

**Review Article**

State-of-Art on Hybridization of Natural Fiber Reinforced Polymer Composites

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Abstract: New improvements are going on to investigate the new thoughts of various applications of composites. Composites produced using natural and synthetic fibers are utilized for numerous applications such as aviation, marine, sports, furniture and different applications. There are studies in progress to durable furniture and new geometrical auxiliary structures and additionally bikes, tricycles and auto bodies. In this the key trust zones are taking after for composite materials are short and long haul innovative work, creation and testing bolster, accessibility and evaluating of crude materials, labor preparing, specialized bolster administrations for materials and procedure determination, process streamlining and outline, product quality improvement. Keeping in this view a thorough review on the manufacturing techniques, material properties and progressive of natural fiber composite materials are studied in this paper.

Keywords: Natural Fibers, Synthetic Fibers, Progress of Natural Fiber, Manufacturing, Material Properties Applications

1. Introduction

Since mid 1960's there has been expansion sought after for stiffer, more grounded materials for the utilization of various applications such as aviation and automobile [1]. Now a day's natural fibers are attracting theses fields of applications because of their outstanding properties and abundant availability on the earth [2]. Synthetic fibers are kind of man made superior simulated fibers, for example, glass, aramide and so forth. Contrast with natural fiber the expenses of synthetic fibers are increasing, on other hand natural fibers are economical and it don't bring about sensitivity to the human body. Favorable circumstances of such fiber over synthetic fibers are more [3-4]. The properties of natural fiber composites are expanded by hybridizing natural fibers with synthetic fibers. Fiber Reinforced polymer composites (FRPCs) are polymer framework composites imbedded with reinforcement materials as fibers in terms high strength fibers [5].

Composites produced using natural and synthetic fibers are utilized for numerous applications, for example, aviation,

marine, games, family unit and different applications. There are studies in progress to durable furniture and new geometrical auxiliary structures, and additionally bikes, tricycles and auto bodies utilizing bamboo. The kenaf bast fiber is utilized for packs, cordage, and the sails for Egyptian water crafts. The employments of kenaf fiber have been rope, twine, protection, attire grade fabric, soil-less preparing blends, creature bedding, pressing material and material that retains oil and fluids. Jute is utilized as bundling material (packs), rug, sponsorship, ropes and yarns. The sisal fibers are discovered financially in a few arrangements: fabric, strings, strips, wire, rolls, and so forth. For brake materials not just astounding tribological properties and synthetic security required additionally good mechanical properties essential. An adequate quality and harm resilience is of incredible significance because of the wellbeing affectability of the brake parts [6, 7].

In recent years there has been expansion in interest towards natural fiber composites for building material

particles, materials, hand creates; live stock sustains [8]. For furniture applications like window and door profile producers are utilizing wood fiber reinforced composites [9]. More than 50 makers are utilizing wood reinforced composites as a part of United States for various applications [10]. Plywood sheets covered with slender layer of polymers are utilized as a part of truck carriages. Group of car is formed with coordinated moldings are of arranged by utilizing fiber reinforced polymers. In aircraft framework the epoxy based composites are utilized to improve the framework quality. Sheets for segments, roof and divider board, strong and punctured building squares, entryway shades, entryways, window edges, level and creased material sheets, screens, tiles, boards, sheets, divider cladding, segments, entryway shutters, panels and pieces bricks and squares for walling roofing sheets, allotments, roofs, sterile product, water stockpiling tanks, channels, entryway pivots, kitchen sinks and so on are fabricated by utilizing fiber reinforced polymer composites.

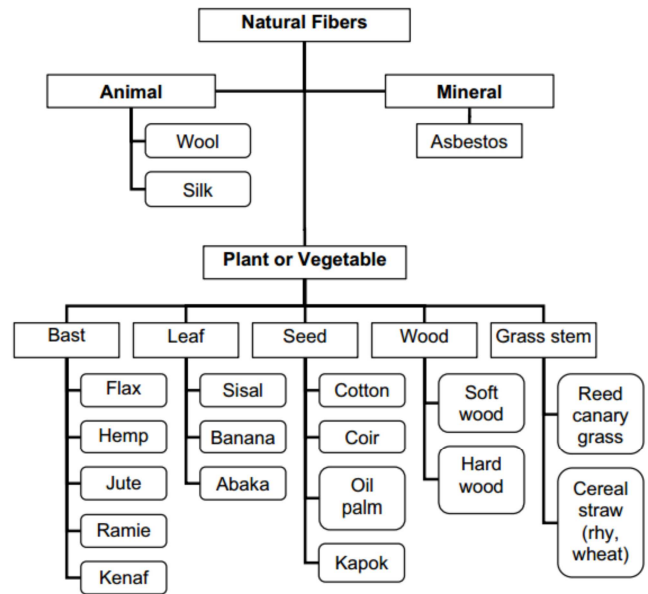


Figure 1. Classification of natural fibers.

