

Development of hybrid E-glass fibre reinforced polymer matrix composite and study of mechanical properties

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ABSTRACT

Fiber reinforced polymer composites are replacing conventional materials because of its better properties which can be effectively used in various applications. Owing to the lower density of fiber reinforced material compared to metals which lead to the higher strength to weight ratio for the composites. There are a number of fibers available for making composite material including synthetic as well as natural fibers. The synthetic glass fiber is chosen for its excellent mechanical strength. In this experimental work, glass fibers like WRM glass fiber, CSM glass fiber, and hybrid using both WRM fiber and CSM fiber are used to prepare a specimen using a thermosetting polymer called unsaturated polyester. The hardener, accelerator, and catalyst are used for the improvement of the process. Various mechanical testing such as tensile test, flexural test, Impact test, hardness test of all three composites material is carried out as per ASTM standard. The properties of the composites made using WRM, CSM, hybrid composite using WRM and CSM were compared. Woven roving mat (E-glass fiber) has good mechanical properties compare to other chopped strand mat reinforced polymer and hybrid composite.

Keywords: Hybrid composites, Glass fiber, WRM, CSM, Unsaturated polyester.

1. INTRODUCTION

Composite material refers to the engineered materials that are made by combining two or more different materials. They adopt the physical and the chemical properties of the materials and offer a better alternative which is more strength, durable and more benign. Incrementing the fiber content results in an increase in the shear modulus and impact strength of the composites. Many studies on natural fibers such as bamboo, flax, hemp, and kenaf reveal that the mechanical properties of fiber reinforced composites depend on fiber parameters like fiber aspect ratio, fiber length, fiber loading, fiber orientation, and fiber-matrix adhesion.

It was found that the adding of relatively small of glass fiber to the polyester matrix predicated pineapple leaf fiber and sisal fiber-reinforced improved the mechanical properties, resulting in a positive hybrid effect. Optimum glass fiber loadings for sisal/glass hybrid polyester and glass hybrid polyester composites are 5.7 and 8.6 weight percentage respectively. It has additionally been found that the degree of moisture absorption of hybrid composites is less than that of single fiber composites. They determined the stress-strain characteristics, of yield stress, tensile strength, and Young's modulus, ductility and toughness as a function of fiber content experimentally. It was optically discerned that by transmuting the fiber loading and by controlling the bonding between the layers of the composite, ameliorations in strength and stiffness amalgamated with high toughness can be achieved. The mechanical properties were found to be optimum for 15 – 20 % of flax fiber loading. It was optically discerned that material properties show the most preponderant degree of variation at higher fiber volume fractions, due to fiber clumping.

It was established that hybridization makes the glass fiber composites more felicitous for a number of applications. This study was predicated on the performance of polypropylene predicated short wollastonite fiber and chopped glass fiber reinforced hybrid composites. The outcome showed that properties of the hybrid glass fiber and wollastonite composite was found to be commensurable to that of polypropylene glass fiber composites. The dissimilarity of mechanical properties of sisal and roselle fibers hybrid polyester composite at dry and wet conditions was studied. The composites of roselle/sisal polyester-predicated hybrid composites with different weight percentages of fibers were used. These fibers at a ratio of 1:1 had been incorporated in the unsaturated polyester resin at sundry fiber lengths. It was found that when the fiber content and length of the sisal fibers and roselle were incremented, the tensile and flexural strength of the composite incremented.

