An Investigation on Mechanical And Thermal Properties of E-Glass/S-Glass Fibers Composites

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Abstract- *Initially, ancient Egyptians made containers by glass fibers drawn from heat softened glass. Continues glass fibers were first manufactured in the 1930s for high-temperature electrical application. Nowadays, it has been used in electronics, aviation and automobile application etc. Glass fibers are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm. It may be in the form of roving's, chopped strand, yarns, fabrics and mats. Each type of glass fibers have unique properties and are used for various applications in the form of polymer composites. The mechanical, tribological, thermal, water absorption and vibrational properties of various glass fiber reinforced polymer composites were reported.*

Keywords- Glass fiber, polymer composites, mechanical property, thermal behaviour, hand-lay-up technique

I. INTRODUCTION

1.1 General Introduction and Background

Composites are materials consisting of two or more chemically distinct constituents, on a macro-scale, having a distinct interface separating them. One or more discontinuous phases are, therefore, embedded in a continuous phase to form a composite. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement, whereas, the continuous phase is termed as the matrix. The matrix material can be metallic, polymeric or can even be ceramic. When the matrix is a polymer, the composite is called polymer matrix composite (PMC).

Over the past few decades, it is found that polymers have replaced many of the conventional metals/materials in various applications. This is possible because of the advantages such as ease of processing, productivity, cost reduction etc. offered by polymers over conventional materials. In most of these applications, the properties of polymers are modified by using fibers to suit the high strength/high modulus requirements. Fiber reinforced composite materials consist of fibers embedded in or bonded to a matrix with distinct interfaces (boundaries) between them. In this form, both fibers 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. In general, fibers are the principal load-carrying members, while the surrounding matrix keeps them in the desired location and orientation. The matrix also acts as a load transfer medium between them and protects the fibers from environmental damages due to elevated temperatures, humidity etc. Thus, even though the fibers provide reinforcement for the matrix, the latter also serves a number of useful functions in a composite material. Many fiber reinforced polymers (FRP) offer a combination of strength and modulus that are either comparable to or better than many traditional metallic materials. In addition, fatigue strength as well as fatigue damage tolerance of many composite laminates are excellent. For these reasons, FRPs have emerged as a major class of structural materials and find applications in almost all material domains such as house furnishing, packaging, sports, and leisure and in many other weight-critical components in aerospace, automotive and other industries.

For many industrial applications of glass fiber reinforced epoxy composites information about their mechanical and thermal behavior is of great importance. When the fiber reinforced epoxy composites are exposed to heat above the glass transition temperature of resin matrix, it leads to reduction in stiffness and strength of material and degrades the mechanical properties due to thermal degradation and combustion of the resin. In this context the study of mechanical, thermal and fire resistance properties of composites are desirable. Now-a-days specific fillers/additives are added to enhance and modify the quality of composites as these are found to play a major role in determining the mechanical, thermal and fire resistance behavior of the composites. The addition of filler materials to an epoxy is a common practice. This improves not only stiffness, toughness, hardness, heat distortion temperature, and mold shrinkage but also reduces the processing cost significantly.

1.2 Fiber reinforced composite

A fiber is a slender, elongated thread like structure, characterized by length and diameter/thickness. The most common fibers used are glass fibers, carbon fibers, and aramid (kelvar) fibers. Fibers are generally circular in cross-section, but can also be in form of tubular, rectangle or hexagonal. The diameter of fiber ranges from 0.0001 inch to about 0.005 inch depending on the material. Fiber reinforced composites can be further divided into discontinuous or continuous type of fibers. Continuous Fiber reinforced composites contain fiber reinforcement having lengths much greater than their cross-sectional dimensions. On the other hand, a composite is considered to be a discontinuous fiber or short fiber composite if its properties vary with fiber length. Discontinuous fiber can also be randomly oriented. Most particles composites that are being developed for engineering application contain discontinuous fibers. FRP composites are used in the manufacturing of doors, windows, bathtubs, boats, yachts, sporting goods, pipes, tanks and vessels, and many internal parts in rail, automotive, aerospace applications.

1.3 Particle reinforced composite

In particular composites, the reinforcement consists of small metallic or ceramic particle embedded in matrix. The particles are either flakes or in powder form, and may be spherical, cubic, tetragonal, a platelet, or other regular or irregular shape. Very small particles less than 0.25 micron in diameter and finely distributed in the matrix, restricts the movement of dislocations and deformation of the material. Particular composites have advantages such as improved strength, increased operating temperature, oxidation resistance etc. a typical example is concrete, where in sand, gavel (reinforcement), and intake manifolds, brakes, piston, cutting tools, electrical products etc. are made from particulate composites.

