AL_2O_3 AND GRANITE POWDER FILLED E-GLASS/JUTE FIBER REINFORCED EPOXY COMPOSITES

Sudeep Deshpande*

T Rangaswamy**

K Devendra***

Abstract

The present work involves fabrication and mechanical property evaluation of Hybrid Fiber Reinforced Epoxy (HFRP) Laminates made of E-Glass/Jute fiber and epoxy resin filled with varying concentration of Al_2O_3 and granite powder. The property evaluation involves tensile strength, flexural strength, tensile modulus, inter laminar shear stress, impact strength and hardness. The obtained test results show that fiber and filler loading significantly effect on the different properties of laminates.

Key words: E-Glass/Jute fiber, Epoxy, Fillers, HFRP Laminates, Mechanical Properties

* Asst. Professor, Dept of Mech. Engg., SKSVMACET, Laxmeshwar, KA, India

** Professor, Dept of Mech. Engg., GEC, Hassan, KA, India

*** Professor, Dept of Mech. Engg., SKSVMACET, Laxmeshwar, KA, India

1. Introduction

In the field of composite materials all the researchers showing interest in using the waste material as a filler material. Natural fibers play an important role in developing high performing fully biodegradable 'green' composites which could solve environmental problems [1-3]. Now a day's natural fiber find a major role in place of traditional fibers because of their low cost, combustibility, lightweight, low density, high specific strength, renewability, non-abrasives, non-toxicity, low cost and biodegradability. 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 [4-9]. Filler materials are used to reduce the material costs, to improve mechanical properties to some extent and in some cases to improve process ability. Filler materials also increases properties like abrasion resistance, hardness and reduce shrinkage. Mechanical properties of hybrid glass/jute fiber reinforced epoxy composites are greatly influenced by the fiber lengths and these laminates find applications in the aerospace, naval industry [10], Automobiles like, dash boards, seat bases, front and rear bumpers, aircraft interior paneling and furniture [11]. The study was focused on the preparation of E-glass and jute fiber reinforced epoxy composite laminates filled with varying concentrations of Al_2O_3 and Granite powder and mechanical properties were evaluated.

2. Experimentation

2.1 Materials

HFRP laminates were made from E-glass fiber (7 mill), jute fiber and epoxy as a resin (L-12). Aluminium oxide (Al_2O_3) and granite powder were used as filler materials. Fabrication was done at room temperature by hand layup technique and laminates were cured at room temperature. The proper volume fraction of fiber, epoxy, fillers and orientation of fibers were controlled [16].

2.2 Fabrication of HFRP laminates

HFRP laminates were prepared by hand lay-up technique [15]. The laminates are prepared with constant 40 Vol. % of E-glass fiber and 10 Vol. % of jute fiber as shown in table 1. Stacking was made in the order of 11G+1J+9G+1J+9G+1J+9G+1J+9G+1J+11G for 10mm thickness laminate and 5G+1J+5G+1J+5G for 3mm thickness laminate. HFRP laminates filled with varying concentrations (10 and 15 Vol. %) of aluminium oxide (Al_2O_3) and granite powder.

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 were mixed thoroughly in a basin and the mixture was subsequently stirred constantly. The glass fiber and jute fiber positioned manually. Mixture so made was brushed uniformly, over the glass plies and jute plies. Entrapped air was removed manually with squeezes or rollers to complete the laminates structure and the composite was cured at room temperature. After 48 hrs the laminates were taken out from the mould and specimens are prepared.

Table 1: List of HFRP Laminates.

HFRP Laminates	Epoxy (% Volume)	Filler Materials (% Volume)
GJE	50	Nil
GJEA1	40	10% Al_2O_3
GJEA2	35	15% Al_2O_3
GJEG1	40	10% Granite Powder
GJEG2	35	15% Granite Powder

2.3 Specimen preparation

The prepared HFRP laminates were taken from the mould and then specimens were prepared for mechanical tests according to ASTM standards as shown in Table 2. The test specimens were cut by using Zigzag board cutter machine. Three identical test specimens were prepared for different tests.

Table 2: ASTM Standards.

