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NATURAL FIBRE POLYMER COMPOSITE: A REVIEW

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Abstract— **Natural fibre polymer composites have been in use for a quite long time due to their good mechanical properties and their application in several fields. This review tells us about the potential of natural fibre which can be used to reinforce the polymer matrix. Chemical treatment of natural fibre is also being mentioned and the benefits of this treatment are highlighted in this review. Different review articles have been studied in order to understand the effect of fibre loading and chemical treatment on the mechanical properties of the NFPCs.**

Index Terms— Natural fibre, chemical treatment, fibre loading, NFPC.

I. INTRODUCTION

Natural Fibre reinforced polymer composites have became a topic of interest for researchers. Natural Fibres like sisal, abaca, flax, jute, hemp, cotton, coir and wheat husk etc. are available in large quantity in developing countries according to the survey done by food and agriculture organisation. Researchers have done a lot of work on composites based on natural fibres. Natural fibre reinforced polymer composites are gaining popularity worldwide as they are light weight, low density, cheap and non abrasive, they also reduce energy consumption and are biodegradable [1]. Natural fibres are increasingly acting as a substitute to synthetic fibres for reinforcement in thermoplastics as they are economical and show good mechanical properties.Natural fibre reinforced composites are becoming one of the high quality composites and are used in large number of applications.Natural fibres are eco-friendly and are cheap in comparison to plastics and synthetic fibres and thus they are becoming popular in non-construction and automotive application. A large number of natural fibres such as jute, coir, sisal, kenaf, flax and hemp are used as reinforcement for thermoplastics like polyethylene, polyester and polypropylene.

Coir has good properties like hardness, hardwearing and thus is famous in automotive industries [2].Jute fibre is also attracting the manufacturer as it has a good potential and can be used in making composites because of its good specific modulus, toughness, high aspect ratio and tensile strength. Jute composites are used in making railway coach interiors, packaging and storage devices [3]. Banana fibre has low microfibrillar angle and high cellulose content which make it desirable to be used as reinforcing material. Banana fibre has good flexural strength, tensile strength and rotting resistance. [4] Natural fibre reinforced composites have large number of engineering applications due to its specific characteristics. Natural fibre polymer composite are developed by prudent selection of reinforcing material and matrix which comparatively gives much better strength and modulus than the prevailing metallic materials [3].The natural fibre reinforced polymer composites reckon on their reinforcing efficiency.This efficiency mainly depends on the stress transfer from the matrix to the fibre and fibre matrix interface. In addition the hydrophobic nature of the thermoplastics and hydrophilic nature of fibres lead to weak interfacial bonding between them [5].Also micro gaps and flaws generates due to incomplete wetting between the fibre and matrix which directly results in swelling. Absorption of water and moisture from all over surroundings in the micro spaces of composites also causes swelling which can deform the dimensions of the finished products which cause cracks in the composites thus degrading their mechanical properties [4]. To overcome this drawback chemical treatment of fibre is done which improves the adhesiveness and reduces the moisture absorption. However the utilization of natural fibres provide a very eco friendly and healthier working condition in comparison to synthetic fibres and thus are being used on a large scale as reinforcement in polymer matrix composites.

II. CLASSIFICATION OF NATURAL FIBRE

Natural fibres are grown from the plants which are categorized as primary and secondary plants. Natural fibres are classified as:

1. Animal fibre: Animal fibres are obtained from the animal bodies. These fibres include goat hair, feathers, horse hair, wool, avian fibre, silk, etc.

2. Plant fibre: Plant fibres mainly consist of cellulose in high percentage. These fibre are grouped as-

a) Fruit fibre: Fruit fibre are extracted from the fruit of the plant example-kapok.

b) Seed fibre: Seed fibres are extracted from the seed case and seed example-kapok, cotton.

c) Stalk fibre: Fibres in reality are the stalk of the plants like barley, rice, wheat and crops like grass and bamboo.

d) Skin fibre: Fibres that are extracted from the bast surrounding the stem or from the skin of the plant have good tensile strength in comparison to other natural fibres. These fibres are mostly used for fabric, paper, packaging, etc.

e) Leaf fibre: Leaves are obtained from the leaves example-agave and sisal

3. Mineral Fibre: Mineral fibres are obtained from the natural fibre procured from mineral or from modified fibre obtained from mineral example-ceramic, asbestos, metal fibre[6]