2. Natural Fibers

Natural fibers can be classified according to their origin. The detailed classification is shown in Figure. 1 [11]. Natural fibers are mainly classified into three type's namely animal fibers, mineral fibers, plant fibers [12]. Natural fibers are not only derived from leaf, bast, seed but also from other sources like animal's wool or birds feathers and these fibers have more advantages compare to other synthetic fibers [13]. Surface of the natural fibers are rough and uneven hence it gives strong adhesion to the matrix materials and fabrication process makes easy.

Many types of natural fibers like sisal, jute, kenaf, hemp and so forth, are bounteously accessible on the earth. Natural fibers are for the most part lignocellulosic in nature, comprising of helically twisted cellulose micro fibrils in a matrix of lignin and hemicellulose. The material with having more fibrous are only used for preparing natural fiber reinforced composites. In that some of the physical and chemical properties like density, stiffness, moist absorption, microfibril angle, percentage of cellulose and percentage of lignin also to be considered before the natural fiber are taken for preparing composites. Table 1 shows some of the chemical composition of natural fiber

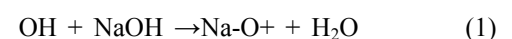
Table 1. Chemical compositions of natural fibers [14-24].

Type of fiber	Cellulose (%)	Hemi cellulose (%)	Lignin (%)	Pectin (%)	Wax (%)	Ash (%)	Moisture (%)
Cotton	82.7	5.7	28.2	5.7	0.6	ND	10.0
Jute	64.4	12.0	0.2	11.8	0.5	0.5-2.1	10.0
Flax	64.1	16.7	2.0	1.8	1.5	13.1	10.0
Sisal	65.8	12.0	9.9	0.8	0.3	4.2	10.0
Bamboo	48.2-73.8	12.5-73.3	10.2-21.4	0.37	ND	2.3	11.7
Hemp	55-80.2	12-22.4	2.6-13	0.9-3.0	0.2	0.5-0.8	6.5
Kenaf	37-49	18-24	15-21	8.9	0.5	2.4-5.1	ND
Abaca	56-63	15-17	7-9	0.3	0.1	3.2	ND
Sugarcane Bagasse	28.3-55	20-36.3	21.2-24	ND	ND	ND	ND
Coir	19.9-36.7	11.9-15.4	32.7-53.3	4.7-7.0	ND	ND	0.2-0.5
Banana	48-60	10.2-15.9	14.4-21.6	2.1-4.1	3-5	2.1	2-3
Pineapple	57.5-74.3	80.7	4.4-10.1	1.1	3.3	0.9-4.7	ND

3. Treatments of Natural Fibers

Treatments of natural fibers are to be carried out before the uses of fibers, frequently treated by method for a suitable chemical treatment with a specific end goal to adjust the fiber surface properties. In other words chemical treatments can be applied that provides enhanced interfacial bond qualities between the fiber and resin matrix, bringing about enhanced

surface wettability of the fiber against the matrix. The main purpose is to remove the 'OH' coating from the natural fiber by means of chemical treatment and to increase fiber surface roughness. A typical example is shown in Eq.1 where the hydroxyl coat (OH) is evacuated through the vicinity of sodium hydroxide (NaOH).



Fiber treatment can upgrade the regular fiber's mechanical

properties and enhance its water absorption take up by the external fiber surfaces making it more hydrophobic and more imperviousness to the vicinity of water. There are different types of chemical treatments reported in the literature. Figure.

2 summarizes the minimum detail where the sole result of treating the fibers is to remove the impurities and 'OH' coating, evacuation of non-cellulosic materials, inorganic substance and wax bringing about a higher fiber surface roughness [25].

