Review Article : Natural fibre composite and its fabrication process

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Abstract — Due to the environment-friendly, low cost and easy accessibility, natural fibre is becoming the strong attention of researchers. Numerous researcher is working on natural fibre composite and have already proven that the NFPC have significant properties for a wide range of application. Microwave energy is one of the new fabrication processes, which gives a tremendous outcome of the composite properties. The review aims to discuss the various types of fabricating processes and the mechanical testing result.

***Index Terms*— Natural Fibre, Polymer composite Processing** *(key words)*

1. INTRODUCTION

It is being observed that there is a sudden environmental consciousness; the international govt. policies and regulations catch the attraction on natural fibre polymer composite. Due to high specific strength, low cost, biodegradability, and renewability, low-density natural fibre has become an automatic choice as an alternative reinforcement. The primary sources of natural wool are from nature. They may be extracted from plants, animals or some geological process. Plant fibres like sisal, coir, and jute are extracted from plant leaves, fruit, steam etc. similar types the animal fibre like silk, wool etc. are extracted from animals. The application of Polymer-based natural fibre composite increasing in the field of domestic as well as engineering fields. The properties of natural fibre are not so good as compared with synthetic fibre but if it is mixed with a polymer matrix then the composite become excellent mechanical properties. Due to its mechanical properties, it is being used for such kinds of applications like cloth, shelters, construction of weapons.

1.1 Classification of natural fibres

Natural fibres classified based on their origin or source. They are diversified into three main categories i.e., Plant-based natural fibres, animal-based fibres and mineral-based natural fibres. The plant-based fibres are generally obtained from the stem, leaves etc. of a plant. On the other hand, animal-based fibres are mainly obtained from the skin of the animals such as wool and silk. The below hierarchy shows the detailed classification of natural fibres into further subcategories.

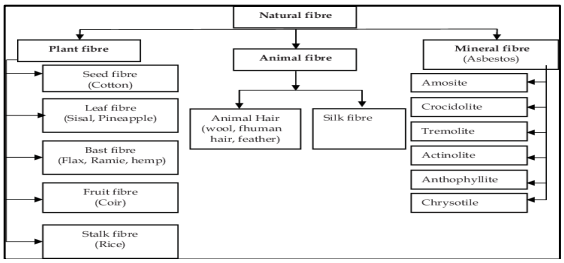

Fig. 1 : Classification of natural fibre

1.2. SOURCES OF NATURAL FIBRE

Different types of natural fibres can be sourced from different countries. The manufacturing of silk and wool fibres mainly originated in china. China is among the largest producers of synthetic fibres in the world. Similarly, India is dominant in the production of jute, cotton and sisal fibres respectively. The below table shows the worldwide sources of natural fibres

Table 1: Worldwide sourece of natural fibre

Worldwide sources of Natural Fibres		
Fibres	***Country***	***World Production (10^3 Tons)***
Flax	Borneo	810
Hemp	China, Yugoslavia	215
Sun Hemp	Nigeria, Guyana, India, Siera leone	70
Roselle	Borneo, Guyana, Malaysia, Sri Lanka, Indonesia, Togo	250
Jute	India, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan, Tanzania	2500
Kenaf	Iraq, Tanzania, Jamaica, South africa, Cuba, Togo	770
Coir	India, Sri Lanka, Phillipines, Bolivia	100
Sisal	India, Bahamas, East africa, Kenya, Tanzania	380

Abacca	Malaysia, Uganda, Phillipines, Bolivia	70
Ramie	Hondurus, Mauritius	100
Bamboo	India, chaina	2700

2. PROCESSING OF NATURAL FIBRE POLYMER COMPOSITE

Processing of composite fabrication is a big challenge due to maintaining the fibre properties. Some of the the conventional technique like hand lay up, injection molding, pultrusion etc. and some unconventional technique like microwave curing, ultrasonic process are being used for fabricating the natural fibre composite. Every processing technique has its own merits and demerits. Our focus is on the processing techniques, which includes Hand Layup, Injection Moulding, Pultrusion and Microwave Processing (curing technique). In the past several years, many researchers have continuously conducted studies on the different types of fibres using different processing techniques (Hand layup, Pultrusion, Injection Moulding, Microwave Processing) and test the several mechanical properties of the fibre reinforced composites formed such as Tensile strength, Flexural strength, Impact strength, Density etc. Our main objective is to find out that which fibre and matrix is most suitable and most preferred in case of each processing technique.

