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*Research Article*

# Characterization of Jute/E-Glass Fiber Reinforced Epoxy with Polyurethane Powder based Hybrid Composites

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***Abstract***

*A Jute is naturally available fiber known for its versatility and due to its cheapness, softness and uniformity .This usage of natural fiber have become across various applications in the field of composite materials .Thus in this project the Jute is reinforced with E-glass fiber used for fabrication a composite materials, to study the mechanical properties by incorporating polyurethane powder in the Jute /E-glass epoxy. Polyurethane is a elastomer that offers a broad and growing applications and benefits. The addition of polyurethane can enhance the appearance of material and increases its life span. Therefore in this project we also study the mechanical properties like tensile strength, hardness and impact test of a composite material incorporated with Pu powder in different proportions.*

***Keywords:*** *E-glass fiber, Jute /E-glass epoxy, Polyurethane, mechanical properties*

## 1. Introduction

The development of composite materials and their related design and manufacturing Technologies are one of the most important advances in the history of materials. Composites are the material used in various fields having exclusive mechanical and physical properties and are developed for particular application. Composite materials having a range of advantages over other conventional materials such as tensile strength, impact strength, flexural strengths, Stiffness and fatigue characteristics. Because of their numerous advantages they are widely Used in the aerospace industry, commercial mechanical engineering applications, like machine Components, automobiles, combustion engines, mechanical components like drive shafts, tanks, Brakes, pressure vessels and flywheels, thermal control and electronic packaging, railway Coaches and aircraft structures etc.

When two or more materials with different properties are combined together, they form A composite material. Composite material comprise of strong load carrying material (known as reinforcement) imbedded with weaker materials (known as matrix).The primary functions of the matrix are to transfer stresses between the reinforcing fibres/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibres/particles in a composite improves its mechanical properties like tensile strength, flexural strength, impact strength, stiffness etc

Composites can be classified according to different criteria. Depending on the type of matrix materials, composite materials can be classified into three categories such as metal matrix composites, ceramic matrix composites and polymer matrix composites. Each type of composite material is suitable for specific applications. When the matrix material is taken as metal like aluminum, copper, it is called as metal matrix composite. These are having high ductility and strength, good fracture toughness, inter-laminar shear strength and transverse tensile strength and also having superior electrical and thermal conductivity.

These materials are high dimensional stable due to low thermal expansion coefficient of matrix and withstand to a high temperature. Due to high elastic modulus of reinforcements they have very high stiffness. When the matrix material is taken as ceramic it is called as ceramic matrix composite. Ceramic material include a wide verity of inorganic materials likes bricks, pottery, titles also include oxide, nitrides and carbides of silicon, aluminum, zirconium etc. They are normally non metallic and processed very often at high temperature. The main objective in producing ceramic matrix composites is to enhance the toughness, high strength and hardness, high temperature properties, wear resistance etc. Now –a-days, scientist and engineers working in the field of

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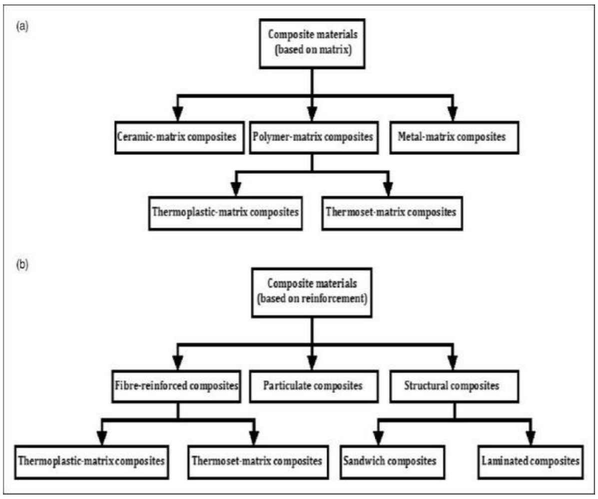
materials are too concerned with sustainability issues and environmental protection. Therefore, environmental friendly, natural, recycled, or biodegradable materials are attracting lot of interest. Due to environmental friendly, bio degradability and sustainability, natural fiber composites are preferred and compared to conventional synthetic fiber Based composites .They are used in diversified domains like building materials, structural purpose, aerospace industry, automotive industry




## Natural fiber composites

Natural fibers are also used in composite materials, much like synthetic or glass fibers. These composites, called bio composites, are a natural fiber in a matrix of synthetic polymers. One of the first bio fiber-reinforced plastics in use was a cellulose fiber in phenolics in 1908.Usage includes applications where energy absorption is important, such as insulation, noise absorbing panels, or collapsible areas in automobiles .Natural fibers can have different advantages over synthetic reinforcing fibers. Most notably they are biodegradable and renewable. Additionally, they often have low densities and lower processing costs than synthetic materials .Design issues with natural fiber-reinforced composites include poor strength (natural fibers are not as strong as glass fibers) and difficulty with actually bonding the fibers and the matrix. Hydrophobic polymer matrices offer insufficient adhesion for hydrophilic fibers.