1.4. Laminated composites

Laminated composites are composed of layers of materials held together by matrix. Plywood is a simple example where thin sheet of veneer wood are bonded together to obtain stronger laminated structure. Plywood layers are glued together with adjacent plies having there grain at right angles to each other for greater strength. This arrangement makes the plywood very hard to bend it perpendicular to grain direction. Laminations may also be constructed using fabric material such as cotton, paper or woven glass fibers embedded in a plastic matrix. Vehicle windshields, corrugated fiber board box, plywood, wear pads, wear strips, wear rings, pipes, cladding of metal, roll welding, explosive welding, sandwich panel etc. are some of the examples of laminated composites.

1.5 Problem Description

The research problem undertaken after a thorough and critical review of the literature is to investigate the effect of filler materials on mechanical, thermal and fire resistance properties of E-glass fiber reinforced epoxy composite laminates and to explore the potential utilization of low cost and easily available filler materials. For many applications mechanical, thermal, and fire resistance properties of composites are ideally required in this respect. Composite properties can be changed by adding a variety of fillers and to develop and characterize a new combination of composites to suit wide range of applications.

II. LITERATURE SURVEY

The purpose of the literature review is to provide background information about the fiber reinforced composites filled with various filler materials. This part outlines some of the recent reports published in literature on mechanical and thermal behavior of composites filled with different types of filler materials.

M. Somaiah Chowdary, M.S.R NiranjanKumar [1] have determined the effect of nanoclay content on the mechanical and morphological behavior of S-glass fiber, reinforced in Polyester with nanoclay as filler. Five different types of composites are fabricated by hand layup technique using 0 wt% nanoclay,1 wt% nanoclay, 3 wt % nanoclay, 5 wt% nanoclay and 7 wt% nanoclay with 40% wt fiber, and polyester. The results of the study show that the incorporation of nanoclay has a significant effect on the mechanical behavior of composites. The optimum loading of clay in the Polyester /glass fiber composites was attained at 3wt%, where the improvement in tensile and bending properties was seen.

S.Pichi Reddy, G.Parmeswari, et al., [2] have studied the effect of fly ash content on tensile strength and flexural strength of 10wt% glass fiber epoxy composites. The fly ash content is varied from 0 to 10grams in steps of 2grams. The composite with 6gramsfly ash exhibited better tensile strength when compared to the other composites. Similarly the composite with 4grams fly ash exhibited better flexural strength.

S.Sivasaravanan, V.K.BupeshRaja [3] have investigated hybrid composites of Epoxy/Nanoclay/Glass fiber were prepared by Hand-layup technique. The glass fiber used in this investigation is E-glass fiber bi-directional: 45˚ orientation). The composite samples were made in the form of a plate. The wt% of nanoclay added in the preparation of sample was varied, ranging from 1wt% to 5wt%. The fabricated composite materials in the form of plate were cut into corresponding profiles as per ASTM standards for impact testing.

K.Devendra, T.Rangaswamy [4] an investigation was made on the mechanical properties of E-glass fiber reinforced epoxy composites filled by various filler materials. Composites filled with varying concentrations of fly ash, aluminum oxide (Al_2O_3), magnesium hydroxide ($Mg(OH)_2$) and hematite powder were fabricated by standard method and the mechanical properties such as ultimate tensile strength, impact strength and hardness of the fabricated composites were studied. The test results show that composites filled by 10% volume ($Mg(OH)_2$) exhibited maximum ultimate tensile strength and hardness. Fly ash filled composites exhibited maximum impact strength.

K.Devendra, T.Rangaswamy (2013), determined the thermal conductivity and thermal expansion coefficients of glass fiber reinforced epoxy composite laminates (GFRP laminates) made using the Hand layup technique. The composite laminates were fabricated by filling with varying concentrations of fly ash, stone powder, aluminium oxide (Al2O3), magnesium hydroxide (Mg (OH)2), Silicon carbide particles (SiC) and hematite powder. The test results show that fly ash filled GFRP laminate exhibited low thermal conductivity. GFRP laminates filled with SiC exhibited maximum thermal conductivity and minimum thermal expansion coefficient.

K.Devendra, T.Rangaswamy, In this research work, mechanical behavior of E-glass fiber reinforced epoxy composites filled with varying concentration of aluminum oxide (Al2O3), magnesium hydroxide (Mg(OH)2) and silicon carbide(SiC) were studied. Composites were fabricated by standard method. The objective of this work was to study the mechanical properties like ultimate tensile strength, impact strength, flexural strength and hardness of the fabricated composites. The experimental results show that composites filled by (10% Vol.) Mg(OH)2 exhibited maximum ultimate tensile strength and SiC filled composites exhibited maximum impact strength, flexural strength and hardness.

