INVESTIGATION OF MECHANICAL PROPERTIES ON DHARBAI FIBER REINFORCED POLYESTER RESIN COMPOSITE

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***Abstract*---Natural fiber reinforced composites is an emerging area in polymer science. Natural fibers have recently attracted the attention of scientists and technologists because of the advantages such as - low cost fibers with low density and high specific properties over conventional reinforcement materials. The tremendous production and use of plastics in every segment of our life has increased the plastic waste in huge scales. To reduce use of plastics, natural fibers are used. This project uses a new variety of Dharbai fiber (Botanical name: Eragrostis cynosuroides) used as reinforcement in polyester matrix which will be subjected to mechanical testing. This project discusses the polyester resins that can be considered nowadays the most important classes of thermosetting polymers. The mechanical properties of fabricated composites will be tested for the following, Tensile strength, Flexural Strength, Impact Strength. These results were compared with other natural fibers such as Banana fiber, Aloe Vera fiber.**

***Keywords* —Dharbai fiber, Reinforced polyester resin composite, mechanical test, Impact test, Tensile test, Flexural test**.

I. INTRODUCTION

The technological advances in various sectors have created demand for newer materials, where they are required to perform in stringent conditions - high pressure & temperature, highly corrosive environments, with high strength requirement, which the conventional materials failed to service. This has triggered the development needs for engineering materials to cater to customized needs. Industry has recognized the ability of composite materials to produce high-quality, durable, cost-effective products.From such a beginning, composite applications have revolutionized entire industries, including aerospace, marine, and electrical, chemical/ pharmaceutical, transportation etc.

Composites have proved to be a worthy alternative to other traditional materials even in the high-pressure situations of chemical processing.The tailor ability of composites for specific applications has been one of its greater advantages and also one ofits most perplexing challenges to adopt them as an alternative material for metallic ones.

2. COMPOSITES

A 'composite' is a heterogeneous combination of two or more materials (reinforcing agents & matrix), differing in form or composition on a macro scale. The combination results in a material that maximizes specific performance properties. The constituents do not dissolve or merge completely and therefore normally exorbitant interface between one another. In this form, both reinforcing agents and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone.

2.1 GENERAL PROPERTIES OF COMPOSITES

Composites have unique properties as follows:

- Excellent corrosion resistance
- Improved torsional stiffness and impact resistance properties
- Appropriate inhibitors/additives can impart very good fire retardant properties in composites
- Improved torsional stiffness and impact resistance properties

2.2 CLASSIFICATION OF COMPOSITES

Composites are commonly classified based on the type of matrix used:

- Polymer matrix composites (PMC)
- Metal matrix composites (MMC)
- Ceramic matrix composites (CMC)

In fiber - reinforced composites, fibers are the principal load carrying members, while the surrounding matrix keeps them in the desired location and orientation. Matrix also acts as a load transfer medium between the fibers, and protects them from environmental damages due to elevated temperatures, humidity and corrosion. The principal fibers in commercial use are various types of glass, carbon and Kevlar. The composites are also classified based on the reinforcement as shown in the fig 1.

CLASSIFICATION OF COMPOSITES BASED ON REINFORCEMENT

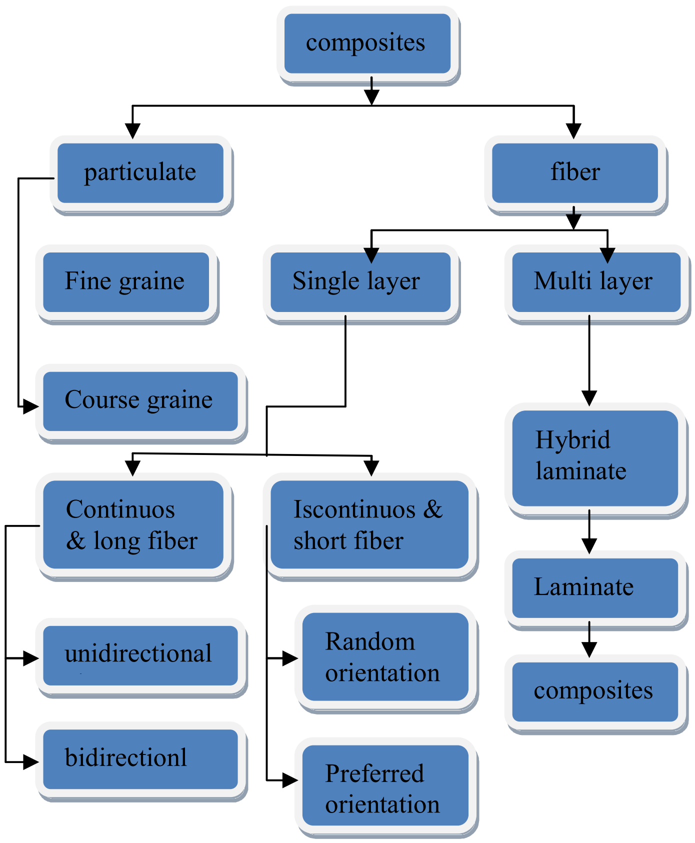


Fig.1 Classification of composites based on reinforcement.

