Characterization Study Of Jute And Glass Fiber Reinforced Hybrid Composite Material

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Abstract

The aim of the present work was to investigate the hybridization of glass fibers with natural fibers for applications in the aerospace and naval industry. Mechanical properties such as tensile, impact and flexural test of hybrid glass/jute fiber reinforced epoxy composites in the forms of lamina and laminates were determined. The lamina prepared with natural fiber mat showed lower mechanical properties compared to laminas with glass mat. For this reason we proposed to use a hybrid design for the various applications which makes use of glass woven fabrics and jute fiber mats. The adoption of this design allowed for a cost reduction of 20% and a weight saving of 23% compared to the current commercial solution. Laminates were fabricated by hand lay-up technique in a mold and cured under light pressure for 1h, followed by curing at room temperature for 48 h. All the laminates were made with a total of 10 plies, by varying the number and position of glass layers so as to obtain six different stacking sequences. One group of all jute laminate was also fabricated for comparison purpose. Total fiber weight fraction was maintained at 42%. Specimen preparation and testing was carried out as per ASTM standards.

Keywords: Hybrid composite, Mechanical properties, hand lay-up.

1. Introduction

Natural fibers exhibit many advantageous properties as reinforcement for composites. They are low-density materials, yielding relatively light weight composite with high specificproperties (Dweib et al., 2004; Rana et al., 2003). Natural fibers also offer significant cost advantages and benefits associated with processing, as compared to synthetic fibers such as glass, nylon, carbon, etc. However, mechanical properties of natural fiber composites are much lower than those of synthetic fiber composites. Another disadvantage of natural fiber compositeswhich makes them less attractive is the poor resistance to moisture absorption (Lackey et al., 2004). Hence use of natural fiber alone in polymer matrix is in adequate in satisfactorily tackling all the technical needs of a fiber reinforced composite. In an effort to develop a superior, but economical composite, a natural fiber can be combined with a synthetic fiber in the same matrix material so as to take the best advantage of the properties of both the fibers. This results in a hybrid composite.Pavithran et al. (1991a,b) evaluated the enhancement in theproperties of coir-polyester composites by incorporating glass as intimate mix with coir. Mohan and Kishore (Kishore, 1985,1983) reported that jute provided a reasonable core material in jute-glass hybrid laminates. They evaluated flexural properties (Kishore, 1985) and compressive properties (Kishore, 1983)of the jute-glass reinforced epoxy laminates fabricated by filament winding technique using flat mandrel. Four different hybrid combinations were studied with different glass fiber volume fractions and the results were compared with jute reinforced plastic. They found substantial increase in flexural and compressive properties with hybridization. Pavithran et al. (1991a,b) determined the work of fracture by impact testing on sisal–glass hybrid composites with two arrangements, one with sisal shell and glass core and the other with glass shell and sisal core. They showed that the sisal shell laminate had the higher work of fracture compared with glass shell hybrid laminates of equivalent volume fraction of sisal and glass fibers. Mishra et al. (2003) studied the effect of glass fiber addition on tensile and flexural strength and izode impact strength of pine apple leaf fiber (PALF) and sisal fiber reinforced polyester composites. K. John et al. have studied the unsaturated polyester based sisal glass composites with 5% and 8% volume fraction and found a considerable enhancement in impact, compression, flexural and tensile properties. In this paper, effect of hybridization of glass and layering sequence effect on tensile, flexural and interlaminar shear properties of woven jute-glass fiber hybrid composites is studied.

