Mechanical Behaviors of Banana Fibers Composites Reinforced Using Various Parameters

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Abstract

The concern for the environmental pollution and the prevention of resources has attracted researchers to develop new eco-friendly green materials based on sustainability principles. In this experimental study, there are six different composite samples were fabricated by using banana and carbon fibers with epoxy resin matrix. The mechanical properties such as tensile strength, flexural strength, impact strength, and water uptake properties of these composites have been evaluated. The composites reinforced with pure carbon fibers can hold the maximum tensile strength of 288.03 MPa, flexural strength of 3.12 kN, impact strength of 4.58 J and water intake percentage of 62.3%. Whereas the composites reinforced with carbon and banana fibers can withstand the maximum tensile strength of 277.06 MPa, flexural strength of 3.07 kN, impact strength of 4.36 J and water intake percentage of 70%.

Keywords: Banana fiber; Carbon fiber; Hybrid composites; Mechanical properties.

1. Introduction

For the past era, researchers from various disciplines are trying to replace the natural fiber from synthetic materials. The synthetic fiber is nylon, rayon, polyester, acrylic, glass and plastic. Synthetic fiber has various advantages as well as disadvantages such as non-biodegradable, high cost and weight. In order to decrease these disadvantages natural fibers are used as reinforcement in thermosetting and thermoplastic matrices [1].

The natural fibers are biodegradable, eco-friendly, renewable, non-abrasive, process a good calorific value, exhibit good mechanical properties and can be incinerated energy recovery have low density and low cost and less weight. Natural fibers have environmental friendly feature which provides the material very useful in engineering such as the construction and automobile industry [2].The natural fibers are important role to play in developing biodegradable composite to solve the current environmental and ecological problem. The composite are made of natural fibres provides the favourable for extensive application of field such as low cost housing, consumer goods and civil structures and many other common application where the beyond one's cost of reinforcement at present use of traditional lightweight reinforced plastics [3].

- Composite materials are gaining popularity in the new generation industries because of their properties such as-
- It is environment friendly nature
- Chemical and corrosion resistance[
- High strength and stiffness
- Economically effective properties
- Easy of fabrication
- It have low density and less weight
- At present the banana fiber is a waste product of banana cultivation. It can be extracted from the pseudo-stem of banana plant with better mechanical property of lingo-cellulosic fiber [4].The short banana fiber, the volume fraction are effects the dynamic mechanical property of the fiber reinforced composite[5]. The thermal property

can be improved by treating banana fiber with Sodium Hydroxide (NAOH) and saturation pressure without plenty deviation in its mechanical behaviour [6]. Hybrid composite have superior properties like flexural and impact strength [14]. It is a cost effective and user friendly composite material with better stiffness and damping behaviour can be ready by hybridizing banana and sisal fiber [7]. Banana/Sisal fiber density and thermal conductivity are increasing by using chemical treatment of NaOH and Polystyrene maleic anhydride (PSMA). It can better result provide contact between the fiber and matrix [8].

1.1 Introduction to Polymers

Atom is a basic structural unit of element, which exhibits all the chemical properties of the constituent element, whereas the group of similar or dissimilar atoms is called as Molecule e.g. Water. But polymer is very larger than molecules. The word POLYMER was first introduced in 1833 by the Sedish Chemist JonsJakob Berzelius. Polymer word is derived from combination of Greek words; Poly meaning – many and mer meaning – part or segment. The average number of molecules in a polymer generally ranges from 10000 to 100,000. This is why sometimes polymers are referred to as "Macro Molecules". Polymers generally form long chain compounds by addition of same units called as mers.

