

DESIGN AND DEVELOPMENT OF NATURAL FIBER COMPOSITES; A CRITICAL SURVEY

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Abstract: Day by day, the researchers are developing new and alternative composites to the existing metal, polymer, synthetic fiber composite material for reducing the impact on our environment. This paper aims to provide comprehensive review of some research work in different types of composite material. Where Natural fiber, PLA, Hybrid composite and composite made in 3D printing is studied. Natural fiber is a wastage material and it reduces the amount of use of metal, plastic, polymer etc. It covers detailed information about composites, process of making, combination of composite material and various types of material using in composites. Different types of material's properties vary with its types, sources & its structure. The research perspective and the current applications status are also discussed in this paper.

Keywords: Natural fiber composites (NFCs), Poly lactic acid (PLA), Hybrid composite, 3D printing.

1. INTRODUCTION

A composite is a material made from two or more different constituent materials having different physical or chemical properties which do not merge in the finishing structure i.e. the individual constituents retain their properties. Nowadays due to the increase in environmental consciousness, manufacturers are looking for more ecologically friendly bio-based materials and easy to available for interior and outdoor products, and in these applications PLA, Polymer based composite and natural fibre-reinforced composites could have great potential. There are many thermoplastic polymers derived from renewable raw materials, which are also biodegradable. These types of composites show good properties that are suitable for applications that do not require long-term durability or elevated mechanical performance at higher temperatures. For higher strength, metal is used with PLA and natural fiber to form composites of good mechanical properties for working operation in design with the help of CAD (Computer Aided Design) and it also helps to reduce the production cost. With the help of 3D printing technology, it is easy to make a suitable desired shape of composites with perfect finishing which consumes very less material & time. PLA and ABS (Acrylonitrile butadiene styrene) material is widely used in making functional prototype. NFCs and some other composites have been used from ancient times for potties, walls, other usable things. So, composite is not a new material, in modern era it is just a upgraded version for wide variety of uses in different applications. The example of different type of material using in composite is Acrylonitrile butadiene styrene, PLA, Natural Fiber etc.

1.1 History: The first known use of composites is credited to the Mesopotamians. They used plywood made with glued wood strips in 3400 B.C. Even in early days, the Egyptians used Cartonnage and layers of linen or papyrus soaked in plaster to make death masks. From the Ancient times, the researchers continued to develop composites of a wider array of materials for more sophisticated applications. Before 1900s, early synthetic resins included celluloid, melamine and Bakelite was used in composites. After that, Bakelite was used in industrial and consumer goods applications including electrical insulators, radio and telephone casings, kitchenware, jewellery, pipe stems, and children's toys in early 1900s. Day by day, new materials were formed for many purposes with different types of composite and its constituent. Today, composites are formed in four categories in bulk phases as below:

- i. Polymer matrix composites
- ii. Metal matrix composites
- iii. Ceramic matrix composites
- iv. Carbon matrix composites