## Jute Fibers

Jute is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads. It is produced primarily from plants in the genus Corchorus, which was once classified with the family Liliaceae, and more recently with Maldacena. The primary source of the fiber is Corchorus clitoris, but it is considered inferior to Corchorus capsularis. "Jute" is the name of the plant or fiber used to make burlap, hessian or gunny cloth.

Jute is one of the most affordable natural fibers, and second only to cotton in the amount produced and variety of uses. Jute fibers are composed primarily of the plant materials cellulose and lignin. It falls into the best fiber category (fiber collected from best, the phloem of the plant, sometimes called the "skin") along with kenaf, industrial hemp, flax (linen), ramie, etc. The industrial term for jute fiber is raw jute. The fibers are off-white to brown, and 1–4 meters (3–13 feet) long. Jute is also called the golden fiber for its color and high cash value. The jute fiber comes from the stem and ribbon (outer skin) of the jute plant. The fibers are first extracted by retting. The retting process consists of bundling jute stems together and immersing them in slow running water. There are two types of retting: stem and ribbon. After the retting process, stripping begins; women and children usually do this job. In the stripping process, non-fibrous matter is scraped off, then the workers dig in and grab the fibers from within the jute stem.

## E- Glass Fibre Manufacture

Glass fibers are generally produced using melt spinning techniques. These involve melting the glass composition into a platinum crown which has small holes for the molten glass to flow.

Continuous fibers can be drawn out through the holes and wound onto spindles, while short fibers may be produced by spinning the crown, which forces molten glass out through the holes centrifugally. Fibers are cut to length using mechanical means or air jets.

Fiber dimension and to some extent properties can be controlled by the process variables such as melt temperature (hence viscosity) and drawing/spinning rate. The temperature window that can be used to produce a melt of suitable viscosity is quite large, making this composition suitable for fiber forming.

As fibers are being produced, they are normally treated with sizing and coupling agents. These reduce the effects of microfiber abrasion which can significantly degrade the mechanical strength of the individual fibers. Other treatments may also be used to promote wetting and adherence of the matrix material to the fiber.

## Composition

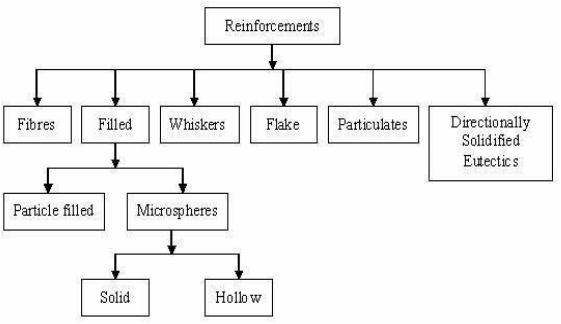
E-Glass is a low alkali glass with a typical nominal composition of $SiO_2$ 54wt%, $Al_2O_3$ 14wt%, CaO+MgO 22wt%, $B_2O_3$ 10wt% and $Na_2O$+$K_2O$ less then 2wt%. Some other materials may also be present at impurity levels

| Fiber | Tensile strength (MPa) | Young'S modulus ( GPa) | Elongation Break (%) | Density (g/cm²) |
|---|---|---|---|---|
| Abaca | 400 | 12 | 3-10 | 1.50 |
| Bagasse | 290 | 17 | -------- | 1.25 |
| Bamboo | 140-230 | 11-17 | -------- | .6-1.1 |
| Cotton | 287-597 | 5.50-12.6 | 7-8 | 1.5-1.6 |

| | | | | |
|---|---|---|---|---|
| Hemp | 690 | 70 | 1.6 | 1.48 |
| Jute | 393-773 | 26.50 | 1.5-1.8 | 1.3 |
| Kenaf | 930 | 53 | 1.6 | ------- |
| Pine Apple | 1.44 | 400-627 | 14.50 | .8-1.6 |
| Sisal | 511-635 | 9.44-22 | 2-2.5 | 1.5 |
| E-glass | 3400 | 72 | -------- | 2.5 |
| Flax | 345-1035 | 27.60 | 2-4.5 | 1.5 |

**Introduction to Reinforcements**

Reinforcements for the composites can be fibers, fabrics particles or whiskers. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape. Whiskers have a preferred shape but are small both in diameter and length as compared to fibers. Figure Shows types of reinforcements in composites.