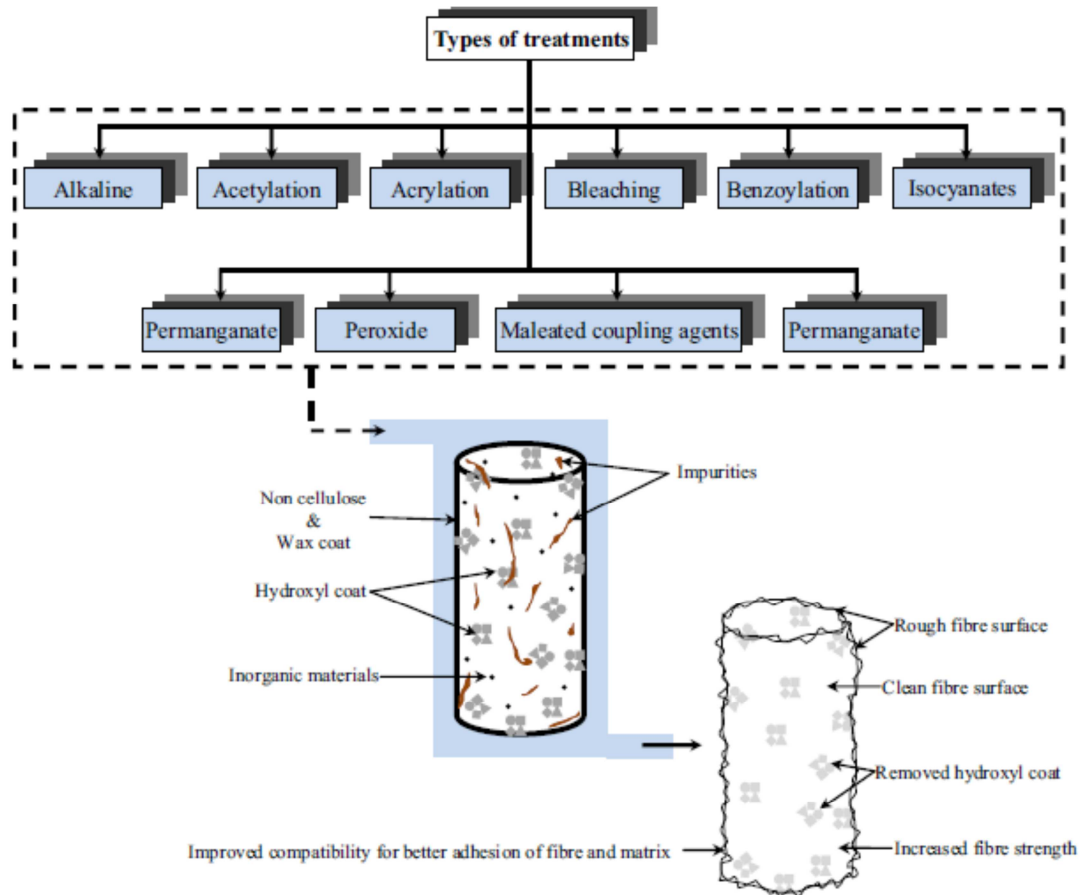


Figure 2. Different types of treatments on natural fibers [26].

4. Moulding Process of Natural Fiber Composites

Many types of moulding process are there to get natural fiber reinforced composites, in that some of the methods are listed and explained below,

- i) Injection moulding
- ii) Compression moulding
- iii) Hot pressing
- iv) Resin transfer moulding (RTM)

Injection moulding of composites is a procedure that forces amount of mixture which contains liquid polymer and fiber into mould pits. Numerous studies have been directed on the capability of utilizing natural fibers as reinforcement for renewable polymers to make a composite through injection moulding [27-32]. Numerous studies have been directed on the feasibility of utilizing natural fibers as reinforcement mixed with renewable polymers to shape another class of biocomposites through compression moulding process [33]. Hot press is positive for basic level examples as just two hot plates are expected to compress, all fiber and matrix together and after heat was applied subsequently. However, the

viscosity of the matrix during the pressing and heating procedures is a concern as it is difficult to be controlled, specifically for think tests [34]. Liquid composite moulding process forms include resin transfer moulding (RTM), vacuum assisted resin transfer moulding (VARTM), structural reaction injection moulding (S-RIM), co-injection resin transfer moulding (CIRTM) and other different subsets where the essential methodology is to independently infuse the liquid resin into a bed of stationary preforms.

5. Mechanical Properties of Natural Fiber Reinforced Composites

Hoto et. al., [35] Investigated on flexural and water absorption behavior of a novel low-cost green composite a symmetric sandwich. A bio-based epoxy resin was used as matrix and the specimens were manufactured using vacuum assisted hand lay-up. From the result they observed that both, the core type and specimens influence the flexural behavior, all specimens showed very good energy absorption behavior during bending tests. The water absorption of the specimens was significantly reduced by the infiltration of resin inside the

core material. Ochi [36] Investigated kenaf/PLA (Poly Lactic Acid) composites with different fiber proportions. Tensile and bending strength as well as Young's modulus increased linearly up to a fiber content of 50%. Pan *et. al.*, [37] Produced kenaf/PLA composites by melt-mixing and injection moulding with fiber mass contents ranging between 0% and 30%. At 30% the tensile strength improved by 30%.