1.2 Classification of Composites:

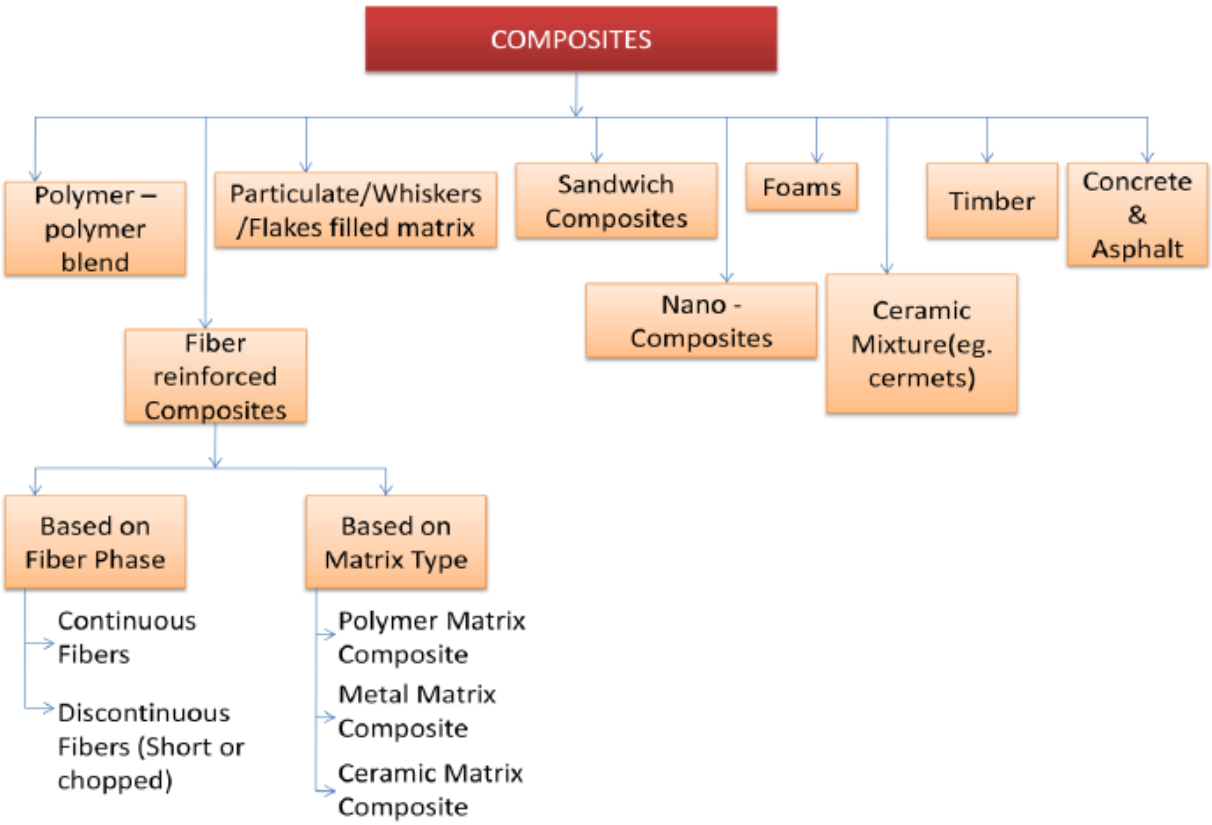

Fig 1: Classification of Composite

- **Polymer-polymer blend**: A polymer blend is a mixture of two or more polymer that have been blended together and create a new material which have different physical properties. The improvement property are observed when the first component is selected as the base component (base polymer) and second component is added to it in less than 40wt%. For example Polycaprolactone and Poly L Lactic acid polymer blend, Sodium Alginate and Poly vinyl pyrrolidone is also one such blend.[9]

- Sandwich composites: A sandwich–composite is a special class of composite material that is fabricated by attaching two thin but stiff skins to a lightweight but thick core. It falls in the category of laminar composites; where layers of reinforcement are stacked onto each other and finally the desired thickness is obtained. Sandwich composites are the structures which basically have 3 main things i.e. two strong thin skin layers to be used as face or covers, then a thick light core that can be of wood, aluminium, polymer etc. to separate the skins and transfer load from one skin to other and lastly adhesive layer. This core can be a foam core, or corrugated core or may possess a honeycomb structure when the compressed. These are different from other composites where reinforcement is mixed with the continuous matrix but in sandwich structure there is a discrete structure is seen.

