Effect of Fillers on Mechanical Properties of E-Glass/Jute Fiber Epoxy Composites

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Abstract— **In this research work, mechanical behavior of E-glass/Jute fiber reinforced epoxy composites filled with varying concentration of aluminium oxide (Al2O3) and Graphite powder 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.) and (15% Vol.) Al2O3 exhibited maximum ultimate tensile strength and the of composites filled by (15% Vol.) Al2O3 exhibited maximum flexural strength.**

***Keywords—** Composites, Fillers, Mechanical, Properties, Strength)*

I. INTRODUCTION

Composite materials are new generation materials developed to meet the demands of rapid growth of technological changes of the industry. Composite materials or composites are engineering materials made from two or more constituents materials that remain separate and distinct on macroscopic level while forming a single component. It consists of short and soft collagen fibers embedded in a mineral matrix called apatite. A composite material is defined as a structural material created synthetically or artificially by combining two or more materials having dissimilar characteristic. One constituent is called matrix phase and other is called reinforcing phase. Reinforcing phase is embedded in the matrix to give desired characteristic.

Now-a-days, in the field of composite materials all the researchers showing interest in using the waste material as a filler material. All shows interest in developing the new natural fiber instead of traditional fibers because of their low cost, combustibility, lightweight, low density, high specific strength, renewability, non-abrasivity, non-toxicity, low cost and biodegradability. Still yet many challenges to overcome in order to become largely used as reliable engineering materials for structural elements. However, their use is steadily also increasing, and many large industrial corporations are planning to use, or have yet commencing to use, these materials in their products. Natural fibers are renewable and biodegradable material and are largely available in the nature in worldwide. Pineapple leaf, oil palm fiber Hemp, sisal, jute, kapok, jute, rice husk, bamboo and wood are the fibers most commonly used as reinforcing natural fibers in polymer matrix. Filler materials are used to reduce the material costs, to improve mechanical properties to some extent and in some cases to improve process ability. Besides, it also increases properties like abrasion resistance, hardness and reduce shrinkage. Adding of ceramic micro fillers into the continuous material drastically increases the wear resistance and the properties also chancing vary rapidly due to the varying of the filler percentage.

Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. Natural fillers and fibers reinforced thermoplastic composite have successfully proven their high qualities in various fields of technical application. As replacements for conventional synthetic fibers like aramid and glass fibers are increasingly used for reinforcement in the thermoplastic due to their low density, good thermal insulation and mechanical properties, reduced tool wear, unlimited availability, low price, and problem free disposal. Composite materials have successfully substituted the traditional materials in several light weight and high strength applications. The reasons why composites are selected for such applications are mainly their high strength-to weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness. Typically, in a composite, the reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated correctly it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material. The strength of the composites depends primarily on the amount, arrangement and type of fiber and /or particle reinforcement in the resin.

II. EXPERIMENTATION AND METHODOLOGY

Two types of Fiber materials are used for reinforcing of epoxy filled composites in the ratio of volume of jute and Glass Fiber and rest volume is Epoxy and fillers.

GLASS FIBER

Glass Fiber is a material consisting of numerous extremely fine Fibers of glass. Glass Fiber in its various forms has been the most common reinforcement for polymer matrices. It forms a very strong and light Fiber reinforced polymer (**FRP**) composite material called Glass reinforced plastic (**GRP**). Glass Fiber has roughly comparable properties to other Fibers such as polymers and carbon Fiber. Although not as strong or as rigid as carbon Fiber, It is much cheaper

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and significantly less brittle. A variety of different chemical compositions is commercially available.

The types of Glass Fiber available are

1. A-glass
2. C-glass
3. E-glass
4. AE-glass

For this work E- Glass (7 mill) selected as reinforcement material.

JUTE FIBER

Jute is a long, soft, shiny vegetable Fiber that can be spun into coarse, strong threads. Jute is replaced by synthetic materials in many of these uses, some uses take advantage of jute's biodegradable nature, where synthetics would be unsuitable. It is also strong, durable, colour and light fast Fiber.