Test	ASTM Standards
Tensile	ASTM-D3039
Flexural	ASTM-D790
Impact Resistance	ASTM-E23
Brinell hardness test	ASTM-E10-00a
Inter Laminar Shear Strength	ASTM-D 2344-84

2.4 Mechanical properties

2.4.1 Ultimate tensile strength

The tensile behavior of prepared samples was determined at room temperature using Universal testing machine**.** The tensile test was carried out according to ASTM-D 3039. The specimen dimensions was 250 mm x 25 mm x 3 mm and load was applied on both the ends.

Details of Universal testing machine: 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).

2.4.2 Flexural test

The flexural test was carried out according to ASTM-D 790. The specimen dimension was 130 mm x 25 mm x 3 mm with a support span length of 100 mm. The flexural test was performed using a three point bending for the laminates.

$$\sigma f = \frac{3PL}{2bh^2} \qquad (1)$$

where, σ_f - Stress in the outer fibers at midpoint (MPa), P - Load at a given point on the load deflection curve (N), L -Support span (mm), b - Width of beam (mm), h - Depth of beam (mm).

2.4.3 Charpy impact strength

The dimensions of Charpy impact strength test specimens were 55mm x 10mm x 10mm, one side surface of the specimen a V-notch has been made at angle of 45^o with root depth of 2mm.

2.4.4 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 2.5 mm 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 (2).

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

where, BHN - Brinell hardness number, P - Applied force (kgf), D - Diameter of indenter (mm), d - Diameter of indentation (mm)

2.4.5 Inter laminar shear strength (ILSS)

The short beam shear (SBS) test was performed on the laminate samples at room temperature to evaluate the value of inter-laminar shear strength (ILSS) [15]. The ILSS values were calculated by equation (3).

$$ILSS = \frac{3F}{4bt} \quad (3)$$

where, ILSS - Inter laminar shear strength, F - Maximum load, b - Width of specimen, t - Thickness of specimen.

3. Results and Discussion

The Ultimate tensile strength, flexural strength, Brinell hardness number, Charpy impact strength, inter laminar shear stress (ILSS), tensile modulus for different filler content of HFRP laminates are presented in Tables 3 and their variations shown in the Figure 1, 3, 5-8 respectively.

Table 3: Mechanical Properties of HFRP Laminates

HFRP Laminates	Ultimate Tensile Strength (MPa)	Flexural Strength (MPa)	Brinell Hardness Number (BHN)	Charpy Impact Strength (J/mm^2)	Interlaminar Shear Stress (MPa)	Tensile Modulus (GPa)
GJE	176	780	55.25	0.1929	7.8	4.221
GJEA1	261.6	1140	34.85	0.2923	9	4.329
GJEA2	258.4	1020	68.39	0.3133	11.4	4.468

GJEG1	184.8	840	28.95	0.3067	8.4	5.317
GJEG2	178.4	960	41.75	0.3375	9.6	5.576

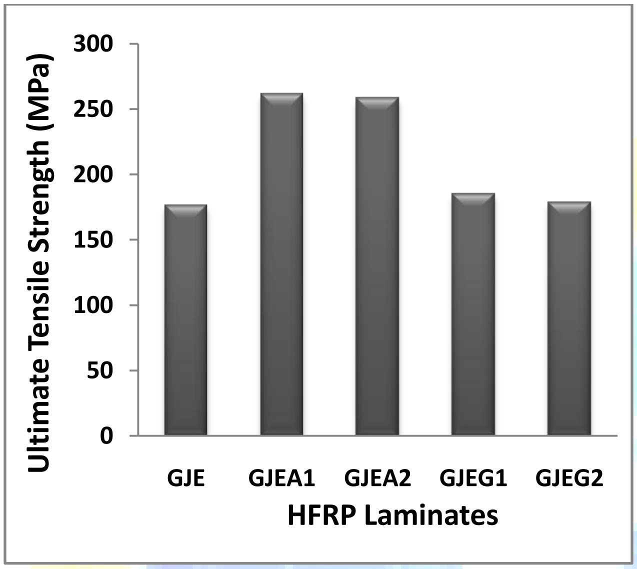

Figure 1: Ultimate tensile strength (MPa)

Figure 2: Ultimate tensile strength tested specimens

3.1 Ultimate tensile strength

Figure 1 indicates that the tensile strength of all laminates having higher values when compared with unfilled laminate (GJE). The increase in the tensile strength of HFRP laminates 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. But tensile strength of HFRP laminates decreases with increase in adding of 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 weak to transfer the tensile stress. A maximum tensile strength was observed in GJEA1 when compared with the other HFRP laminates, due to good bonding strength between matrix and filler material.