1.2 Classification: The composites made of different types of fiber arrangement are classified as shown below:

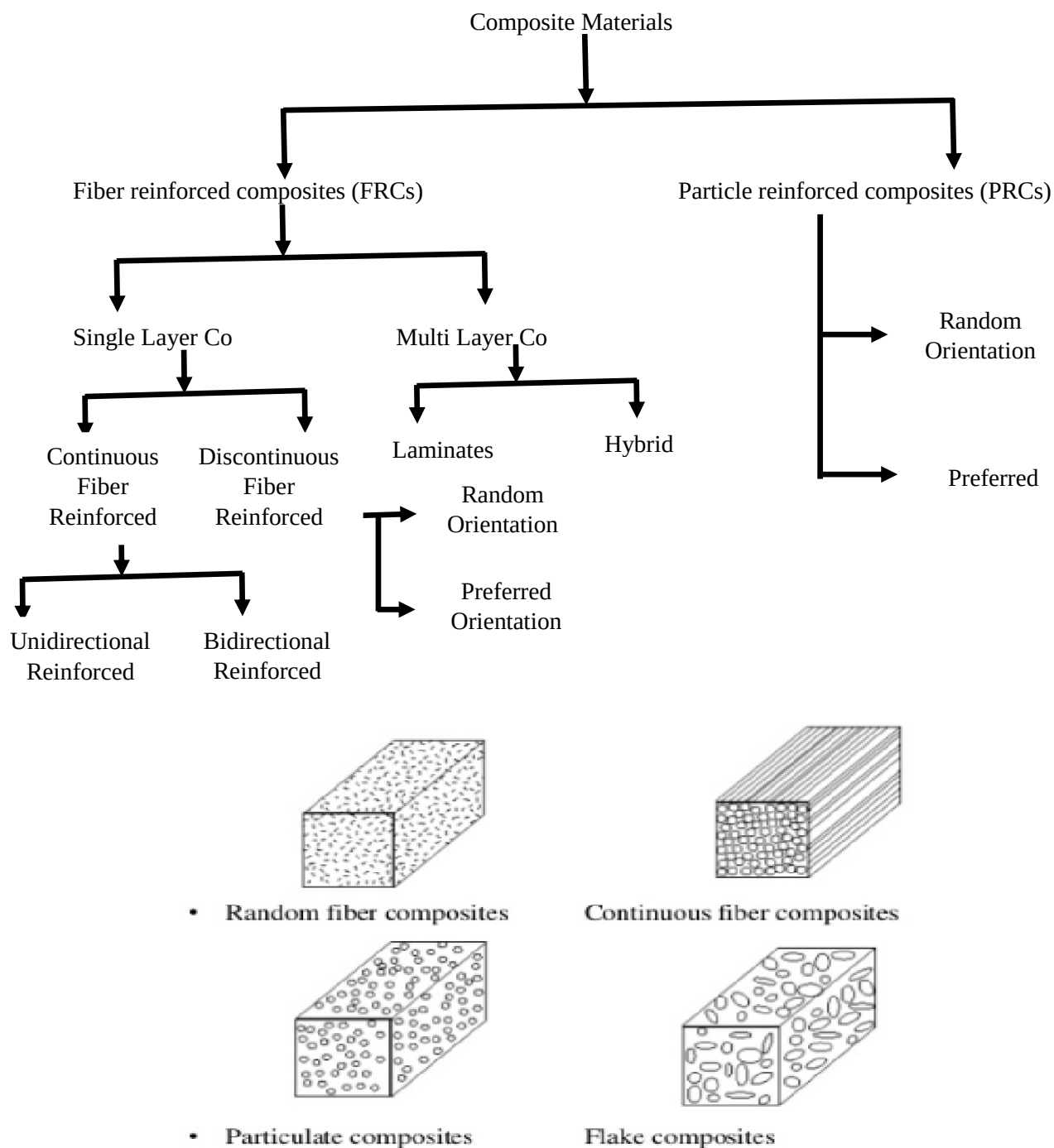


Fig.1.1: Different types of composites [32]

2. NATURAL FIBER COMPOSITES (NFCS)

2.1 Natural Fiber: It is a renewable sources and a alternative of synthetic fiber in composites. Natural means it is already present in nature and fiber means hair like or thread structure, which has high aspect ratio. It is divided on the basis of its origin; plant fiber and animal fiber. This material is eco-friendly in nature and its property is good for using in making composites for variety of applications. Kamrun N. Keya and et.al. [11] studied and summarized the mechanical characterisation, application of different natural fiber reinforced polymer composite (NFRPc) and its future scope ,challenges and opportunities in civil applications. In this paper, application of NFRPc in different industry like automobile, medical, aerospace etc. Is discussed and still further research on this material is going on. Tushar Sonar and et.al. [12] have explained about the research and development in properties of natural fibre reinforced polymer composites with its application. In their work, the researcher found that chemical modification is needed for adhesion between the hydrophilic

fibers and hydrophobic matrix. This type of composite has wide application in different areas and a substitute of synthetic fiber because of good mechanical properties of fiber and its eco-friendly nature. Amirhossein Lotfi and et.al. [13] have given overview on the materials, manufacturing techniques and machinability of natural fiber reinforced composites(NFRC).