2.1 HAND LAY-UP PROCESS

The hand layup technique is the open moulding method and one of the oldest processes for fabricating composite. Most of the cases the resin-type polymer (liquid) are applied as a matrix material. The steps of fabricating process are as follows. a. mould preparation b. gel coating c. layup and d. curing. At first, fibres in the form of woven or stitched are manually placed in the mould, and with the help of a brush, the resin matrix is applied to the reinforcing material. A hand roller is used to roll the composite for ensuring the interaction between the matrix and fibre. It also confirms that the fibre, matrix mixed uniformly, and uniform resin distribution.

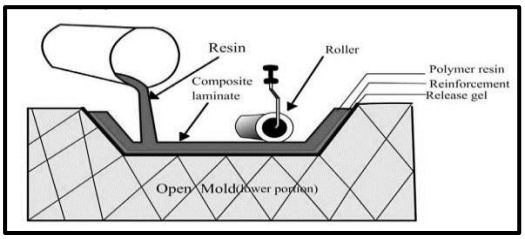

Fig. 2. Hand layup technique.

Various types of natural fibre have been applied for fabricating the composite by hand layup process. In table, no 1 we have tried to put the experimental data regarding the hand layup technique and possible outcome of the research observation.

Table 1. Data for hand layup process

HAND LAYUP PROCESS					
Sl. No.	***Fibre***	***Matrix***		***Examined properties***	***YOP***
1	Natural flax	HDPE		Charpy test, impact strength, tensile strength	2003
2	Sisal/glass	Unsaturated polyester		Impact strength, compressive strength	2004
3	Banana, sisal, coconut, hemp	wax		Tensile test, impact test, Izod impact test.	2012
4	Jute fibre	Epoxy resin		Flexural strength, tensile strength, shear strength	2013
5	Banana, hemp, glass	Epoxy resin	***2000 - 2022***	Tensile, flexural, impact strength.	2014
6	Banana, flax	Epoxy resin		Ultimate Tensile strength, impact, shear, flexural,	2014
7	Sisal, banana	Epoxy resin		Tensile, impact.	2017
8	Kenaf fibre	Resin		Charpy test, flexural strength, impact strength.	2018
9	Banana, sisal, hemp, sugar tree	Resin		Tensile, flexural, impact, ASTM	2019

				standard.	
10	Banana, coconut, jute	Epoxy resin		Tensile test, compression test, hardness test, compression strength.	2019
11	Flax fibre	Epoxy resin		SEM, tensile strength, thermogrammetric analysis	2019

From the table, it is clear that in most of the fabrication processes, the matrix material is used as epoxy resin. As epoxy is in a liquid state, so it is very easy to fabricate through the hand layup process. It is also observed that this process covers most of the mechanical properties like tensile strength, impact test, and flexural test. Fig. 3 shows a graphical representation of matrix material used in the fabrication process.