3.2 Flexural strength

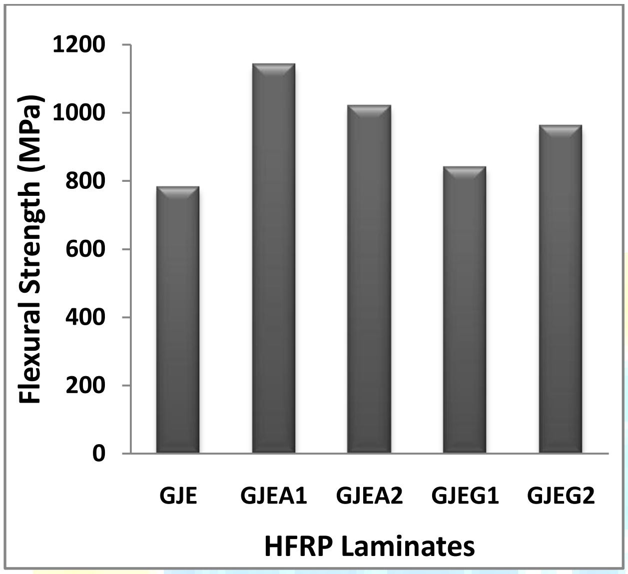

Figure 3: Flexural strength (MPa)

Figure 4: Flexural strength tested specimens

Figure 3 indicates that the flexural strength of HFRP laminates increases by increasing the addition of filler content. The space between the granite powder particles was filled with the blend matrix, thus minimizing the presence of voids and bubbles and leading consequently to an increase in strength. Due to the more compatibility between fibers, matrix and filler materials GSEA1 laminate having higher flexural strength as compared with other HFRP laminates.

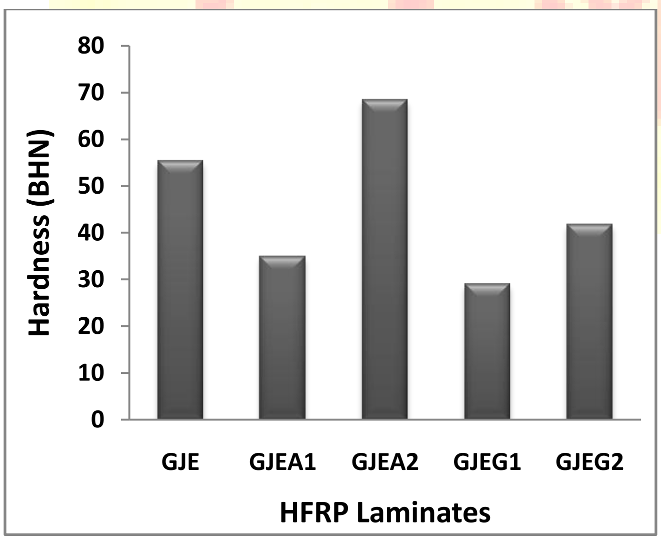

Figure 5: Hardness (BHN)

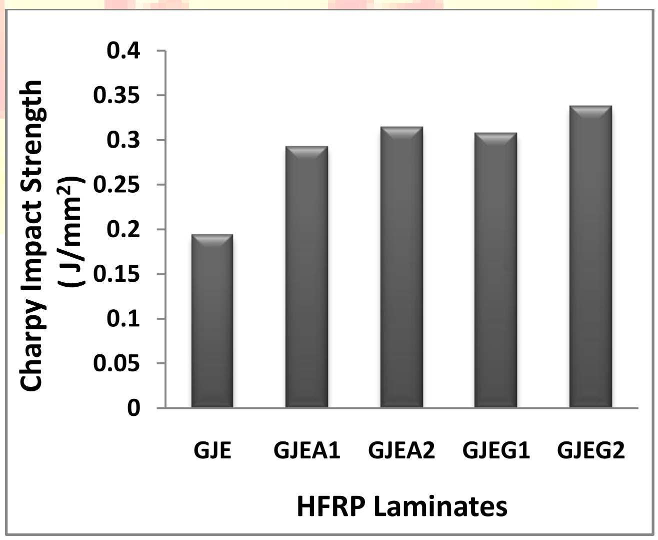

Figure 6: Charpy impact strength (J/mm^2)