The use of fiber composites based on glass fibers is wide spread in the industry when low cost and good performances are needed. Among the different applications one of particular interest is that for pipe systems of chemical plants. The advantages of replacing metal pipes with composites pipes are lower weight, increased resistance to aggressive fluid, easiness to build complex shapes[1]. The advantage of the easy building of complex shapes, at low production numbers, is related to the possibility to build on demand using cheap techniques such as hand lay-up. Currently glass fibers only are used as reinforcement for these applications.The use of natural fibers as reinforcements for composite is attracting interest for a wide range of industries. Natural fiber mats are used in the automotive sector in interior and exterior components[2,3]. Among natural fibers for composites the bast fibers, extracted from the stems of plants such as jute, kenaf, flax, ramie and hemp are widely accepted as the best candidates due to their very good mechanical properties. Hemp was shown to have very promising tensile properties for applications where mechanical propertiesare a requisite [4–7]. Natural fibers are lighter and cheaper than glass fibers [4]. However, one drawback is their lower mechanical properties compared to glass fibers. Currently most studies on natural fibers are concerned on the fundamental understanding of their behavior as reinforcement for composites. The focus is on the study of the mechanical properties,the interface between fiber and matrix, the chemical modification of the fiber surface and the composite processing. In all these studies the composites manufactured contains only natural fibers as reinforcement. However, very few studies exist on the use of hybrid solutions with lay-up containing both glass and natural fibers [8–11]. None of these studies are focused the use of hemp fibers. The aim of the present work was to study the hybridization of glass mats by natural fiber mats in a typical fitting used in the pipeline of a chemical plant. The fitting consisted of a curved pipe with flanges at both ends and with a nominal diameter of 100 mm. The study was conducted at first performing mechanical analysis oneach single ply lamina and then designing, on the basis of the results of the mechanical results, a novel lay-up for the fitting. Mechanical test for the lamina with the final lay-up were also performed. The curved pipe designed was also tested under pressure to simulate the real in-use conditions. Mechanical tests of the laminas after exposure to acid solutions were also performed. The costreduction of the proposed design was investigated. Some natural fibers alternatives to hemp were also evaluated.

2. Materials and Methods

2.1 Fiber Preparation

The trend in studies of glass fiber composites in recent years has been towards developing materials with high physical and mechanical characteristics. Attention has also been concentrated on the creation of heat-resistant composites. Aluminized glass fiber composites present potential advantages, namely the improvement of thermal and electrical conduction, and impact and fatigue properties. Until now this innovative material has only been used in military applications. Therefore, its advantages must be experimentally confirmed by mechanical and physical properties characterization in order to make possible comparisons with the more common glass fiber composites and to explore possible civil applications. Glass fibers currently used in composites production have relatively high-strength and high modulus. Some types of glass fibers have high heat resistance or particular dielectric characteristics. Epoxy resin are widely used in the production of glass fiber composites due to their wetting power and adhesion to glass fiber, low setting shrinkage, considerable cohesion strength and adequate dielectric characteristics[1]. Glass fiber composites based on epoxy resin belong to the composites group for which maximum long-term strengths can be achieved. This fact determines their application in critical structures even at elevated temperatures. The endurance limit of epoxy-based composites is also very high.

Glass fibers are made of silicon oxide with addition of small amounts of other oxides. Glass fibers are characteristic for their high strength, good temperature and corrosion resistance and low price. There are two main types of glass fibers: E-glass and S-glass. The first type is the most used, and takes its name from its good electrical properties. The second type is very strong (S-glass), stiff, and temperature resistant. Used as reinforcing materials in many sectors, e.g. automotive and naval industries, sports equipments, etc. They are produced by a spinning process, in which they are pulled out through a nozzle from molten glass (thousands of meter/min).

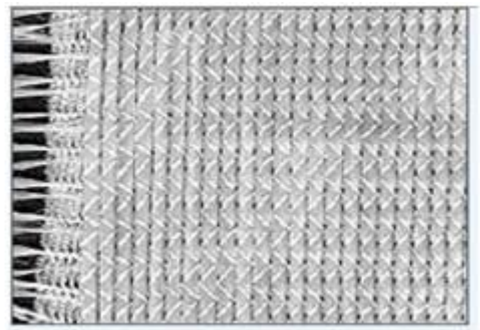

Fig 1 Glass Fiber

2.2 Properties of Glass Fibers

Table 1 Properties of Glass Fibers

Property	Glass Fiber
Density (gms./cc)	2.55
Elongation at break (%)	4.8
Tensile strength (Mpa)	2000
Young's modulus (Gpa)	80

2.3 Selection of chopped fiber:

Chopped fibers are short-length fiber materials, with typical fiber lengths of 3mm to 25mm, depending upon the exact specification. When mixed with a polymer, glass fibers offer increased mechanical reinforcement and an increase in modulus. Glass fibers are both electrically and thermally conductive, and polymers containing short glass fibers can be customized for resistivity - from anti-static, through static dissipative to conductive. Chopped fibers offer higher structural and conductive properties than those of shorter milled fibers. The unsized fibers are compatible with most thermo set and thermoplastic matrix systems.

