fibers and is very easily cultivated, it has short renewal times and grows wild in the hedges of fields and railway tracks. The sisal fibers have many advantages, such as high tenacity and tensile intensity, abrasion resistance, acid and alkali resistance, sea water resistance, corrosion resistance, and so on [20].
8) *Abaca:* The abaca/banana fiber, which comes from the banana plant, is durable and resistant to seawater. Abaca, the strongest of the commercially available cellulose fibers, is indigenous to the Philippines and is currently produced there and in Ecuador. It was once the preferred cordage fiber for marine applications [27].
9) *Bagassase:* Bagassase is the fibrous residue which remain after sugarcane stalk are crushed to extract their juice. It is currently used as a renewable natural fiber for the manufacture of composites materials [27].
10) *Pineapple Leaf Fiber:* Pineapple (Ananas comosus) is a tropical plant native to Brazil. Pineapple leaf fiber is rich in cellulose, relatively inexpensive and abundantly available. Furthermore, it has the potential for polymer reinforcement. At present, pineapple leaf fibers are a waste product of pineapple cultivation and therefore these relatively inexpensive pineapple fibers can be obtained for this purpose [27].
11) *Coir Fiber:* Coir comes from the husk of coconut fruit fiber. Coir has more life compared to other natural fibers due to its high lignin content [21, 22]. Among the natural fibers, the coir fiber has remarkable usefulness owing to its hard wearing quality and high hardness (not fragile like glass fiber), good acoustic resistance, moth-proof, non toxic, resistance to microbial and fungi degradation, and not easily combustible [23]. The coir fibers are also more resistant to moisture than other natural fibers and withstand heat and salt water [24].

G. Applications of Natural Fibre Reinforced Polymer Composites

As properties discussed above, like low cost, low density, low energy input and comparable mechanical properties, natural fibres now dominate the automotive, construction and sporting industries [3].At present, most of the automobile companies of Germany (like Mercedes, Audi, BMW, Ford, Opel etc.) are using natural fibre composites for interiors, door lining and panelling, wood fibres are used to enclose the rear side of seat backrest. Cotton fibres are used as sound proofing material. Coconut fibres are used in cars for interior trim and seat cushioning [13, 14]. Also to provide weight reduction door trims are made of polyurethane reinforced with a mixed flax/sisal mat is used. Soya based form filling are used in seats with natural fibres. Improvement in noise reduction is due to use of a cellulose based cargo floor tray [13].Kenaf fibre is used for making boards with polypropylene [14].

The hemp fibre is used in lightweight lotus designed seats. This fibre when used with polyester forms a hybrid composite. Sisal has been used for the carpet in Eco Elise as it is tough, abrasion resistant material and is obtained from renewable crop [13-15].

H. Advantages and Disadvantages

On the basis of above discussion we can have following advantages and limitations of natural fibre reinforced polymer composite materials:

I. Advantages

They are eco-friendly, biodegradable, available in large amounts, renewable, cheap and have low density as compared to synthetic fibres such as glass, aramid, carbon and steel fibres:

1) Low cost and high performance of NFRPCs contented the economic aspect of the industry.
2) The disposal of NFRPCs is simple as compared to SFRPCs.
3) The abrasive nature of fibre is much lower which leads to advantages in regard to technical process and recycling process of the composite materials.
4) Natural fibre composites are used in place of glass mostly in non-structural applications. Automotive components such as doors, bonnets etc. made from Glass fibre reinforced composites are now being replaced by NFRPCs.

J. Disadvantages

1) High moisture absorbing property is the major drawback of the natural fibres. This phenomenon reduces the interfacial bonding between the polymer matrix and fibre and causes detrimental effects on the mechanical properties.
2) These have: poor wet ability, incompatibility with some polymeric matrices.

Plant fibres cannot be used directly in its natural form. It requires chemical modification to remove the waxy layer to improve the interfacial adhesion between fibres and polymer matrix.

II. CONCLUSION

Natural fibre reinforced polymer composite material are replacing artificial materials to a great extent due to its eco-friendly, non-toxic and eco-friendly nature. This material is cheap and has good insulation property, machine wear, low density and abundance in quantity. Chemical modification is required to enhance its properties and workability. Thus, these are being used in many automobile, constructional and household applications.