2.2.1 POLYMER MATRIX COMPOSITES (PMCS)

Polymers are the most widely used matrix material for fiber composites and are used in more than 95% of the composite products in use today. Their chief advantages are low cost, easy process ability, good chemical resistance and low specific gravity.

2.2.2 METAL MATRIX COMPOSITES (MMCS)

Metals such as aluminum, magnesium, lead and copper are extensively used as matrix. Metal matrices are generally used by reinforcing with high modulus fibers, which are also light.The reinforcement phases in metal matrix composite systems are either metallic or non-oxide ceramic (silicon carbide, carbon and boron) or oxide ceramic (alumina and glass). As the MMCs have higher temperature resistance than other composite systems they are preferred for service temperatures above 150^{0}C. An interesting possibility for MMCs is the chemical interaction between the fiber and matrix, leading to enhanced physical properties particularly at elevated temperatures.

2.2.3 CERAMIC MATRIX COMPOSITES (CMCS)

Ceramics are strongly bonded materials with ionic and covalent character, which results in high strength and hardness. However, a consequence of this is that, there is little dislocation movement and the material is brittle. The development of composite materials based on ceramic matrices has received a considerable boost in the recent past, particularly with ceramic fibers since they can be operated at very high temperatures of about 1800°c.

2.3 MATRIX

The constituent that is continuous and is often (but not always) present in greater quantity is termed as matrix. Matrix provides toughness and ductility to the composite. They have a strong influence on several mechanical properties of the composite such as transverse modulus and strength, shear properties and properties of compression..

The main role of the matrix is to transmit and distribute stresses along the reinforcement phase. Physical and chemical characteristics of the matrix such as melting or curing temperature, viscosity, and reactivity with fibers influence the choice of fabrication process. Commonly used matrix materials include polymers, metals, and ceramics.

2.4 POLYMERS

Polymers are the most widely used matrix materials for fiber composites. Their chief advantages are low cost, easy process ability, good chemical resistance and low specific gravity. On the other hand, low strength, low modulus and low operating temperatures limit their use. They are also degraded by prolonged exposure to ultraviolet light as well as some solvents.

2.5 THERMOSETTING AND THERMOPLASTIC POLYMERS

Based on their structure and behaviour, polymers can be classified as thermoplastics or thermosets. The thermoplastics are incorporated into the composite system by melting and then they are solidified by cooling; the physical reaction being reversible in nature. They can be reshaped by application of heat and pressure and are either semi crystalline or amorphous in structure.

Examples include polyethylene, polystyrene, nylons, polycarbonate, polyacetals, polyamide-imide, polyether-ether ketone, and polysulfone polyphenylene sulphide and polyether imide. Once solidified by cross-linking process, they cannot be reshaped. Common examples of thermosetting polymers include epoxies, polyesters, phenolics, urea, melamine, silicone and polyimides.

3. SELECTION OF MATERIALS POLYESTER RESIN

The workhorse of thermoset matrices is unsaturated polyester, which offers an attractive combination of low price, reasonably good properties and uncomplicated processing. A polyester resin is unsaturated (reactive) polyester solid dissolved in a polymerisable monomer. Unsaturated polyesters are long chain linear polymers containing a number of carbon double bonds. They are made by a condensation reaction between a glycol and an unsaturated dibasic acid (maleic or fumaric).

The polymerizable monomer such as styrene which also contains carbon double bonds, act as cross linking agent by bridging adjacent polyester molecules at their unsaturation points. The monomer also acts as a diluent, reduces viscosity, and makes it easier to process.

Since there is no by-product of the reaction, the curing is done at room temperature or elevated temperature with or without application of pressure. The structure of typical polyester made from maleic acid and diethylene glycol is shown below.