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Fig 2 Chopped Fiber

2.4 Selection of Jute Fiber:

Jute fiber is obtained from two herbaceous annual plants, white Corchoruscapsularis (white jute) originating from Asia and Corchorusolitorius (Tossa jute) originating from Africa. Next to cotton, it is the second most common natural fibre, cultivated in the world and extensively grown in Bangladesh, China, India, Indonesia, Brazil. The jute plant (Fig. 3) grows six to ten feet in height and has no branches. The stem of the jute plant is covered with thick bark, which contains the fibers. In two or three month time, the plants grow up and then are cut, tied up in bundles and kept under water for several days for fermentation. Thus, the stems rot and the fibers from the bark become loose. Then the cultivators pull off the fibers from the bark, wash very carefully and dry them in the sun.

Fig 3 Harvest of jute plant

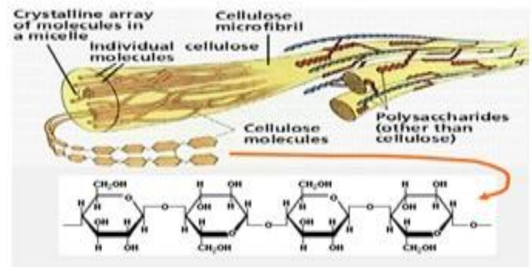

Fig 4 Structure of Cellulose as it occurs in a Plant Cell Wall

Jute is multi celled in structure (Fig. 3.3). The cell wall of a fibre is made up of a number of layers: the so-called primary wall (the first layer deposited during cell development) and the secondary wall (S), which again is made up of the three layers (S1, S2 and S3). As in all lingo cellulosic fibers, these layers mainly contain cellulose, hemi cellulose and lignin in varying amounts. The individual fibers are bonded together by a lignin-rich region known as the middle lamella. Cellulose attains highest concentration in the S2 layer (about 50%) and lignin is most concentrated in the middle lamella (about 90%) which, in principle, is free of cellulose. The S2 layer is usually by far the thickest layer and dominates the properties of the fibers. Cellulose, a primary component of the fibre, is a linear condensation polymer consisting of Danhydro - glucopyranose units joined together by ß-1, 4-glucosidic bonds. The long chains of cellulose are linked together in bundles called micro-fibrils (Fig. 4).

Table 2 Chemical Composition

Substances	Weight Percent (%)
Cellulose	61-71.5
Hemicellulose	13.6-20.4
Pectin	0.2
Lignin	12-13
Moisture content	12.6
Wax	0.5

Hemicelluloses are also found in all plant fibers. Hemicelluloses are polysaccharides bonded together in relatively short, branching chains. They are intimately associated with the cellulose micro fibrils, embedding the cellulose in a matrix. Hemicelluloses are very hydrophilic and have lower molecular masses than both cellulose and lignin. The degree of polymerization (DP) is about 50 – 200. The two main types of hemicelluloses are xylans and glucomannans. Lignin is a randomly branched polyphenol, made up of phenyl propane (C9) units. It is the most complex polymer among naturally occurring high-molecular-weight materials with an amorphous structure. Of the three main constituents in fibers, lignin is expected to be the one with least affinity for water. Another important feature of lignin is that it is thermoplastic (i.e., at temperatures around 90°C it starts to soften and at temperatures around 170°C it starts to flow). The structure of the jute fibre is influenced by climatic conditions, age and the fermentation process, which influence also the chemical composition (Table 2).

Fig 5 Jute fiber obtained from stem of Jute plant

The jute fibre possesses moderately high specific strength and stiffness. Therefore, it is suitable as reinforcement in a polymeric resin matrix. However, it exhibits considerable variation in diameter along with the length of individual filaments. The properties of the fibre depend on factors such as size, maturity and processing methods adopted for the extraction of the fibre. Properties such as density, electrical resistivity, ultimate tensile strength and initial modulus are related to the internal structure and chemical composition of fibre.

2.5 Selection of resin and hardner:

Epoxy or poly-epoxide is a thermosetting polymer formed from reaction of an epoxide “resin” with polyamine “hardener”. Epoxy has a wide range of applications, including fiber-reinforced plastic materials and general purpose adhesives.

