A Review on Natural Fiber Reinforced Polymer Composites

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Abstract: **Natural fibers are getting attention from researchers and academician to utilize in polymer composites due to their ecofriendly nature and sustainability. The aim of this review article is to study about the natural fibers and reinforcements as well as widely used natural fiber reinforced polymer composites (NFRPCs) and their applications. The properties of NFRPCs vary with fiber type and fiber source as well as fiber structure.A number of drawbacks of NFRPCs like higher water absorption, inferior fire resistance, and lower mechanical properties limited its applications. Impacts of chemical treatment on the water absorption, and adhesive bonding for the fiber and matrix composition and energy absorption flames retardancy, and biodegradability properties of NFRPCs were also highlighted. The applications of NFRPCs in automobile and construction industry and other applications are demonstrated. It concluded that chemical treatment of the natural fiber improved adhesion between the fiber surface and the polymer matrix which ultimately enhanced mechanical and thermochemical properties of the NFRPCs.**

Keywords: Natural fibers, Composites, Polymer, Reinforcement, mechanical behaviour

I.INTRODUCTION

The increase in environmental consciousness and community interest, the new environmental regulations and unsustainable consumption of petroleum, led to thinking of the use of environmentally friendly materials. Natural fiber is considered one of the environmentally friendly materials which have good properties compared to synthetic fiber [1]. Recently, natural fibers have attracted a great attention due to its biodegradability and renewability. Current pointers are that interest in NFRPCs industry will keep on growing quickly around the world. The utilization of NFRPCs has expanded considerably in the shopper merchandise as developing industry sectors throughout the last few years. As indicated by evaluations, over 5 years (2011–2016), the NFRPCs industry is estimated to grow 10% worldwide [2]. Natural fibers in simple definition are fibers that are not synthetic or manmade. They can be sourced from plants or animals [3]. The use of natural fiber from both resources, renewable and non renewable such as oil palm, sisal, flax, and jute to produce composite materials, gained considerable attention in the last decades, so far. The plants, which produce cellulose fibers can be classified into bast fibers (jute, flax, ramie, hemp, and kenaf), seed fibers (cotton, coir, and kapok), leaf fibers (sisal, pineapple, and abaca), grass and reed fibers (rice, corn, and wheat), and core fibers (hemp, kenaf, and jute) as well as all other kinds (wood and roots) [4].

The wide applications of NFRPCs are growing rapidly in numerous engineering fields. The different kinds of natural fibers reinforced polymer composite have received a great importance in different automotive applications by many automotive companies such as German auto companies (BMW, Audi Group, Ford, Opel, Volkswagen, Daimler Chrysler, and Mercedes), Proton company (Malaysian national carmaker), and Cambridge industry (an auto industry in USA). Beside the auto industry, the applications of natural fiber composites have also been found in building and construction industry, sports, aerospace, and others, for example, panels, window frame, decking, and bicycle frame [8]. In a review of chemical treatments of natural fibers, Kabir and coworkers [9] concurred that treatment is an important factor that has to be considered when processing natural fibers. They observed that fibers loose hydroxyl groups due to different chemical treatments, thereby reducing the hydrophilic behavior of the fibers and causing enhancement in mechanical strength as well as dimensional stability of natural fiber reinforced polymer composites. Their general conclusion was that chemical treatment of natural fibers results in a remarkable improvement of the NFRPCs.

Table I
COMMERCIALLY MAJOR FIBER SOURCES [10]

Fiber source	World production (10^3 ton)
Bamboo	30.000
Sugar cane bagasse	75.000
Jute	2300
Kenaf	970
Flax	830
Grass	700
Sisal	375
Hemp	214
Coir	100
Ramie	100
Abaca	70

Natural Fiber Reinforced Polymer Composites (NFRPCs)

Natural fiber polymer composites (NFRPCs) are a composite material consisting of a polymer matrix embedded with high-strength natural fibers, like jute, oil palm, sisal, kenaf, and flax [10]. Usually, polymers can be categorized into two categories, thermoplastics and thermosets. The structure of thermoplastic matrix materials consists of one or two dimensional moleculars, so these polymers have a tendency to make softer at an raised heat range and roll back their properties throughout cooling. On the other hand, thermosets polymer can be defined as highly cross-linked polymers which cured using only heat, or using heat and pressure, and/or light irradiation.

Many researchers [8, 11, 15–17] have examined and researched the suitability, competitiveness, and capabilities of natural fibers embedded in polymeric matrices. The researchers [4, 18, 19] concentrated on the effect of the fiber surface modifications as well as manufacturing processes in improving fiber/polymer compatibility. On the other hand, some researchers studied and compared between different natural fiber composites and their stability in various applications [20]. Al-Oqla and Sapuan [20] investigated the proper-ties of jute/plastic composites such as crystallinity, fiber modification, thermal stability, weathering resistance, durability, in addition to their suitability to the automotive industry throughout eco design components. while Mohanty et al. [21] studied the effects of jute fiber on the mechanical properties of pure biodegradable polymer (Biopolymer), the mechanical properties of the resulted composites, impact strength, tensile strength, and bending strength, showed an increase when compared with pure Biopolymer. The tensile strength of jute Biopolymer was enhanced by 50%, while bending strength and impact strength of the composites were enhanced by 30% and 90% in comparison to pure Biopolymer.

Table 2

CHEMICAL COMPOSITION OF SOME COMMON NATURAL FIBERS [4].

