EXPERIMENTAL ANALYSIS OF FIBRE REINFORCED COMPOSITES (EPOXY+E GLASS) ALONG WITH THE FILLERS Al_2O_3, $CaCo_3$ AND PbO

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Declaration of competing interest

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Abstract

Fiber based composite material became more applicable thing in automobile, aerospace and household industries, because of vast availability of source material and its mechanical strength. The fiber based composites are most reliable due to simple fabrication techniques, which can enhanced its mechanical properties by adding simple material like fillers, hardener, mesh and increase number of layer in the composite mixer. In this current research article E-glass fiber and Epoxy matrix composite material properties was enhanced by adding three different filler materials. There different types filler materials such as metallic, non-metallic, carbon based etc., here ceramic based composite namely aluminium oxide(Al_2O_3), calcium carbonate ($CaCo_3$) and lead oxide(PbO) was utilized as a filler material. The fabrication techniques and weight percentage of filler was constant for all composite samples. The mechanical strength of composite samples and ability of filler materials was analyzed through tensile strength, flexural strength and impact load withstand capacity. The tensile strength and flexural strength are evaluated by engaging universal testing machine (UTM), and the impact load carrying was measured by Charpy hammer test. The result show ceramic based filler reinforced composite samples has better and improved mechanical properties compare to fiber composite without fillers. Especially PbO filler reinforced sample show significant result in all comparative aspect, due its high dispersive ability, blending and oxidization properties.

Keywords: composites, reinforcing constituents, filler material, mechanical properties.

INTRODUCTION

In the day to day application wood based household equipment like furniture's, door, roof, paper and its products are mostly undeniable. Trees are the major source for such product, so tones of trees and natural source were destroyed for the years[1,2]. For protect the nature and tree research found the solution called composite materials. Among the composite materials fiber composite are alternative for the conventional wood product. Based on the production methods and its mechanical strength fiber based composite became key factor in automobile and household industries[3,4]. Application of fiber based composite was increased because its unique properties and availability. Most of the fiber material sources from byproduct of other industries, which can used by regenerative technologies. Environmental protection was a huge problem in over a few decades. Composite materials are solution for many environmental aspect problems like waste management, hazardous disposal and quick disposal[5,6]. Normally composite materials are prepared by mixing or blending two or more materials, here two material phase namely fiber phase and matrix phase was consider for fabrication. Fiber phase included fiber and reinforced materials and matrix phase includes resin and hardener. Glass fiber composites with reinforcement behave differently depending on the type of material used and the application mechanism. Glass fiber is favored if these are the constraints in comparison to other fibers, which include low electrical and thermal conductivity and maybe melting temperature conditions as well[7]. Tensile strength of fibers was a key factor to the composite fabrications and fiber selection, glass fiber has comparatively high tensile strength other natural fibers[8]. Ceramic matrix composites(CMC) have ceramic matrix such as alumina, calcium, alumina silicate reinforced composite through epoxy resin[9,10]. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density[11]. Rani et al.[12] proposed the recycle ability of the glass fibre and carbon fiber composite, which is better for economic and environmental conservation. Kumar et al.[13] analysis the flexural strength of composite plate and reveals that the reinforcement was significant factor for all mechanical properties. Chinnasamy et al.[14] developed a hybrid composite with glass and Kevlar fiber and its shows higher thermal stability than other composite materials. The mechanical strength polymer composites can be further enhanced by the filler material[15,16]. The materials are normally in powder form in some cases liquid filler are also used for reinforcement with matrix material[17]. Ceramic based filler material like aluminium oxides, boron carbide were enhance stiffness properties of composite materials[18,19]. Suresh, G et al.[20] and Hunain et al.[21] developed the nano filler reinforce glass fiber composite and analyzed the mechanical characterization, the result shows nano filler significantly influence the structural integrity and mechanical strength. Megahed et al.[22] analyzed effect of wt% of filler material on composite mechanical strength, after some threshold limit effect of filler material gets reduced over mechanical strength of composite material and proposed 3% is an appropriate limit for e-glass fiber composite fabrication. In this Present work, a comparative study was made on E-Glass fibre reinforced composites with different materials such as Al_2O_3,$CaCo_3$ and PbO. The properties of fiber reinforced composites are characterized and determine the effect of filler on mechanical behaviors.