3.3 Brinell hardness number

The experimental results shown in Figure 5 indicated that GJEA2 laminate exhibited maximum hardness number 68.31BHN due to uniform dispersion of Al_2O_3 particles. Resistance to indentation increases by increasing the addition of filler content [12]. But hardness of GJEG1 and GJEA1 decreased because of porosity and weak bond strength between the matrix and reinforcements.

3.4 Charpy impact strength

Figure 6 shows that the impact strength of HFRP laminates increases with increasing the addition of filler content because the particles restrain the crack growth through the laminates and its dislocation, the crack will change its shape and direction, thus the cracks will transfer as micro cracks. This change in the cracks behavior and decrease in the crack energy lead to increase in the impact strength [14]. The maximum impact strength was observed in GJEG2 as compared to other laminates due to reduce in inter particle distance of filler particles and void formation.

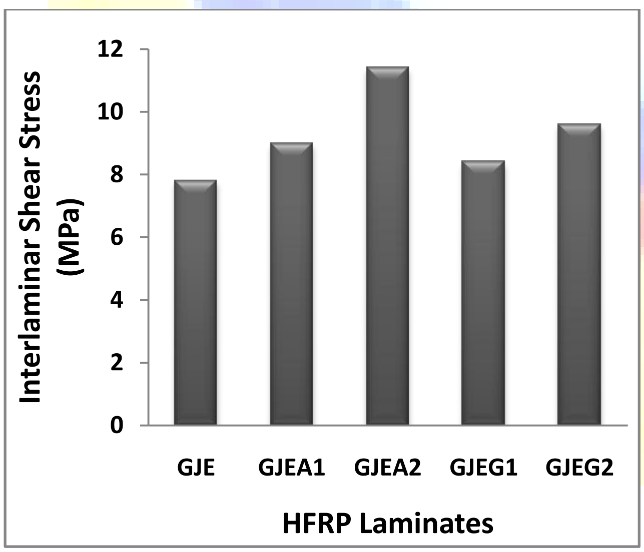

Figure 7: Inter Laminar shear strength (MPa)

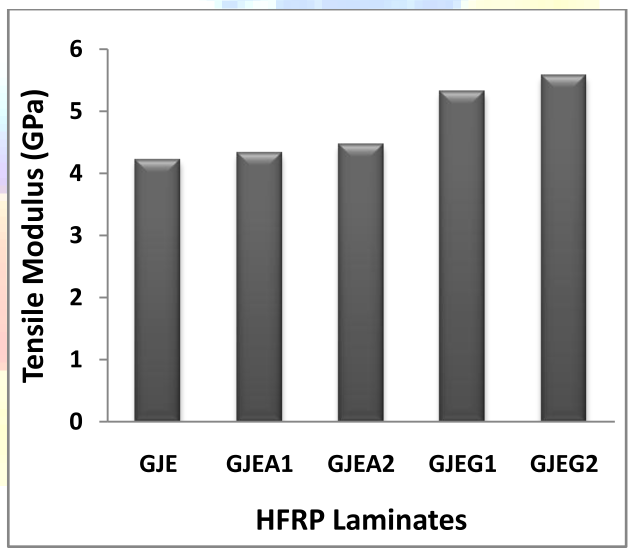

Figure 8: Tensile modulus (GPa)

3.5 Inter laminar shear stress (ILSS)

Figure 7 indicates that GJE laminate exhibited lower inter laminar shear stress value of 7.8MPa. Addition of filler particles to the HFRP laminates increases the ILSS. Inter laminar shear strength depends primarily on the matrix properties and fiber–matrix interfacial strength rather than the fiber properties. ILSS can be improved by increasing the matrix tensile strength and matrix volume fraction. The maximum value of ILSS for GJEA2 is 11.4MPa due to higher tensile strength of epoxy and better adhesion of epoxy with glass fibers and filler material.

