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A Comprehensive Review on Natural Fiber Reinforced Polymer Composites

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***Abstract*— This century plays the dominant role in the development of high-performance material made from natural resources in all over the world. The large variations in characteristics and properties are the supreme challenges in the development of natural fiber polymer composites. The number of variables such as fiber-type, matrix materials and applications are prejudiced natural fibers reinforced with polymer composite properties. Finally, the new development of natural fiber reinforced polymer composites will be studied and concluded.**

***Index Terms*— Natural fiber, Matrix material, Performances, Applications.**

I. INTRODUCTION

Over the recent years, research and development has increased in natural fiber as filler and /or reinforce in polymer composites. The growing trend to use natural fiber in manufacturing of natural fiber polymer composites due to its flexibility in processing, biodegradable-renewability, non toxic and good mechanical properties and low cost makes it attractive to manufacturer. So many natural fibers such as jute, kenaf, sisal, coir, straw, hemp, banana, pineapple, rice husk, bamboo, wood fiber [1] and wood floor have explored demands as reinforcement for polymer composites in this century. The thermoplastic and thermoset materials used as matrices for biofibers such as polypropylene (pp), polyethylene, poly vinyl chloride, epoxy phenolics and polyesters are important raw materials. Globally, the demand of development of bio based plastic has tentatively increased from 2.33 million metric tons by 2013 to 3.45 million metric tons in 2020. This large production volume of biocomposites will be PLA, PHA and starch based plastic [68].

II. REINFORCING FIBERS

The researchers have keen interest in the area of renewable sources of reinforces fibers because the non – renewable resources are limited and petroleum products are costly. This age is called the cellulosic age in the field of natural fiber composites because thousands of varities of fiber are available over worldwide and day by day new plant resources are discovered for the products. It is fact that fiber itself is not renewable but the sources of fiber, living plant are sustainable and renewable. These fibers are easily available, abundant and light in weight. So many researches and patent filed in the field of natural fiber reinforced polymer composites from 1995-2007 are shown in Figure 1.

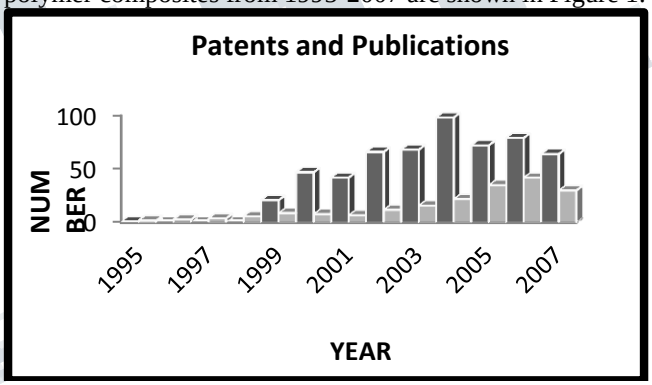

Figure1. Overview of publications and patents on biodegradable lignocellulosic fiber based composites from 1995–2007 [2].

The classification of fiber is based on the parts of tree or types of plants from which we get fiber. According to figure 3 [8], Natural fibers are broadly of six types, Straw fibers (wheat, corn and rice), bast fibers (jute, flax, hemp, ramie and kenaf), leaf fibers (sisal abaca, and pineapple), seed fibers (coir, cotton and kapok), grass and reed fibers (bamboo, switch grass) and all other types (wood and roots).

A. Flax

Flax is the oldest fiber crop in the world. Basically flax is stem fiber and it is harvested in moderate temperature region. Nowadays, the textile industries have huge demand of flax bast fiber for higer value added products. The mechanical properties [3], fracture behavior and toughness [4], alkaline fiber treatment [5], chemical treatment and processing parameters [6] on the successive decortication stages of flax fibers reinforcing epoxy composites have also

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been evaluated.

B. Hemp

Hemp is another outstanding performance bast fiber. This is also grown in moderate climatic conditions. Technique of batch mixing is used to prepare hemp fiber reinforced PP composites, functionlized and compatibilization [7]. The study of the improvement by the effect of chelator, white rot fungi and enzyme treatment on the fiber and interfacial shear strength of hemp fiber with PP matrix has been done [8-9].

C. Jute

Jute is the cheapest natural fiber. It is the stem fiber and has highest production volume in the world. India, Bangladesh and China's climatic conditions are best suitable for jute crop. Jute has more than 100 varieties. The mechanical, dynamic, thermal and impact fatigue behaviour of treated fiber with alkali compared with untreated jute fiber vinyal ester composites have been investigated by Ray and co-workers [10-12].

D. Kenaf

Kenaf is bast fibre. It has about 300 varieties and belongs to hibiscus. Kenaf is recently grown in United States. Researchers show the interest in new Kenaf fibres as reinforcement in composite [3-6].

[13-14], epoxy [15]; PP [16] and anionic polyamide-6 [17] as a matrix were done.

E. Coir

The fiber placed between the bark and outer shell of coconut is called coir husk fibers. It is by-product of coconut. Only 10% of the production of coconut is used The treatment of ferric nitrate salts with coir fiber reinforced thermoplastic morphology behaviour [18] and coir/PP composite with chemical; physical-mechanical properties [19,20], effect of fiber physical, chemical and surface properties on coir/PP composites thermal and mechanical properties were studied and evaluated.

F. Bamboo

Bamboo is a persistent plant, cultivated in mansoon climates. It acquires 40 m height. It has large applications in textile, carpentry, construction, furniture and curtains. Bamboo fiber has quality to absorb ultraviolet rays. PCL reinforced by isothermal crystallization kinetics of modified bamboo cellulose [21], mechanical properties of bamboo/ glass fiber polymer matrix hybrid composite influence by environmental aging [22] were investigated.