K.Devendra, T.Rangaswamy, This paper compares the values of the thermal and fire resistance properties of composites made using the hand layup technique. E-Glass fiber reinforced epoxy composites was fabricated by filling varying concentration of aluminum oxide (Al2O3), magnesium hydroxide (Mg(OH)2), silicon carbide (SiC), and hematite powder. The main aim of this work was to determine the thermal conductivity, thermal expansion coefficient, time to ignition and flame propagation rate of composites. Experimental results show that Al2O3 and Mg (OH)2 filled composites exhibited low thermal conductivities. Composites filled by SiC particles exhibited low thermal expansion coefficient when compared with other filled composites. Fire test results indicated that increase the loading of Al2O3, Mg(OH)2, and hematite powder increase the time to ignition and reduces the flame propagation rate of composites.

K.M. Kelvin Loh and C.K. Willy Tan [5] Wet layup, vacuum bagging and hot press were successfully employed to fabricate the silk fabric-epoxy composite in this study. Based on the three point flexural bend test results, incorporating silk fabric into epoxy was found to increase the flexural strength of the composites up till a optimum volume percentage of 33% silk fiber reinforcement content. This favorable result indicated the potential to further explore and utilize natural silkworm silk-epoxy resin composite for actual high performance applications.

C.Elanchezhian, B.VijayaRamnath, et al.,[6] silk fiber was selected owing to the extensive properties possessed by it. Fabrication was done by hand layup technique in which three samples were manufactured. One sample was silk based biocomposite, another was hair based biocomposite and the third was hybrid biocomposite made from hair and silk fiber. Alternate vertical and horizontal orientations of fibers was introduced to improve the mechanical strength at inter laminar level. The biocomposite was tested for mechanical properties like tensile strength, compressive strength, flexural strength, impact strength and hardness. Mechanical tests conducted showed that silk based biocomposite was better in compression, flexural and impact strengths. Hair based composite showed higher tensile strength and it had highest break load. Hardness was same among all the three composites as it is a property exhibited by the matrix material constituted by epoxy resin. Analysis of hybrid composite showed that properties of hybrid composite were in between that of silk and hair composite. Hence it is suggested that hair may be included in the composite to reduce the overall cost of the composite, considering the exorbitant cost of silk.

P.Ramesh, J.Ayyamperum, et al., [7] silk & flax fiber reinforced epoxy composites were prepared and the mechanical properties of these composites are evaluated. The composite samples with different fiber weight ratio were prepared by using the compression molding process with 1500 psi pressure at 800c temperature. The samples were subjected to the mechanical testing such as tensile, flexural and impact loading. The fiber & resin ratio 40:60 having more tensile strength, flexural strength and impact strength. This hybrid composite having good flexural strength. The impact strength is better when it compared with other natural fiber composite materials.

U.S.Bongarde, V.D.Shinde, [8] they focused on the progress of natural fiber reinforced composites. Industries are in constant search of new materials to lower costs and profit margins. Due to the challenges of petroleum based products and the need to find renewable resources. Natural fibers have cost and energy advantages over traditional reinforcing fibers such glass and carbon. The combination of different natural fibers found to give better mechanical and physical properties. Several limitations must be overcome in order to exploit the full potential of natural fibers. At first proper fiber surface treatment should be developed and implemented. Secondly properties of composites are greatly depended on the volume percentages of fibers and resin. The quality at fiber matrix interface should be improved.

Zeng-xiaoCai, Xiu-mei Mo [9] determined the Chitosan, a naturally occurring polysaccharide with abundant resources, has been extensively exploited for various biomedical applications, typically as wound dressings owing to its unique biocompatibility, good biodegradability and excellent antibacterial properties. In this work, composite nanofibrous membranes of chitosan (CS) and silk fibroin (SF) were successfully fabricated by electro spinning. The morphology of electro spun blend nanofibers was observed by scanning electron microscopy (SEM) and the fiber diameters decreased with the increasing percentage of chitosan. Further, the mechanical test illustrated that the addition of silk fibroin enhanced the mechanical properties of CS/SF nanofibers. The antibacterial activities against Escherichia coli (Gram negative) and Staphylococcus aureus (Gram positive) were evaluated by the turbidity measurement method; and results suggest that the antibacterial effect of composite nanofibers varied on the type of bacteria.