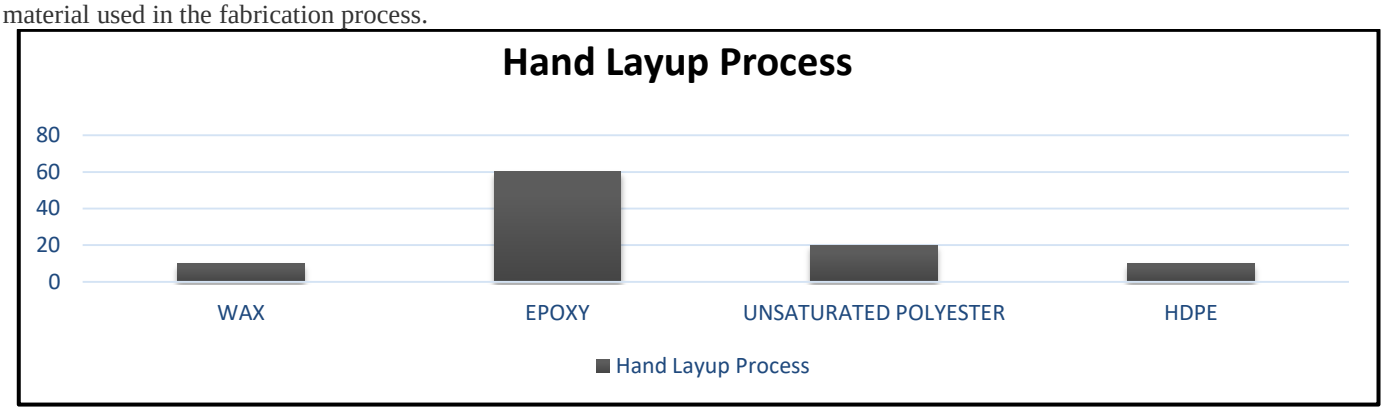

Fig 3. Paper published by hand layup technique.

2.2 INJECTION MOULDING

The excellent application zone like automotive, hardware, medical and bundling application injection moulding process become a fast development process. This process provides an improvement of material properties in the form of object and a wide application cover by it. Today more than 33% of polymeric items are created with the utilization of injection moulding. The following steps is to be follows for creating an object by injection molding process.

a. charging the cylinder b. mold closing c. polymerization d. injection and pressure e. cooling f. Ejection or removal of finished product.

Table 2 describes the researched data of the Injection Moulding carried out by the analysis of various research papers.

Table 2. Injection Moulding process

INJECTION MOULDING PROCESS					
Sl.No	***FIBER***	***RESIN***		***EXAMINED PROPERTIES***	***YOP***
1	Sisal	Polypropylene		Mechanical properties Best: - fibre length>10mm, fibre mass fraction 15-35%	2002
2	Bleached kraft, pulpier, flax , hemp, wood flour, Core hemp	Hybrid polypropylene		Tensile (MPa), flexural (MPa) Best: - bleached kraft pulp fibre	2003
3	Kenaf, bagasse	Polypropylene		Tensile test Flexural modulus	2006
4	Jute, cellulose	Polypropylene	***2000 - 2020***	Heat distortion temp (HDT) stiffness, Tensile strength, Tensile modulus	2009
5	Hemp	Polypropylene		Tensile strength, Flexural strength	2010
6	Jute	Polypropylene		Tensile strength, Tensile modulus	2010
7	Kenaf, flax, hemp	Nylon-6		Tensile strength, Flexural strength	2013
8	Pine, agave	Polypropylene		Impact strength, Tensile strength	2014
9	Jute	polylactide		Tensile modulus, Tensile strength	2014
10	Sisal, hemp	polylactide		Tensile strength, Flexural strength, Water absorbing capacity	2019

From the table it is observed that the common natural fibre , avaliable in the market like hemp,jute, sisal etc. were examined by this process including Biodegradable polymer like lactic acid was used as matrix material. Fig. 4 shows the schematic diagram of injection molding process.