2.6 Properties of Resin

The choice of a resin system for use in any component depends on a number of its characteristics, with the following probably being the most important for most composite structures:

1. Adhesive Properties
2. Mechanical Properties
3. Micro-Cracking resistance
4. Fatigue Resistance

2.7 Functions of Epoxy Resins

The curing process is a chemical reaction in which the epoxide groups in epoxy resin reacts with a curing agent (hardener) to form a highly crosslinked, three-dimensional network. In order to convert epoxy resins into a hard, infusible, and rigid material, it is necessary to cure the resin with hardener. Epoxy resins cure quickly and easily at practically any temperature from 5-150^{o}C depending on the choice of curing agent.

2.8 Epoxy and hardener

A wide variety of curing agent for epoxy resins is available depending on the process and properties required. The commonly used curing agents for epoxies include amines, polyamides, phenolic resins, anhydrides, isocyanates and polymercaptans. The cure kinetics and the T_g of cured system are dependent on the molecular structure of the hardener. The choice of resin and hardeners depends on the application, the process selected, and the properties desired. The stoichiometry of the epoxy-hardener system also affects the properties of the cured material. Employing different types and amounts of hardener which, tend to control cross-link density vary the structure.

Table 3 Typical composition of jute fiber

Property	Epoxy Resin
Appearance	Pale yellow colour
Viscosity(cps) at 25˚C	10000
Density(gms/cc)	1.15-1.20
Elongation at break (%)	0.8
Tensile strength(Mpa)	85
Young’s modulus(Mpa)	968

3. Methodology

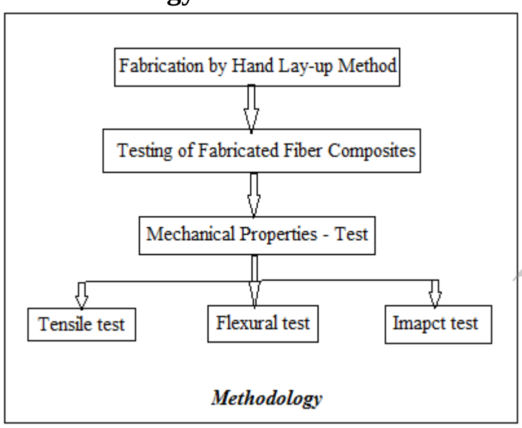

Fig 6 Methodology

4. Fabrication of composite Materials

This chapter deals with the fabrication stages carried out to obtain the composite material. The materials used in our fabrication process are

1. Fiber reinforcement material (say glass fiber 600 g.s-m)
2. Matrix (Epoxy LY 556 and Hardener HY 951)
3. OHB sheet
4. Wax
5. Acetone
6. Roller
7. Gloves

4.1 COMPOSITIONS OF FIBER REINFORCED POLYMER COMPOSITE

Fabrications of polymer composites are compositions with various fiber lengths. The compositions of polymer composites are given in the Table 4.

Table 4 Designation of Composites

COMPOSITES	FIBER DIAMETER	COMPOSITIONS			
		Fiber wt (%)			Resin wt (%)
		Glass	Jute	Chopped	
C1	0.5cm	10	10	10	70
C2	1cm	10	10	10	70
C3	2cm	10	10	10	70
C4	3cm	10	10	10	70

4.2 STAGES IN HAND-LAY-UP METHOD

1.First, cut the fiber mats into 300 x 300 x 3 mm size.

2.Then, prepare the matrix by mixing of Epoxy LY556 and Hardener in the ratio of 1:10.

3.Then, three OHB sheets be placed in the floor and apply the wax in the sheets.

4.Then, apply the mixed matrix on the OHB sheets.

5.Then keep the fibre mat as a first layer and roller be rolled properly on the mat.

6.Again apply the mixed matrix on the first layer of fiber and rolled properly.

7.Then second layer of fiber mats kept above the first layer and apply mixed matrix and again rolled properly.

8.Similarly the consecutive layer can be formed up to required thickness..

9.Then the laminates are allowed for curing in atmospheric condition for 2 days.

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Fig 7 Glass Fiber Mat

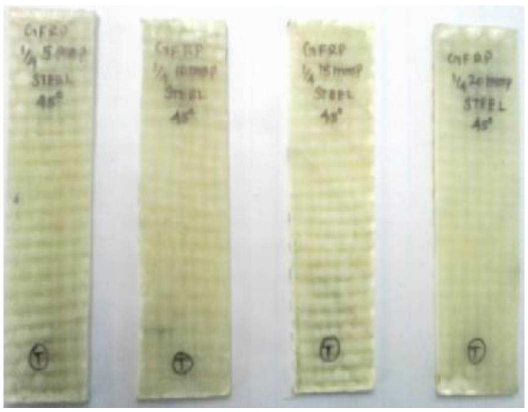

Fig 8 Fabricated Specimen

1. Mechanical property testing:

The following mechanical properties of the composites were determined during the course of present investigation.