The layers of the composite, amendments in strength and stiffness cumulated with high toughness can be achieved. The mechanical properties were found to be most favorable for 15 – 20 % of flax fiber loading. It was withal optically discerned that material properties show the most preponderant degree of variation at higher fiber volume fractions, due to fiber clumping. The properties studied included flexural modulus and strength, hardness resistance and di-hydrogen monoxide absorption. The outcome was the hardness and flexural modulus incremented as a function of incrementing wood flour and glass fiber content. In distinction, the flexural strength and screw withdrawal resistance decremented as a function of incrementing wood flour content, albeit the resistance was impervious to wood flour content up to 35 wt%. Albeit it was found that the addition of glass fibers has a positive effect. The effect of integration of polypropylene matrix reinforcement with bamboo- glass fiber matrix (BGRP) and fiber loading was taken as a constraint. The outcome showed that the composites prepared with 30% fiber loading and 2% Maleic Anhydride-Grafted Polypropylene (MAPP) concentration showed most favorable mechanical

performance. As correlated to the virgin polypropylene, with glass fiber and bamboo concentration of 15:15, the flexural strength, tensile strength and the impact strength incremented by 86%, 69%, and 83% respectively. In the case of BGRP, less fiber pullout was described in a case of hybrid composites. The present study focuses on the research work to study the mechanical properties of the Fiber Reinforced composites. To develop a new class of hybrid fiber based polyester composites to explore the potential of laminates of E-glass fiber using WRM, CSM and both WRM and CSM. To study the effect of mechanical behaviour of chopped strand mat, woven roving mat and both CSM and WRM reinforced polyester based composites. Evaluation of mechanical properties such as tensile strength, flexural strength, impact strength, hardness test is carried out.

2. MATERIALS DETAILS

The materials utilized and methodologies followed during the fabrication, sample preparation, mechanical testing and performance of the hybrid composites. The materials utilized in the study are unsaturated polyester resin, glass fiber (E-glass) catalyst, accelerator, chopped strand mat and woven roving mat.

Glass Fiber: Glass Fibers are among the most multifarious industrial materials uses today. They are rarely engendered from raw materials, which are available in virtually illimitable supply. All glass fibers described in this article are derived from compositions containing silica. They exhibit utilizable bulk properties such as hardness, transparency, resistance to stability, chemical attack, and inertness and favorable fiber properties such as strength, flexibility, and stiffness. Glass fibers are utilized in the manufacture of structural composites, printed circuit boards and General-purport glass fibers like E-glass variants are considered which provides an in-depth detail of compositions, melt properties, fiber properties, methods of manufacture, and paramount product types. Glass fibers and fabrics are utilized in ever incrementing varieties for a wide range of applications. A data book is available that covers all available E-glass fibers, which can be employed for reinforcement insulation, filtration, and other applications. It lists all manufacturers, agents, sales offices, subsidiaries, and affiliates, consummate with addresses, and telephone and fax numbers. It also tabulates key properties and pertinent supply details of all E-glass fiber grades that are available in the market today.

Chopped Strand Mat: Chopped strand mat or CSM is a form of reinforcement utilized in fiberglass. It consists of glass fiber laid desultorily across each other and covered by a binder. It is typically processed utilizing the hand lay-up technique, where sheets of materials placed in a mold and brushed with resin because the binder dissolves in resin, the material facilely conforms to different shapes when wetted out. After the resin remedies, the hardened product can be taken from the mold and culminated. Utilizing chopped strand mat gives a fiberglass with isotropic in-plane material properties.

Woven Rowing Mat: Woven Rowing is made from perpetual glass fiber roving which is interlaced into cumbersomely hefty weight fabrics. Utilized in most application to increment the flexural and impact strength of laminates. Ideal for multi-layer hand lay-up applications where material strength is vital. With woven roving, the general rule estimation for the resin/reinforcement ratio is 1:1 by weight. Woven Roving is available in weaves, weights, widths and culminates to suit much application.

Unsaturated Polyester Resin: Polyester is a copolymer; that is, it is composed of two different chemicals. These are referred to as the "resin" and the "hardener". Hardener is utilized as a function of expeditious setting for the composite laminate. Variants of hardeners available are HY 951, HT 972, HY 974 and HZ 978. As the preparation of laminate is to be at room temperature we can use HY 951 as the hardener. It is one of the Thermoplastic polymers, softens when heated and hardens when cooled. On a molecular level, as the temperature is increased, secondary bonding forces are diminished so that the relative kinetics of adjacent chains is facilitated when a load is being applied. Irreversible degradation results when a molten thermoplastic polymer is increased to very high temperature. The thermoplastics are relatively soft. Thermoplastic are linear polymers and branched structures with flexible chains.