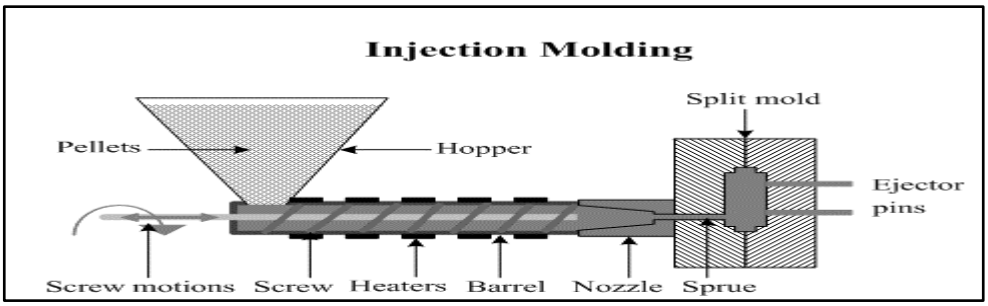

Fig. 4. Injection Moulding (Source - AV plastics)

2.3 Pultrusion Process

This is the oldest process which produce fibre reinforce polymer composite. This process is applicable in both thermoplastic and thermosetting. The process speed depends on profile size and geometry. The commonly used profile size and speed are 0.02 mm and 3 m/min.In this process; the fibers are passes through a heated die. While passing through the heated die, a fixed pressure is applied, as a result the resin melting and its impregnation into the fibrous reinforcement. The quality of manufactured product depends on many factors including the temperature of the die, method of preheating, and the speed of the fibre passing. Fig. 5 shows the pultrusion process for making long fibre based composite. The application of pultrusion composite are aerospace, automotive and construction industries.

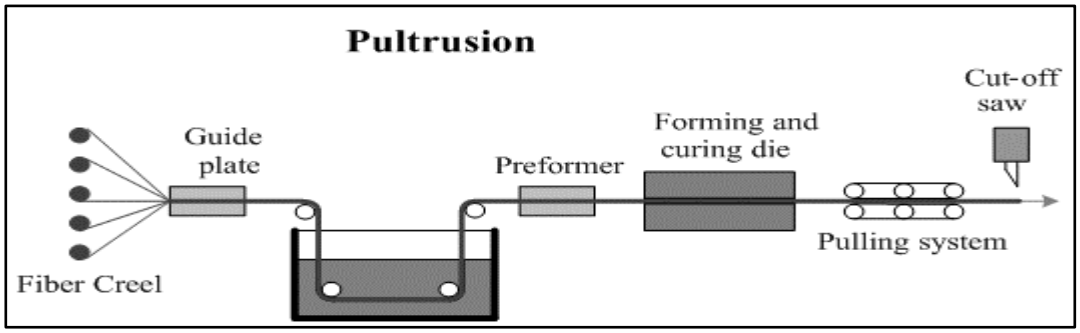

Fig 5. Pultrusion Process

Table 3 describes the researched data of the Pultrusion process carried out by the analysis of various research papers published in between 2000 – 2022.

Table 3. Pultrusion Process

PULTRUSION PROCESS					
Sl.No	***Matrix***	***Resin***		***Examined properties***	***Year of publish***
1.	Jute/ glass	Unsaturated polyester resin	***2000 - 2022***	UTS, SEM, Flexural, young's modulus	Jan, 2014
2.	Jute/wood	HDPE, starch		UTS, elastic modulus density	Aug, 2018
3.	Jute/glass	Unsaturated polyester		Flexural strength, compressive strength, density, tensile, young's modulus	Sep, 2011
4.	jute	PLA		Young's modulus, tensile strength	2013
5.	flax	Polypropylene		Density, thermal conductivity, specific heat.	Oct, 2007
6.	Jute/kenaf	Unsaturated polyester		Compressive strength, compressive modulus, striking velocity.	April, 2010
7.	jute	Unsaturated polyester		Tensile strength, young's modulus, density, flexural properties, thermal properties.	Sep, 2013
8.	Glass/flax	Polypropylene / PLA		Density, tensile strength, young's modulus, flexural strength	2011

The pultrusion process covers most of the long fibre. As the fibre, size is play, a big role for making composite properties then pultrusion is one of the best conventional process. Although there are some disadvantage of the process like uniform properties, orientation etc.

