A Review on Polymer/Fiber Properties of Reinforced Natural Composites

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Abstract—**In recent times, the world is changing and gearing up with latest and new technologies in that scenario the development and growth of the composite materials is increasing day by day. Most of the applications are replaced with the composite materials. Natural fibres are given first priority compared all types of fibres because of their advantages such as biodegradable nature, low cost and minimal health hazards. In this review paper, different methods which are used in the preparation of the composite is explained as well as the electrical conductivity and dielectric property of the fibre reinforced polymers were analysed and compared.**

Index Terms— **Dielectric, Electrical Conductivity, Natural fibres.**

I. INTRODUCTION

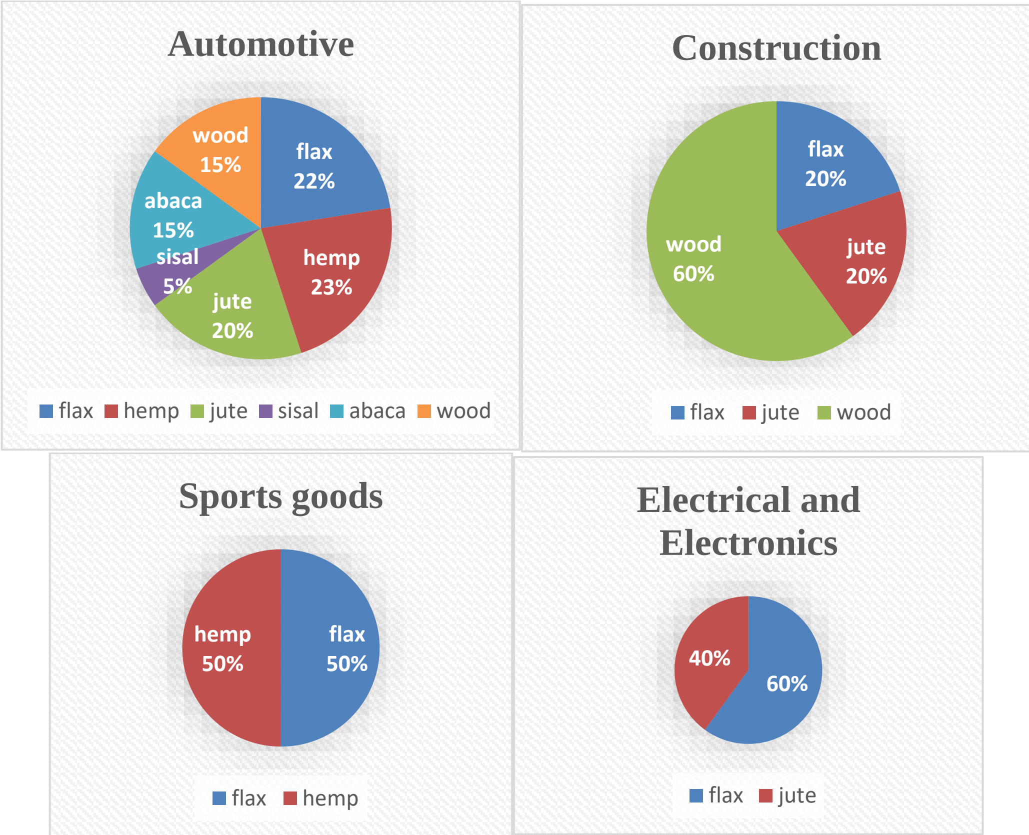
Many years ago, humans have been making composite materials for many applications. Earlier in 1500 B.C Egyptian and Mesopotamian pioneers used straw and mud to make solid structures. Later in 1200 A.D Mongols developed a bow with composite material. This bow is made up of wood bone and creature stick. Till the development of explosive this weapon was mostly used on the earth. In 1937 the business people started using composite materials. The Owens Corning fiberglass organisation started its business to sell fibre glass to the people of United States [1]. The glass fibre has high strength when compared to all-natural fibres, but the natural fibres are biodegradable, low cost and minimal health hazards and also have lower durability. Due to these plusses, present days natural fibers attain more priority than the synthetic fibres.