These materials are generally fabricated by the same application of heat and pressure. Most linear polymers are thermoplastics. Some of the key properties are one of the toughest of polymer films, better fatigue, and tear strength. It has resistance to humidity, acids, greases, oils, and solvents. To customize the properties of a polymer, with different molecular groups suspended from the backbone (usually, they are suspended as part of the monomers join together to appear as the polymer chain).

Most of the polymers are partially crystalline and partially amorphous in the molecular structure, giving them both a melting points (the temperature at which the alluring intermolecular forces are overcome) and one or more glass transitions (temperatures above which the enhancement of localized molecular flexibility is substantially incremented). The semi-crystalline plastics include polypropylene, polyethylene, poly (vinyl chloride), polyamides (nylons), polyesters and polyurethane. Some polymers are exceptionally amorphous, such as polystyrene and its copolymers, poly (methyl methacrylate), and all thermosets. Thermoplastic and hypo-plastic are the two plastic families.

3. EXPERIMENTAL METHODS

Sample Preparation: The chopped strand mat, woven roving mat E- Glass fibers are commixed with unsaturated polyester resin by simple mechanical stirring and the coalescence was poured into sundry moulds, keeping in view the requisites of testing conditions and characterization standards. The composite samples of three different compositions are prepared.

Methods of Preparations: Before the Un Saturated Polyester resin for chopped strand mat and woven roving mat is laid upon the mould, the mould should be dried and cleaned. Using a clean brush, the Un Saturated Polyester is laid up uniformly for the first layer onto the mould. The Un Saturated Polyester is blended with the fiber. The commixed Un Saturated Polyester and with the fiber is poured into the mould. The mould is closed and the composite material was pressed uniformly for 24h for remedying. After the composite laminate is completely dried, then it is disunited from the mould then the mould is compression mould machine.

Preparation of Mold: The mould utilized for woven composite fibers is made from rectangular glass piece of 300mm in length and 300mm in width, and it is covered with plastic OHP sheet. The upper side of the mould is additionally made in a rectangular glass piece of 300mm in length, and 300mm in width and covered with plastic sheet. The functions of this upper side of the glass are to cover the fiber after the unsaturated resin is supplied and additionally to eschew the debris from entering into the composite components during the remedying time. Predicated on the thickness of specimen four small of glass plenary covered with plastic is placed in the rectangular shape to prepare the laminate.

The commixing that is utilized to fabricate the composite specimen is US resin it is commixed with methyl ethyl ketone peroxide (catalyst) HY 951 of density 0.946 g/cm³ and cobalt naphthalene. The weight ratio of matrix US resin and hardener is 10:1. The matrix should be stirred well so that the commixing would be felicitous. Six layers were made utilizing WRM and CSM discretely in US polyester. Six layers were made in hybrid composites with WRM, CSM in US polyester.

4. RESULT AND DISCUSSIONS

Tensile Test: The tensile test has widely performed the test to determine several mechanical properties of a material that are paramount in design. In this test, a standard specimen is subjected to a gradually incrementing uniaxial tensile load until it fractures. The macrocosmic testing machine is utilized to perform the tensile test. The specimen is mounted between the upper and lower crossheads. The lower cross head is movable and is designed to elongate the specimen at a constant rate. The applied load and resulting elongation are quantified simultaneously and perpetually. After making the laminates, specimens have to be cut according to the ASTM standards. The standard used for the tensile test is ASTM E8. The experimental is conducted using a universal testing machine. Ultimate tensile strength found using UTM in composite materials are shown in table.1.

Table.1.Ultimate tensile strength of composite samples

Composite	Tensile strength (MPa)
WRM reinforced polymer	265
CSM reinforced polymer	27.5
Hybrid composite	105

The tensile stress of E- glass WRM has more tensile strength than CSM reinforced polymer and hybrid composites. It is due to the density of WRM is very high compared to other composites.