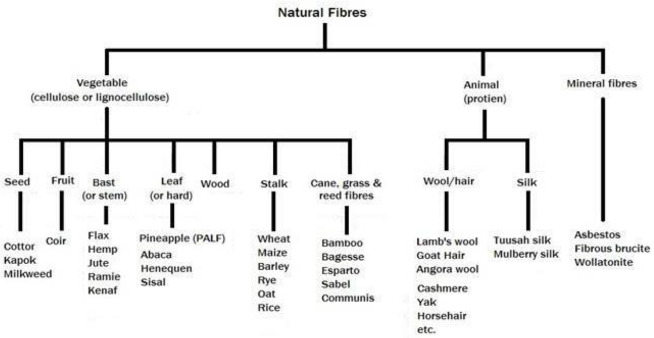

Fig 1. Classification of natural fibres [6]

Chemical composition of some natural fibres [8]:

Fibre	Cellulose(wt%)	Hemicellulose (wt%)	Lignin (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	—
Curraua	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

III. APPLICATIONS:

Over the last two decades the use of natural fibre reinforced polymer composite has been largely increased in automobile industry in North America and Europe .These composites were used in door panels, instrumental panels, package trays, internal engine covers and exterior under floor panelling. Nowadays all the automotive manufacturers increased the use of natural fibre polymer composites. In India these composites have replaced the medium density fibre board used in rail cars. Also the aircraft industries have also adopted natural fibre polymer composite for interior panelling of air craft. Apart from this the natural fibre polymer composites have replaced synthetic fibres which were used in making funeral articles, marine railings, toys, packaging and cases for electronic device such as mobile phones and laptop.Other than automobile and aircraft industries natural fibre polymer composite are used in sports applications such as making surfing boards. Recent research showed that natural fibre polymer composite can be used for top plates of string musical instruments. In USA, natural fibre polymer composite such as wood fibre/PP or wood fibre/PE are used in construction industries extensively in decking. Natural fibre polymer composite are also used in non-constructional applications and used for window frame, wall insulation, doors and flow lamination. Natural fibre polymer composites due to its good mechanical properties have been a very good replacement for wooden laminates which were used for insulating structural panels [7].

Applications of different Natural fibre composites in industries [8]:

Jute Fibre: Used in door frames, door shutters, geotextiles, chip boards and building panels.
Coir Fibres: Used for making brushers and brooms, bags, and mats, yarns and ropes for nets, seats cushions padding for matrices.
Kenaf Fibres: Insulations, mobile cases, animal bedding, packing material.
Sisal Fibres: Used in construction industries for making doors, roofing sheets, panels and also for manufacturing papers.
Rice husk Fibres: Used for building materials such as bricks, panels, window frames, fencing and railing system.
Wood Fibres: Decking, door shutters, window frames, fencing and railing system.
Hemp Fibres: For manufacturing of pipes, furniture, bank notes, electrical, construction products, paper and packaging and geo textiles.
Ramie Fibres: Used for paper manufacturing, packing materials, filter clothes, fishing nets.
Flax Fibres: Railing system, window frames, decking, panels, tennis racket, fork and laptop cases.
Cotton Fibres: Textile and yarn, furniture industry.
Stalk Fibre: Furniture panels, building panels, bricks, and constructing pipelines and drains.

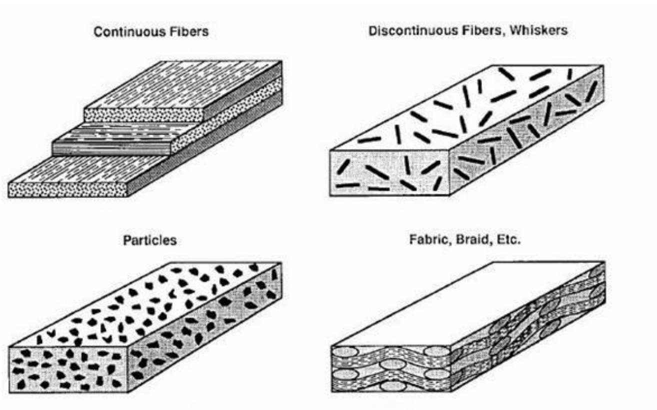

Fig.2 Reinforcement Form

IV. MECHANICAL PERFORMANCE OF NATURAL FIBRES COMPOSITES IS AFFECTED BY THE FOLLOWING FACTORS [7]:

- Matrix selection
- Fibre selection
- Fibre orientation
- Fibre dispersion
- Porosity
- Interfacial strength
- Composite Manufacturing Process

1. Matrix selection: Polymeric matrices are the most commonly used matrices as they can be processed at low temperatures and are light in weight. Matrix act as a barrier to protect the surface of the fibre from the adverse environment. Thus matrix is one of the most important part of the Natural Fibre Reinforced Composite. Natural fibres have been used with both thermoplastic and thermoset polymers.Usually the natural

fibres become thermally unstable above 200° C and due to this limitation only those polymers are used which can be softened below this temperature limit.