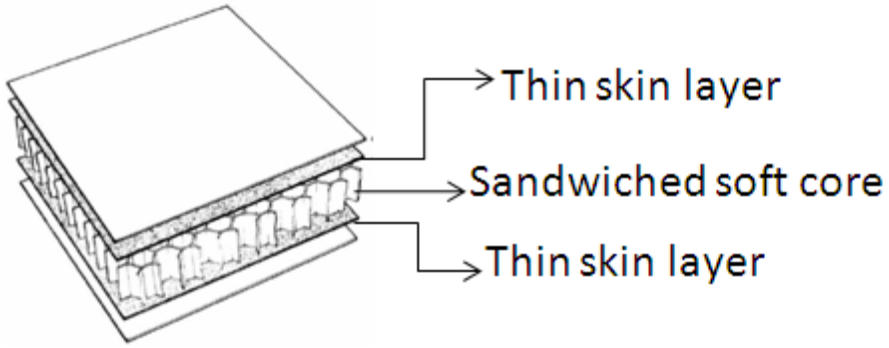

Fig 2: Sandwich Composite Structure

- **Fibres Reinforced Composites**: Fibers are a good reinforcement and provide much improving the properties of composites. Fibers are usually defined as the materials which possess length/diameter (l/d) ratio greater than or equal to 10:1. Commonly used fibres' are boron fibers, aramid fibers, glass fibers etc. Fibers can be amorphous such as glass fibers, or they can be polycrystalline such as boron fibers or may exist as single crystals like alumina, SiC etc. Fiber Reinforced Composite can be also classified as organic and inorganic fibers. Mechanical properties such as stiffness and strength, flexibility and elasticity of fibers are much higher than their parent material.

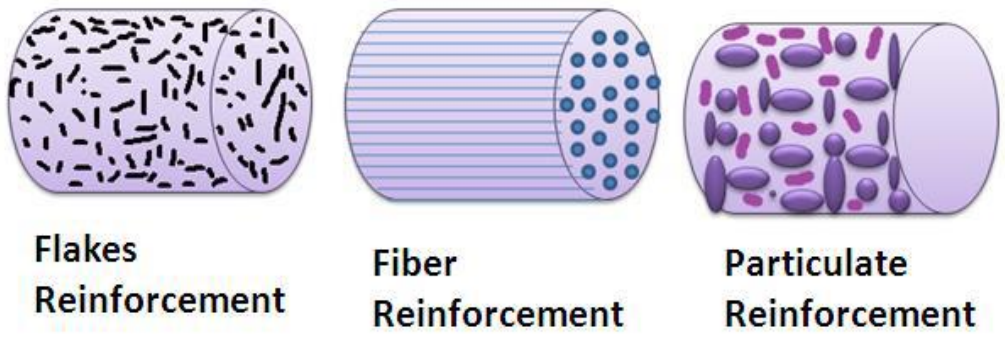

Fig 3: Different types of Reinforcement

The property of fiber is mainly deciding the parameter like length, shape and orientation of fiber. The properties of the fiber do not change with length then they are continuous fibers or otherwise they will be categorized in discontinuous fibers. Discontinuous fibers can be weak in strength but obtain high toughness and high modulus and the low ductility and medium quality matrix will solve the purpose. Continuous fibers always need a high strength matrix to resolve the complex issues.

Selection of Fibers:

- They must be agreeable with the matrix.

- Discontinuous fibers have the intermediate properties of continuous fibers and particulates. Since they are weak in terms of strength compatibility fits with a high strength material matrix. If Particulates and Whiskers are used as reinforcement then major load carrying role is of the matrix. They only contribute to the strength and stiffness of the composite. If continuous fibers are used as reinforcement then the large amount of loads taken by the fibers itself.