The researcher focused to find challenges in physical properties of the fibers and manufacturing process on the machinability, along with the essential machining parameters that affect the quality of the machined surface. In this paper, the researchers found that the use of these materials to replace petroleum-based and non-renewable resources in reinforcing composite materials. It also reduces the production cost and it has several industrial applications including load bearing and outdoor applications. Pradeep Ranga and et.al. [14] have investigated the use of various fiber as reinforcement in composites with innovation in physical, chemical, thermal and mechanical properties of the composite which is used in various purposes. It is found that Fiber reinforced composites are one of the resources to utilize the natural resources and due to soon diminishing nature, there is a great need to maintain and procure them for the future use. Layth mohammed and et.al. [22] have given overview of natural fiber reinforced composites and its application and analyzed that some drawback of NFPCs like higher water absorption, inferior fire resistance, and lower mechanical properties limited its applications. In their work, effect of chemical treatment and biodegradability of natural fiber studied and analysed.

Ekkachai Yooprasertchai and et.al. [23] investigated the use of sisal and jute fiber composites in short RC columns for preventing brittle shear failures in it. The researchers found that these sisal and jute mixed fiber composites have ability to replace the carbon fiber sheet polymer (CFRP) and also the strengthening cost per column decreases as compare to the CFRP. S. Ramaswamy and et.al. [24] compared and analysed the application of four composites (Bamboo composite furniture, Kevlar composite Aero wing, Natural composite safety Helmet and Bullet proof vehicle's body) with Classical Lamination Plate theory for validation. In their work, higher order lamination plate theory showed, it was a better than classical lamination plate theory. This analysis helps to analyse the strength of composite structure and their applications. Rajeshkumar Selvaraj and et.al. [25] have worked to characterise the mechanical and dynamic properties of natural fiber reinforced composite sandwich plates with multiple core layer. Where, jute fibers reinforced polymer composites as face layers and the natural rubber and cork as core layer. XRD, FTIR, TGA, SEM analysis was performed to study the crystallinity, chemical composition, thermal stability, and surface micrographs of natural jute fiber material.

There are some important fibers, which is used in making composites for different purposes. Table 1 shows different types of fiber with its mechanical properties [11].

Table-1 Mechanical properties of natural fiber

Fiber	Tensile Strength(MPa)	Elongation at break (%)	Young's modulus (GPa)	Density
Jute	400-800	1.5	10-30	1.46
Kenaf	930	1.6	53	1.45
Coconut	131-175	15-40	4-6	1.2-1.5
Hemp	550-900	1.6	70	1.48
Sisal	400-700	05-14	09-12	1.45
Coir	175	30	4-6	1.2
Cotton	287-597	2-10	6-10	1.21
Pineapple	413	1.6	6-21	1.526
Abaca	980	10-12	9-28	1.5
Oil palm	71	11	1.703	0.77-1.55
Flax	500-1500	2.7-3.2	60-80	1.5
Banana	10.854	6.085	1.63	1.02
Sugarcane	290	1-3	17	1.5
Bamboo	73-505	4.11	10-40	4.3
Date palm	97-196	2-4.5	2.5-5.4	1-1.2

Table 2 shows the world production of natural fiber [30] as tabulated:

Table-2 Annual production of natural fiber

Natural fiber	Origin	World production (x 10³ Tons)
Coir	Fruit	100
Banana	Stem	200
Bamboo	Stem	10,000
Jute	Stem	2,500
Hemp	Stem	215
Flax	Stem	810
Abaca	Leaf	70
Kenaf	Stem	770
Roselle	Stem	250
Ramie	Stem	100
Sisal	Leaf	380
Cotton lint	Fruit	18,500
Wood	Stem	17,50,000
Broom	Stem	Abndant
Elephant grass	Stem	Abundant
Linseed	Fruit	Abundant
Oil palm	Fruit	Abundant
Rice husk	Fruit/grain	Abundant

The different types of natural fiber i.e. Bamboo, Sisal, Flax, Jute, Cotton etc. are shown in Fig 1.