CLASSIFICATION OF COMPOSITES

Composites can be categorized into groups based on the type of matrices that each type possesses in order to keep things uncomplicated. The matrix's and the reinforcing fibers' physical and chemical properties have an impact on the fabrication processes as well.

Metal matrix composites

A few matrices found in these composites are titanium, magnesium, and aluminium. Silicon carbide and carbon are common components of fibre. Metals are mostly strengthened to meet design requirements. For instance, The use of fibers such as silicon carbide has the potential to decrease the thermal expansion coefficient and electrical and thermal conductivity of metals, while simultaneously enhancing their elastic stiffness and strength.

Ceramic matrix composites

Ceramic matrix composites consist of silicon carbide-reinforced alumina, calcium, and alumina silicate. High strength, hardness, low density, chemical inertness, and high ceramic service temperature Some of the advantages of CMC are its limits. High temperatures are naturally resisted by ceramic materials yet they can also break and become brittle. Fibers constructed of silicon carbide are used to strengthen composites that are successfully created using ceramic matrices. With less density, these composites provide the identical high temperature endurance as super alloys. Ceramics are fragile, which makes it challenging to fabricate composites. The majority of CMC production processes typically call for powdered starting ingredients.

Polymer Matrix Composites

The most widely used kind of matrix materials are polymeric ones. There are couple of causes for this. For many structural applications, polymers' mechanical qualities are generally insufficient. In comparison with metals and ceramics, they are especially weaker and less rigid. By using polymers to reinforce other materials, these challenges are solved. Additionally, Less equipment is required to create polymer matrix composites. complex. Because of this, polymer composites saw a quick development and quick rise in use in structural applications. They aren't as brittle as ceramics, but they have a higher modulus of elasticity than the plain polymer. An epoxy, thermoplastic polycarbonate, unsaturated polyester, or thermoset, polyvinyl chloride, polystyrene and nylon matrix is used in polymeric matrix composites, together with embedded Kevlar (dispersed phase) fibers, steel, carbon, or glass. Figure 1. shows fabrication process of polymeric matrix composites.

Thermosets and thermoplastics are the two primary categories of polymers. After curing, thermosets have properties like a well-bonded dimensional molecular framework. As they harden, they break down rather than dissolving. To determine the resin's other properties and adjust the circumstances for curing, one need only modify the resin's basic composition. Thermosets are particularly flexible since they may be kept for extended periods of time in a partly cured state as well. As a result, they work best as matrix bases in complex situations.

Materials and fabrication

E-GLASS FIBER

E-Glass, occasionally referred to as electrical grade glass, was first developed as a standoff insulator for electrical lines. Because of its exceptional fiber-forming properties, it is currently utilized nearly solely as a reinforcement component in the substance that is referred to as fiber glass. Glass fiber, often known as glass fiber, is a material made up of many incredibly tiny glass fibers. Although glassmakers have been experimenting with glass fibers throughout history, the development of finer machines tooling was the only thing that allowed glass fiber to be mass manufactured. Glass fiber is created by extruding tiny glass strands with a silica base or another formulation into numerous fibers with tiny diameters that are appropriate for textile processing. Although the process of melting and pulling glass into fine fibers have been known for millennia, it is only recently that these fibers have been used in textile applications. Up until this point, glass fiber was only produced as staples, or groups of brief fiber lengths.

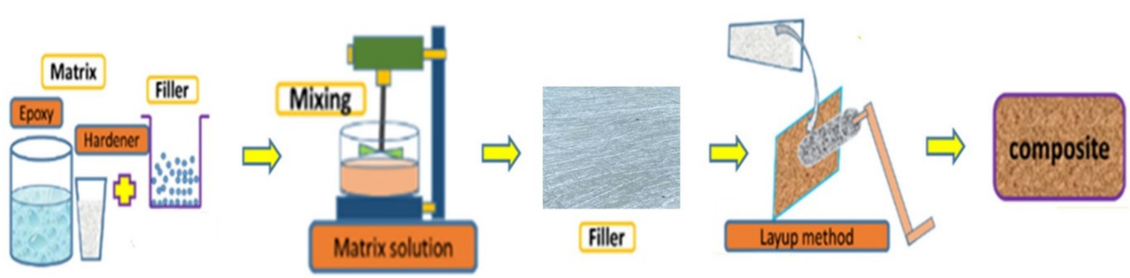

Fig.1. Shows Schematic of fabrication process.

