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Potential of reinforcement of natural fibers for polymer composites and effect of alkali treatment on fibers. A Review

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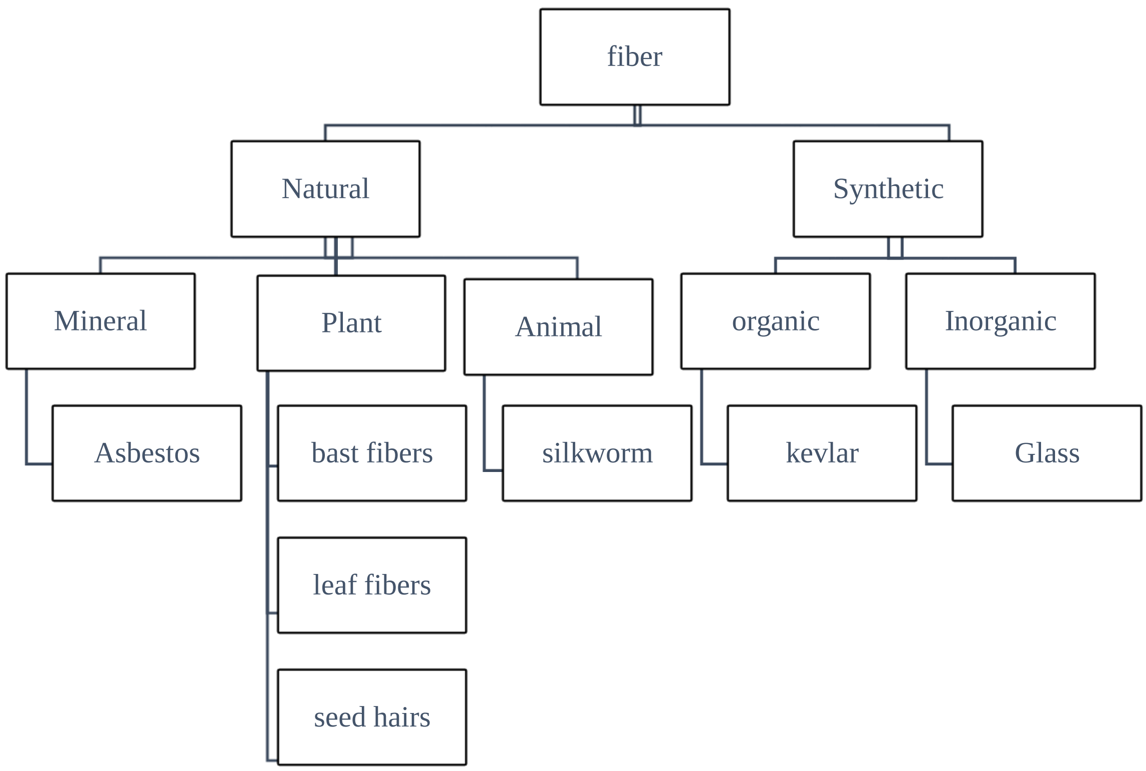
Abstract. The demand of natural fibers as reinforcements for polymer-based composites increases day by day as compared to conventional synthetic fibers (i.e carbon, kevlar, glass fibers). However, if we talk about conventional synthetic fibers they have good mechanical properties than natural fibres but can be beneficial for aircraft and military applications. Natural fibres provide various benefits such as low cost, available in abundance, low density, biodegradability, recyclability, flexibility, high specific strength, fracture resistance, etc. Besides these benefits, natural fibers based composites have some limitations such as absorption of moisture is high and shows poor adhesion between fiber and matrix. Therefore, many researchers make use of chemical treatment for improving surface roughness of fiber. Many researchers use different types of natural fibers like jute, banana, ramie, cotton, bamboo, etc. as reinforcement for polymer composites. This review paper studies the mechanical properties of different natural fibers and alkali treatment (NaOH) of natural fibers to improve the adhesion properties between the fiber and the matrix and to improve the strength of the fibers.