**Types of Reinforcement**

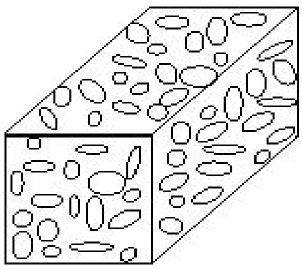
Based on the form of reinforcement, common composite materials can be classified as follows:

1. Fibers as the reinforcement (Fibrous Composites)

A) Random fiber (short fiber) reinforced composites
B)Continuous fiber (long fiber) reinforced composites

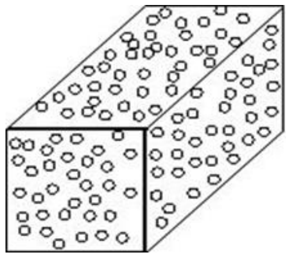
2. Particles as the reinforcement (Particulate composites)

3. Fillers as the reinforcement (Filler composites

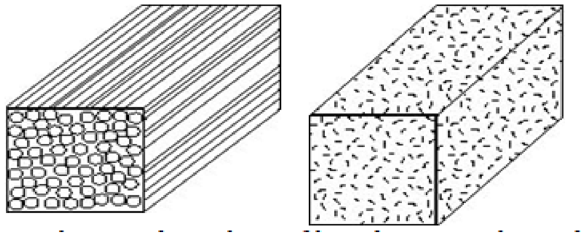


**2. Literature Review**

In the recent years there is a vast growth in natural fiber based polymer composites due to its various attractive features likes biodegradability, no abrasiveness, flexibility, availability, low cost, light weight etc. Different researchers have performed various experiments to enhance the mechanical properties of natural fiber based polymer composites. Biswas studied the effect of length on mechanical behavior of coir fiber reinforced epoxy composites and observed that the hardness is decreasing with the increase in fiber length of 10cm.polyester composites and found that jute fiber based composites shows better strengths than those of wood based composites. The mechanical properties of coir fiber/polyester composites were evaluated and the effect of the molding pressure on the flexural strength of the composites is studied. Luo and Netravali studied the tensile and flexural properties of polymer composites with different pineapple fiber content and compared them with the virgin resin.



A great deal of work has been done on various aspects of polymer composites reinforced with banana fibers. Chawla and Bastos investigated the effect of fiber volume fraction on Young's modulus, tensile strength and impact strength of untreated jute fiber in unsaturated polyester resin. Schneider and Karmaker studied the mechanical behavior of jute and kenaf fiber based polypropylene composites and reported that jute fiber provides better mechanical properties than kenaf fiber. A systematic study on the properties of henequen fiber and pointed out that these fiber have mechanical properties suitable for reinforcement in thermoplastic resins by Cazaurang et al. Shinichi et al. have studied the effects ofthe Volume fraction and length on flexural properties of kenaf and bagasse fibers based composites. The mechanical behavior of unidirectional hemp fiber reinforced epoxy composites is studied by Hepworth et al. Sapuan and Leenie investigated the tensile and flexural behavior of musaceae/epoxy composites. Pavithran et al. studied the fracture energies for sisal, pineapple, banana and coconut fiber reinforced polyester composites and reported that, except for the coconut fiber, increasing fiber toughness was accompanied by increasing fracture energy of the composites. Harriette et al. investigated the mechanical properties of flax/polypropylene composites. Tobias analyzed the influence of fiber length and fiber content in banana fiber reinforced epoxy composites and reported that the impact strength increased with higher fiber content and lower fiber length. Santulli investigated the post- impact behavior of plain-woven jute/polyester composites subjected to low velocity impact and reported that the impact performance of these composites is poor.



**3.Methodology and materials**

This chapter describes the selection of materials, the experimental setup and the equipment used for testing. Before starting the layup process the mound is prepared. The mound is prepared by cleaning the mound and applying a releasing agent in order to avoid the polymer resin to stick. The mound is prepared by tapping the mound to the table top. After the preparation of mound, the polymer resin and E-Glass fiber hardener are mixed. The proportion of weight by volume is maintained accurately as required. The mixing is performed in the mixing containers with the flat mixing stick slowly.