EPOXY RESIN

The thermosetting epoxide polymer known as epoxy, or poly-epoxide, cures (forms polymers and crosslinks) when combined with a catalyzing agent, sometimes known as a "hardener". The most widely used epoxy resins are created when bisphenol-A and epichlorohydrin combine. Composite materials, adhesives, and coatings are only a few of the of the numerous applications for epoxy-based materials with reinforcements like fiberglass and carbon fiber.

FILLER MATERIALS

ALUMINIUM OXIDE (Al_2O_3)

Among the metallic elements found in the earth's crust, aluminium is most prevalent in felspar and mica-containing rocks. Aluminium oxide is the aluminum's amphoteric oxide. In the fields of ceramics, materials science, and mining, it is also frequently referred to as aloxite or alumina. α-Al2O3 and γ-Al2O3 are the two types of anhydrous Al2O3. α-Al2O3 exhibits stability at elevated temperatures and indefinite metastability at reduced temperatures.

CALCIUM CARBONATE ($CaCO_3$)

A different acronym for calcium carbonate is calcium trioxocarbonate(CaCO3), is one of the most accessible chemical substances in the world. Approximately seven per cent of the earth's crust is thought to consist of it, and it occurs naturally there. Several common names for CaCO3 include calcite, which limestone, chalk, and pearl, marble, aragonite, etc,. Chalk and lime-stone are two of the most common varieties of rock that are formed by CaCO3, one of the min-erals that is most prevalent in the earth's crust.

LEAD OXIDE (PbO)

Lead oxide (PbO) is an inorganic substance that is also referred to as lead monoxide. There are two polymorphs of lead oxide: massicot, which has an orthorhombic crystal structure, and litharge, which has a tetragonal crystal structure. PbO is mostly used in lead-based industrial ceramics nowadays, such as computer components. This oxide is amphoteric. PbO has a molecular mass of 223.20 g/mol and is a red or yellow powdered in appearance.

CURING AGENT (HARDENER)

When the resin alone applied during composite fabrication, it developed a composite sample with soft surface and with lots of voids. To overcome such problem and make a strong bond between polymer components some catalyst or hardener solution are used. Hardener enhanced the dispersive quality of polymer resin and developed a strong chemical bond between fillers and resin. The hardener and resin are mixed in the ratio of 1: 10 respectively. If the level hardener become more than optimum level, then the resin became harder and difficult for fabrication. This class includes compounds containing amine, amide, hydroxyl, acid, or acid anhydride groups. They typically produce an amine, the ether, or ester through polyaddition reaction with epoxy resin. The most often used amine type curing agents include polyamides, their derivatives, and aliphatic and aromatic polyamines. The half-lives of aliphatic amines are brief and highly reactive.

COMPOSITION OF MATERIALS

We utilized liquid unsaturated resin (polymer + additive) and the Additive is Methyl Ethyl Ke-tone Peroxide (MEKP) catalyst and hardener (conc. cobalt 0.6%). The following are the compo-sitions of the composite materials:

a. 65% of Resin + 35% of Fibre

b. 62% of Resin and 3% of Al_2O_3 and 35% of Fibre

c. 62% of Resin and 3% of $CaCO_3$ and 35% of Fibre

d. 62% of Resin and 3% of PbO and 35% of Fibre

PREPARATION OF SPECIMEN

It is done by hand layup technique. Take 2*2 feet tiles and pour wax and remove in order to fill the minute pores present in tiles. Make 20% Poly vinyl alcohol solution, brush it over the tiles and give some time to dry. Measure the amount of epoxy, e-glass and fillers to be present in the material composition. Mix the epoxy and fillers by using mechanical for 30 minutes with 600rpm. Brush the epoxy filler mixer on the tiles and sandwich the e-glass and mixer. Compress the specimen and make it to dry for 2 days.