Fig 2 Polyester Resin

3.1 FIBERS

Based on their origin and chemical structure, fibers are broadly classified into two types: man-made (synthetic) and natural. Fibers in which the basic chemical units have been formed by chemical synthesis followed by fiber formation are called synthetic fiber. Fiber which come from natural sources like animals, plants and minerals and do not require fiber formation or reformation are classified as natural fibers.

3.1.1 NATURAL FIBERS

Natural fibers are further classified into three categories based on their origin, coming from plants, animals, minerals. Mineral fibers are composed of naturally occurring minerals.For example, asbestos is a mineral fiber. All plant fibers are composed of cellulose while animal fibers consist of proteins (hair, silk, and wool).

3.1.2 PLANT FIBERS

Fibers obtained from the various parts of the plants are known as plant fibers. Plant fibers include bast (or stem or soft sclerenchyma) fibers, leaf or hard fibers, seed, fruit, wood, cereal straw and other grass fibers. With the exception of synthetic polymers, most economically important products, such as paper, cordage (cords and rope) and textiles, are derived from plant fibers. Fibers are elongated cells with tapering ends and very thick, heavily lignified cell walls. The lumen or cavity inside mature, dead fiber cells is very small.

When viewed in cross section. Fibers are one of the components of sclerenchyma tissue, along with shorter, thick- walled sclereids (stone cells), which produce the hard tissue of peach pits and the gritty texture in pears. Fibers are also associated with the xylem and phloem tissue of monocot and dicot stems and roots, but generally not in the wood of gymnosperms.

In fact, the primary reason why gymnosperm woods are generally softer and lighter than angiosperm woods is the presence of dense clusters of heavily lignified, thick-walled fiber cells in angiosperm wood. Cloth, artificial leather, raincoats, motion picture and photographic film. It is also used in the manufacture of pharmaceuticals, in microscopy, in veterinary medicine, as a dehydrating agent, in perfumes, fruit essences, and as a flavoring agent in foods and beverages.

3.2 DHARBAI FIBER

Fig 3 Dharbai fiber

- Dharbai fiber is one of the natural fiber
- Here, it is used as a reinforcement in polyester matrix
- Dharbai fibers is extracted from Dharbai leaves through the retting process was used as reinforcing material.
- A botanical name of Dharbai fiber is "*Eragrostis cynosuroides*".

3.3 CATALYST

Fig 4 Catalyst (MEKP)

- MEKP (Methyl ethyl ketone peroxide).
- 10 ml or 8ml for 1lt resin dependingon climatic condition.
- Its increases the chemical reaction.
- A substance, usually used in small amounts relative to the reactants, that modifies and increases the rate of a reaction without being consumed in the process.

3.4 HARDENER

Fig.5 Hardener (Cobalt Octoate)

- Cobalt Octoate Hardener.
- Added to resin for curing depend in purpose.
- Added to suitable quantity depending on the usage or volume of resin.

4. EXPERIMENTAL METHODOLOGY

Dharbai fibers extracted from Dharbai leaves through the retting process was used as reinforcing material. The unsaturated polyester resin was used as matrix material Cobalt octoate and methyl ethyl ketone peroxide (MEKP) were employed as accelerator and catalyst, respectively, to enhance the reaction rate and ensure uniform curing of the composite sheets.

4.1 MANUFACTURING METHOD

There are various methods to fabricate the composites. They are hand lay-up process, pultrusion process, filament winding process, resin transfer molding, sheet molding compound, reaction injection molding. Here we used the compression molding machine for the fabrication of hybrid composites.

4.2 COMPRESSION MOLDING METHOD

- With the dies apart, the prepared polymer "dough" is placed into the cavity.
- With the die closed, the article is formed and the small amount of flashing on each side will be removed later.
- When the die is closed, heat and pressure are maintained until the condensation polymerization process is completed.

4.3 PROCESS

Compression molding is a forming process in which a plastic material is placed directly into a heated metal mold, then is softened by the heat, and forced to conform to the shape of the mold as the mold closes.

Compression molding is a method of molding in which the molding material, generally preheated, is first place din an open, heated mold cavity. The mold is closed with atop force or plug member, pressure is applied to force the material into contact with all mold areas, while heat and pressure are maintained until the molding material has cured.

The process employs thermosetting resins in a partially cured stage, either in the form of granules, putty - like masses, or preforms. Compression molding is a high-volume, high-pressure method suitable for molding complex, high-strength fiber glass reinforcements. Advanced composite thermoplastics can also be compression molded with unidirectional tapes, woven fabrics, randomly oriented fiber mat or chopped strand.

Fig 6 Compression molding machine

In compression molding there are six important considerations that an engineer should bear in mind.