1. Introduction

Composites consist of two or more distinct materials which combined together to form a new material having higher properties over the individual materials. Composites basically have two phases i.e. reinforcing and matrix phase. The reinforcement is used to strengthening the composite while the matrix serves to transfer load, shield the fibres from environmental and mechanical effects. There are three main types of matrix composites as CMC (ceramic matrix composites) in which the matrix is made up of ceramic materials embedded with reinforcement to remove the limitations (i.e. brittleness, low fracture toughness), MMC (metal matrix composites) which consists of metal as the matrix, PMC (polymer matrix composites) in which the matrix consists of polymer material and fiber as reinforcement [1]. The fiber used for reinforcement can be natural or synthetic fiber. Natural fibers can be achieved from plants, animals and from minerals. On the other hand, synthetic fibers are man-made fibers and are further divided into organic and inorganic fibers. This fiber has lot of moisture content and shows weak adhesion bonding between matrix and fiber. To reduce these limitations, researchers use various types of chemical treatments [2] such as Benzoylation, Acrylonitrile Grafting, Acrylation , Silane, Alkali, Acetylation, and peroxide treatment, etc.[3].These fibers are obtained from different sources and the flowchart of different sources of fibers is as below.[4]



2. Density

Density is defined as the mass per unit volume and it is denoted by rho. It is found that natural fibers have low density as compare to the synthetic fibers.

Table 1.1 shows the density of some of the natural fibers[5].

S.NO	FIBERS	DENSITY (g/cm^3)
1	Flax	1.40
2	Vakka	0.81
3	palm	1.03
4	Bamboo	0.60-1.10
5	Coconut	1.150
6	coir	1.260
7	wool	1.300
8	sisal	1.330
9	kenaf	1.450
10	Hemp	1.480
11	Ramie	1.50
12	Jute	1.30-1.50
13	Alfa	0.89
14	Harakeke	1.27
15	Curaua	1.40

3. Mechanical Properties

Mechanical properties are used to distinguish and classify the different materials. Each and every material shows different mechanical properties. Some of the common mechanical properties are tensile strength, hardness, Impact strength, flexural strength[6]. Every industry uses different types of natural fibers according to the application of the fibers.

MR. Rashnal et. al. [7] made an attempt to develop the jute composites with the help of VARI (Vacuum Assisted Resin Infiltration) Techniques. In this, the jute fiber is placed in a staking sequence (0/0/0/0), (0/+45/-45/0) and 0/90/90/0). Two tests were conducted on jute composite, first one is a tensile test and another one is 3 point bend test. Tensile tests were carried out in the longitudinal and transverse direction and 3 points bending test are conducted for finding the correlation between strength as well as stiffness vs. composition of composite. The conducted tensile and stiffness testing concluded that in the longitudinal direction 0-0 laminated composites shows better tensile strength and stiffness as compared to 0-45, or 0-90 laminated composite. However, in transverse direction almost reverse trends have been observed. In transverse direction, 0-0 laminated composites shows lower tensile as well as stiffness as compared to 0-45, or 0-90 laminated composite.

Boopalan et. al [8] were made hybrid fiber composites with the help of jute and banana fiber. The composites were prepared with the help of the molding technique. Different ratio of jute and banana fiber were used (100-0, 75-25, 50-50, 25-75 and 0-100). Boopalan et. al., observed that there is a strong positive correlation between mechanical as well as thermal properties of composites and composition of banana fiber up to 50% by weight. They also identified the strong negative correlation between moisture absorption property and composition of banana fiber in composites.

Vijay Chaudhary et.al.[6] studied on the mechanical and morphological characterization of a hybrid composites which is developed using jute reinforced in epoxy resin based matrix material composites through hand layup techniques. The roller was rolled after every layup so that the trapped gases at different layers can be easily removed. Mechanical properties like hardness, density, tensile, impact strength and flexural testing were conducted.

Toshihikp HOJO et. al. [9] provided a generic studied based on the bamboo, kneaf mat, and jute based composite. They discussed the various mechanical properties like tensile strength, After testing of tensile properties the cross-section of the composites were checked by using SEM micrograph. From the last few decades, the applications of composites are increasing continuously due to its properties like low density, low cost, renewability, biodegradability, etc. In this paper, the unsaturated polymer used as matrix and natural fiber mat was used as reinforcement and were fabricated with the help of hand lay-up methods. Threes composites were prepared named Bamboo/UP, Jute/UP and Kenaf/UP. In this regard, tensile strength of bamboo and jute have almost aligned with each other while, Kenaf contain higher Young's modulus, strength, and ultimate tensile strength. The reason for existing higher tensile strength of Kenaf as compare to bamboo and jute is also conform from the SEM micrograph. The SEM micrograph clearly shows the existence of single fiber in terms of large interfacial adhesion in terms of matrix of the composite of Kneaf.