MATRIX MATERIAL (EPOXY)

Unsaturated polyester, **resin L-12 (3202)**, manufactured by Atul LTD is used as matrix material. **Epoxy** resins are most commonly used resins. It is the most popular polymer composite matrix (PCM). 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.

FILLERS

Fillers are ingredients added to enhance the properties such as strength, surface texture, hardness and to enhance wear properties and lower the cost of polymers.

Aluminium oxide is an amphoteric oxide with the chemical formula Al_2o_3.Aluminium oxide particles is a ceramic powder commonly used filler. It is commonly referred to as Alumina, or in its crystalline form, as well as many other names, reflecting its widespread occurrence in nature and industry. Its most significant use in the production of aluminium metal, although it is also used as abrasive due to its hardness and as a refractory material due to its high melting point . Low reactivity and low cost make this reinforcement very attractive that require moderate strength, and stiffness improvement while retaining good wear resistance.

Granite powder, a by-product obtained during the sizing of granite stones by processing granite slabs has no end use. In the present study, granite powder is used as the reinforcement to the matrix system to prepare composites.

Granite powder is always massive, hard and tough so it has gained widespread use. It is the by-product material generated by cutting and shaping of building stones in stone cutting plants. The water used for cooling up the cutting saw flows out carrying very fine suspended particles as high viscous liquid known as stone slurry. The stone slurry was oven dried, ground and sieved. The average density of stone powder is between 2.65 and 2075g/cm^3, its compressive strength usually lies above 200MPa, and its viscosity near STP is 3-6×10^{19} pa-s. Melting temperature is 1215-1260^{0}c.

2.1 FABRICATION OF COMPOSITES

The E-glass-Jute/Epoxy based composites filled with varying concentrations (0, 10 and 15 Vol %) of aluminium oxide (Al_2O_3), sieved stone powder were prepared. The volume fraction of Fiber, epoxy and filler materials were determined by considering the density, specific gravity and mass. The required ingredients of resin, 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 Jute plies. Entrapped air is removed manually with squeezes or rollers to complete the laminates structure and the composite is cured at room temperature.

Hybrid laminates of woven jute and glass mat were prepared by hand lay-up technique. For quick and easy removal of the composite sheet a mould release sheet was put over the glass plate. Mould release spray (Biolene) was also applied at the inner surface of the mould wall after it was set on the glass plate. Stacking was made in the order of 11G+1J+9G+1J+9G+1J+9G+1J+9G+1J+11G for 10mm thickness specimen and 5G+1J+5G+1J+5G for 3mm thickness specimen. Jute and glass fabrics were pre-impregnated with the matrix material consisting of epoxy resin and hardener in the ratio of 10:1. Care was taken to avoid formation of air bubbles during pouring. Pressure was then applied from the top and the mould was allowed to cure at room temperature for 72 hrs. During the application of pressure some polymer squeezes out from the mould. For this, care has already been taken during pouring. After 72 hrs the samples were taken out of the mould, after curing the laminate was cut into required size of erosion and other mechanical tests by Zig-zag cutter machine.

Table 2.1 Designation and detailed composition of the composites

DESIGNATION	COMPOSITION
GJE	Jute Fiber(10%)+Glass Fiber(40%)+Epoxy(50%)+ Filler(0%)
GJEA1	Jute Fiber(10%)+Glass Fiber(40%)+Epoxy(50%)+ Al_2o_3 Filler(10%)
GJEA2	Jute Fiber(10%)+Glass Fiber(40%)+Epoxy(50%)+ Al_2o_3 Filler(15%)
GJEG1	Jute Fiber(10%)+Glass Fiber(40%)+Epoxy(50%)+ Granite powder Filler(10%)
GJEG2	Jute Fiber(10%)+Glass Fiber(40%)+Epoxy(50%)+ Granite powder Filler(15%)

SPECIMEN PREPARATION

The prepared slabs of the composite materials were taken from the mould and then specimens were prepared from composite slabs for different mechanical tests according to ASTM standards as shown in table 2.2. The test specimens were cut by laminate by using Zig-Zag board cutter machine. Three identical test specimens were prepared for different tests.