SudeepDeshpande, T Rangaswamy [10] he determined the "Effect of Fillers on E-Glass/Jute Fibre Reinforced Epoxy Composites". Investigation was carried out on E-glass fiber/jute fiber reinforced epoxy composites filled with varying concentrations of bone and coconut shell powder. The results it was found that the mechanical properties of the composites increased with the increase in filler content. Composites filled with 15% volume coconut shell powder exhibited maximum flexural strength; inter laminar shear strength (ILSS), tensile modulus and hardness. Maximum impact strength was achieved by addition of filler (15% Vol.) of bone powder.

Lawrence J Fernandes1, Vinay B U [11] he investigated "Shellfish shell as a Bio-filler: Preparation, characterization and its effect on the mechanical properties on glass fiber reinforced polymer matrix composites" Shellfish shell (SS) filler was introduced on glass fiber reinforced polymer matrix composites. The different volume percentage of SS filler in polymer such as 0%, 5%, 10% and 15% are used. The conclusions drawn from the present work are, the maximum tensile strength and maximum flexural strength is obtained for 10% Vol. of SSp among all the different volume percentage. Composite filled by 15% Vol. of SSp exhibited maximum hardness number, this may be due to uniform dispersion and decrease in inter particle distance with increasing particle loading in the matrix results in increase of resistance to indentation.

Suhas Y. Nayak, Srinivas Shenoy H [12], he investigate by "use of egg shell particulate as fillers in e-glass/epoxy composites" Results of tests showed drop in tensile strength while tensile modulus and impact strength increased with inclusion of egg shell fillers.

C. Venkateshwar Reddy 1, R.Ramnarayanan2 [13] , he conducted experimental "study on effect of filler (sio_2) on mechanical properties of glass/epoxy composite" the composite with 10 % of sio_2 filler has shown the improved properties than the composite without filler, further increase of filler material decreases hardness, flexural strength and flexural modulus and inter laminar shear strength.

Wasim Akram, Sachin Kumar Chaturvedi [14], he conducted experimental "Comparative Study of Mechanical Properties of E-Glass/Epoxy Composite Materials with Al_2O_3, $CaCo_3$, SiO_2 AND PBO Fillers" The results of various mechanical characterization tests are reported here. It is evident from the results Lead Oxide (PbO) as a filler material added in resign and Fiber composites (52% Resin + 13% PbO + 35% Fiber) has a better mechanical tensile properties as compared to others, Silica Oxide (SiO_2) as a filler material added in resign and Fiber composites (52% Resin + 13% SiO_2 + 35% Fiber) has a better mechanical torsion properties and hardness properties as compared to others, resin and fiber composite without filler (65% + 35% Fiber) has a better mechanical energy absorbed properties as compared to others.

2.1 The Main Objectives of the Project Work

1. To prepare the glass fiber reinforced polymer (GFRP) composite laminates filled with varying concentration of additive materials by hand lay-up technique.
2. To investigate the mechanical properties of S-glass ane E-glass fibre composites like tensile strength, bending test and hardness test of GFRP composite laminates.

3. Analysis and discussion of various test methods and approaches in evaluating and characterizing the mechanical and thermal properties of composites for design and analysis needs.

III. MATERIAL SELECTION AND METHODOLOGY

3.1 Introduction

The purpose of this chapter is to provide the information about material selection and methodology involved the glass fiber reinforced composites filled with various filler materials. This chapter outlines the reason behind selection of specific reinforcing material and matrix material along with the fibers.

3.2 Fiber Material

Generally, fiber is the reinforcing phase of a composite material. The present investigation employs E-glass and S-glass as artificial in the epoxy matrix to fabricate a series of glass fiber composites.

3.3 Glass Fiber

Glass fibers are most commonly used fibers. They come in two forms: Continuous fibers & Discontinuous or “staple” fibers. Chemically, glass is silicon-di-oxide (SiO2). Glass fibers used for structural applications come in two “flavours”: E-Glass, and S-Glass. E-glass is produced in much larger volumes. Glass fibers are coated with chemicals to enhance their adhesion properties. These chemicals are known as “coupling agents”. Many of coupling agents are silane compounds. For producing continuous fibers, molten glass passes through multiple holes to form fibers. These fibers are quenched through a light spray of water. Subsequently, fibers are coated with protective and lubricating agents. Staple fibers are produced by pushing high pressure air-jet across fibers, as they emanate from holes during the drawing process. These fibers, are subsequently collected, sprayed with a binder, and collected into bundles known as “slivers”. These slivers may subsequently be drawn and twisted into yarns.

During production, glass fibers are treated chemically. These treatments are known as sizes. There are two types of sizes: Temporary and Compatible.