Tensile Strength
Flexural Strength
Impact Strength

5.1 Tensile Test

Tensile test was carried out by applying tensile load. Tensile test was carried out by using Universal Testing Machine. The figure 4.4 shows the tensile test specimen. The figure 4.5 shows the Universal Testing Machine (UTM-100). This machine can be used to apply a maximum load of 40KN and this machine is interfaced with a computer and results are obtained in graphs. The specimen size is 24cm X 3cm X 0.3cm.

5.2 Tensile Test Results

Tensile test had been carried out using UTM for a specimen having dimension of 24cm length, 3cm width and 0.3cm thickness. The various parameters determined as follows

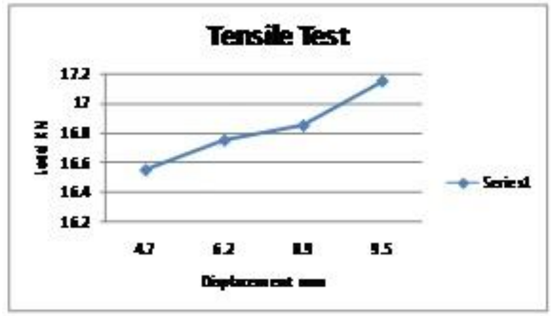

Fig 9 Load Vs Displacement on Tensile Test

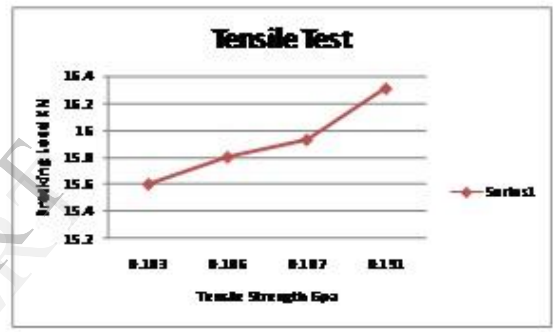

Fig 10 Breaking Load Vs Tensile Strength

5.3 FLEXURE TEST

Flexure test is done by applying a point load at centre of composite material. It is also carried out by using Universal Testing Machine. The specimen size is 24cm X 3cm X 0.3cm. Flexure test was carried out using UTM for a specimen having dimension of 24cm length, 3cm width, 0.3cm thickness and the various parameters determined as follows

Table 5 Comparison of Flexural Test Results

Composites designation	Experimental Parameters					
	Peak load in KN	Disp at Fmax in mm	Breaking load in KN	Max Disp in mm	Area in sq.mm	Ultimate stress in GPa (Flexural strength)
C1	14.550	13.40	14.45	24.60	90	0.162
C2	14.700	14.50	14.50	29.10	90	0.163
C3	14.900	21.40	14.55	23.20	90	0.166
C4	15.20	22.50	14.60	21.50	90	0.168

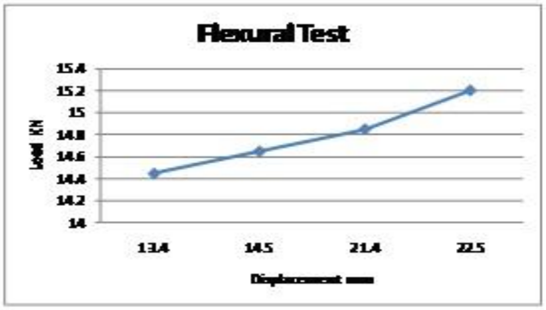

Fig 11 Load vs Displacement on Flexural test

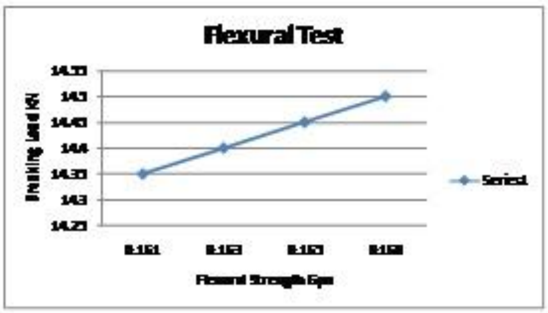

Fig 12 Breaking load vs Flexural Strength

5.4 IMPACT TEST

The specimen size for Charpy impact test bed is 9cm X 1.5cm.