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Table 2.2 Test Standards

TEST	ASTM STANDARD
Tensile	ASTM-D3039
Flexural	ASTM-D790M
Impact Resistance	ASTM-E23
Brinell Hardness Test	ASTM-E10-00a

EXPERIMENTATION

Introduction

This chapter describes the details of processing of the HFR composites and the experimental procedures followed for their Mechanical properties evaluation. Tensile, Flexural, impact and hardness tests were carried out using Universal testing machine, impact machine and hardness testing machine respectively. Three identical samples were tested for tensile strength, Flexural, impact strength and hardness.

Density

Density is also a major factor influencing the selection of a material for any application. Density is defined as the mass per unit volume. It is observed that the composite density values are calculated theoretically from weight fractions by Eq. (1) are not equal to the experimentally measured values [4]. This difference is due to the presence of voids and pores in the composites. The observation shows that more voids are found in the composites with the addition of Fiber as well as filler material.

$$\rho c_t = \frac{1}{\left(\frac{Wf}{\rho f}\right) + \left(\frac{Wm}{\rho m}\right) + \left(\frac{wp}{\rho p}\right)} \quad \text{.......... (1)}$$

Where,

W and ρ represent the weight fraction and density correspondingly. The suffix f, m and ct stand on behalf of the fiber, matrix and the composite materials respectively. The composites under this investigation consists of three components namely matrix, fiber and particulate filler and the suffix 'p' indicates the particulate filler materials.

The actual density (ρce) of the composite can be obtained experimentally by simple water immersion technique. The volume fraction percentage of voids (Vv) in the composites is calculated by the following equation (2):

$$Vv = (\rho ct - \rho ce)/\rho ct \quad \text{--------- (2)}$$

Table 2.3 Density and void content of different composites

Designation	Theoretical Density	Measured Density	Void fraction
GJE	1.6183	1.5621	3.472780078
GJE A1	1.5363	1.4816	3.560502506
GJE A2	1.4984	1.3884	7.341163908
GJE G1	1.7315	1.4358	17.07767831
GJE G2	1.7942	1.5093	15.87894326

MECHANICAL PROPERTY TESTING

Tensile, bending, impact and hardness tests were carried out using Universal testing machine, impact machine and hardness testing machine respectively. Three identical samples were tested for tensile strength, bending, impact strength and hardness.

The tensile behavior of prepared samples was determined at room temperature using Universal testing machine in accordance with ASTM D3039. Test specimens having dimension of length 250 mm, width of 25 mm and thickness of 2.5 mm. The specimen was loaded between two manually adjustable grips of a 60 KN computerized universal testing machine (UTM) with an electronic extensometer. Each test was repeated thrice and the average value was taken to calculate the tensile strength of the composites. Details of Universal Testing Machine Make- Micro Control Systems Model- MCS-UTE60 Software-MCSUTE STDW2KXP System uses add-on cards for data acquisition with high precision and fast analog to digital converter for pressure/Load cell processing and rotary encoder with 0.1 or 0.01 mm for measuring cross head displacement (RAM stroke). These cards are fitted on to slots provided on PC's motherboard WINDOW9X based software is designed to fulfill nearly all the testing requirements. MCS make electronic extensometer is used with a extremely accurate strain sensor for measuring the strain of the tensile samples.