Natural fibres are attained from the plants, animals and geological process. Plant fibres are sub divided into seed fibre, leaf fibre, Bast fibre, Fruit fibre and stalk fibre. Mainly the fibre obtained from the plants compose of cellulose, hemi cellulose, pectin and lignin. Hemi cellulose mainly has important role in bio degradation, moisture absorption and thermal degradation [2]. Lignin causes UV degradation and ensures thermal stability. These fibres consist of 60%-90% of cellulose ,5%-20% of lignin and 20% of water. These mostly consist of hydrogen bonds and other linkages which provide strength as well as stiffness [5]. Animal fibres are sub divided into animal hair fibre, silk fibre, Avian fibre. Asbestos is major source for the mineral fibres, these fibres were avoided in many countries due to effect on humankind. They have six minerals which are classified as "asbestos ".

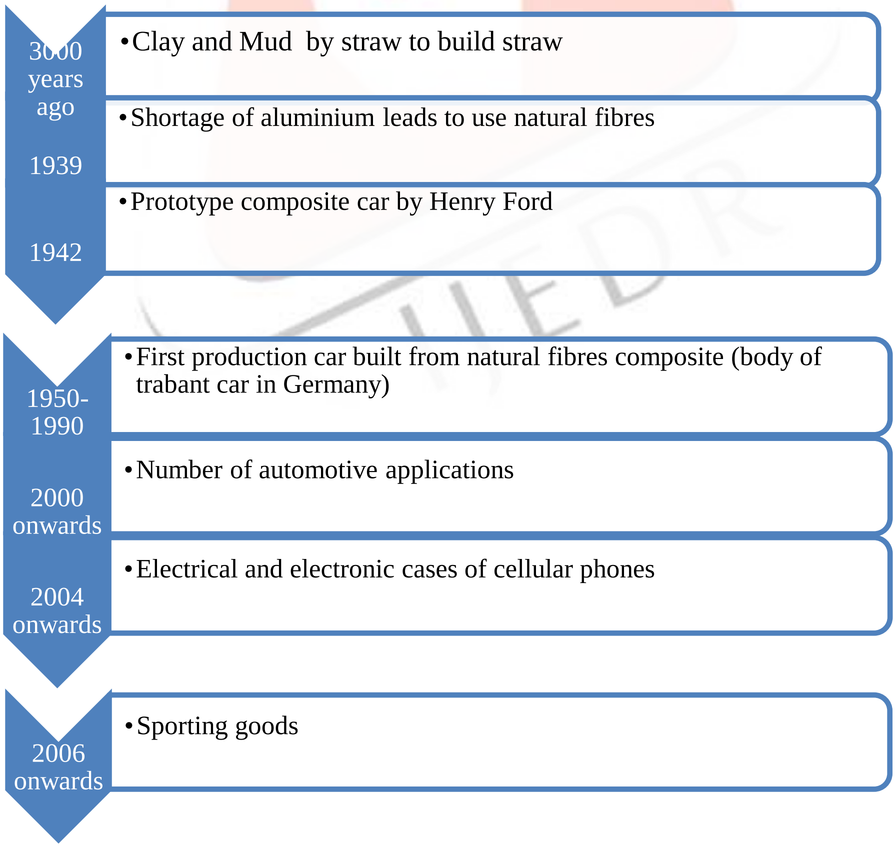
The natural fibres are renewable sources and also can be produced with little effort. The main advantage of these fibres are low density and high specific strength, stiffness. They produce oxygen to the environment by absorbing little amount of carbon dioxide [3]. If the moisture content increases the strength increases and due to increase in the temperature it decreases. Due to the hyperbolic nature, they tend to absorb more moisture which leads to swelling [6]. This swelling leads to dimensional stability of the composite material when these fibres were reinforced with polymers. The natural fibres have less strength and stiffness when compared with synthetic fibres. Properties of the fibres decreases with age of the fibre, soil variations and also climatic conditions. The younger fibre has more strength and elastic modulus when compared to older fibre.