2. Fibre selection: Fibres are of two types- plant and animal fibres. Cellulose is present at a high percentage in most of the plant fibres. The animal fibres mainly contain protein as the major content. High performance plant fibres contain more strength and stiffness in comparison to animal fibres. Plant fibres are generally more suitable in comparison to animal fibres and can be easily grown in many countries.

3. Fibre orientation: Fibre orientation or alignment is very important. A number of fibre alignmentsare done but the fibre which is aligned parallel to the direction of the load shows the best results and better mechanical properties. There are different types of alignment method like injection moulding, dynamic sheet forming, compression moulding etc. To get good alignment mostly long natural fibres are used as it gives good mechanical performance in comparison to short natural fibres.

4. Fibre dispersion: Fibre dispersion is one of the major factors in improving the properties of short fibre composites. Use of long fibre can increase the tendency to agglomerate. If fibre dispersion is properly done, it gives good interfacial bonding and also reduces voids . Fibre dispersion can be improved by using additives such as Stearic acid and MAPP. Fibre modification can also be done through grafting but it is expensive. More intensive mixing process such as twin screw extruder can be used instead of a single screw extruder and gives better fibre dispersion.

5. Porosity: Porosity directly affects the composites and is increased with the increased percentage of fibre. It appears due to wettability of fibres, air inclusion, etc. Another reason of porosity is the low ability of fibres to compact.

6. Interfacial strength: Interfacial strength or bond between the fibre and matrix plays a very important role with respect to the mechanical properties. Optimum reinforcement can be achieved by a good interfacial bond. Plant fibres do not have a good interfacial bond due to their hydrophobic nature. Suitable fibre wetting is needed for a good bond as it affects the flexural and tensile strength of composites. Thus several physical and chemical approaches are been carried out to obtain a good interfacial bond.

7. Composite manufacturing process: Common methods used for forming natural fibre polymer composites are injection moulding, extrusion, compression moulding. For thermoset matrices resin transfer moulding (RTM) is also used and for flax/PP yarn composite and thermoset matrix composites, pultrusion is used. Injection moulding can be used for thermoplastic and thermoset matrices but is mostly used for thermoplastic matrices. In extrusion thermoplastics are softened in the form of pallets or beads and is softened and mixed with the fibre which is supplied by means of single or two rotating screw. This mixture is compressed and forced out at a uniform rate through a die.

V. Chemical Treatment:

One of the most commonly used chemical treatments of natural fibres is alkaline treatment or mercerization. This treatment of natural fibre is done when they are used to reinforce the polymers. This treatment is done with the help of Sodium Hydroxide. This treatment causes the hydrogen bond to disrupt in the network structure which increases the surface roughness. Certain amount of wax, lignin, oil covering is being removed from the outer surface of the fibre cell wall. Alkaline treatment of the fibre increases the surface adhesion between the fibre and the matrix material. In this treatment the natural fibre is immersed inside the NaOH solution for about 3hrs at 78°C. The concentration of the NaOH solution can be varied according to our will, but most common concentration is 5% to 10%. Before immersing the natural fibre in the NaOH solution, these fibres are dipped in detergent solution (2%) for about an hour and then washed with distilled water. After the treatment with NaOH solution is done the natural fibre is washed with dilute acid to wash away any remaining of the alkali particles and then it is air dried. The wettability of the natural fibres is enhanced to a great extent due this treatment [9][10].

VI. Literature Survey:

Influence of fibre reinforcement on Mechanical Properties:

S. Jayabal et al evaluated the tensile, impact and flexural properties of the coir fibre reinforced polyester composite at different fibre length and different fibre loading percentage. It was found out that there has been variation in the mechanical properties due to variation in fibre length and fibre loading percentage. The mechanical properties were observed, showed good result between 19% to 29% of fibre loading with long fibre length [11]. S. Jayabal et al evaluated the mechanical properties and machinability of coir fibre reinforced polyester composites in two different conditions. At first an untreated coir fibre is used to reinforce the matrix material and then a chemically treated coir fibre is used to reinforce the matrix material. Both these samples are tested and the result showed that the treated coir fibre polyester composite had better mechanical properties compared to the untreated coir sample. The machining error for both the treated and untreated samples was less but the treated sample had more error compared to the untreated one [12]. Nadir Ayrilmis et al studied the physical, mechanical, and flammability properties of coconut fibre reinforced polypropylene composite panels were evaluated for different composition of fibre by weight. The study showed that this natural fibre polymer composite is a very good replacement of heavy and costly glass fibre reinforced composites. Its mechanical properties get enhanced due to coir fibre loading. And the study also shows that this improvement is up to a certain level of loading i.e. 26% to 35%. Also the water resistance and the internal bond strength of the composites were negatively influenced by increasing coir fibre content [2].