- Temporary sizes are used to reduce degradation of fiber strength attributable to abrasion of fibers due to inter-fiber friction during fiber drawing process. They are also used to bind fibers for easy handling. They are made from starch-oils (starch, Gelatin, polyvinyl alcohol, etc.). These sizes inhibit good resin-fiber adhesion. They also promote moisture absorption.
- During composite fabrication, these sizes are removed by heating the fibers at 340 C for 15-20 hours. Post their removal, these fibers are coated with coupling agents (also known as finishes), which promote resin-fiber adhesion. These agents also inhibit deteriorating effects of humidity on the fiber-resin bond. Many of these agents are organo-functional silanes.

Figure 1: E-glass

Figure 2: S-glass

Principal advantages

- Low cost
- High strength

Limitations

- Poor abrasion resistance causing reduced usable strength
- Poor adhesion to specific polymer matrix materials
- Poor adhesion in humid environments

Table 1: Composition and Properties of Glass Fiber

Important Properties of Glass Fibers		
Property	E-Glass	S-Glass
Specific gravity	2.54	2.49
Tensile strength (MPa)	3450	4590
Tensile modulus (GPa)	72	86
Diameter range (microns)	3 to 20	8 to 13
CTE (per million per C)	5	2.9

Typical Chemical Composition of E & S Glass in %		
SiO_2	54.3	64.2
Al_2O_3	15.2	24.8
CaO	17.2	0.01
B_2O_3	8.0	0.01
MgO	4.7	10.3
Na_2O	0.6	0.27
BaO		0.2.0
FeO		0.21
Others		0.03

IV. MATRIX MATERIAL

4.1 Epoxy

Epoxy resins are the most commonly used resins. It is the most popular Polymer composite matrix (PMC). More than 2/3rd of polymer matrix used in aerospace applications is epoxy based. The main reasons for epoxy being the most used polymer matrix material are high strength, low viscosity and low flow rates, which allow good wetting of fibers and prevent misalignment fiber during processing, available in more than 20 grades to meet specific property and producing requirements.

Commercially, epoxies are available as “two-part” system, as well “one part” system. While the “two-part” epoxies require mixing of hardener and resin, “one-part” systems come are essentially pre-mixed systems (of hardener and resin). Typically, one-part systems have to be stored at low temperatures, so that curing process gets significantly slowed down, and the epoxy does not get cured while being stored.

Figure 3: Epoxy Resin L12

Table 2: Properties of E-glass Fiber and Epoxy

Properties	E-glass	Epoxy
Specific gravity	2.54	1.28
Young’s modulus	70 GPa	3.792 GPa
Ultimate tensile strength	3447 MPa	82.74 MPa
Coefficient of thermal expansion	5.04 µm/m/^{0}c	-

4.2 Fillers

Fillers are ingredients added to enhance the properties such as strength, surface texture, and ultraviolet absorption of a polymer and to enhance the flame retardancy and lower the cost of polymers. For this investigation filler materials are: **Polypropylene.**

Polypropylene (PP), also known as polypropylene, is a thermoplastic polymer used in a wide variety of application including packaging

Figure 4: Polypropylene

and labeling, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, transvaginal mesh and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids. Polypropylene has a relatively slippery "low energy surface" that means that many common glues will not form adequate joints. Joining of polypropylene is often done using welding processes.

Table 3: Properties of Polypropylene

Property	Unit	Value
Density	g/cm^3	0.91-0.94
Tensile strength	Psi (Pound/sq. in.)	3200-5000
Water absorption, 24hr	%	0.01
Elongation	%	3-700
Softening point, T_g	°C	140-150
Melting point, T_m	°C	160-166
Thermal expansion	10-5 in./in. °C	5.8-10
Specific volume	cm^3/Ib	30.4-30.8

The density of PP is between 0.895 and 0.92 g/cm³. Therefore, PP is the commodity plastic with the lowest density. With lower density, moldings parts with lower weight and more parts of a certain mass of plastic can be produced. Unlike polyethylene, crystalline and amorphous regions differ only slightly in their density. However, the density of polyethylene can significantly change with fillers. The Young's modulus of PP is between 1300 and 1800 N/mm².Polypropylene is normally tough and flexible, especially when copolymerized with ethylene. This allows polypropylene to be used as an engineering plastic, competing with materials such as acrylonitrile butadiene styrene (ABS). Polypropylene is reasonably economical. Polypropylene has good resistance to fatigue.