In the fibre reinforced composite material matrix has an important role. It acts as a barrier from adverse environmental conditions. It protects the fibres from mechanical abrasion and transfer of load [3]. The most commonly used matrix for natural fibres are polymeric because they are light weight as well as they can be processed at low temperature. Thermoplastic and thermoset polymers were most commonly used as matrix for natural fibres. The natural fibres are used in many applications. It is used for preparation papers, felt, automobile exterior parts and fabric materials. The mostly used animal fibre are wool, camel hair, silk and angora whereas coming to plant fibres, flax, hemp, jute and cotton are most commonly used[7]. The value of natural fibres is better than glass fibres when considering certain modulus of it.

These fibres are used in various kind of applications like Automotive, Building constructions, Electrical and electronics, Sports goods. Globally natural fibre market reached 2.1 billion dollars in 2010. In automotive and constructions, a very large amount of natural fibre is used [4]. Automotive industries use natural fibre in making door panels, seat back, headliners, dash boards, trunk liners. In building constructions, it is used in door panels, decking, railing, window frames. In the electrical and electronics, it is used in mobile cases and laptop cases. In sports goods it is used in tennis racket, bicycle frames, snow boards.



There is a vast change in the development of the fibre. The above graph shows the percentage usage of the natural fibre composite in different sectors.



II. Methods Of Fiber Extraction

2.1 Manual Method: Natural fibre are mostly obtained from root of the plant, leaf and waste stalk. There are two processes for extraction of fibre. One is bacnis process and loenit process. Bacnis process one of the simple stripping process in which sheath is undressed by pulling the trunk apart. By removing pulpy and pulling away the ribbons (tuxy) the fibres are obtained whereas in loenit process, for obtaining ribbons a knife or the sharp tool is used. From one sheath a time, the ribbons were obtained [8]. Generally, the natural fibre is obtained from the outer sheath of stem. The ribbons of strips were peeled -off according to the size of 5-10cm wide and 2-5 mm thick along the length of the sheath. The ribbons are called as Tuxies and the undressing process is called as tuxying.

2.2 Chemical Extraction: For chemical extraction, there are many treatments like alkali, saline, retting etc. For example, in alkali treatment, the alkali NaOH helps in reducing the roughness of fibre and to obtain good quality of fibre . In addition, sulphuric acid, hydrogen peroxide, protease, pectinase and sodium citrate were used.

$$\text{Fiber-OH} + \text{NaOH} \text{ -------} \text{Fiber-O-Na}^{+} + H_2O$$

Thus, the time period taken for completion of the whole process is the main disadvantage [9-10]. This process is very costly and there is lot of wastage.

2.3 Mechanical Extraction:

In this the roller is placed in between two fixed supports. The roller consists of horizontal stainless-steel blades with blunt edges on it. In general, 27 blades were used and 1hp motor is used for providing power to machine. The machine mainly reduces the labour work and also increases fibre production by 20-25 times when compared to manual process [11]. Due to crushing fibre is obtained by removing the pulpy part. Roller is mainly used for applying the squeezing force on stem/bark of plant and separating the pulp, leaving only the fibre. The quality of the fibre mainly depends on type of the roller used in the machine [12]. The plain roller is used to separate a good texture of leaf sheath. While saw tooth bar type is used to damage the texture of leaf sheath.

Fig.1: Manual process

Fig. 2: Mechanical process

Fig.3: Chemical process

III. Fiber Orientation

The fibres are prepared by web formation by carding or by air lay or wet lay process and then web stacking by parallel lay, cross lay and perpendicular process. The popular configuration of bi-components is side by side structure, sheath core structure, segmented pie structure and islands in the sea structure, tipped structure, segmented ribbon structure. Among these the sheath core structure is mostly used. Three sheath core structures are famous in polyester core and co polyester sheath bi-component fibre.