G. Rice husk

Rice is main grain crop and rice husk is the waste product of rice. Influence of dynamic vulcanization and filler and fiber loading[23], effects of compatibilizer and a silane coupling agent[24], effect of hydrothermal aging , water absorption and morphological properties of rice husk reinforced polypropylene composites were investigated.

H. Oil palm

Oil palm fiber is extracted from empty fruit bunch. It is the evaluation from two species of the arecaceae and plam family. Stress relaxation behavior in oil plam fiber influences fiber loading, fiber treatment, physical ageing and strain level of oil palm empty fruit bunch fibers reinforced thermoplastic and thermoset [25-27] were evaluated.

I. Bagasse

Bagasse is the waste product of sugarcane and fibrous residue. When sugarcane is crushed and juice is separated from stalk, rest product is called bagasse. It is easily available and cheap. So it is used as reinforcement in composites. Quaba is producing sugar cane at the highest volume in the world [28-29].

III. MATRICES FOR BIOCOMPOSITES

Composites form, figure, surface finish, environmental aging and durability depend on matrix, (Strength, structural loads and stiffness). Mechanical properties are dominated by fiber reinforcements. Both the thermosets and thermoplastics matrices were comprehensively investigated. Thermoplastics: General thermoplastic like polyethylene, polypropylene, polyvinyl chloride and polystyrene used as matrix. These show good behavior as matrix material with natural fiber.

Table 1. Reported work on natural fiber thermoplastic composites.

Fiber	Matrix	References
Flax fiber	Recycled high density polyethylene(HDPE)	[30]
Sisal fiber	Polyethylene	[31]
Rice straw fiber	Virgin polyethylene(PE)/polypropylene	[32]
Hemp, hardwood ,rice hulls and E-glass fiber	HDPE	[33]
Rape straw flour	HDPE	[34]
Cotton stalk,rice straw, bagasse and banana fiber	Low density polyethylene(LDPE)	[35]

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Wheat straw fiber	LDPE	[36]
Ramie fiber	Polypropylene	[37]
Hemp fiber	Polypropylene	[38]
Short bamboo/glass fiber	Polypropylene	[39]
Abaca strands fiber	Polypropylene	[40]
Bamboo fiber	Polyvinyl chloride	[41]
Bagasse fiber	PVC	[42]
Banana pseudo-stem	Unplasticized Polyvinylchloride(UPVC)	[43]

B. Thermosets:

Thermosets- polyester, epoxy resin, phenol formaldehyde and vinyl ester. Thus these have large application as matrix material with natural fiber reinforced polymer composites.

Table 2. Reported work on natural fiber thermosets

Fiber	Matrix	References
Date palm fiber	Polyester	[44]
Short banana/sisal fiber	Polyester	[45]
Sisal/jute fiber	Polyester/epoxy	[46]
Sisal fiber	Polyester	[47]
Banana fiber	Epoxy/polyester	[48]
Short banana /sisal fiber	Polyester	[49]
Sisal, kenaf, hemp, jute and coir fiber	Polypropylene	[50]
Jute fiber	Epoxy and unsaturated polyester	[51]
Vakka, sisal,bamboo and banana fiber	Polyester	[52,53]
Sisal fiber	Epoxy	[54]
Untreated kenaf fiber	Epoxy	[55]
Oil palm fruit bunch fibers	Low viscosity epoxy and phenolics resin	[56]
Hemp/flax fiber	Epoxy	[57]
Sisal, kenaf, hemp, jute and coir fiber	Polypropylene	[51]

IV. DEVELOPMENT AND APPLICATIONS

In the developing countries, the uses of natural fiber composites exhibit several social environment and economical benefits to produce green automotive parts. The jute fibers reinforced composites were used for front bonnet of an off road vehicle instead of glass fiber. Life cycle assessement technique presents the chances to use the natural fiber in view of social, environmental, cost effective or economical and technical benefits. The four aspects of jute fiber composites show the superior properties as compared to glass fiber except technical aspects.

Composite	Application	References
Flax FRP confined coir fibre reinforced concrete Composites	Column	[61]
Bamboo-reinforced concrete beams	Light weight beam	[62]
Bagasse fiber for reinforcement of cementitious composites	Structural applications	[63]
Jute fiber reinforced composites	All car body panels	[64].
Natural fiber based composites	27 components of Mercedes	[65]
Flax fiber reinforced polyester composites	Dash board and door panels	[58]
Jute reinforced composites	Mercedes E-class door panels	[59]
Flax/hemp composites	Ford automobiles internal panels	[60]
Cotton reinforced polymer composites	Car body	[66]
Jute polymer composites	A-class Mercedes benz interior	[60]
Flax/sisal polyurethane composites	Audi door trim panel	[60]
Flax cork basalt bio based epoxy sandwiches composites	Interior aesthetic panels	[67]

Table3. Applications of natural fiber composites

Applications of natural fibre composites are given in Table3 with references. Kenaf, Abaca and Sisal fibres reinforced polymers are used in plasters. While Sisal externally wrapped with jute FRP composite is used for concrete cylinders. Current scenario Daimler Chrysler, Mercedes, Volkswagen, BMW, audi group, opel and ford car companies use natural fibers reinforced polymer composites in several applications .

V. CONCLUSIONS

Natural fiber reinforced biocomposites and bio polymer have developed radically in last decades because of renewable, environment friendly biodegradability, light in weight, cheap and good in specific strength with ease and flexibility in fabrication. The natural fibers reinforced polymer composites get attention and increasing demand in construction, automobile industry, aerospace and many other industrial applications. Preface of new biocomposites and biodegradable polymer change the world market senerio and discover the more application in close proximity futre in world wide.

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