2.4 MICROWAVE PROCESSING

Science 1980 the microwave curing technique has been employed to process thermoset-based composites. It have a no of benefit like less power consumption, faster processing, and eco-friendly. The interaction of electromagnetic fields at the molecular level transfer's energy to materials, and the effect of the electromagnetic field on the material is ultimately determined by the dielectric characteristics. An external electric field has an impact on the dipoles in the dielectric polarization mechanism and will try to rotate itself into alignment with the field. Due to the high electric field frequency, the dipoles do not have enough time to react to the oscillating field. Because of this phase lag, the dipoles crash with one another when they attempt to follow the field, dissipating power that might otherwise be used to heat the material.

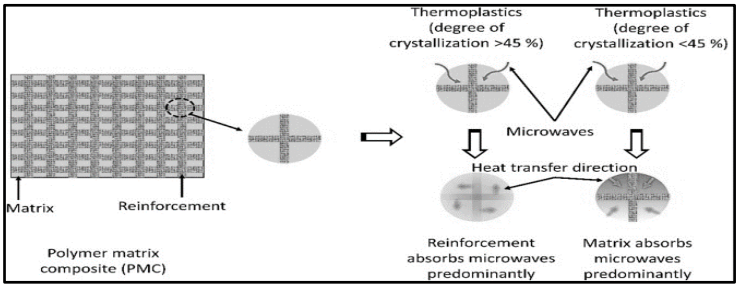

Fig. 6. Microwave curing (Tejas PramodNaik et.al.)

Table 4 describes the researched data of the Microwave process carried out by the analysis of various research papers published in between 2000 – 2022.

Table 4. Microwave Process

MICROWAVE PROCESS					
S.no	***Fibre***	***Resin***		***Examined properties***	***YOP***
1	Rattan, coir, Bamboo.	Polypropylene		Strength, Heating time	2013
2	Coir	NA		Tensile testing, tensile strength	2018
3	Carbon fibre	Aromatic polysulphide		Mechanical properties, electrical properties	2005
4	Bamboo	LDP	***2000-2022***	Na	2007
5	Sisal	Polypropylene		Mechanical properties, tensile strength	2002
6	Coir	HDPE		Mechanical properties, tensile strength, tensile modulus.	2018
7	Carbon fibre	Polypropylene		Tensile strength, impact strength	2010
8	Sisal	Polypropylene, EVA		Tensile strength, flexural strength, impact strength	2010
9	Bamboo, coir	HDPE		Mechanical properties, tensile strength and impact strength	2015
10	Expanded graphite (EG)	Aromatic polysulphide		Tensile strength, flexural strength	2005

Most of the work have been carried out by thermoplastic polymer as matrix material and for reinforcement, most common fibre covered. It was also observed that the mechanical properties give a significant change. It is also seen that the mechanical properties also changed with good result.

3. COMPRESSION STUDY OF FABRICATION PROCESS

At the last stage, a comparison study is presented in the table 5. Most of the process give a significant result and covered the basic mechanical properties. However, in the table it is also seen that the microwave curing process gives a well-accepted process with better result.

Table 5. Compression study of mechanical properties for common fabrication process.

	Ultimate tensile strength	*Flexural strength*	*Impact strength*	*Density*	*Compression strength*	*Young's modulus*
Hand layup process	✓	✓	✓	X	✓	✓
Pultrusion process	✓	✓	✓	✓	X	✓
Microwave processing	✓	✓	✓	✓	✓	✓
Injection moulding	✓	✓	✓	X	X	✓

4. CONCLUSION

After studying the above data, it was found that

1. Microwave curing is one of the major fabrication process due to their own material processing technique. Due to ability of couple energy directly to the material, microwave processing is better advantage than the other conventional processing.
2. India is becoming the lager producer of natural fibre for replacing the use of polymer due to the environmental effect.
3. It was also found that the most of the polymer including thermoplastic and thermosetting was covered in this process.

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