Study of Characteristic of Natural Fiber Reinforced Polymer (NFRP) Composites: A Review

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Abstract— Composite materials have fully established themselves as workable engineering materials and are now quite common place around the world. To produce composite materials provided a growing interest in utilizing fiber (natural or synthetic) as reinforcement to fibers, Natural Fiber-reinforced polymer matrix composites have gained commercial success in the semi structural and structural applications such as aircraft, automobiles, sporting goods, electronics, and appliances are quite dependent on natural fiber-reinforced plastics, and these composites are routinely designed, manufactured and used in place of synthetic fiber reinforced polymer composites. The objective of this paper is to study the behaviour of composite materials. The study is made to show the difference between synthetic and natural fibers and composites, process for their production for high performance, low cost and less weight, and study and compare different results of Mechanical Test on NFRPC.

Key words: Composites, Polymers, Natural Fibers, Synthetic Fibers, Polymer Matrix Composites

I. Introduction

Composites can be defined as materials that consist of two or more chemically and physically different phases separated by a distinct interface. The different systems are combined judiciously to achieve a system with more useful structural or functional properties non attainable by any of the constituent alone. These separate constituents act together to give the necessary mechanical strength or stiffness to the composite part. Composite materials are composed of matrix phase and dispersed phase and having bulk properties expressively different from those of any of the ingredients.

A high stiffness and strength to weight ratio is provided by polymeric materials reinforced with synthetic fibers such as glass, carbon, and aramid as compared to conventional construction materials, i.e. wood, concrete, and steel. But also synthetic fiber-reinforced polymer composites are less used as compared to NFRPC because of their high-initial costs, their use in non-efficient structural forms and most importantly their adverse environmental impact.

In the light of this, an attention to the use and role of natural fiber composite (i.e. bio-composites) which are composed of natural or synthetic resins, reinforced with natural fibers, accordingly, manufacturing of high-performance engineering materials from renewable resources has been pursued. The study shows that the renewable raw materials are environmentally sound and do not cause health problem. In this present work the advantages and characterization of natural fiber reinforced polymer composites have been discussed.

II. Background

Over the last fifty years composite materials, plastics and ceramics have been the principal emerging materials. The volume and number of applications of composite materials have grown steadily, probing and celebratory new markets uncompromisingly. Modern composite materials constitute a significant proportion of the engineered materials market vacillating from everyday products to refined place applications.

The composites industry has arisen to diagnose that the commercial applications of composites possibilities to offer much larger business prospects from aircraft to other commercial in recent years.

For certain applications, the use of composites rather than metals has saved the cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc.

Composites are now extensively being used for rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity. Unlike conventional materials (e.g., steel), the properties of the composite material can be designed considering the structural aspects. The design of a structural component using composites involves both material and structural design.

III. Composites

A typical composite material is a system of materials consisting of two or more materials (mixed and bonded) on a macroscopic scale, in which fiber material is called the reinforcing phase, and is embedded in the other material called the matrix phase.

Less exotic composites, used primarily for cost reduction- namely, particulate- or mineral –filled plastics- are increasingly used in industries, are their usage will continue to grow as long as minerals remain more abundant than the raw materials utilized for synthesizing polymers.

The high stiffness-to-weight ratio, low electromagnetic reflectance, and the ability to embed sensors and actuators have made fiber reinforced composites an attractive alternative construction material for primary aircraft structures. In many other cases natural fiber reinforced polymer composite materials are being developed and used to replace metal components, in particular in corrosive environments.

Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. It combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material.