Fiber	Cellulose (wt%)	Hemicellulose (wt%)	Ligning (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

General Characteristics of NFRPCs

The properties of natural fiber composites are different to each other according to previous studies, because of different kinds of fibers, sources, and moisture conditions. The performance of NFRPCs relies on some factors, like mechanical composition, microfibrillar angle [20], structure [10], defects [22], cell dimensions [23], physical properties [4], chemical properties [24], and also the interaction of a fiber with the matrix [25]. Since every product in market has drawbacks, similarly, natural fiber reinforced polymer composites also have drawbacks. The couplings between natural fiber and polymer matrix are problem taken into consideration, as a result of the difference in chemical structure between these two phases. This leads to ineffective stress transfer during the interface of the NFRPCs. Thus, the chemical treatments for the natural fiber are necessary to achieve good interface properties. Natural fibers include a functional group named as hydroxyl group which makes the fibers hydrophilic. During manufacturing of NFRPCs, weaker interfacial bonding occurs between hydrophilic natural fibre and hydrophobic polymer matrices due to hydroxyl group in natural fibres. This could produce NFRPCs with weak mechanical and physical properties [8].

Mechanical Properties of the NFRPCs.

There are considerable enhancement and suggestions for the natural fibers that can be implemented in order to enhance their mechanical properties resulting in high strength and structure. Once the base structures are made strong, the polymers can be easily strengthened and improved [26]. There are number of aspects that effects of composite are performance level or activities, of which to name a few are the following; (a) orientation of fiber [5], (b)strength of fibers [8], (c)physical properties of fibers [27],(d) interfacial adhesion property of fibers.

Table 3

PHYSICOMECHANICAL PROPERTIES OF NATURAL FIBERS [38].

Fiber	Density (g/cm^3)	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)
Hemp	1.48	550–900	70	1.6
Jute	1.46	400–800	10–30	1.8
Ramie	1.5	500	44	2
Coir	1.25	220	6	15–25
Sisal	1.33	600–700	38	2-3
Abaca	1.5	980	—	—
Cotton	1.51	400	12	3–10
Kenaf (bast)	1.2	295	—	2.7–6.9
Kenaf (core)	0.21	—	—	—
Bagasse	1.2	20–290	19.7–27.1	1.1
Henequen	1.4	430–580	—	3–4.7
pineapple	1.5	170–1672	82	1–3
Banana	1.35	355	33.8	53

Natural Fiber Reinforced Polymer Composites Application

The applications of NFRPCs are growing rapidly in numerous engineering fields. The different kinds of natural fibers such as jute, hemp, kenaf, oil palm, and bamboo reinforced polymer composite have received a great importance in different automotive applications, structural components, packing, and construction [5, 22]. NFRPCs are finding in electrical and

electronic industries, aerospace, sports, recreation equipment, boats, machinery office products, and so forth. The widespread application of NFRPCs in polymer composites due to its low specific weight, relatively high strength, relatively low production cost, resistance to corrosion and fatigue, totally biodegradable, improving the surface finish of molded part composites, relatively good mechanical properties, avail-able and renewable sources as compared to synthetic fibers [5, 30]. On the other hand, there is a physical disadvantage of the NFRPCs such as moisture absorption, restricted processing temperature, and variable quality and this disadvantage led to limiting their performance [23]. Most of the car companies in the world have done a lot of investigation in order to insert the NFRPCs in their products. The car manufacture in Europe has done various researches to increase the applications of NFRPCs in automotive industry, especially in car interior such as seat backs, parcel shelves, boot linens, front and rear door linens, truck linens, and door-trim panels [29]. Beside the use for car interior parts in automobile industry, natural fiber embedded in polymers has been used for high requirement applications for exterior auto body components, such as the middle section between the headlights above the fender of a passenger bus [18].

BMW Group has a lot of NFRPCs into its automobiles. BMW Group used about 10 000 tonnes of natural fiber in 2004 [20]. Each BMW 7 series car boats 24 kg of renewable raw materials, with flax and sisal in the interior door lining panels. Also use cotton in the soundproofing, wool in the upholstery, and wood fiber in the seat back. Daimler-Benz in Germany is also working with a range of natural fibers as sisal, jute, coconut, European hemp, and flax as reinforcing fibers in high-quality polypropylene components in order to replace glass fibers. Daimler-Benz has developed the dashboards and center armrest consoles along with seat shells and paneling on seat backs. Moreover, it increased the utilization of NFPCs in some automobiles by approximately 98% over earlier models by utilizing natural fibers, for example, abaca and flax. Toyota, Proton, Volvo, and other automobile companies used cellulose fiber to make car parts.

II.CONCLUSION

Natural fiber reinforced polymer composites have beneficial properties such as low density, less expensive, and reduced solidity when compared to synthetic composite products, thus providing advantages for utilization in commercial applications (automotive industry, buildings, and constructions). Using natural fibers as reinforcement for polymeric composites introduces positive effect on the mechanical behavior of polymers. This paper evaluates the characteristics and properties of natural fiber reinforced polymer composites: mechanical, thermal, energy absorption, moisture absorption, biodegradability, properties. Also the application of NFRPCs in automobile and industry is reported. The effects of chemical treatment of the natural fiber properties were also addressed. The physical and mechanical properties of these NFRPCs can be further enhanced through the chemical treatment, while moisture absorption of the NFRPCs can be reduced through surface modification of fibers such as alkalization and addition of coupling agents.

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