Fig 1: Natural Fibres

2.2 PLA (Poly lactic acid) : Poly lactic acid based materials have withdrawn the attention of the scientific community due to their biodegradability, good performance, high young's modulus, high tensile strength & suitable for number of application in today's world. The polymer compositing method, which includes the reinforcement of PLA with fillers or nanofillers to form PLA composite materials, has attracted great interest as an easy and cheap method for promising materials for a wide variety of applications.



Fig 2; PLA cycle in nature [34]

Rachid h. And et.al[2] have worked in the area of advanced composite materials based on thermoplastic polymers ,elastomer polymers and thermosetting polymers. they reinforced the advanced composite materials with organic or in- organic fibres and developed using various fillers such as organic, mineral and metallic. They presented the synthesis of several macromolecular matrices namely Polycarbonate, polyhexamethylene sebacic, polyether sulfone, polyether ether Ketone. In their work it appeared that composite materials thermosetting showed exceptional mechanical and thermal resistance at high temperature. Technological composite materials reinforced by glass fibers and carbon fibers present excellent high tensile and compressive strength. G. Rajeshkumar and et.al.[19] aims to summarized the different types of natural fibers and their influence on the unique properties of PLA based natural fiber reinforced composite for academicians, industry personnel and researchers. In their work, there is overview of characteristic of PLA materials and fabrication of natural fiber based PLA composites, where it shows good mechanical and thermal properties due to addition of natural fiber. Tarinee Nampitch [20] designed PLA/Natural Rubber/bagasse fiber composite foams with balanced stiffness and toughness. Where compression moulding is used to making composite foams and mechanical characterisation has analyzed on different machine. In their work, composites has been made through compression moulding machine and showed the some property of PLA/Natural Rubber/Baggase fiber composites. PLA composites and its properties are shown in Fig 3 along its various applications in different areas.

2.3 Hybrid composites: Hybrid composites are materials that are fabricated by combining two or more different types of fibers within a common matrix. Modern industries are adopting newer technologies in manufacturing sectors to sustain and excel in terms of quality at minimal cost. Because of the fast growth of technology and the requirement for outstanding mechanical, thermal, wear, and physical qualities at a cheap cost, manufacturing sectors are always on the lookout for novel materials, it is termed as hybrid material to enhance its mechanical properties. P. Singh and et.al. [5] summarized recent development on polymer based hybrid composite material in which employing natural fiber to reinforce hybrid polymer composites and increase its mechanical property. Conclusion of this study, natural fiber is a better alternative than glass, aramid, and others to improve quality. In their work, it showed that natural fiber hybrid composites are being used in non-structural and semi-structural parts in industries other than automotive and aerospace.

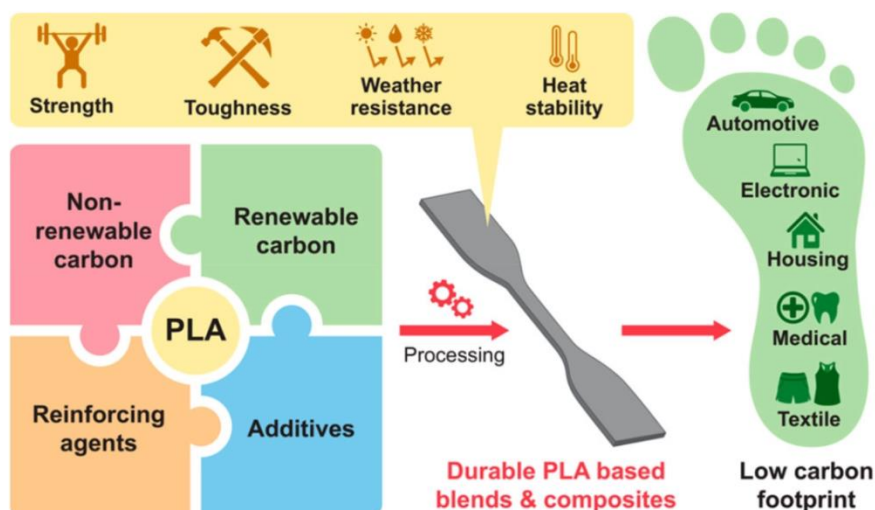


Fig 3; PLA Composites, properties and its application [31]

S.P. Jani and et.al. [17] have studied the performance of machinability through abrasive water jet process of hybrid NFCs. In this, it is designed and optimize the production cost of making this composite. In their work, the proposed method can be adopted to better the process parameter of abrasive water jet (AWJ) cutting on hybrid natural fibre composite. A.Alavudeen and et.al. [27] worked and analysed the effect in mechanical properties of weaving patterns and random orientations of banana/kenaf fiber reinforced hybrid polymer composites using hand layup method to manufacture the hybrid composite and performed some chemical treatment in natural fiber to enhance the mechanical properties.