- Determining the proper amount of material.
- Determining the minimum amount of energy required to heat the material.
- Determining the minimum time required to heat the material.
- Determining the appropriate heating technique.
- Predicting the required force, to ensure that shot attains the proper shape.
- Designing the mold for rapid cooling after the material has been compressed into the mold.

4.4 DIE DIAGRAM

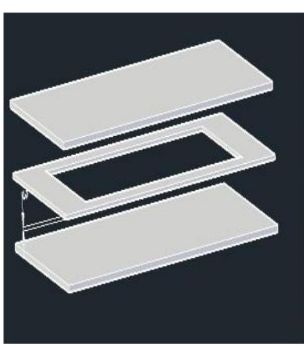


Fig 7 Diagram for Die

Fig 8 Machine die photo

5. FABRICATED MATERIAL

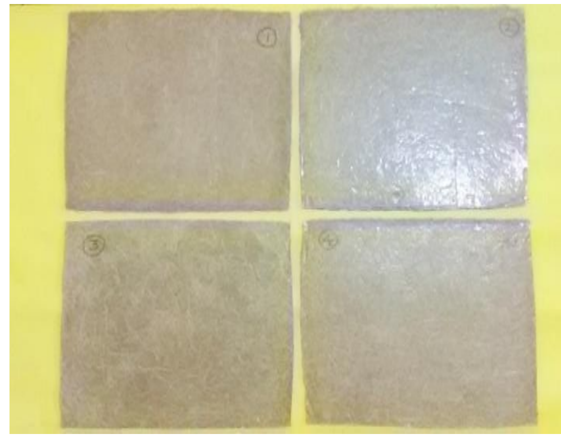


Fig 9 Fabricated material

6. MECHANICAL TESTS

- Testing is the essential part of any engineering activity.
- Testing is applied to materials, components, and assemblies.
- It consists of measurement of fundamental properties or measurement of responses to particular influences such as load, temperature, and corrodants.
- It can be noted that the tests need to be conducted according to standard procedures so that one can have confidence in published test results.

6.1 DESTRUCTIVE TESTING

In this type of testing, the component or specimen to be tested is destroyed and cannot be reused, it is carried out on the sample of the component.

Examples: - Tensile test, Impact test, Bend test, Fatigue test, Torsion test, Creep test, etc.

6.2 NON- DESTRUCTIVE TESTING

In this type of testing the component to be tested is not destroyed and can be reused after the test; it is carried out directly on the component.

Examples: - radiography, ultrasonic inspection, etc.

6.3 TENSILE TEST

The tensile test is one of the most widely used of the mechanical tests. A tensile test of a material is performed on ductile materials to determine tensile properties such as:

Fig 10 Tensile test machine

- Limit of proportionality
- Maximum tensile strength
- Breaking strength
- Percentage elongation

6.4 IMPACT TEST

The impact test is performed to study the behaviour of materials under dynamic load i.e., suddenly applied load.The capacity of a metal to withstand blows without fracture, is known as impact strength or impact resistance.

The impact test indicates the toughness of the material i.e., the amount of energy absorbed by the material during plastic deformation. In an impact test, a notch is cut in a standard test piece which is struck by a single blow in a impact testing machine.

Then the energy absorbed in breaking the specimen can be measured from the scale provided on the impact testing machine.

6.5 TYPES OF IMPACT TESTS

Based on the types of specimen used on impact testing machine the impact tests can be classified into:

- Izod test
- Charpy test

6.5.1 IZOD TEST

- Izod test uses a cantilever specimen of size 75mm*10mm*10mm, as shown in fig. the V-notch angle is 45° and the depth of the notch is 2mm.
- The Izod specimen is placed in the vise such that it is a cantilever.

6.5.2 CHARPY TEST

- The Charpy test uses a test specimen of size 55mm*10mm*10mm, as shown in fig. the V-notch angle is 45° and the depth of the notch is 2mm.
- The Charpy specimen is placed in the vise as a simply supported beam.