Haydar U. Zaman et al studied and evaluated the coir fibre reinforced polypropylene composite at various fibre percentages ranging from 10% to 40%. Also the coir fibre is also chemically treated which resulted in improved mechanical properties and good adhesion between the fibre and matrix material. From this study it was found that the mechanical strength goes on increasing upto a certain level of fibre loading and then on further increase in fibre quantity the strength starts decreasing. The best results were obtained at 30% of fibre loading [1]. In this research Zh. H. Xu et al took natural rubber and polyethylene composites and mixed them with coir fibre and then evaluated its mechanical properties. The coir fibre is treated firstly with saline and then with Sodium Hydroxide to improve interfacial adhesion between the fibre and the polyethylene matrix. Due to this alkali treatment the tensile property of the coir fibre is significantly improved. The new composite formed by addition of coir fibre show improved mechanical properties. The best result is obtained at 25% fibre content. Post this quantity of coir fibre the tensile strength starts decreasing [13].

Nirupama Prasad et al fabricated coir fibre reinforced low density polyethylene composites using compression moulding with different fibre loading percentage ranging from 10% to 30% by weight. At 20% fibre loading the results was optimum and showed maximum mechanical properties. Alkali treatment of fibre was done which further improved the mechanical properties of the fibre and reduced the water absorption ability of the fibre. The result of treated and untreated coir fibre low density polyethylene is compared which shows that the treated fibre composite showed better mechanical strength [5].

Salma Siddika et al studied and observed the mechanical properties of Jute-Coir fibre reinforced hybrid polypropylene composite with variation in fibre loading and chemical treatment of fibre. Also the fibre ratios of coir to jute fibre were varied i.e. 1:3, 3:1, 1:1 at 20 % fibre loading. Both jute and coir fibre were treated using 5% and 10% NaOH solution. The tensile strength decreased with increase in fibre loading but the young's modulus improved. The tensile strength improved due to chemical treatment. The result was good for 10% NaOH treatment and 20% fibre loading [14]. In this review Sandhyarani Biswas et al has given an overview of the development and characterization of a new set of a natural fibre polymer composite which consists of coconut coir as reinforcement and epoxy resin as matrix material. The fibre length was varied and was observed that hardness is decreasing with increase in fibre length upto 20 mm. On further increasing the fibre length the hardness increased. The tensile strength and flexural strength was greatly influenced by fibre lengths [15]. Md. Mominul Haque et al in this research have fabricated the chemically treated coir fibre reinforced polypropylene using injection moulding and evaluated and compared its mechanical properties with those of the untreated one. The chemical treatment is done with NaOH solution with 1% concentration for 72 hrs. It was found out that the treated coir fibre composite showed better mechanical properties compared to the untreated one [16]. Ankita Nandi et al prepared Coir fibre and polypropylene composites using m-isopropenyl-a-a-dimethyl benzyl isocyanate grafted polypropylene as a coupling agent. Tensile, impact and flexural properties were investigated for different concentration of coupling agent. It was observed that the tensile and flexural strength increased with increase in concentration of coupling agent and the optimum results were seen at 5% concentration. This also improves the interaction between PP and coir fibre. But the impact strength decreased with increase in concentration of coupling agent [17].

CONCLUSION

We have studied several review articles in order to understand the effect of fibre loading and chemical treatment on the NFPC. From the study it was observed that chemical treatment of the natural fibre roughens the fibre surface and improves the surface adhesion between the fibre and matrix material which gives better mechanical strength compared to an untreated fibre. Sodium Hydroxide (NaOH) is used for treatment and the concentration should be maintained low, else it would damage or reduce the fibre strength. Due to fibre reinforcement the tensile, flexural and impact strength of the NFPC was improved to a great extent. Although good results were obtained between 10% to 30% fibre loading but the optimum result was obtained at 20% fibre loading. Due to these properties these natural fibre are emerged as a very good alternative to synthetic fibres composites.

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