3.6 Tensile modulus

Figure 8 indicates that GJEG2 laminate having a maximum tensile modulus [13]. The tensile modulus increased with increase in filler content because the increase in the tensile modulus 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. The fibers in the laminate restrain the deformation of the polymer matrix, reducing the tensile strain. During tensile loading partially separated micro spaces are created which obstruct stress propagation between the fibers and matrix.

4. Conclusions

The test results on the effect of fiber and filler loading on mechanical properties of HFRP laminates leads to the following conclusions

- The present investigation reveals that fiber and filler loading significantly effect on the different properties of laminates.
- The flexural strength, hardness, tensile modulus and ILSS of laminates increase with increase in filler loading. GJEA2 having maximum flexural strength, hardness and ILSS value. GJEG2 laminate shows maximum tensile modulus.
- The experimental result reveals that the laminate GJEA1 and GJEA2 shows better tensile strength properties.
- The impact strength of GJEA2 and GJEG2 laminates shows nearer values and higher than the GJE laminate.

References

[1] Joshi et al., 2004, Are natural fiber composites environmentally superior to glass fiber reinforced composites, Composites Part A, 35, pp 371–376.

[2] Gulbarga and Burli, 2013, State of art, low investment, in house and manual preparation of injection moldable bio-composite granules, Int J Sci Res, 3(8), pp 1-6.

[3] Kasama and Nitinat, 2009, Effect of glass fiber hybridization on properties of sisal fiber–polypropylene composites, Composite Part B, 40, pp 623-627.

[4] Alok et al., 2013, Study of mechanical properties and absorption behavior of coconut shell powder epoxy composites, Int J Material Sci App, 2(5), pp 157-161.

[5] Girisha et al., 2012, Tensile properties of natural fiber reinforced epoxy hybrid composites, Int J Modern Engg Res, 2(2), pp 471-474.

[6] Naveen and Yasaswi, 2013, Experimental analysis of coir-fiber reinforced polymer composite materials, Int J Mech Engg Rob Res, 2(1), pp 10-18.

[7] Swain and Biswas, 2014, Physical and mechanical behavior of Al_2O_3 filled jute fiber reinforced epoxy composites, Int J Current Engg Tech, 2, pp 67-71.

[8] Sudhabindu, 2014, Static analysis and experimentation of jute fiber reinforced with E-glass, Int J of Innov Res Adv Engg, 1(1), pp 1-3.

[9] Mishra, 2013, Strength and corrosion testing of jute/ glass- epoxy hybrid composite laminates, Plastic and Polymer Tech, 2(2), pp 48-54.

[10] Muthuvel et al., 2013, Characterization Study of Jute and Glass Fiber Reinforced Hybrid Composite Material, Int J Engg Res Tech, 2(4), pp 335-344.

[11] Ravishankar et al., 2013, Experimental investigation and analysis of mechanical properties of injection molded jute and glass fibers reinforced hybrid polypropylene composites, Int J Mech Engg Tech, 4(4), pp 197-206.

[12] Devendra and Rangaswamy, 2012, Determination of mechanical properties of $Al2O_3$, Mg $(OH)_2$ and Sic filled e-glass/ epoxy composites, Int J Engg Res App, 2(5), pp 2028-2033.

[13] Aseel Kareem, 2013, Mechanical properties of granite powder as a filler for polycarbonate toughened epoxy resin, Int J Pharma Sci, 3(4), pp 254-257.

[14] Ranganatha and Ramamurthy, 2013, Investigation on mechanical behavior of filler Al_20_3 in CFRP composites, Int J Advanced Engg Tech, 4(3), pp 105-107.

[15] Sabeel Ahmeda and S Vijayarangan, 2008, Tensile flexural and interlaminar shear properties of woven jute and jute-glass fabric reinforced polyester composites, J Material Processing Tech, 207, pp 330 - 335.

[16] Soma Dalbehera and Acharya, 2014, Study on mechanical properties of natural fiber reinforced woven jute-glass hybrid epoxy composites, Advances in Polymer Sci Tech, 4(1), pp 1-6.