Next an adequate quantity of mixed polymer resin & E-Glass fiber hardener is deposited in the mold and a brush or roller is used to spread it around all surface. An estimated amount of resin is added to the jute fiber cloth. The first layer of fiber reinforcement is then laid. This layer is wetted with polymer resin and then softly pressing using a roller making the resin that was added in the previous step wick up through the fiberglass cloth. The layer is rolled over properly and made sure that there are no air bubbles present in the layer. The part is cured at elevated temperatures using an oven at room temperature.Various samples are prepared by this method and tensile and hardness tests are conducted on those samples to find out the optimum composition.

**Hand lay-up**

Hand lay-up is the simplest and oldest open molding method of the composite fabrication processes. It is a low volume, labor intensive method suited especially for large components, such as boat hulls. Polypropylene sheet or other reinforcing material or woven fabric or roving is positioned manually in the open mold, and resin is poured, brushed, or sprayed over and into the sheet piles. Entrapped air is removed manually with squeegees of rollers to complete the laminates structure.Room temperature curing epoxies are the most commonly used matrix resins. Curing is initiated by a catalyst in the resin system, which hardens the fiber reinforced resin composite without external heat. For a high-quality part surface, a pigmented gel cost is first applied to the mold surface

**Specimen Preparation**

This is one of the most important functions in the molding cycle. Mold preparation requires a thorough machine buffing and polishing of the mold. After the desired finish has been attained, several coats of paste wax are applied for easy release of mold. The choice of release agent depends on the type of surface to be molded; the degree of luster desired on the finished product.

## Gel Coating

When good surface appearance is desired, the first step in the open-mold processes is the application of a specially formulated resin layer called the gel coat. It is normally epoxy, mineral–filled, pigmented, no reinforced layer or coating. It is applied first to the mold and thus becomes the outer surface of the laminate when complete. This produces a decorative, protective, glossy, colored surface that requires little or no subsequent finishing. The gel coating may be painted on; air- atomized with gravity or pressure feeding, or sprayed by an airless sprayer

**Equipment required**

1. A Roller
2. A paint brush
3. Hand gloves
4. Beakers
5. Stirrer
6. Scissor

**Physical properties of Jute fiber**

| Physical properties | Jute fiber |
|---|---|
| Density (%) | 1.4 |
| Elongation in break (%) | 1.8 |
| Cellulose content (%) | 50-57 |
| Lignin content | 8-10 |
| Tensile strength | 700-800 |
| Young's Modulus | 30 |

**Physical properties of E-glass fiber**

| Physical properties | Glass fiber |
|---|---|
| Density | 1.15-1.2 g/cm3 |
| GSM | 280 |
| Young's Modulus | 73 |
| Tensile strength | 40 |
| Shear Modulus | 30.42 |

**Designation of Composition**

| Material | Type of fiber | Pu powder (%) | Composition (%) |
|---|---|---|---|
| M1 | 4G+3J | 5 | Epoxy wt(64)+Fiber |

| | | | |
|---|---|---|---|
| | | | wt(32)+Harder(6) |
| M2 | 4G+3J | 7 | Epoxy wt(64)+Fiber wt(32)+Harder(6) |
| M3 | 3G+2J | 5 | Epoxy wt(73)+Fiber wt(20)+Harder(7) |
| M4 | 3G+2J | 7 | Epoxy wt(73)+Fiber wt(20)+Harder(7) |
| M5 | 4J+4G | 5 | Epoxy wt(60)+Fiber wt(34)+Harder(6) |
| M6 | 4J+4G | 7 | Epoxy wt(60)+Fiber wt(34)+Harder(6) |
| M7 | 10G | 5 | Epoxy wt(46)+Fiber wt(50)+Harder(4) |
| M8 | 10G | 7 | Epoxy wt(46)+Fiber wt(50)+Harder(4) |
| M9 | 4J+3G | 5 | Epoxy wt(70)+Fiber wt(24)+Harder(7) |
| M10 | 4J+3G | 7 | Epoxy wt(59)+Fiber wt(36)+Harder(6) |

### Fabrication Procedure

In this study, manual hand layup method is used for preparing composite laminates. Thin plastic sheets are used at the top and bottom of the wooden block to get a good surface finish of the product. Reinforcement in the form of woven mat jute fabrics and E-Glass fibers are cut as per the wooden block size and placed at the surface of wooden block after perspex sheet. Then epoxy in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and polyurethane is also mixed a small proportion and all the three mixed with each other and poured onto the surface of mat already placed in the block . The epoxy and polyurethane is uniformly spread with the help of the brush. The second layer of mat is then placed on the epoxy surface which is having a polyurethane powder over on it and a roller is moved with a mild pressure on the mat-epoxy layer to remove any air trapped as well as the excess epoxy and polyurethane powder is present. The process is repeated for each layer of epoxy and mat, till the required layers are stacked.