4.3 Hardeners

Hardeners are substances which are added to polymers for aiding in curing of composites. Approximately 10% of hardener is added while fabricating the composite materials. An agent which does not enter into the reaction is known as a catalytic hardener or catalyst. A reactive curing agent or hardener is generally used in much greater amounts than a catalyst, and actually enters into the reaction. Hardener is a curing agent for epoxy resin. Epoxy resins require a hardener to initiate curing. It is also called the catalyst, the substance that hardens the adhesive when mixed with resin. It is the specific selection and combination of the epoxy and hardener components that determine the final characteristics and suitability of the epoxy coating for a given environment. Hardener is usually classed as a corrosive, and as an irritant when in contact with the skin or by inhalation. We are using K-6 hardener. Its viscosity at 25℃ is less than 10 Pa-s. It is generally has low vapor pressure.

Figure 5: Hardener

V. FABRICATION METHOD

5.1 Hand layup technique

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after Perspex sheet.

Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release Gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied.

After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The schematic of hand lay-up is shown in figure 5.1. The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Stacking was made in the order ***1S-1E-2S-2E-1P-3S-3E-2P-4S-4E-3P-5S-5E-4P-6S-6E-5P-7S-7E-8E-8S for set A* and**

1S-1E-1P-2S-2P-2E-3P-3S-4P-3E-5P-6P-4S-7P-4E-8P-5S-9P-5E-10P-6E-6S for set B.

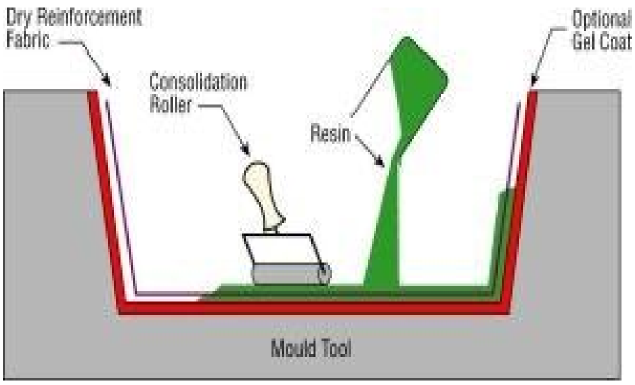


Figure 6: Schematic Representation of Hand Lay Up Technique

Figure 7: Fabricating By Hand Lay Up Technique

5.2 Fabrication Procedure

The E-glass-Polypropylene/Epoxy based composites filled with varying concentrations were powered. The volume fraction of fiber, epoxy and filler materials were determined by considering the density, specific gravity and mass. The required ingredients of resins, hardener and fillers are mixed thoroughly in a basin and the mixture is subsequently stirred constantly. The glass fiber positioned manually. Mixture so made is brushed uniformly, over the glass plies and polypropylene plies. Entrapped air is removed manually with squeezes or rollers to complete the laminates structure and the composite is cured at room temperature.

Table 4: Designation and detailed composition of the composites

Material Designation	% of glass fiber(Volume)	% of epoxy (Volume)	% of Filler materials(Volume)
GFE	50	50	Nil
GFE_1	50	45	5
GFE_2	50	40	10
GFE_3	50	35	15

5.3 Specimen Preparation

The prepared composites laminates were taken out from the mould and specimens of suitable dimension were prepared from the laminates of mechanical and thermo-mechanical tests according to ASTM standards. The test specimens were cut by composite laminates by diamond tip cutter and different tool in the workshop. Three identical test specimens were prepared for different tests.

Table 5: ASTM Standards

Test	ASTM Standards
Tensile	ASTM-D3039
Impact Resistance	ASTM-E23
Brinell hardness test	ASTM-E10-00a

VI. EXPERIMENTATION

6.1 Introduction

This chapter describes the details of processing of the GFR composites and the experimental procedures followed for their Mechanical evaluation. Tensile, Bending were carried out using universal testing machine and hardness test on hardness testing machine. Three identical samples were tested for bending strength, tensile strength and hardness test.

6.2 The Fabricated Specimens Were Tested for

Mechanical properties:

The mechanical properties of the composite materials depends upon the strength and modulus of the fibers, the strength and chemical stability of the matrix, the bonding of filler material, the fiber matrix interaction and the fiber length.

- Tensile strength
- Bending strength
- Rockwell hardness

6.2.1 Ultimate Tensile strength

The tensile strength and failure of the composites was measured at room temperature in accordance with ASTM D3039. The test was carried out using universal testing machine. The sample is loaded at a constant rate and the stress applied is recorded. ASTM D3039 states that this test method is intended for tensile testing of fiber-reinforced thermosetting laminates. This test method can be used for testing materials of any thickness up to 14mm. The standard dimensions of the specimens are 250mm x 25mm x 2.5mm.