EXPERIMENTAL RESULTS

TENSILE TEST

The highest tensile stress a material can withstand before failing is known as its tensile strength. An applied uniaxial force via the specimen's two ends during the test. The specimen measures (3x15x80) mm. When evaluating a material, typical points of interest are the ruptured (R) or the fracture point, which occurs when the specimen shatter into pieces, the offset strength of yield (OYS), indicating a point considerably beyond the start of irreversible deformation, and the greatest possible tensile force (UTS strength), also known as maximal stress. Tensile strength for composite samples is determined by analyzing the tensile test results, which are carried out in the Instron 1195 is a universal test machine (UTM) with ASTM standard of D3039 [17] of sample size of 250 x 25 x 3mm. Tensile test result was shown in table 1. Figure 2. Shows sample after tensile test.

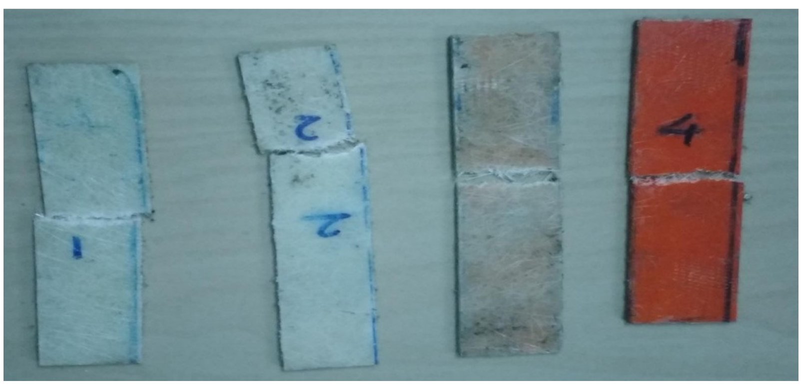

Fig2.Specimens after tensile test

Table 4.1 Tensile test

TEST PARAMETERS	OBSERVEDVALUES			
	EGLASS+ EPOXY	EGLASS+ EPOXY+ Al_2O_3	EGLASS+ EPOXY+CaCo3	EGLASS+ EPOXY+PbO
	ID-1	ID-2	ID-3	ID-4

GAUGE WIDTH(mm)	28.48	27.72	30.62	32.93
GAUGE THICKNESS (mm)	2.80	3.10	2.76	3.01
ORIGINAL CROSS SECTION AREA (mm^2)	79.74	85.93	84.51	99.12
ULTIMATETENSILE LOAD(kN)	3.85	4.75	4.71	4.85
ULTIMATE TENSILE STRENGTH(N/mm^2or MPa)	48.00	54.00	53.50	56.70

FLEXURAL TEST

A material's flexural strength is its capacity to withstand deformation under load. To determine the value for interlaminar shear strength (ILSS), composite sample short beams shear are con-ducted. This test, defined as the three-point bend, typically induces inter-laminar shear failure. This examination is carried out with UTM in accordance with ASTM standards of D790 [19]. A specimen must be loaded into the intended shape with a length which exceeds at least several times the depth in order to be measured. The kind, size, and amount of coarse aggregate used will deter-mine flexural MR might range from 10 to 20 percent of strength during compression. Some-times by as much as 15%, the MR determined by center point loading is higher than the MR determined by third- point transferring. Both tensile as well as flexural tests are performed by universal testing machines. Figure 3 shows sample after flexural test. The best correlation, however, is obtained by testing in laboratories for provided materials and mix the design. Flexural test result shown in table 2.