After placing the plastic sheet, release gel is sprayed on the inner surface of the top wooden block which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature at 60°C - 80°C, the specimen is removed from wooden block is opened and the developed composite part is taken out and further processed. For epoxy based system, normal curing time at room temperature is 24 - 48 hours.

First a mat is placed on wooden block and later the mixture of epoxy and polyurethane is poured over the mat and with the help of brush we made to patch the resin over the mat to attach every corner and another mat is placed over and continued same process by putting the different fibers over

### Results

### Impact Test

The composites were made from jute and E-glass fibers with the epoxy resin , polyurethane powder and the sheets prepared were subjected to mechanical property evaluation for strength , impact and hardness test .

Here we evaluated the impact tensile of material of M1, M2, M3, M4, M5, M6, and M9

Impact Testing:

I=K/A J/mm$^2$

The value of k is 2

**M1**

=I= K/A =2/ (10*0.6) J/ mm$^2$

= 0.33 J/ mm$^2$

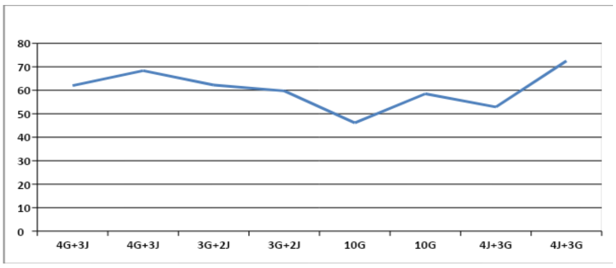
**M2** =

I= K/A =2/ (10*0.5) J/ mm$^2$

= 0.4 J/ mm$^2$

Therefore the material M1(4G+3J) has less impact capacity when compared with M2(4G+3J) because in material M2 we increased the composition of polyurethane percentage slightly 2% more than

| Material | PU | Composition | Resin (WEIGHT) | Harder (WEIGHT) | Impact (J/ mm$^2$) Result |
|---|---|---|---|---|---|
| M1 | 5% | 4G+3J | 64 | 32 | 0.33 |
| M2 | 7% | 4G+3J | 64 | 32 | 0.4 |




**M3** =

I= K/A =2/ (10*0.4) J/ mm$^2$

= 0.5 J/ mm$^2$

**M4** =

I= K/A =2/ (10*0.3) J/ mm$^2$

| Material | PU | Composition | Resin (WEIGHT) | Harder (WEIGHT) | Impact Result (J/ $mm^2$) |
|---|---|---|---|---|---|
| M3 | 5% | 3G+2J | 73 | 7 | 0.5 |
| M4 | 7% | 3G+2J | 73 | 7 | 0.66 |

Therefore the material M3(3G+2J) has less impact capacity when compared with M4(3G+2J) Because in material M4 we increased the composition of polyurethane percentage slightly 2% more than M3

**M5** =
I= K/A =2/ (10*0.35) J/ $mm^2$
= 0.57 J/ $mm^2$
**M6** =
I= K/A =2/ (10*0.3) J/ $mm^2$
= 0.66 J/ $mm^2$

| Material | PU | Composition | Resin (WEIGHT) | Harder (WEIGHT) | Impact (J/ $mm^2$) Result |
|---|---|---|---|---|---|
| M5 | 5% | 4J+4G | 60 | 6 | 0.57 |
| M6 | 7% | 4J+4G | 60 | 6 | 0.66 |

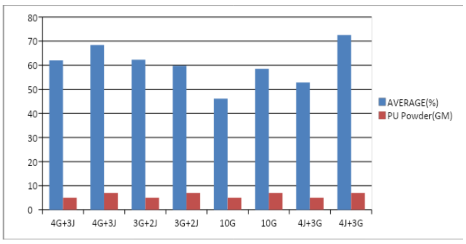
Therefore the material M5(4J+4G) has less impact capacity when compared with M4(4G+4J) because in material M6 we increased the composition of polyurethane percentage slightly 2% more than M
**M7**
I= K/A =2/ (10*0.3) J/ $mm^2$
= 0.66 J/ $mm^2$