Kin-tak Lau et. al. [10] studied about the different application in structural engineering of composite based on natural fiber. Natural fibers were used from the last century when people used to mixed mud and straws for making walls for their houses. At that time no one was no focused on the strength of the natural materials. Nowadays, we make use of natural fiber composites for interior purposes and for automotive parts due to some limitations i.e. degradability, high coefficient of thermal expansion but there is a room of using these natural fibers for high level structural applications because light weight and low cost which make them promising materials beyond glass fiber. Table 1.2 shows the mechanical properties of some of the natural fibers [11].

S.NO	**FIBERS**	**TENSILE STRENGTH (MPa)**	**FLEXURAL STRENGTH (MPa)**	**YOUNGS MODULUS (GPa)**
1	Flax	345-1500	165	27.6-80
2	Abaca	400-980	-	6.2-20
3	Bamboo	140-800	32	11-32
4	Banana	600	76.85	17.85
5	Cotton	287-597	43.3	5.5-12.6
6	Hemp	550-900	-	70
7	Jute	392-800	45	10-30
8	Palm	377	24.4	2.75
9	Ramie	220-938	-	44-128
10	Sisal	400-700	288.6	9-38
11	Vakka	549	-	15.85
12	Coconut	500	58	2.50
13	Pineapple	413-1627	-	34.5-84.5
14	Kenaf	930	-	53
15	Coir	175-220	6	4-6

4. Alkali treatment

Alkali treatment is a special type of versatile methods which is used for chemical treatment of fiber. The rearrangement of hydrogen bonding is possible during alkali treatment. Therefore, surface roughness of the fiber will increase and the composite will shows different mechanical properties. During alkali treatment, wax, oil, and lignin detached from the outer surface of the fiber [3]. The detachment will leads towards the conversation of cellulose into monomers. In this way, lastly hydroxyl group will ionized and converted into alkoxide [12].

$$\text{Fiber - OH + NaOH} \rightarrow \text{Fiber - O - Na + water}$$

For alkali treatment, we need to submerge the fibers in NaOH solution for a specified time. This time should be optimal so that proper chemical reaction should taking place.

Fiore et. al. [13] suggested that 48 hrs is an optimal time for treatment of kneaf fiber with NaOH solution which results better mechanical properties. Better mechanical properties is observed only due to existence of strong adhesion in between matrix and fiber.

Dipa ray et. al. [14] used 5% NaOH solution and immerse the jute fibers into it for 0, 2, 4, 6 and 8 h at 30 degrees C. It is found that the modulus increased by 12, 68 and 79% with 4, 6 and 8 h of alkali treatment and the percentage breaking strain with 8 hrs of treatment was reduced by 23%.

Mahjoub et. al.[15] treated the kenaf fibers with NaOH solution having 5, 7 10 and 15% of the concentration in weight for 3 and 24 h and found that 5% NaOH solution shows good results.

Poor wettability of the fiber composite can be improved by alkali treatment. Poor wettability is a major huddle for natural fiber composite. Therefore, by using alkali treatment not only surface roughness of fiber is going too improved but also, water absorption capacity of the fiber will improve.

In nut shell, on the basis of above literature survey, poor water resistance, low melting point, existence of insufficient adhesion, and poor surface roughness of natural fiber based polymer composite leads towards less applicability in today's real life application. Therefore, some pre-treatment is necessary for getting the desire properties of natural fiber based polymer composite. Plasma treatment, and graft copolymerization is an innovative way for improving the water absorption capacity, and increasing the surface roughness properties of natural fiber.

Vinyal monomers is used during the graft copolymerization of natural fiber and this graft copolymerization technique is very useful for improving the adhesion bonding in between fiber and matrix.

After alkali treatment, natural fiber based composite will be very useful for different applications such as automotive, aviation, rail, rail compartment, bus internal decoration etc.

5. Conclusion

Based on the results obtained from different researchers, the natural fibers can be easily reinforced in polymer composites for various types of applications such as packing, furniture, interior parts of automobiles, domestic products and construction industries. The advanced composites can be used for many applications but there are few problems criticized by the public like they cannot be recycled and can cause many environmental issues, the product made of advanced materials may be over strength due to the presence of carbon, the household products have high cost due to the use of advanced materials. The major problem existence in natural fiber is the existence of poor adhesion with the matrix due to hydrophilic nature and can be removed with the help of chemical treatment.

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