Masirek *et. al.*, [38] Prepared composites with hemp fibers, poly (ethylene glycol) (PEG) and PLA by compression-moulding. Mechanical tests showed that the composites' Young's modulus markedly increased with the hemp content, in the case of crystallized PLA reinforced with 20 mass% hemp, whereas the elongation and stress at break decreased with an increasing amount of fibers. Plasticization with PEG did not improve the tensile properties of the composites. Prasad *et. al.*, [39] Experimented on tensile and flexural behaviour of composites made by reinforcing jowar as a new natural fiber into polyester resin matrix. The samples were prepared up to a maximum volume fraction of approximately 0.40 from the fibers extracted by retting and manual process, and compared with established composites like sisal and bamboo developed under similar laboratory conditions. Results of this study indicate that using jowar fibers as reinforcement in polyester matrix could successfully develop a composite material in terms of high strength and rigidity for light weight applications compared to conventional sisal and bamboo composites.

Mylsamy *et. al.*, [40] Studied on Composites based short Agave fibers (untreated and alkali treated) reinforced epoxy resin using three different fiber lengths (3 mm, 7 mm and 10 mm length) are prepared by using hand layup and compression mould technique. The materials were characterized in terms of tensile, compressive, flexural, impact, water absorption properties and machinability behaviour. All mechanical tests showed that alkali treated fiber composites withstand more fracture strain than untreated fiber composites. Mei-po Ho *et.al.*, [41] Investigated on hybridization of a glass fiber reinforced using low cost short silk fibers as a medium to enhance its cross-ply strength. The comparison on the tensile and impact properties of the composite reinforced by the short silk fiber (with the content from 0.3 to 0.6 wt%) with a pristine glass fiber composite was done. It was found that the addition of 0.4 wt% short silk fiber into glass fiber composite was shown to be the advisable reinforcement content to achieve better tensile and impact strengths.

Mahjoub *et. al.*, [42] Studied on physical and mechanical properties of continuous unidirectional kenaf fiber epoxy composites with various fiber volume fractions. The composites materials and sampling were prepared in the laboratory by using the handlay-up method with a proper fabricating procedure and quality control. Results observed that, increasing the fiber volume fraction in the composite caused the increment in the tensile modulus and reduction in the ultimate tensile strain of composite. Alavudeen *et. al.*, [43] Evaluated effect of weaving patterns and random orientation on the mechanical properties of banana, kenaf and

banana/kenaf fiber-reinforced hybrid polyester composites. Composites were prepared using the hand lay-up method with two different weaving patterns, namely, plain and twill type. The mechanical strength of woven banana/kenaf fiber hybrid composites increases due to the hybridization of kenaf with banana fibers. Tensile, flexural and impact strengths of the woven hybrid composite of banana/kenaf fibers are superior to those of the individual fibers. Fractography studies showing the fracture behavior of the composite indicate that a better fiber-matrix adhesion exists in the hybrid composite due to the interlocking of fibers.

Lebrun *et. al.*, [44] Investigated on unidirectional hemp/paper/epoxy and flax/paper/epoxy composites and are manufactured by adding one or two sheets of paper at the surface of a unidirectional layer of hemp or flax fibers before molding. The composites are tested under tensile loads, results show a significant increase in strength and modulus repeatability when the paper layer is present and also significant increase in strength and modulus was also obtained compared to the base epoxy properties. Haameem *et. al.*, [45] Studied on mechanical properties of Napier grass fiber-reinforced composites. Napier grass fibers were extracted through water retting process. The effect of alkali-treatment on the tensile properties and morphology of the fibers was investigated. The tensile and flexural strength of the untreated Napier fiber/ polyester composites increased as the fiber volume fraction increased. Overall, the composite with a 25% volume fraction of Napier fiber yielded the optimum tensile and flexural properties.