A. Classification of Composite Material:

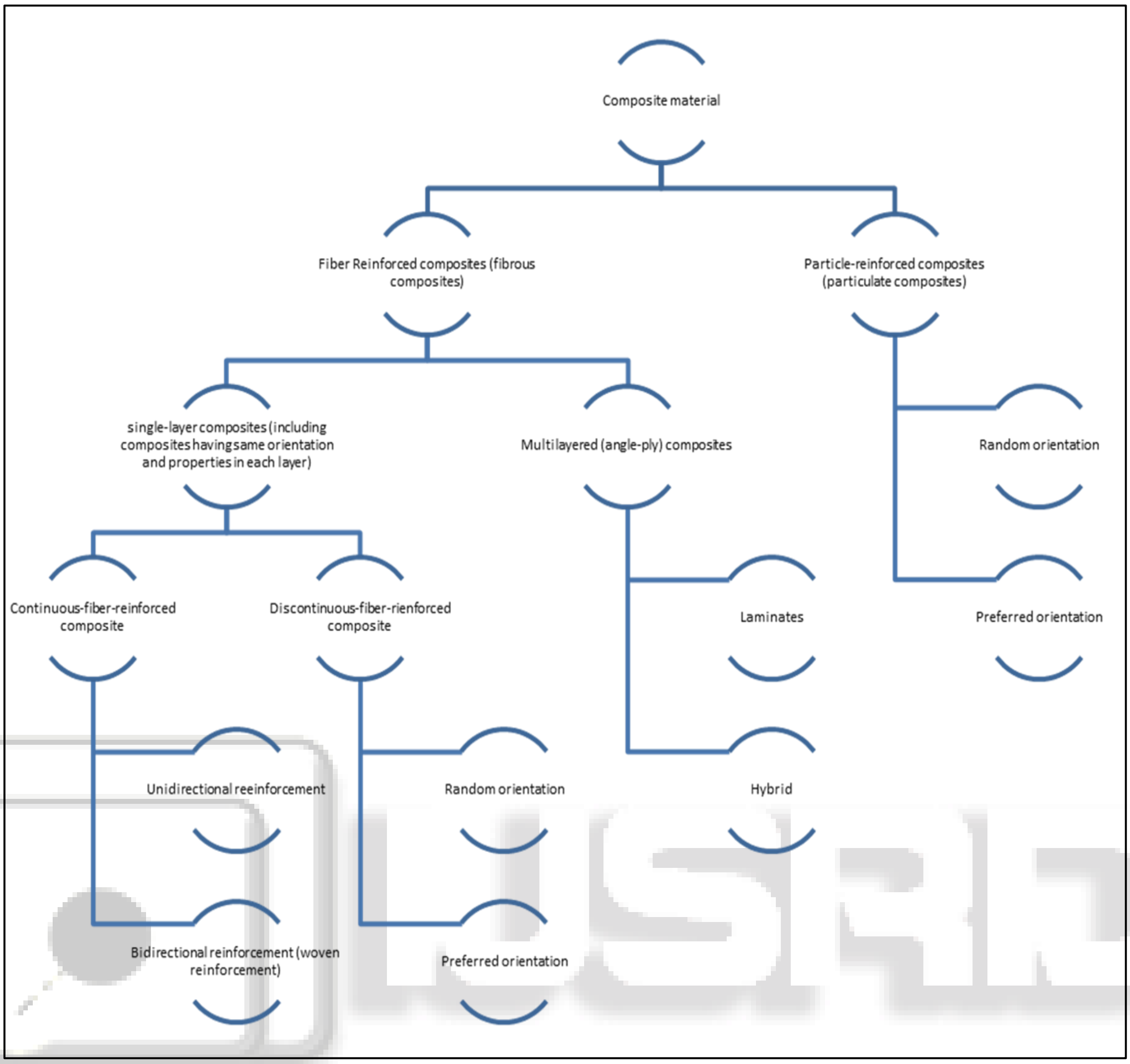

Fig. 1: Shows the Proper Classification of Composite Material

B. Components of Composite Materials:

Reinforcement: fibers	Matrix materials	Interface
Glass Carbon Organic Boron Ceramic Metallic	Polymers Metals Ceramics	Bonding surface

Table 1: Components of Composite Materials

IV. HYBRID COMPOSITES

Hybrid composites are those composites that have a combination of two or more reinforcement materials (continuous or fragments) in a matrix or binder. This type of composite is usually used when a combination of properties provided by different types of fibers is desired, or when longitudinal as well as lateral mechanical performances are required.

Mixing or hybridizing different types of reinforcement fibers within a structure can be accomplished in two ways: 1) interply hybridization, where layers (lamina) of different fiber types are laminated together, and 2) intraply hybridization, where different fiber types are mixed within the individual layers (lamina).

Composite materials represent acoustically and thermally heterogeneous materials where a variety of defects with different dimensions may be formed. Typical defects of composite materials include fiber breaks, micro cracks, micro splits, foreign objects, and pores in the bonding medium, and detachment of fibers from the bonding material.

V. POLYMER

A polymer is a large molecule composed of many repeated subunits, known as monomers. Because of their broad range of properties, both synthetic and natural polymers play an essential and ubiquitous role in everyday life.