6.5.3 FLEXURAL TEST

Fig 11 Flexural testing machine

6.5.4 FLEXURAL TEST SPECIMEN

BEFORE TESTING AFTER TESTING

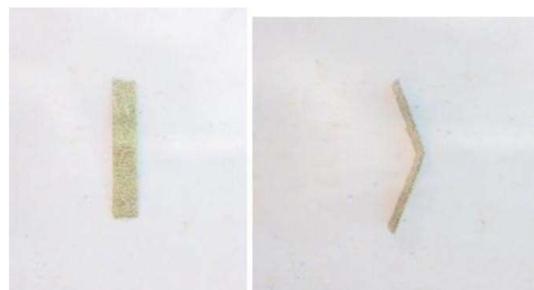


Fig 12 Flexural test specimen

7 .RESULT ANALYSIS

7.1 IMPACT TEST RESULT

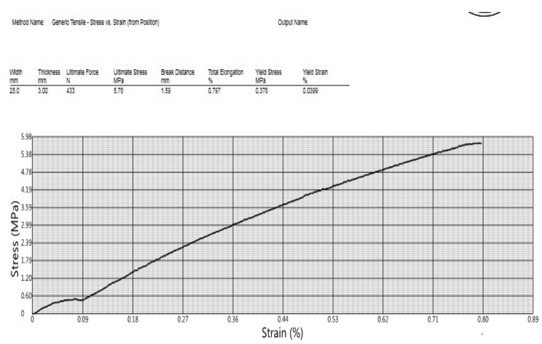
Charphy test : V –notch
Specimen size : 2*10*5 mm

Test name	Specimen thickness	Impact value in joules
Charpy	10mm	06

Table1 Impact test readings

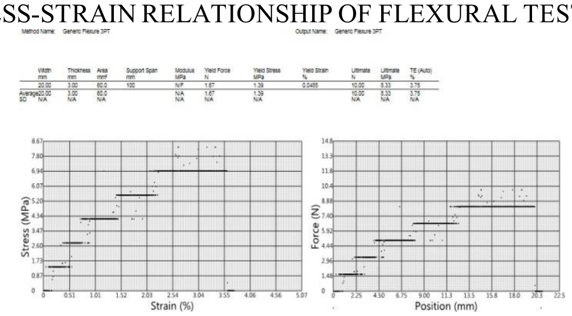
7.2 TENSILE TEST RESULT

STRESS-STRAIN RELATIONSHIP OF TESILE TEST



7.3 FLEXURAL TEST RESULT

STRESS-STRAIN RELATIONSHIP OF FLEXURAL TEST



8. COMPARISION OF DHARBAI FIBER WITH BANANA & ALOE VERA FIBER

8.1 CHARPHY IMPACT TEST RESULT

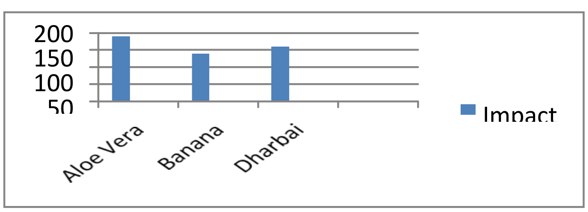


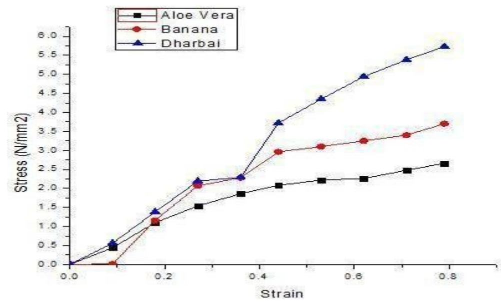
Table.2 Charphy impact test result

The mechanical behaviour of the Dharbai fiber, aloe Vera, banana fiber based polyester composites depends on fiber parameters. The Impact strength of all these fibers are compared and result is shown in Figure.

The result itself clearly shows that the fabricated material (Dharbai fiber) has a fine impact strength(160N/mm²) than the banana fiber whose impact strength is 140N/mm² and it has average impact strength when compared with aloe Vera fiber (190 N/mm²).

Hence we can conclude that the Dharbai fiber has average impact strength while comparing with banana & aloe Vera fiber.

8.2 TENSILE TEST RESULT



Graph.. Tensile test result of 3 fibers

9. CONCLUSION

A lot of research has done on natural fiber reinforced polymer composites but research on Dharbai fiber (Botanical name: Eragrostis cynosuroides) polymer composites is very rare. When comparing tensile test result, Dharbai composite stands good. The ultimate stress for Dharbai fiber is 5.76 N/mm².

When comparing both Impact and Hardness test results looks good. The impact value is 6 joules respectively**.** After the completion of above mentioned tests, then the results of Dharbai fiber is compared with another two natural fibers such as banana fiber & aloe Vera fiber.

On comparison, Dharbai fiber has well breaking strength, good elongation and has extradinary flexural properties.By seeing the comparison results, we can use our fabricated material (Dharbai fiber) for various industrial applications.

10. REFERENCES

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