Fig 2.1 Computerized UTM

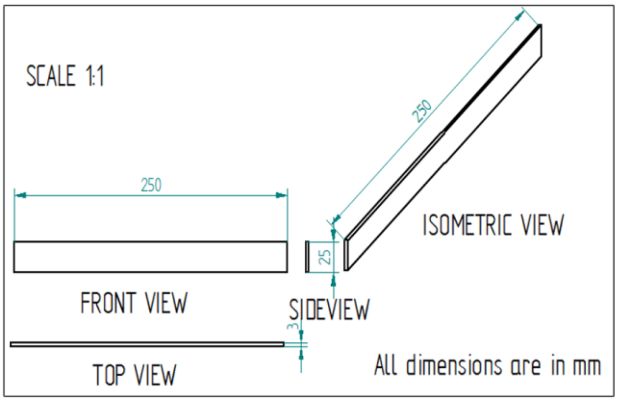

Fig 2.2 Tensile test specimen

IMPACT STRENGTH

The charpy impact strength of composites was tested using a standard impact machine as per ASTM E23 standard. The standard test specimen 55mm long 10 x 10mm2 cross section, having 45o V-notch and 2mm deep (Fig 2.3) were used for the test. Each test was repeated thrice and the average values were taken for calculating the impact strength.

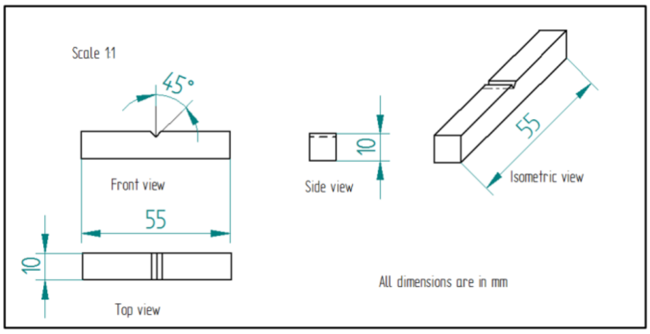

Fig 2.3 Impact test specimen

FLEXURAL STRENGTH

Flexural strength is determined by 3-point bend test. The test specimen of dimension 130 mm × 25mm×3.2 mm were used for test. This test method determines the flexural properties of fiber reinforced polymer composites. Flexural strength is calculated by the following equation (3) from the standard ASTM D 790

$\sigma f=3FL/2bt^2$------------------- (3)

Where
σf = Stress in the outer fibers at midpoint (MPa)
F = Load at a given point on the load-deflection curve (N)
L = Support span, (mm)
b = Width of beam tested, (mm)
t = Depth of beam tested, (mm)

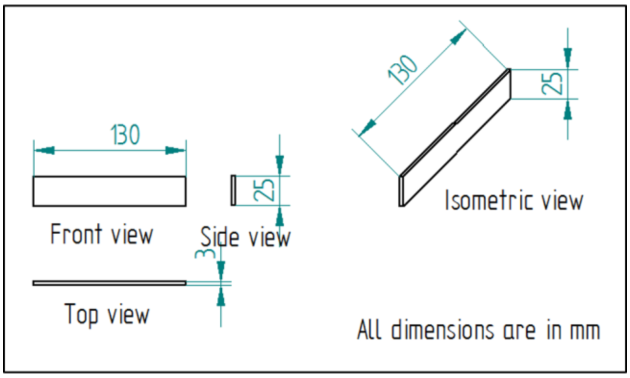

Fig 2.4 Flexural test specimen

BRINELL HARDNESS TEST

Brinell hardness test was conducted on the specimen using a standard Brinell hardness tester. A load of 250 kg was applied on the specimen for 30 sec using 5mm diameter hard metal ball indenter and the indentation diameter was measured using a microscope. The hardness was measured at three different locations of the specimen and the average value was calculated. The indentation was measured and hardness was calculated using equation (4).

$$BHN = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$ ---------(4)

Where
P = Applied force (kgf)
D = Diameter of indenter (mm)
d = Diameter of indentation (mm)

III. RESULTS AND DISCUSSION

The ultimate tensile strength, impact strength, flexural strength and Brinell hardness number for different composition of composite materials are presented in tables 3.1 and their variations shown in figures 5 to 8 respectively.