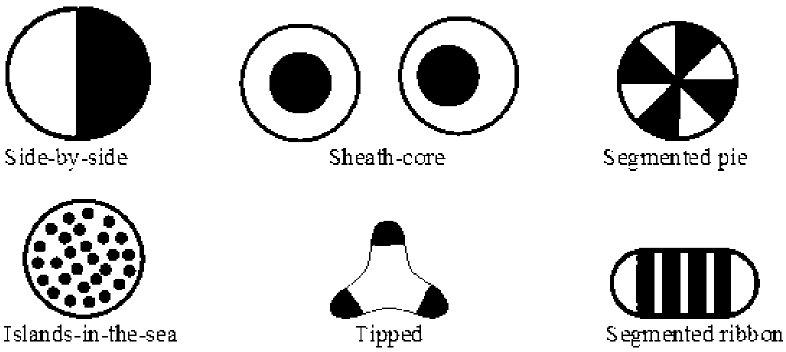


Fig.4: Fibres orientation steps

IV. Composite Preparation

The composite material is prepared with the help of some techniques. The techniques used are bladder moulding, autoclave and vacuum bag, mandrel wrapping, wet layup, chopper gun, filament binding, pultrusion, resin transfer moulding and compression moulding. These techniques help in making of composite materials of required shape and size which we require.

The different composite process preparation methods are:

4.1 Bladder Moulding: In this type the sheets are mostly wrapped around bladder and placed in mould cavity. The mould is closed and pressure is applied inside the bladder so that the bladder expands pushing the pre-impregnated fibres in the mould cavity [13]. Certain amount of heat is applied so that the material in the mould cavity is solidified. After material is solidified the obtain product is obtained. It is used for parts which have complex geometry. The main advantages of this technique are good dimensional control, excellent surface finish, up to 500% elongation etc., The main drawbacks are large size of the mould cannot be used, temperature limit of 300degress Celsius,3-5% shrinkage from mould to finished product. The bicycle frames were prepared by the bladder moulding process.

Fig.5: Bladder moulding

4.2 Resin Transfer Moulding: In this process the fibre reinforcement is packed in mould cavity of desired shape and mould is closed [14-16]. Low viscosity resin is used and pumped into the mould under certain pressure, displacing the air at the edges till the mould completely filled. The mould is heated so that the material is solidified and gel coats were used to provide a high quality and durable finished products. It is suited for the mass production of 100 to 10000 units /year. The resin transfer moulding can be done at room temperatures. It has many advantages such as labour savings, tooling flexibility, good surface finish, design flexibility, short production cycle. The main drawback of this technique is complex mould cannot be used, large wastage of material etc. It is used to prepare parts like boat hulls, wind turbine blades. medical composite, aerospace and automobile parts.

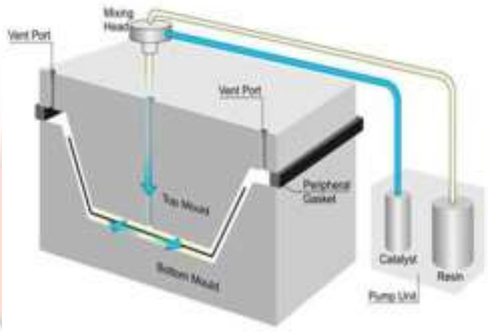


Fig.6: Resin transfer moulding

4.3 Compression Moulding: It was first developed for manufacture the composite parts so that it can replace the metal. In this type the mould set is placesd in a hydraulic or mechanical moulding press and the moulds were heated from 250 deg to 400deg F[17-19]. The pressure is applied after the two halves are closed. After cure the mould is opened and finished product is obtained. The main advantages of this technique is low cost of tooling, good for large parts and good for small production runs etc. The drawbacks of this techniques is not suitable for complex moulds, greater waste is obtained, slower process time, high labour cost etc. Many automobile components, furniture, structural components were prepared.