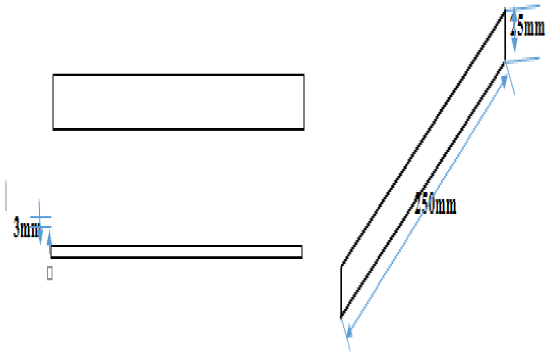


Figure 7: Tensile Test Specimen

Figure 8: Computerized Universal Testing Machine

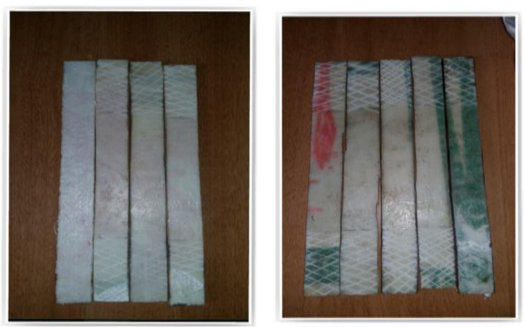


Figure 9: Specimen Tensile Tested for Set 1 and Set 2

6.2.2 Charpy Impact Test

Impact tests are designed to measure the resistance of failure of a material to a suddenly applied force. The Impact strength was measured in accordance with ASTM E23. The test specimens were made according to the ASTM standards. The dimensions of the specimens are 55mm x 10mm x 10mm size on one side surface of the specimen a V-notch has been made at an angle of 45^0 with root depth of 2mm. Standard Charpy-Impact test is defined by ASTM E23. To apply Charpy- Impact loading to a specific component, we choose the SI-1C3 Pendulum Impact Tester.

$$\text{Impact resistance (K)} = \frac{\text{Avg energy observed}}{\text{area ofc/sofbelow notch}} \ldots \text{N-M/mm}^2$$

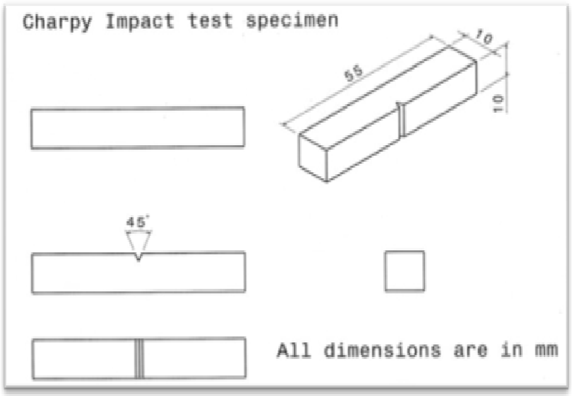


Figure 10: Impact Test Specimen

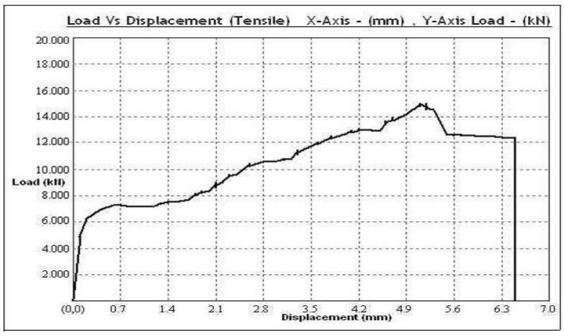
Figure 11: Impact Testing Machine

VII. RESULTS AND DISCUSSION

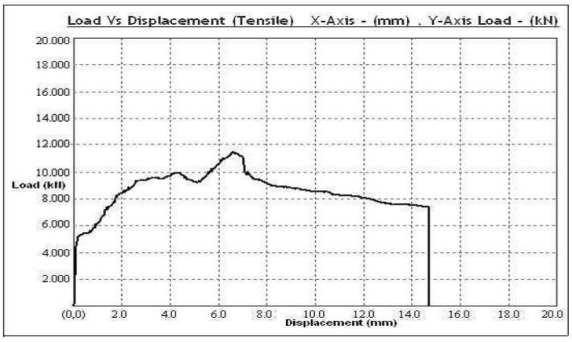
Presents the physical and mechanical properties of the composites under study and includes the erosion characteristics of glass-epoxy composites (with and without different particulate fillers. It establishes the validation of the proposed theoretical model through experimentation and studies the effect of the fillers on the erosion behavior of the composites.