### Hardness test

The composites were made from jute and E-glass fibers with the epoxy resin, polyurethane powder and the sheets prepared were subjected to Hardness Test. Here we evaluated the Hardness Test with a load of 150kgf with the material of M2, M3, M4, M5, M6, M7, M9, and M10.

| Specimen composition | P.U powder (GRM) | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| 4G+3J | 5 | 57 | 58 | 64 | 69 | 62 |
| 4G+3J | 7 | 64 | 52 | 80 | 75 | 68.37 |
| 3G+2J | 5 | 67 | 74 | 62 | 58 | 62.25 |
| 3G+2J | 7 | 55 | 63 | 67 | 54 | 59.75 |
| 10G | 5 | 38.5 | 37 | 61 | 48 | 46.12 |
| 10G | 7 | 61 | 60 | 59 | 54 | 58.5 |
| 4J+3G | 5 | 72 | 75 | 58.5 | 66 | 52.87 |
| 4J+3G | 7 | 70 | 65 | 74 | 81 | 72.5 |

Average of Hardness Test in Line Graph




Average of Hardness Test in Bar Graph

### Tensile Test

The composites were made from jute and E-glass fibers with the epoxy resin, polyurethane powder and the sheets prepared were subjected to Tensile Test of M5 material

| | |
|---|---|
| Machine model : | TUE-E-200 |
| Machine serial no : | 2013/50 |
| Specimen shape : | Flat |
| Specimen material M5, with | (4J+4G 5%OF PU) |
| Specimen width | 54.35 mm |
| Specimen Thickness : | 4.05 mm |
| Initial G.L. For % e-long : | 50 mm |
| Pre load value : | 0 kN |
| Max. Load : | 200 KN |
| Max Elongation : | 200 mm |
| Specimen Cross Section Area : | 220.118 mm2 |

**Table: Output data**

| | |
|---|---|
| Load at Peak | 7.453 KN |
| Elongation at Peak | 8.170 mm |
| Tensile Strength | 33.859 N/mm2 |
| Load at Break | 7.453KN |
| Elongation at Break | 8.170 mm |

**For Material M6**

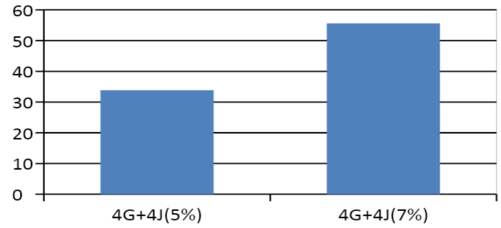
| | |
|---|---|
| Machine model | TUE-E-200 |
| Machine serial no | 2013/50 |
| Specimen shape | Flat |
| Specimen material M6 with | (4J+4G 7%OF PU) |
| Specimen width | 53.62mm |
| Specimen Thickness | 4 mm |
| Initial G.L. For % e-long | 50mm |
| Pre load value | 0KN |
| Load | 200 KN |
| Max Elongation | 200mm |
| Specimen Cross Section area | 214.48 $mm^2$ |

**Table: Output data**

| | |
|---|---|
| Load at Peak | 11.9933KN |
| Elongation at peak | 5.480mm |
| Tensile strength | 55.63KN/$mm^2$ |
| Load at break | 6.655 |
| Elongation at break | 5.740mm |

| Material | PU | Composition | Resin WEIGHT | Harder WEIGHT | Tensile Test (N/mm2) |
|---|---|---|---|---|---|
| M5 | 5% | 4J+4G | 60 | 6 | 33.859 |
| M6 | 7% | 4J+4G | 60 | 6 | 55.63 |

**Graph: Tensile test with 5% and & 7%**




## Conclusion

The results of the present study showed that useful composite with good strength could be successfully developed using Jute and E-glass as a reinforcing agent for the epoxy matrix with polyurethane powder. Tensile strength, Hardness Test, Impact strength of the composites increased with increasing of fibre weight fraction in the E-glass/Jute/Epoxy and also with increasing the polyurethane powder percentage compared with pure resin. Outer layer containing Jute-Jute and Glass- Glass having low strength property as compared to other layers of jute-glass-jute-glass-jute and glass-jute-glass-jute-glass with each other and also jute- glass- jute- glass- jute- glass-jute , glass-jute glass-jute - glass- jute- glass composites.

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