  Filament is a continuous fiber having l/d ratio equal to infinity.
- **Particulates**: Particulates are the particles of varied shapes and sizes of organic and inorganic material like Square, sphere, triangular, polyhedron etc can be possible shapes of particulates. Short fibers also called as particulates. Particulates are provides the improvement in the creep resistance and material toughness. The strength to the particulate system is given by hydrostatic coercion of fillers. Example: Concrete this is a mixture of cement + hard particles (like gravel)
- **Whiskers**: whisker is actually crystal but in the form of fiber. They are crystals with zero defects. Their length to width ratio is one.
- **Flakes**: Flakes are used when desired densely packed structures. Flakes in polymer matrix are so closely spaced that the material gets enhanced I terms of electrical properties and conductivity of the material increases sharply or clearly. Sometimes flakes provide better qualities to the matrix material as compared to fibers. The only one drawback that it leads to f=defects in end product due to uncontrollable size and shape factors.
- **Nano Composites**: Like all other composite systems this also has a matrix and reinforcement only difference is that the reinforcement particles are the Nano dimensions or not easily visualise. Due to their large per unit surface area contributes to strength and stiffness of the composites.

2. Metal Matrix Composites: Like all the composites it also contains at least two different phases. The matrix is metal element in which reinforcement if any type (flakes, particulate, whisker, fibersetc) are embedded. Need of Metal Matrix Composite arises from the fact that polymers are generally operational till 180°C and maximum up to 350°C in rare cases; but MMC breaks this barrier and capable to withstand high temperature limits so MMC are work on high temperature. Metal alloys are also left behind after the introduction of MMC, as many properties that MMC show are far better than traditional metal alloys. These MMC are better than polymer matrix composite in every aspect such as modules, stiffness, strength, thermal properties etc.

2.1 Ceramic Matrix Composites: Ceramic Matrix Composite is an inorganic and non-metallic material. These composites are working temperature of around 1500°C. These processes are strong ionic and covalent bonding and have high melting point. They also have high Peierl's yield stress but are prone to catastrophic failure. They find major application in the area of automobiles for automotive engines and aero engines. Any type of reinforcement is suitable but since ceramic have a low strain rate so it is brittle in nature and the reinforcement with high modulus of elasticity will serve the purpose of property enhancement.

2.2 Cermets - Ceramic and Metal combination are called Cermets. So only it possesses both the properties of metal as well as ceramic. They are generally developed by the method of pyrolysis and reinforced with carbon under high pressure. Generally phenol resins are employed in the manufacturing process. They are widely used in capacitors, resistors etc.

Fabrication Processes For Polymer Matrix Composite:

3. Hand lay-up technique:

This is the simplest technique of processing a Polymer Matrix Composite. The hand lay-up techniques is minimum required equipments and set up for this process.

Procedure:

- Firstly a mould release agent is applied on the lower surface of the mould to enable easy removal of polymer from the mould after curing. To get a good surface finish plastic sheets are also put on top and bottom surface of the mould plate.
- Thermo set polymer is mixed with hardner in suitable ratio and poured in the mould up till a desired thickness of polymer layer,
- Then reinforcement in the form of woven mats are cut in accordance with the mould dimensions and placed onto the polymer layer.
- Applying mild pressure with the help of roller air trapped is removed. And after this another layer of thermo set polymer is applied.
- This process is repeated again for another layer of reinforcement, and desired layers and thickness of sample is achieved.
- After this mould with the polymer and reinforcement layers is left for some time to settle the polymer.
- Meanwhile mould release agent is applied on the inner side of the top cover to the mould, and then placed onto the mould.
- After this it is left for curing at room temperature or at specific temperature depending on the requirement.
- Mould is opened and developed polymer matrix composite is taken out and further processed.

Major drawback of hand lay-up process is the rate of production is less and difficult to achieve high volume fractions of reinforcement. Hand Lay-up technique can be used some areas like: Aircraft components, boat hulls, automotive parts. Generally raw materials which can be easily worked on by hand lay-up process are given in the table.