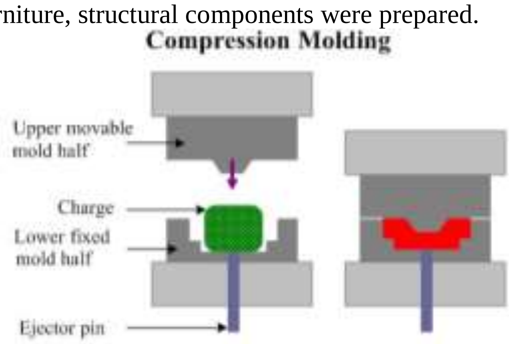


Fig.7: Compression Moulding

4.4 Pultrusion: It is a process where the fibres are dipped into the resin and resin-soaked fibre is send out to the die or mould and heated so that we can obtain the required product and with the help of pull mechanism the product is pulled from the die and then hardened [20].A complex series of tensioning devices and roving guides are directed the roving into the die. The advantages of this process are good surface, production rate is high and it is a continuous process, easy handling and low maintenance. The drawbacks of this process are control of fibre orientation is not possible, Thin walls parts cannot be produced, Tapered and complex shapes cannot be produced.

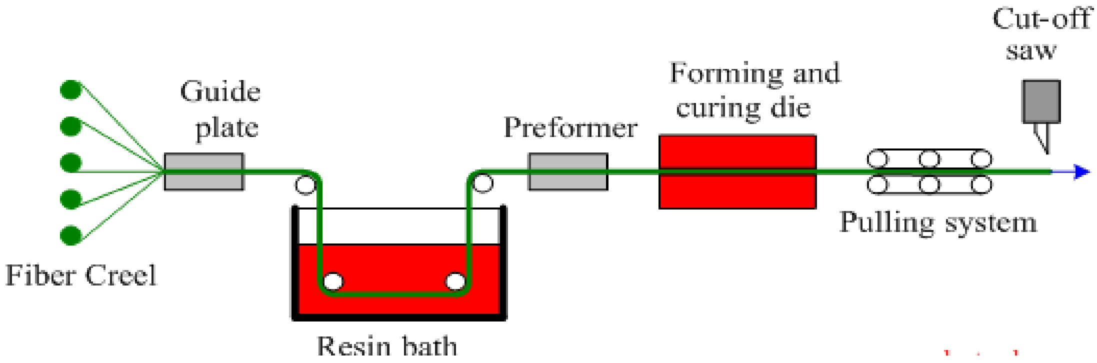


Fig.8: Pultrusion

4.5 Wet layup process: It is a process layers of reinforced fibre is combined with liquid resin to create a laminate. In this reinforcement material is kept in layers in the mould. These layers were impregnated with a liquid resin with the help of brush or roller [21]. Curing is performed at room temperature depending upon the resin system. It has some benefits like it is easy processing, low capital investment, low tooling cost, the process is simple. The drawbacks of this process are the resin should be less viscous, uniform distribution cannot be obtained.

4.6 Hand layup process: It is one of the moulding process were fibres reinforcement takes place with the help of hand. Single sided tool is used for this process. This process is flexible in nature, produces only one smooth surface, low cost to tool and somewhat inconsistent in part thickness [21-22]. The gel coat is first applied to the mould and it is cured sufficiently, roll stock fibre glass reinforcement is manually placed on the mould. The laminating resin is applied by pouring, brushing etc. End grain balsa, foam and honeycomb are low density core materials which are commonly used to stiffen the laminate. The advantages of the process are low equipment cost, less investment etc. The drawbacks of this process are production efficiency is low, resin must be less viscous, there is no uniform distribution of the resin.

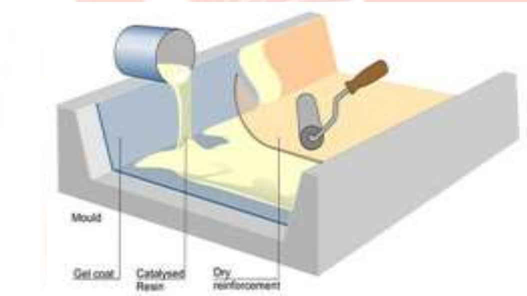


Fig.9: Hand layup process

The properties of polymer reinforced composites are reformed with respect to their mechanical and electrical properties of their advanced applications in automobile sector. These composite materials are used in different experimental techniques in their property. The properties are as shown in bellow table 1 & 2.

