Mechanical Properties of Fiber Reinforced Polymer Composites

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Abstract*: *The usage of composite materials has been increasing in all fields of manufacturing applications as it has tremendous mechanical properties. The variation in the property of the materials can be observed through the addition of matrices. Polyester, vinyl ester and epoxy are some of the resins which are commonly used as matrix in manufacturing composite materials. Hence this study intends to explore the mechanical properties such as impact and flexural for different fibers used in combination with different matrices. It is found that epoxy resin has higher impact (334 N/mm2) and flexural strength (132 MPa) with bamboo fiber and polyester resin has higher impact (24.2 kJ/m2) and flexural strength (80.2 MPa) with pineapple leaf fiber.

Keywords* : *Composites, Fibers, Matrix, Mechanical Properties.

I. INTRODUCTION

The application of composite materials have been increased in the field of automobiles, aircraft, maritime, sports equipment's etc. as these materials have excellent mechanical properties and are eco-friendly in nature. The properties include corrosion resistance, high strength, low density and reasonable cost [1-4]. In addition to these general properties composite materials are also flexible, high resistance to impact and minimum irritation to skin and respiratory tracts [5]. The two major phases of the composite materials are the matrix phase and the reinforcement phase. Due to high performance of the composite materials, they are also used in different erosive environment as they can withstand higher than traditional materials [6]. A topical research forecasted that the natural fiber composite materials has a total market value of about US$ 289.3 million across the globe and it can double within three years [7]. Polymer composites made of natural fibers are renewable resources and its development [8] is shown in Fig. 1. Some of the natural fibers are jute, sisal, coir, pineapple leaf, kenaf, kapok, flax, hemp etc. [9]. As the fiber reinforced composites are made of natural fibers they can be recycled and used again which won't affect the environment in any aspect. Hence this research intends to study and evaluate the mechanical properties such as impact and flexural strength of the natural fibers reinforced with epoxy and polyester matrix.

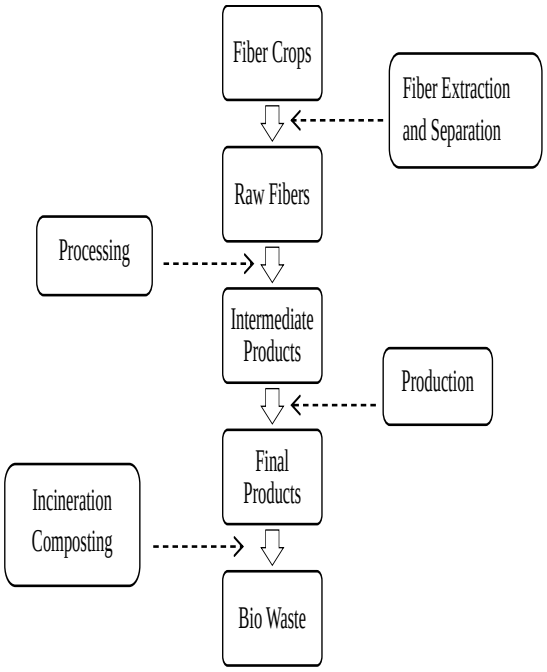

Fig. 1 Development of natural fibers from crops [8]

II. FABRICATION OF SPECIMEN

Most of the researchers adopted hand lay-up technique whereas some of the researchers used compression moulding technique. ASTM standards were followed for the dimension and testing of fabricated specimens. The steel mould is fully applied with wax or mould release spray for easy removal of the specimen. The fibers are placed in the mould and pre compression is done for suitable arrangement. If epoxy resin is used for fabrication appropriate amount of hardener is mixed and it is poured above the pre-compressed fibers. If polyester resin is used, methyl ethyl ketone peroxide which is a catalyst and cobalt napthalate which acts as an accelerator is added in certain proportions. Finally the specimen is to be compressed and cured for a period of 24 hours. Thus to know about the strength of materials, mechanical properties such as impact, flexural and tensile test are done as per ASTM standards. Scanning Electron Microscope (SEM) or morphology test is done to know about surface details of the composites or debonding of the fibers and fiber matrix interaction [10, 11, 12].

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III. MECHANICAL PROPERTIES OF NATURAL FIBERS REINFORCED WITH EPOXY MATRIX

Epoxy resins are significant among the thermosetting polymers as they are used as adhesives in wider applications including aerospace. Researchers have been attracted by epoxy resin as they have enhanced mechanical properties such as mechanical response, thermal stability, electrical resistance, low density. But it is also known that epoxy resin fail in their mechanical properties due to improper curing agent. Hence mixing and curing ratio is also an important factor [13, 14]. Epoxy resins are produced by combining epichlorohydrin with bisphenol. These resins also have good insulating properties, good environmental and chemical resistance [15].

A. Comparison between Epoxy and Polyester Resin

The general comparison between epoxy and polyester is listed in Table I. Both the resins have some distinct features. The strength of the materials can be determined when these resins are mixed with the fibers at certain proportions. After mixing both the fibers and resins compressing the specimen and allowing it to cure as per the standards also play a major role in manufacturing high strength materials.

Table I Difference Between Epoxy and Polyester Resin [15,16]

S.No	Epoxy	Polyester
1.	Relative strength is 2000 lbs. per square inch	Relative strength is less than 500 lbs. per square inch
2.	Resistance to wear and crack	More fragile
3.	High cost	Low cost
4.	High moisture resistant	Minor moisture resistant
5.	Ventilation required while using epoxy	Ventilation required while using polyester
6.	Less odor	High odor

The mechanical properties such as impact and flexural strength for different natural fibers are listed in Table 2. It is observed that carbon fiber reinforced with printed circuit board has high impact and flexural strength.