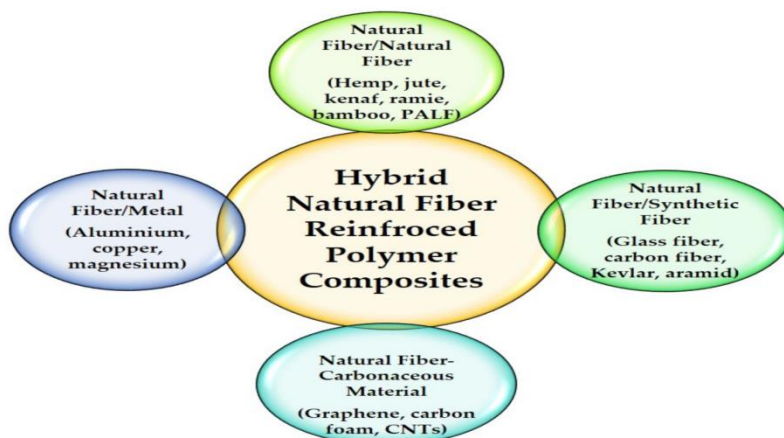


Fig 3; Different types of hybrid NFCs [33]

It is found that this type of composites shows good mechanical properties. Fig 3 shows the different types of Hybrid Composites of high mechanical properties used in different useful purposes.

3. COMPOSITE USING 3D PRINTING

The process of building three-dimensional physical objects from digital models using additive manufacturing is commonly known as 3D printing that involves layer-by-layer deposition of materials including plastic, metal, ceramics, or even living cells. 3D printing is used for the design of Composites material with the application of CAD/CAM software. This technology has a revolutionary impact on product fabrication for applications in industries, healthcare, aerospace, transportation, the food industry, art, textiles, fashion and construction, which has attracted increasing attention globally.

Lai Jiang and et.al. [15] aims to summarized the use of biofibers as reinforcements together with different resin systems as the starting material for 3D printing processes attempts to use biofibers as

reinforcements together with different resin systems as the starting material for 3D printing processes. In this paper, it is found that biofiber (natural fiber) used in 3-D printing with rapid prototyping in different techniques has wide application.

Xiaoyu Bi and et.al. [21] have analyzed the current research work on 3D printing in the area of natural fiber and their derivatives -degradable polymer based biocomposites and its application in different areas, where composites are made in 3D printing through fused deposition modelling. In this paper, 3D printing technology of fibers and their derivatives has been extensively researched on a large scale in the fields of smart manufacturing; biomedicine and electronic products, there are still some shortcomings that hinder its wide application in practical production life.

4. CONCLUSION

During literature survey, it has been observed that natural fiber has great potential to reduce in a large scale of synthetic fiber. It is eco-friendly in nature and easily available in the market. It has been observed that the crystallinity, molecular weight, and mechanical properties of PLA are interdependent, which have to be controlled for durable applications. This polymer is obtained from nature and it is bio-degradable & reproduced, which fulfils the need of current and future generations.

Hybrid composites have better impact strength, durability, bending, and tensile strength than other fiber composites. It is used in automotive, household or furniture and packaging industries due to its good performance. Today 3-D printing technology is widely used for making composites through fused deposition modelling and other process to get the product with high accuracy in finishing and no wastage of material.

Complex composite can be obtained from this technology. One may do the research in the area of composite materials using 3D printing technology. Research may be to develop composites with variation in density, orientation, combination of material. Effect of various parameters of 3D printing may also be investigated for composite materials developed by 3D printing.

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