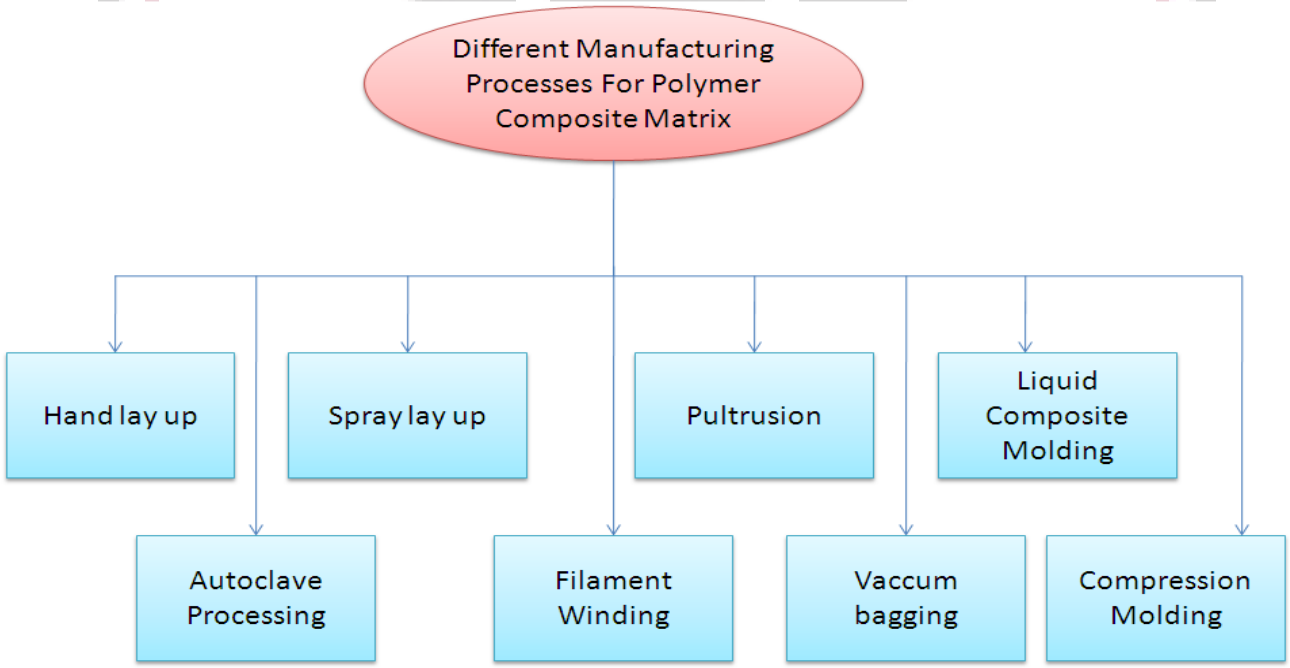

Fig 4: Fabrication Processes for Polymer Matrix Composites

Table 1: Matrix and Reinforcement

MATRIX	REINFORCEMENT
Polyvinyl Alcohol, Epoxy, Polyester, Polyvinyl Ester, Phenolic Resin, Unsaturated Polyester, Polyurethane Resin etc.	Glass Fiber, Aramid Fibers, Natural reinforcement (like Sisal, hemp, Flax, Banana etc), Carbon Fibers etc.

Advantages of Hand lay-up Process:

- Flexibility in material design
- Simple or Easy Operation
- Low cost of tooling and less maintenance cost
- Any type thermoset polymer can be used.
- In this required ideal for lower volumes and length of fibers can be used as compared to spray lay-up method.

Disadvantages of Hand lay-up Process:

- Better quality is achieved if a skilled laminator does it. Proper resin mixing and placing of reinforcement lies in the hands of the laminator and higher cycle times.
- Low volume fractions of resin cannot be achieved as it will create voids and produce only one smooth surface.
- Thermoset with low molecular weight are usually volatile in nature and hence chances of inhaling by the laminator and penetration from the clothes is high.
- Using open moulds, there are chances if evaporation of styrene in environment and that is not desirable.
- Somewhat inconsistent in part thickness.
- Matrix material has to be of low viscosity to be able to work by hands.