Table1: Polymer Reinforced Composites and its properties

FIBRE/REINFORCEMENT	POLYMER/MATRIX	TECHNIQUE	DIELECTRIC PROPERTY	ELECTRICAL CONDUCTIVITY	Ref.no
Natural rubber	Polypyrrole	In-situ polymerization	_	$8.3x10^{-4}$ s/cm	[5]
Rice husk	Epoxy resin	Experimental setup	_	1.1 $x10^{-5}$ohm mts	[6]
Hibiscus sabdariffa	Phenol formaldehyde	Compression moulding	7.5		[7]
Oil palm + Carbon black (Nano powder)	low density polyehtylene. (LDPE)	Compression moulding	_	2.0E-4 s/cm	[8]
Sisal fibre and Alumina	Vinyl esters	Compression moulding	2.4	_	[9]
Sisal fibre and Coconut	Vinyl esters	Compression moulding	2.56	_	[9]

Sisal fibre	Polyester resin	Resin transfer moulding	3.54	_	[10]
Coir fibre	Epoxy resin	Wet lay process	27	_	[11]
Banana fibre	Phenol formaldehyde	Compression moulding, Hand layup process	33	_	[12]
Roystonea regia	Epoxy resin	Compression moulding, hand layup process	56.5	_	[13]
Sisal oil palm hybrid	resorcinol and hexamethylene tetramine	Alkali treatment, roll mill method	5	_	[14]
Banana, hemp and agave	HDPE	Compression moulding	_	2.3 ohm	[15]

Table: 2: Processing Techniques for Polymer Composites

S.No	Technique	Type of Polymer Composite Processed/Manufactured
1	Hand layup	Bi-directional Jute Fiber EpoxyComposites [02]
		Sisal–jute–glass fiber reinforced polyester composites [14]
		Hybrid Glass Fiber- Sisal/Jute Reinforced Epoxy Composites [13]
		Banana Fiber Reinforced Polymer Composites [12]
		Calotropis Gigentea Fruit Fiber Reinforced Polyester Composites [05]
2	Spray layup	Sisal and Jute Fiber Composites [06]
		PLA-based green composites [07]
		Coconut sheath fiber reinforced epoxycomposites [15]
		Nano silicon dioxide and different flax structures [16]
		Development of a Kraft Paper Box Lined with Thermal-Insulating Materials by Utilizing Natural Wastes [20]
3	Compression moulding	Short natural-fibre reinforced polyethylene and naturalrubber composites [19]
		Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices [16]
		Banana/sisal reinforced hybrid composites [5]
		Natural fibres as reinforcement in polylactic acid (PLA) composites [7]
		Sugarcane bagasse fibers reinforced polypropylene composites [7]
4	Filament winding	Cellulose aceto-butyrate (CAB) and natural rubber (NR) reinforced with renewable polymer matrices. [17]
		Ramie fiber yarn reinforced composites [04]
		Jute yarn-Biopol composites [13]
		A Multi-Component Fiber-reinforced PHEMA-based Hydrogel/HAPEXTM Device for Customized Intervertebral Disc Prosthesis [19]
		Natural fiber-based reinforcements inepoxy composites processed by filament Winding [21]
5	Injection winding	Woven Sisal Fibers and Natural Rubber Modified Epoxy Resin [14]
		bamboo-glass fiber reinforced polymer matrix hybrid composites [24]
		Vetiver–polypropylene composites [20]
		Sugarcane bagasse fibers reinforced polypropylene composites [21]
		Polypropylene Reinforced Palm Fibers Composites [15]

V. Conclusion

In this review paper electrical properties of natural fibres were analysed and compared

- The fibre which has more moisture content shows more conductivity.
- With the help of heat treatment, the resistivity of the composite material increases.
- The dielectric constant increases with increase in the temperature due to the movement of dipole molecular chain.
- The dielectric loss decreases with increase in the frequency at certain temperature.
- Thus, these composite materials act an insulator and they are used in many applications such as terminals, connectors, switches etc.
- Researchers were doing many research works consistently and systematically for the better future.

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