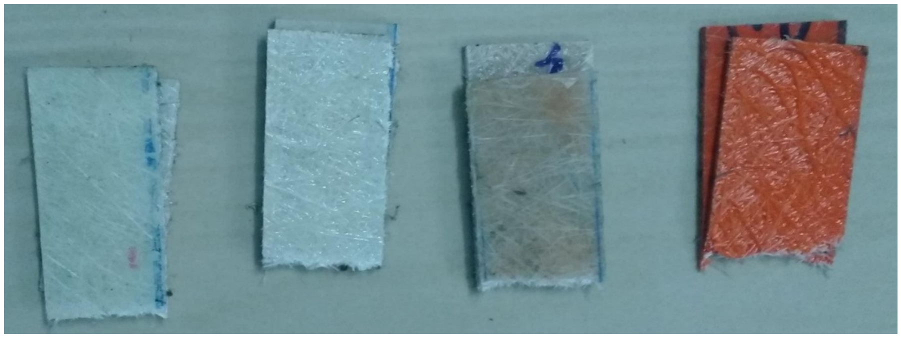

Fig 3. Specimens after flexural test

Table 4.2 Flexural test result

TESTPARAMETERS	**OBSERVEDVALUES**			
	EGLASS+ EPOXY	**EGLASS+ EPOXY+ Al2O3**	**EGLASS+ EPOXY+CaCo3**	**EGLASS+ EPOXY+PbO**
	ID-1	**ID-2**	**ID-3**	**ID-4**
FLEXURAL STRENGTH(Nmm^{2}or MPa)	119.04	149.5	144.24	153.16

IMPACT TEST

This test uses a Charpy impact instrument, a bar of material is struck in the middle after being sustained as a beam. By measuring the difference between the swing of a pendulum with and without a sample, the energy received by the blow may be ascertained. The specimens were sliced, impact test performed under ASTM standard of D256 [22]. Figure 4. Shows specimens after Charpy impact test. Table 4. Shows impact test result.

Fig4.Specimens after Charpy impact test

RESULTS AND DISCUSSION

Mechanical properties of glass fiber composite has been evaluated with ultimate load carrying capacity, flexural strength and energy absorption during impact load. From the result it reveals clearly that the filler material added to composite reinforcement enhanced its mechanical strength. Especially in terms of energy absorption during impact load has been double compare to the composite material without any fillers. Among the fillers lead oxide comparatively enhanced the mechanical properties more. Figure 5. Shows graphical comparison of ultimate load and flexural strength of composite samples.

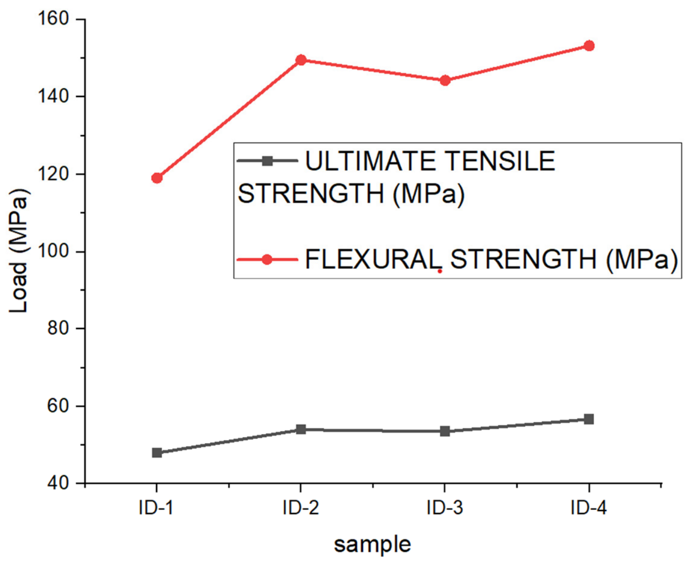

Figure 5. show graphical comparison of ultimate load and flexural strength of composite samples.

CONCLUSION

E-glass fiber based composite material was successfully fabricated with hand layup method. The mechanical strength of composite sample analyzed by tensile strength, flexural strength and impact load absorption capacity. The influence of filler material on the mechanical characterization also analyzed and drawn the following conclusions.

1. Hand layup method was one of the finest fabrication techniques for composites, with uniform distribution of epoxy over glass had developed glass fiber composite with better mechanical properties even without any fillers.
2. Among the composite sample lead oxide (PbO) reinforced glass fiber composite shows high tensile and flexural strength due its chemical structure and high dispersive quality with epoxy.
3. During impact test energy absorption was double for filler reinforced composites. For the fabrication of composite samples uniform blending filler of materials with epoxy resin and proper curing methods causes higher load absorption ability.

Author Contributions

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Supervision, conceptualization and editing: V.Kumaran

Writing—original draft preparation, Data curation : Venkatesh R

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