Table 3.1 Tensile Strength

HFR Composites	Ultimate Tensile Strength (MPa)
GJE	176
GJEA1	261.6
GJEA1	258.4
GJEG1	184.8
GJEG2	178.4

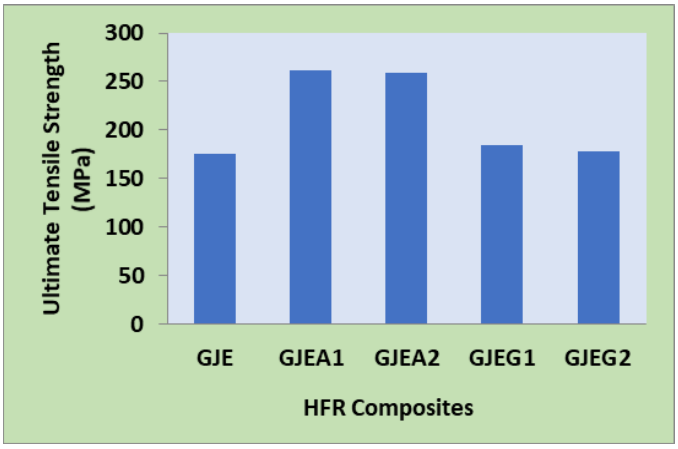

Fig. 3.1 Effect of fillers on Tensile Strength

Fig. 3.2 Tested Specimen of Tensile Strength

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The variation in tensile strength of HFR composites as shown in fig.3.1 We observed that the tensile strength of all composite materials having higher values when compared with unfilled one (GJE).The increase in the tensile strength may be due to the restriction of the mobility and deformability of the matrix with the introduction of mechanical restraint, and the filler particle size [4]. But tensile strength decreases with increase in filler content from (10%vol) to (15%vol).This decrease in strength may be due to the presence of pores at the interface between the filler particles and the matrix and the interfacial adhesion may be too weak to transfer the tensile stress. A maximum tensile strength is observed in GJEA1 than the other composite materials.

FLEXURAL STRENGTH

The variation in flexural strength of HFR composite material as shown in table 3.2 from the fig 3.3 it is noted that the increased in flexural strength as increase in wt% of filler content. It was assumed that the space between the filler particles was filled with the blend matrix, thus minimizing the presence of voids and bubbles and leading consequently to an increase in both strength and modulus [4]. From the fig 3.3 we observed that GSEA1 composite material having more flexural strength as compared to remaining materials.

Table 3.2 Flexural strength

HFR Composites	Flexural Strength
GJE	520
GJEA1	680
GJEA2	760
GJEG1	560
GJEG2	640

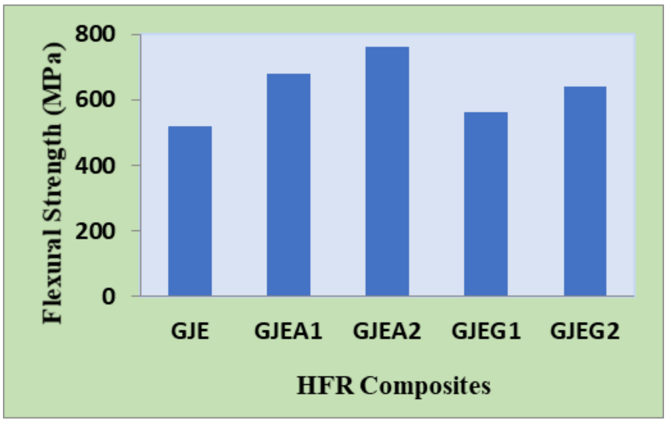

Fig. 3.3 Effect of fillers on Flexural Test

Fig. 3.4 Tested Specimens of Flexural Strength

IMPACT STRENGTH

From the fig.3.5 we observed that the increased in impact strength as increased in filler content because the particles restrain the crack growth through the composite material and it is dislocation, the crack will change its shape and direction, thus the cracks will transfer to micro cracks. This change in the cracks behavior and loss the crack energy lead to increase in the impact strength [3]. The maximum impact strength is observed in GJEG2 as compared to other materials.