B. Mechanical properties of natural fibers reinforced with polyester matrix

The polyester resins have good resistance to chemicals, low density, reduced cost and high process ability. These resins are classified under thermosetting and have wide range of applications such as buildings, water pipes, automotive etc. [16]. To study the properties of polyester resin in various fibers, some researchers tested the fabricated specimen using water absorption test and then determined the mechanical properties.

Dhakal et. al [17] studied the mechanical properties of hemp fiber after water absorption. The specimens with the fiber content of 0, 10, 15, 21 & 26 were fabricated and subjected to compression and curing. Then the specimen is immersed in water at different temperatures such 25^{o} Celsius and 100^{o} Celsius to determine the properties at varying time duration. Result shows that the percentage of water absorption increases due to increase in fiber content. This may be due to the cellulose and voids present in the fiber. Four layer of hemp fiber which has 21% of fiber weight exhibited high tensile modulus as 1.22 GPa at dry, 0.62 GPa at wet and flexural modulus of 7.30 GPa at dry temperature. The flexural modulus reduced at wet temperature at the same fiber content.

S.No	Type of fiber	% of fiber	Impact test	% of fiber at which maximum strength is attained	Flexural test	% of fiber at which maximum strength is attained	Source
1.	Jute	11%, 22%, 33%, 44%, 55%	110.74 J/m^2	44% of Jute + Epoxy	47.67 MPa	44% of Jute + Epoxy	[19]
2.	Carbon (C), Printed Circuit Board Powder (PCBP)	1. 48% C, 52% PCBP 2. 50% C, 50% PCBP 3. 52% C, 48% PCBP	334 N/mm^2	52% C, 48% PCBP	20 MPa	52% C, 48% PCBP	[20]
3.	Luffa	Varying the percentage of luffa	2.7 J	40% Luffa + 60% Epoxy	1.83 KN	40% Luffa + 60% Epoxy	[21]
4.	Palm	Varying the percentage of palm	2.9 J	40% Palm + 60% Epoxy	2.14 KN	40% Palm + 60% Epoxy	[21]
5.	Bamboo	Varying the percentage of bamboo	2.3 J	40% Bamboo + 60% Epoxy	1.4 KN	40% Bamboo + 60% Epoxy	[21]
6.	Glass, Jute	1. 45% Glass 2. 32% Glass, 6% Jute 3. 20% Glass, 10% Jute 4. 12% Glass, 20% Jute 5. 23% Jute	72.24 J/m	32% Glass + 6% Jute + 62% of Epoxy	100.78 MPa	12% Glass + 20% Jute + 68% Epoxy	[22]
7.	Bamboo, Glass	Varying the percentage of bamboo and glass	200 kJ/m^2	30% Bamboo + 70% of Glass + Epoxy	132 MPa	30% Bamboo + 70% of Glass + Epoxy	[23]

Table II Mechanical Properties of Natural fibers Reinforced with Epoxy

Sreekumar et. al [18] studied the mechanical properties of sisal polyester composites. Sisal fibers were chopped with an equal size of 30 mm length. Cobalt napthenate and methyl ethyl ketone peroxide of equal ratio such as 1 weight % was mixed with isophthalic polyester resin. Then this chemical mixture is passed into a closed mould at 1 kg/cm2 of pressure. Six different samples of 40% fiber content which underwent heat treatment, benzoylation, permanganate treatment, silane treatment and mercerization were fabricated. Then the fabricated specimen is left for curing up to a period of 12 hours. Results showed that 40% fiber content which underwent silane treatment has good tensile and flexural strength as 76 MPa and 105 MPa.

The impact and flexural strength of the different natural fibers reinforced with polyester resin is shown in Table 3. It is noted that 30 % of pineapple leaf fiber with polyester resin attained higher impact and flexural strength. It is also said that each natural fiber with different proportion of fibers and matrix can able to attain maximum impact and flexural strength.

S.No	Type of fiber	% of fiber	Impact test	% of fiber at which maximum strength is attained	Flexural test	% of fiber at which maximum strength is attained	Source
1.	Jute	11%, 22%, 33%, 44%, 55%	148.58 J/m^2	44% of Jute + Polyester	20.23 MPa	44% of Jute + Polyester	[19]
2.	Straw	Varying the percentage of straw in equal proportion	2.6 KJ/m^2	30%	47 MPa	30% of straw	[24]
3.	Sisal	Varying the percentage of sisal in equal proportion	11 KJ/m^2	30%	53 MPa	30% of sisal	[24]
4.	PALF	Varying the percentage of PALF in equal proportion	24.2 KJ/m^2	30%	80.2 MPa	30% of PALF	[24]
5.	Coir	10%, 17%, 25%, 33%	967 J/m	25%	61 MPa	25%	[25]
6.	Napier Grass	10%, 15%, 20%, 25%, 30%	Not Reported	Not Reported	39.5 MPa	25%	[26]

Table III Mechanical Properties of Natural Fibers Reinforced with Polyester

IV. CONCLUSION

In this research the mechanical properties of different natural fibers reinforced with epoxy and polymer resin have been studied. It is noted that 52 % of carbon fiber attained high impact strength and 30 % of bamboo fiber attained high flexural strength with epoxy resin. It is also noted that 30 % of PALF fiber attained high impact and flexural strength with polyester resin. Therefore it is concluded that each and every natural fiber with suitable proportions of fiber and resin can attain high mechanical properties but their applications may differ accordingly. As natural fibers are decomposable and environmental friendly this types of composites can be used in all fields of applications.

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