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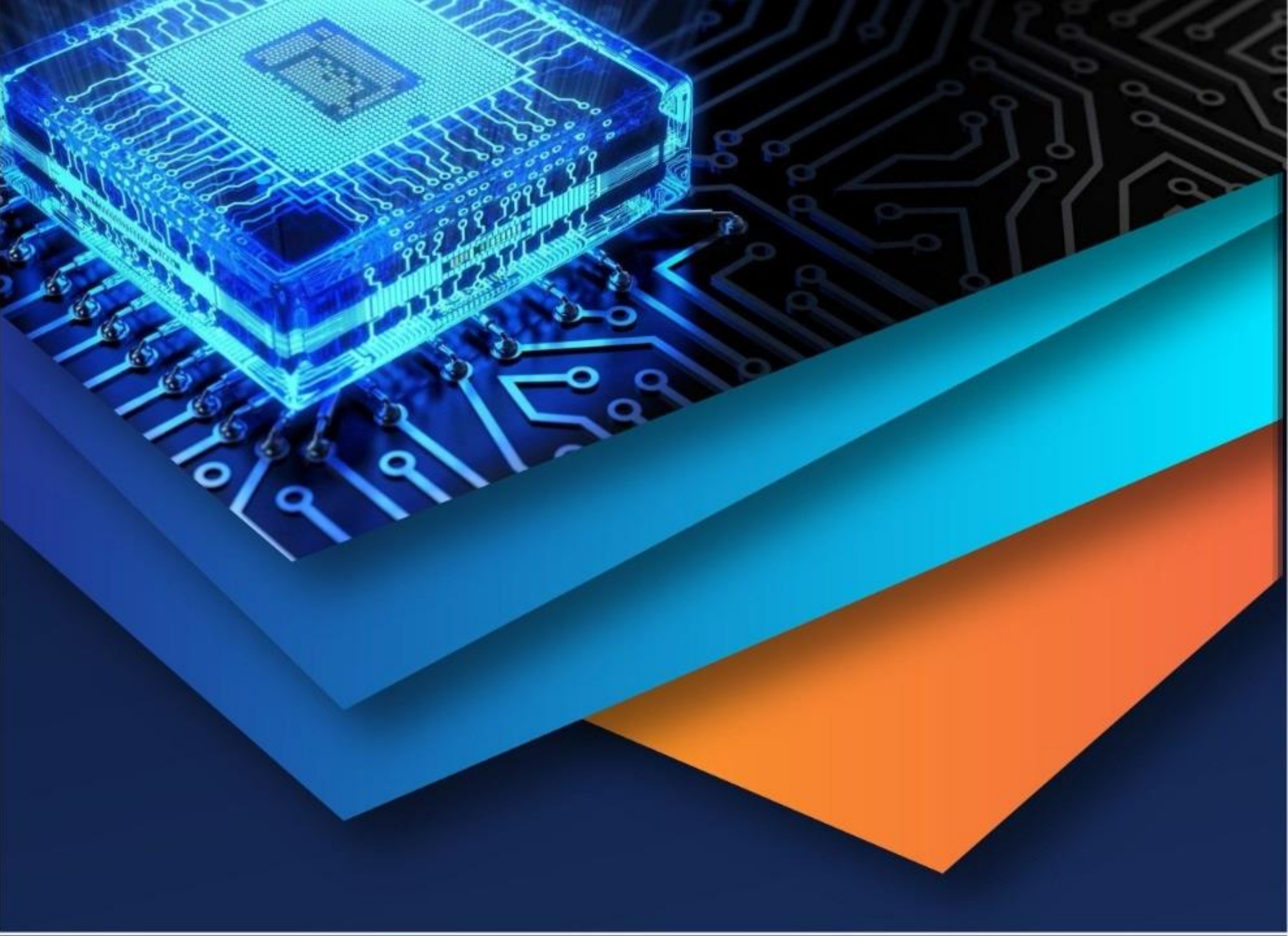

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