Flexural Test: The three-point bending test is very prevalent and a macrocosmic testing machine can be utilized for this purport. The specimen is of rectangular cross-section and is fortified by two bottoms fortifies. By applying the load on the top member and causing bending, the specimen is subjected to tension at its lower surface. The load and the deflection of the specimen are quantified. The stress at fracture in bending is kenneas flexural strength or Transverse rupture strength.

$$\text{Flexural strength} = 3PL / BD^2$$

Where,

P - Fracture load, (N)

L - Distance between the bottom supports (mm)

B - Width of the specimen (mm)

D - Thickness of the specimen (mm)

Another most consequential property that is quantified for the composite utilized in the structural application is the flexural vigor and modulus. The flexural test was carried out according to the standard ASTM E8. Three-point bend test was used to quantify flexural strength. The samples were 250mm long and 25mm wide. Thickness depended on upon the number of layers. Flexural strength of glass fiber composites are listed below in table.2

Table.2.Flexural strength of composite samples

Composite	Flexural strength (N/mm ²)
WRM reinforced polymer	22.5
CSM reinforced polymer	2.5
Hybrid composite	3.4

From the flexural test outcome, Woven roving mat fiber reinforced polymer has more flexural strength compared hybrid composites. It is due WRM E-glass fiber stacking arrangement is better than other composites. Hybrid Composites flexural strength is very low compared to WRM E-Glass fiber reinforced polymer

Impact Test: The composite samples of 55×10×10mm are fabricated for performing impact test which is shown in figure.1. The Charpy impact test was done on composite samples based on ASTM E8 standard.

**Figure.1.Impact Test Specimen of Composites**

At the point of impact, the striker has known the amount of kinetic energy. The impact energy is calculated predicated on the height to which the striker had risen if no test specimen was placed, and this compared to which the striker elevates, the tough material absorbs a more amount of energy, whereas brittle materials tends to absorb very less energy prior to fracture. Impact energy of composite materials is listed in the table. 3.

Table.3.Impact energy of composite samples

Composite	Impact energy (joules)
WRM reinforced polymer	4
CSM reinforced polymer	5
Hybrid composite	6

From the impact test outcome, it is obvious that hybrid composite has more impact energy than the other composite material. The impact energy is increased in hybrid composite due to the presence of CSM. The random arrangement of E-glass fiber is vital. The toughness is increased while going for hybrid composites.

Hardness Test: Hardness is a quantification of resistance offered by a material to plastic deformation. The Indentation Hardness Method that is Rockwell Hardness was performed on the composite samples which are shown in figure 2.

**Fig.2.Hardness Test Specimen**

Indentation Hardness: It is a quantification of resistance offered by a material to plastic deformation. We choose the Indentation Hardness Method that is Rockwell Hardness.

Composite Details:

Specimen Size: (50 x 50 x 10) mm

Test Machine: Rockwell Hardness Machine.

Indenter=1/16" ball load=100kg for Polyester Composite.

The Average Value of hardness is shown in table.4

Table.4.Impact energy of composite samples

Composite	Impact energy (joules)
WRM reinforced polymer	B98
CSM reinforced polymer	B62
Hybrid composite	B79

From the hardness test, it is clear that E-glass WRM fiber has more Rockwell hardness than the other composite material and Hybrid composite.

5. CONCLUSION

Based on the exploration of the test results the following inferences were made. In comparison with CSM reinforced polymer and hybrid composite, WRM reinforced polymer has higher tensile strength and hardness. In comparison with CSM and hybrid composite, the E- glass fiber laminate have higher Flexural strength. When comparing with WRM fiber and CSM fiber laminate, hybrid composite laminate has higher Impact energy. So, hybrid glass fiber composites can be preferred over other composites if impact energy is critical in the application. The density of WRM is higher than CSM so it has better mechanical property than hybrid glass fiber. It can be effectively utilized for bathtub, furniture, spa tubs, and ducting.

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