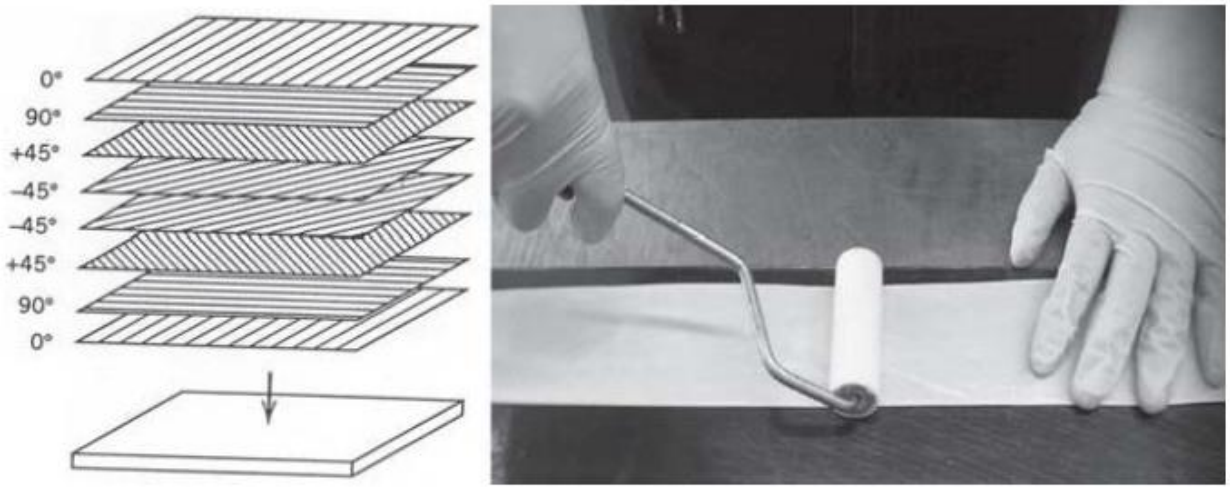

Fig 5: Schematic of the hand-lay-up fabrication method and a representative lay-up sequence. Individual layers can be cut by hand or by a computerized machine cutter. The layers can be stacked one on top of the other by hand or by a robot.

3.1 Spray lay-up method:

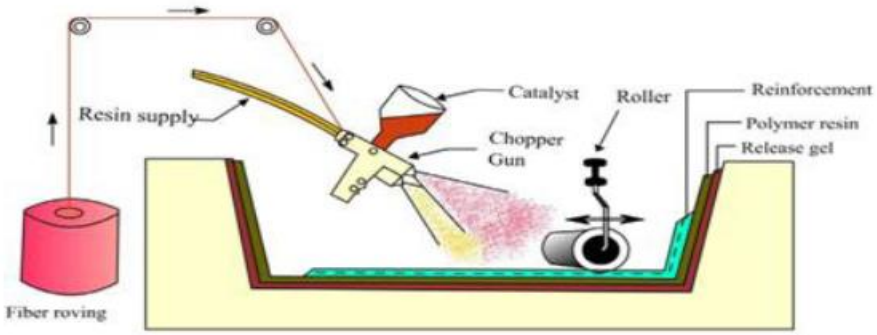

Fig 6: Spray Lay-Up method

In this process can be consider an extension of the hand lay-up method. Here both the polymer resin and matrix material are sprayed onto the mould with the help of spray gun. In this reinforcement not required to be in mat form and they are chopped with chopper gun and sprayed uniformly on the resin material. High volume fractions of reinforcement can be easily achieved by spray lay–up method. Only one thing to be kept in mind that is resin has to be of low viscosity to be able to spray. It drawback of this method, that it can has low load carrying capacity. So can be used for low load carrying parts like bath tubs, small boats etc.

Conclusion

This paper presents the composite and PVA+Banana+Flaxfiber hybrid composite by using hand layup method. The work compares their mechanical and Co related properties. From the tests and comparisons, the following conclusions are below:

- From the Flexural test it is clear that the hybrid composite has a higher flexural strength of 20.415 Mpa than composite PVA+Banana and PVA+Flax with value of 9.275 Mpa and 15.435 Mpa. Hence, hybrid composite has good flexural properties.
- The flexural modulus of hybrid composite 2712.6775 Mpa is higher compare to the PVA+Bananafiber composite is 1539.15 Mpa and PVA+Flaxfiber composite is 2275.435 Mpa.
- Future possibilities of the work include modifying the layout of the hybrid composite using different orientation of the constituent fibres. Further, a new layer of fibre can be added in between the existing layers of banana and flax and its properties can be found.

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