Polymerization is the process of combining many small molecules known as monomers into a covalently bonded chain or network. During the polymerization process, some chemical groups may be lost from each monomer.

1) Modification of Natural Polymers

Naturally occurring polymers such as cotton, starch and rubber were familiar materials for years before synthetic polymers such as polyethene and perspex appeared on the market.

2) Polymer Properties

Polymer properties are broadly divided into several classes based on the scale; Physical basis which describes its identity of constituent monomers and microstructure. Chemical basis, at the nano-scale, describe interaction at various physical forces and at the macro-scale, the bulk polymer interacts with other chemicals and solvents.

Standardized polymer nomenclature

There are multiple conventions for naming polymer substances. Many commonly used polymers, such as;

Common name	ACS name	IUPAC name
Poly(ethylene oxide) or PEO	Poly(oxyethylene)	Poly(oxyethene)
Poly(ethylene terephthalate) or PET	Poly(oxy-1,2-ethanediyloxycarbonyl-1,4-phenylenecarbonyl)	Poly(oxyetheneoxyterephthaloyl)
Nylon 6	Poly[amino(1-oxo-1,6-hexanediyl)]	Poly[amino(1-oxohexan-1,6-diyl)]

Table 2:

A. *Classification of Polymer:*

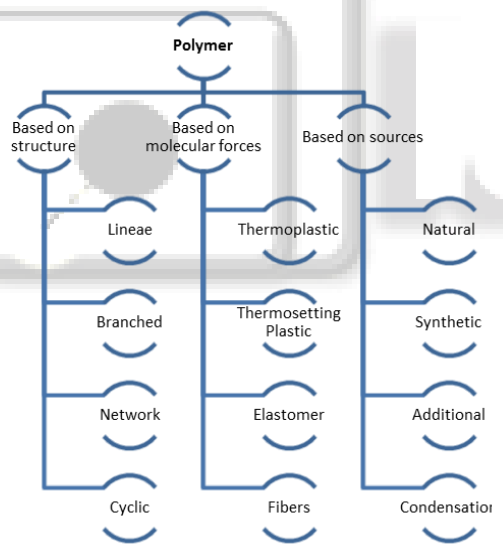

Fig. 2: Classification of Polymer

Basically two types of Industrial Plastics and their subtypes are used:

1) *Thermo Plastics:*

– Acrylonitrile-butadiene-styrene (ABS):

Characteristics: Outstanding strength and toughness, resistance to heat distortion; good electrical properties; flammable and soluble in some organic solvents.

Application: Refrigerator lining, lawn and garden equipment, toys, highway safety devices.

– Acrylics (poly-methyl-methacrylate)

Characteristics: Outstanding light transmission and resistance to weathering; only fair mechanical properties.

Application: Lenses, transparent aircraft enclosures, drafting equipment, outdoor signs

– Fluorocarbons (PTFE or TFE)

Characteristics: Chemically inert in almost all environments, excellent electrical properties; low coefficient of friction; may be used to 260oC; relatively weak and poor cold-flow properties.

Application: Anticorrosive seals, chemical pipes and valves, bearings, anti-adhesive coatings, high temperature electronic parts.

– Polyamides (Nylons)

Characteristics: Good mechanical strength, abrasion resistance, and toughness; low coefficient of friction; absorbs water and some other liquids.

Application: Bearings, gears, cams, bushings, handles, and jacketing for wires and cables

– Polycarbonates

Characteristics: Dimensionally stable: low water absorption; transparent; very good impact resistance and ductility.

Application: Safety helmets, lenses light globes, base for photographic film

– Polyethylene

Characteristics: Chemically resistant and electrically insulating; tough and relatively low coefficient of friction; low strength and poor resistance to weathering.

Application: Flexible bottles, toys, tumblers, battery parts, ice trays, film wrapping materials.

– Polypropylene

Characteristics: High heat resistance temp, Excellent chemical resistance, High bending fatigue strength, Improved transparency, impact strength, improved low-temperature impact resistance, Improved rigidity, Low yield

Application: Injection molding, Daily goods, Sheets, Home appliances, Automobiles, etc.

2) *Thermo Setting Polymers:*

– Epoxies

Characteristics: Excellent combination of mechanical properties and corrosion resistance; dimensionally stable; good adhesion; etc.