Table 3.3 Impact strength

HFR Composites	Charpy Impact Strength(J/mm^2)
GJE	0.1929
GJEA1	0.2923
GJEA2	0.3133
GJEG1	0.3067
GJEG2	0.3375

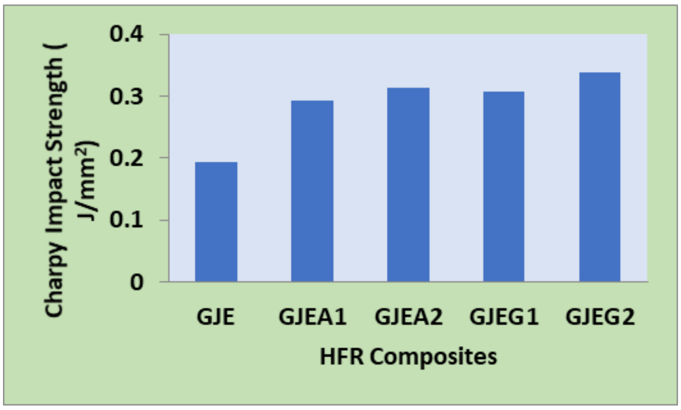

Fig. 3.5 Effect of fillers on Charpy Impact Test

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Fig. 3.6 Tested Specimen of Impact Strength

HARDNESS TEST

Hardness numbers of all the composites are presented in the table 3.4

Table 3.4 Comparison of the Brinnell hardness number

HFR Composites	Brinnel Hardness Number(BHN)
GJE	55.25
GJEA1	34.85
GJEA2	68.39
GJEG1	28.95
GJEG2	41.75

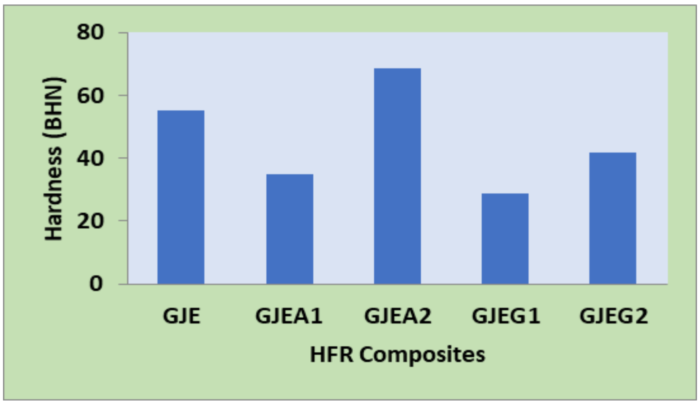

Fig. 3.6 Effect of fillers on Hardness Test

The experimental results indicated that GJEA2 composite material exhibited maximum hardness number (68.39BHN) this due to uniform dispersion of Al_2O_3 particles and decrease in inter particle distance with increasing particle loading in the matrix results in increase of resistance to indentation. From the obtained results it is observed that increase in addition of Al_2O_3 increases the hardness of the composites [1].

CONCLUSIONS:

The experimental study on the effect of fiber and filler loading on mechanical behavior of GJE, Aluminium oxide and Granite filled GJE composites leads to the following conclusions:

1. The present investigation reveals that fiber and filler loading significantly effect on the different properties of composites.
2. The void content of composites increased with increase in fiber and filler loading. The composite GJEA1 shows minimum void content as compare to Granite filled composite material.
3. The experimental result reveals that the composite GJEA1 and GJEA2 shows better tensile strength properties.
4. The flexural strength of composites increases with increase in filler loading. GJEA2 having maximum bending strength.
5. The impact strength of composite material increases with increase in filler loading. GJEA2 and GJEG2 shows nearer values.
6. The hardness of the composites increased with the increase in filler loading. It has been observed that composite GJEA2 exhibits maximum hardness value.
7. The tensile modulus of composite increase with the increase in filler loading. GJEG2 composite shows maximum tensile modulus as compared to other materials.
8. It has also been observed that the ILSS of the composite increases with the increase in filler loading.

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