5.4.1 IMPACT TEST RESULTS

Impact Test was carried out by using charpy impact test machine. The specimen size is 9cm X 1.5cm X 0.3cm, the test results are shown in the Table 6

Table 6 Comparison of Impact Test Results

Length of the Fiber in cm	PolyGJC0.5cm	PolyGJC1cm	PolyGJC2cm	PolyGJC3cm
Energy required for fracture in joules (Average of three samples)	11.3	14.4	18.66	25.33

5.4.2 Impact Strength Result

Table 7 Comparison of Impact Strength

Composite Designation	C1	C2	C3	C4
Impact strength in J/sq.cm	25.1	32	41.46	56.28

5.4.3 IMPACT STRENGTH CALCULATION:

Formulae used

$$I = K/A$$

Where,

I – Impact strength of the specimen in J/sq.cm

K–Energy required for fracture in Joules

A– Area of Cross section in sq.cm.

Model calculation for aspect ratio 0.5cm of Glass, Jute fiber and Chopped fiber :

$$I = 11.3/0.45$$
$$= 25.1 \text{ J/sq.cm}$$

6 RESULTS AND DISCUSSIONS

The results obtained from the various tests are presented and possible reasons for the mechanical behavior of the composite material are discussed in this chapter.

6.1 EFFECT OF FIBER LENGTH ON TENSILE PROPERTIES

The tensile test result shows that the tensile strength of the composite increases with increase in the fiber length and composite having aspect ratio of 3cm posses highest tensile strength 0.191GPa

6.2 EFFECT OF FIBER LENGTH ON FLEXURAL PROPERTIES

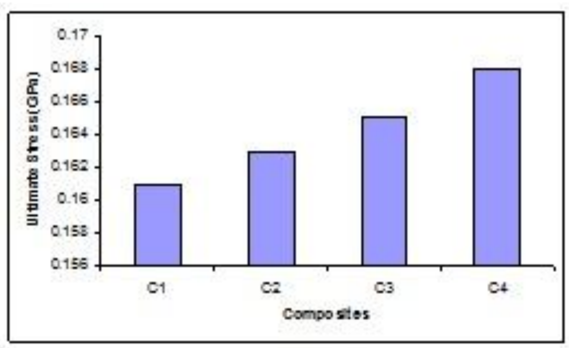

Fig 13 Effect of Fiber Length on Flexural Properties

The flexural test results as shown fig 11 indicate that the experimental parameters such as peak load and ultimate tensile test increase with increasing aspect ratio of the fiber and the maximum displacement decrease with the increasing aspect ratio of the fiber. The composite having aspect ratio of 3cm posses highest flexural strength 0.168GPa

6.3 EFFECT OF FIBER LENGTH ON IMPACT PROPERTIES

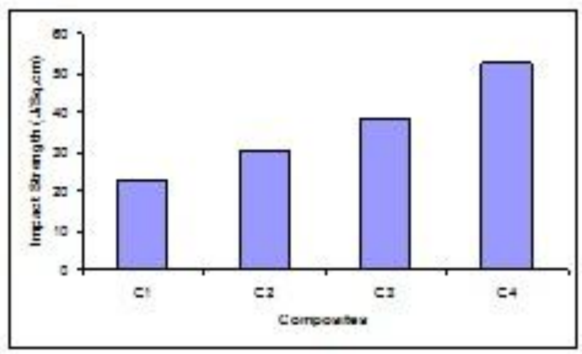

Fig 14 Effect of Fiber Length on Impact Properties

From the values obtained through impact test its quite very clear that the impact strength of the composite seems to be increasing with respect to increase in aspect ratio of glass , jute and chopped fiber, this trend indicates that a effective load transfer takes place from matrix to the fiber when sudden load is applied. The Composite having aspect ratio of 3cm posses the highest impact strength 56.28J/sq.cm.

7. CONCLUSION

The investigation of jute and glass fiber hybrid composite leads to the following conclusions:

Successful fabrication of Glass, Jute fiber and chopped fiber reinforced polyester composites with different fiber lengths is possible by simple hand lay-up technique.

The mechanical properties of the composites such as tensile strength, flexural strength and impact strength of the composites are also greatly influenced by the fiber lengths

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