Application: Electrical moldings, sinks, adhesives, protective coatings, used with fiberglass laminates.

– Phenolics

Characteristics: Excellent thermal stability to over 150oC; may be used as resins, fillers, etc.

Application: Motor housing, telephones, auto distributors, electrical fixtures.

VI. Processing of Plastics

A. *Thermoplastic*

1) Can be recycled
2) Heat until soft, shape as desired, then cool
3) Ex: polyethylene, polypropylene, etc.

B. *Thermoset*

1) When heated forms a molecular network
2) Degrades (doesn't melt) when heated
3) A prepolymer molded into desired shape, then chemical reaction occurs
4) Ex: urethane, epoxyetc.

VII. Natural fibers vs. Synthetic fibers

1) Natural polymeric materials such as wool, silk and natural rubber have been used for centuries. A

variety of other natural polymers exist, such as cellulose, which is the main constituent of wood and paper.

2) The list of synthetic polymers includes synthetic rubber, nylon, PVC, polyethylene, polypropylene, silicone, and many more.

Natural Fibers		
PLANT BASED (Cellulose or Lignocelluloses)	Wood	Soft Wood, Hard Wood
	Cane, Grass & Reed Fiber	Bamboo, Bagasse, Esparto, Sabei, Phraginites, Communis, Canary Grass, Elaphant Grass
	Stalk	Wheat, Maize, Barley, Rye, Oat, Rice
	Leaf	Sisal, Abace, Henequen, Pineapple, Palm, Harakeke Flax
	Bast (Stem)	Flax, Hemp, Jute, Ramie, Kenaf
	Seed	Cotton, Kapok, Milk Wheet, Rice Husk
	Fruit	Coir
ANIMAL BASED (Protein)	Wood / Hair	Lamb's Wood, Got Hair, Angoora Wood, Cashmere, Yak, House Wair, Feather Down
	Silk	Tusaar Silk, Mulberry Silk, Spider Silk
MINERALS	Absestos	Fibrions, Brucite, Wollastonite, Imorganic, Whiskers.

Table 3: Natural Fibers

VIII. LITERATURE REVIEW

S.V. Joshi, et.al., 2003, review the comparative life cycle assessment studies of natural fiber and glass fiber composites, and resulted that natural fiber are emerging as low cost, lightweight appears to be bright and apparently environmentally superior alternatives to glass fibers. Future research should hence focus on achieving equivalent or superior technical performance and component life.

Dieter H. Mueller, et.al., 2004, describes the effects of fiber fineness composition of important composites. A comparison study of characteristics between natural plant fibers and an alternative glass fiber reinforced parts has been done. This results that a strong impact on mechanical data, especially, the higher fiber fineness results in an improved fiber length to diameter relation and an increased contact surface between fiber and matrix. It leeds in a decrease in stress concentration with an increased amount of fibers in the composite.

H.N. Dhakal, et.al., 2006, study the effects of water absorption on the mechanical properties of Hemp fibre reinforced unsaturated polyester composites (HFRUPE) by water immersion tests. Here tensile and flexural properties of water immersed specimens are compared alongside dry composite specimens. The result shows that the decrease in tensile and flexural properties of HFRUPE specimens with increase in percentage moisture uptake and fibre volume fraction increases due to increased voids and cellulose content.

A S SINGHA, et.al., 2008, Present work reveals with various test methods for the mechanical, Thermal (TGA/DTA/DTG) and morphological studies (SEM) behaviour of urea–formaldehyde resin when reinforced with the fiber. In case of mechanical behaviour particle reinforcement of the UF resin has been found to be more effective as compared to short fiber reinforcement. These results suggest that Hibiscus sabdariffa fiber has immense scope in the fabrication of natural fiber reinforced polymer composites having vast number of industrial applications.

Ramakrishna Malkapuram, et.al., 2009, This review article describes the recent benefits i.e. low-cost, recyclable, and eco-friendly nature of natural fiber reinforced polypropylene (PP) composites, compared with the conventional glass and carbon fibers. This study results that the chemical, mechanical, and physical properties of natural fibers have distinct properties; depending upon the cellulosic content of the fibers which varies from fiber to fiber. Eco-friendliness and bio-degradability of these natural fibers may replace the glass and carbon fibers.