7.1 Mechanical Properties of GFR Composites

7.2.1 Tensile Strength



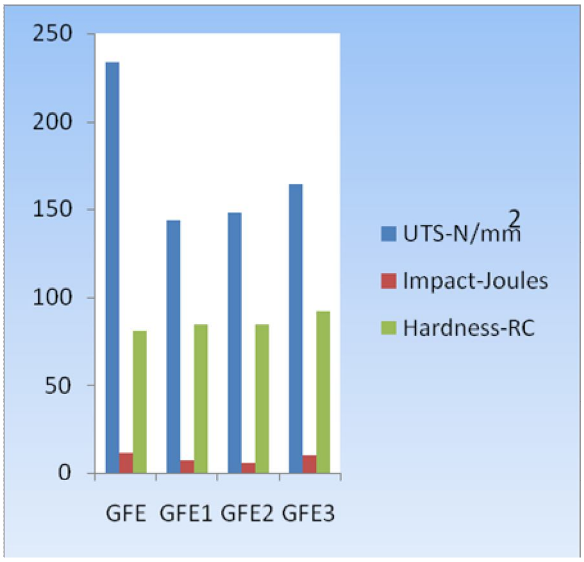
Graph 1: Load Vs Displacement for Set 1



Graph 2: Load Vs Displacement for Set 2

Table 6. UTS, Impact and Hardness of Composite material at atmospheric temperature

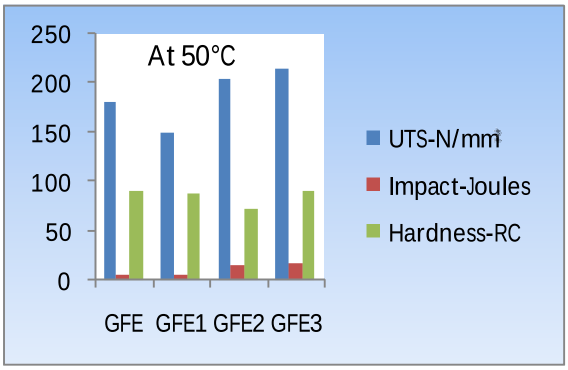
Composites	UTS	Impact	Hardness
GFE	233.6	11	81
GFE1	144	7	84
GFE2	148.2	6	84
GFE3	164	10	92



Graph 3: Comparison of UTS, Impact and Hardness of Composite material at atmospheric temperature

Table 7.UTS, Impact and Hardness of Composite material at 50°C.

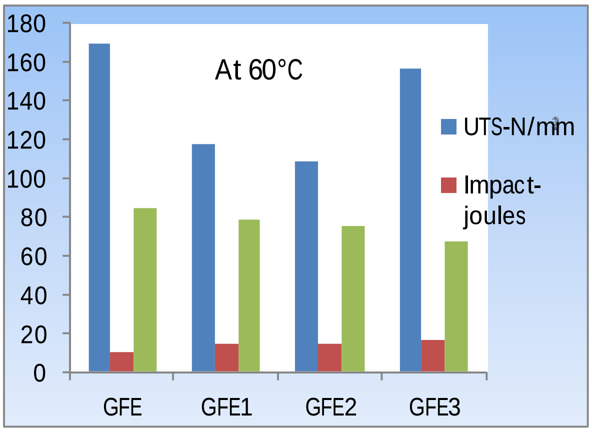
Composites	UTS	Impact	Hardness
GFE	181.6	6	90
GFE1	150.4	6	89
GFE2	205.6	16	72
GFE3	215.2	18	90



Graph 4: Comparison of UTS, Impact and Hardness of Composite material at 50°C temperature

Table 8. UTS, Impact and Hardness of Composite material at 60°C.

Composites	UTS	Impact	Hardness
GFE	169.6	10	84
GFE1	117.6	14	78
GFE2	108	14	75
GFE3	156.8	16	67



Graph 5: Comparison of UTS, Impact and Hardness of Composite material at 60°C temperature

VIII. CONCLUSION

The trial ponder on the impact of fiber and filler stacking on mechanical conduct of GPE composites prompts the accompanying conclusion: The introduce examination uncovers that fiber and filler stacking altogether impact on the diverse properties of composites. The test result uncovers that the composite GPE1 and GPE2 indicate better elasticity properties. The hardness of the composites expanded with increment in filler stacking.

It has been watched that the ILSS of the composite increments with the expansion in filler stacking. These increments in properties of the concentrated material could make this relevant in parts of Automobiles like Dashboards, Seat bases, Front and back guards, flying machines inside framing and furniture.

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