Sathishkumar *et al.*, [46] Studied on the tensile properties of the snake grass fiber and are compared with the traditionally available other natural fibers. The mixed chopped snake grass fiber reinforced composite is prepared by using the isophthallic polyester resin and result shows that the volume fraction increases the tensile, flexural strength and modulus of the snake grass fiber reinforce composite. Farias *et al.*, [47] Investigated the effect of bi-dimensional orientation of leaf stalk fibers from peach palm in impact, tensile strength behavior and water absorption profile of polyester/fiber reinforced composites. Samples reinforced with peach palm powder and weave were processed by hand layup technique. Tensile properties analyzed and show better results than the composites with both weave and powder, indicating that oriented fibers give better mechanical properties than randomly oriented fibers. Braga *et al.*, [48] Investigated and compare the mechanical and thermal properties of raw jute and glass fiber reinforced epoxy hybrid composites. To improve the mechanical properties, jute fiber was hybridized with glass fiber. Epoxy resin, jute and glass fibers were laminated in three weight ratios (69/31/0, 68/25/7 and 64/18/19) respectively to form composites. Results shows that addition of jute fiber and glass fiber in epoxy, increases the density, the impact energy, the tensile strength and the flexural strength, but decreases the loss mass in function of temperature and the water absorption.

Landro *et al.*, [49] Studied on the characteristics and performance of a thermoset bio epoxy resin, which is partly

based on natural components, to be used in hemp reinforced laminates. The permeability of the hemp fabric as well as the rheological and thermal behavior of the resin was studied in view of their fabrication by resin infusion techniques. The results showed that laminated composites could be easily obtained with a vacuum assisted resin transfer molding process. Alomayri et al., [50] Studied on synthesis of cotton fiber-reinforced geo polymer composites and the characterization of their mechanical properties. The effects of cotton fiber content (0–1.0 wt. %) and fiber dispersion on the mechanical characteristics of geopolymer composites have been investigated in terms of hardness, impact strength and compressive strength. Increase in cotton fiber content beyond 0.5 wt. % led to fiber agglomerations with a concomitant reduction in mechanical properties by virtue of increased viscosity, voids formation and poor dispersion of fibers within the matrix.

Gupta et al., [51] Investigated on the tensile and flexural behaviour of sisal fiber reinforced epoxy composites, the composites were prepared by using hand layup method with 15, 20, 25 and 30% of sisal fiber into epoxy matrix. Tensile and flexural behaviour of sisal fiber reinforced epoxy composites both in unidirectional and mat form are found to be maximum at 30%. Velmurugan et al., [52] Studied on properties of (randomly mixed) palmyra fiber, glass fiber hybrid composites. Two types of specimens are prepared, one by mixing the palmyra and glass fiber and the other by sandwiching palmyra fiber between the glass fiber mats. The mechanical properties of the composites are improved due to the addition of glass fiber along with palmyra fiber in the matrix. The glass fiber skin–palmyra fiber core construction exhibits better mechanical properties than dispersed construction.

Muralidhar et al., [53] Investigated the thermal, mechanical and thermomechanical properties of flax hybrid perform reinforced epoxy composites. Flax plain weave fabric and 1x1 weft rib knitted structures were together used as reinforcements and the composites were produced using hand lay-up technique. Laminate with knitted preform as skin layer exhibits superior mechanical properties and improved tensile properties at lower fiber volume fraction, reinforces the opinion that hybrid preform composites can offer significant benefits in terms of performance, weight and overall cost. Boopalan et al., [54] Investigated and compare the mechanical and thermal properties of raw jute and banana fiber reinforced epoxy hybrid composites. The jute and banana fibers were prepared with various weight ratios (100/0, 75/25, 50/50, 25/75 and 0/100) and then incorporated into the epoxy matrix by moulding technique to form composites. The tensile, flexural, impact, thermal and water absorption tests were carried out using hybrid composite samples. Addition of banana fiber in jute/epoxy composites of up to 50% by weight results in increasing the mechanical and thermal properties and decreasing the moisture absorption property.

Kulkarni et al., [55] observed that the failure of banana fiber in tension is due to pull-out of microfibrils accompanied by tearing of cell walls. The tendency for fiber pull-out decrease with increasing speed of testing. Sreekala M S et. al., [56]

Investigated the performance of mechanical properties of oil palm fiber with glass fiber and used phenol formaldehyde as resin. The investigation revealed that maximum mechanical performance occurs at 40 wt% loading.

6. Conclusions

Nowadays biodegradable materials are being gives much significance in light of the fact that after end use arranged off effortlessly without influencing environment. Natural fibers are playing very important part in the present natural conditions to determine current biological and ecological issues. Composites produced using natural and synthetic fibers are utilized for numerous applications, for example, aviation, marine, games, family unit and different applications. Thus it can be concluded that with methodical and constant research there will be a good possibility and better expectations for natural fiber polymer composites in the future.

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