Mei-po Ho, et.al., 2011, In this paper, a detail study of different manufacturing processes and their suitability for natural fibre composites, based on the materials, mechanical and thermal properties of the fibres and matrices are discussed.

Jyoti Prakash Dhal, et.al., 2012, In this paper, study of method preparation of a brown grass flower broom reinforcement polymer composite is done with its properties like lowest porosity, homogeneous surface structure, and the greatest interface bonding with a less cost compared to other polymer composites. It also discusses that the dielectric constant and dielectric loss factor decrease with the increasing frequency.

Ing. Eva Aková, 2013 , The article reviews the recent development of natural fiber reinforced polymer composites, including an experiment on composites reinforced with hop fibers. This study results that the hop natural fibers are low-cost fibers with high specific properties and low density.

V. Chaudhary, et.al., 2015, here author has studied the properties of composites, i.e. high, medium and low strength, of Fibers reinforcement materials, for various applications, and got that the composite materials which are more environmentally friendly, energy efficient and recyclable have great potential market. The methodology of development of cotton-polyester composites using filament winding technology and hand layup method has also being discussed.

IX. ADVANTAGES OF COMPOSITES

Advantages of composites over their conventional counterparts are the ability to meet diverse design requirements with significant weight savings as well as strength-to-weight ratio. Some advantages of composite materials over conventional ones are as follows:

1) Tensile strength: four to six times greater than steel or aluminium.
2) Improved torsional stiffness and impact properties.

3) Higher fatigue endurance limit (up to 60% of ultimate tensile strength).
4) 30% - 40% lighter for example any particular aluminium structures designed to the same functional requirements.
5) Lower embedded energy compared to steel, aluminium etc.

The main advantages of natural fiber composite are:

1) Low specific weight, and higher specific strength and stiffness than glass fiber.
2) A renewable source produces O2 and intakes CO2 at little energy consumption.
3) Producible with low investment at low cost.
4) Reduced wear of tooling, healthier working condition, and no skin irritation.
5) Thermal recycling is possible while glass causes problem in combustion furnaces.
6) Good thermal and acoustic insulating properties.

X. APPLICATIONS OF NATURAL FIBER COMPOSITES

The reasons for the application of natural fibers in the automotive industry
Include:

1) Low density: which may lead to a weight reduction of 10 to 30%?
2) Acceptable mechanical properties, good acoustic properties.
3) Favorable processing properties, for instance low wear on tools, etc.
4) Options for new production technologies and materials.
5) Favorable accident performance, high stability, less splintering.
6) Favorable ecobalance for part production.
7) Favorable ecobalance during vehicle operation due to weight savings.
8) Occupational health benefits compared to glass fibers during production.
9) No off-gassing of toxic compounds (in contrast to phenol resin bonded wood and recycled Cotton fiber parts).
10) Reduced fogging behavior.
11) Price advantages both for the fibers and the applied technologies.
12) Use of composite material is spreading from cutting edge technology to everyday applications like: fuel cylinder of natural gas,etc..
13) NFRP: Power generation and Transmission, bridge building, surface transportation, automobile railways and the telecommunication industries.

The natural fiber composites can be very cost effective material for following applications:

1) Building and construction industry: panels for partition and false ceiling, roof tiles, mobile or pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc.
2) Storage devices: post-boxes, grain storage silos, bio-gas containers, etc.
3) Furniture: chair-table, bath units, etc.
4) Electric devices: electrical, pipes, etc.
5) Everyday apps.: suitcases, helmets, etc.
6) Transportation: Interior in railway coach, etc.
7) Toys

XI. METHODS FOR FABRICATION OF POLYMER COMPOSITES

1) Hand Lay –Up Method
2) Spray up moulding
3) Compression moulding
4) Injection Moulding
5) Reaction Moulding
6) Pultrusion
7) Filament

XII. CONCLUSION AND DISCUSSION

The resistivity of fiber reinforced composites depend on the moisture content, crystalline and amorphous component present, presence of impurities, chemical composition, cellular structure, microfibrillar angle etc. The shapes of reinforcement determine the interparticle contact, which affect the conductivity of the system

1) The use of natural fiber as reinforcing agent in polymer based composites were reviewed from viewpoints of Literature survey and future expectations of natural fibers in general, structure and surface modifications are studied.
2) It is worth mentioning that these composites can be used as a substitute for plastics. However, suitable cost-effective design and fabrication techniques for manufacture should be developed.

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