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EVALUATION OF MECHANICAL BEHAVIOUR OF CARBON FIBER, JUTE FIBER, GLASS FIBER REINFORCED WITH EPOXY RESIN MATRIX

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ABSTRACT: Fibre reinforced polymer composites has been used in a variety of application because of their many advantages such as relatively low cost of production, easy to fabricate and superior strength compare to neat polymer resins. Reinforcement in polymer is either synthetic or natural. Synthetic fibre such as glass, carbon etc. has high specific strength but their fields of application are limited due to higher cost of production. Recently there is an increase interest in natural fibre based composites due to their many advantages. In this connection an investigation has been carried out to make better utilization of sisal fibre for making value added products. The objective of the present research work is to study the physical, mechanical and water absorption behaviour of carbon fibre, jute fiber reinforced epoxy based hybrid composites. The effect of fibre loading and length on mechanical properties like tensile strength, flexural strength, hardness of composites is studied. Also, the surface morphology of fractured surfaces after tensile testing is examined using scanning electron microscopy (SEM).

Keywords: isophthalic, mercerization, Bambusoideae, reinforcement, morphology.

I. INTRODUCTION

The development of composite materials and their related design and manufacturing technologies is 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 aluminium, 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, aluminium, 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.

Polymer matrix composites consist of a polymer resin as the matrix material which filled with a variety of reinforcements. This kind of composite is used in the greatest diversity of composite applications due to its advantages such as low density, good thermal and electrical insulator, ease of fabrication, and low cost. The properties of polymer matrix composites are mainly determined by three constitutive elements such as the types of reinforcements (particles and fibres), the type of polymer, and the interface between them. Polymers are divided into two categories such as thermoplastics and thermosets. Thermoplastic are in general, ductile and tougher than thermoset materials. They are reversible and can be reshaped by application of heat

and pressure. Thermoplastic molecules do not cross-link and therefore they are flexible and reform able. Generally, thermoplastics show poor creep resistance, especially at elevated temperatures, as compared to thermosets. Their lower stiffness and strength values require the use of fillers and reinforcements for structural applications. The most common materials used in thermoplastic composites are nylon, polyetheretherketone, Acetal, polyphenylene sulfide, polycarbonate, teflon, polyethylene etc. Thermoset are materials that undergo a curing process through part fabrication and once cured cannot be re-melted or reformed. Thermoset materials are brittle in nature and offer greater dimensional stability, better rigidity, and higher chemical, electrical, and solvent resistance. The most common resin materials used in thermoset composites are epoxy, polyester, phenolics, vinyl ester, and polyimides.

Based on the types of reinforcement, polymer composites can be classified as particulate reinforced polymer composite and fibre reinforced polymer composites.

II. EXPERIMENTAL

1. Materials used

Fig.1 carbon fiber

Carbon fibers or **carbon fibres** (alternatively CF, graphite fiber or graphite fibre) are fibers about 5–10 micrometers in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These properties have made carbon fiber very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively expensive when compared with similar fibers, such as glass fibers or plastic fibers. To produce a carbon fiber, the carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fiber as the crystal alignment gives the fiber high strength-to-volume ratio (making it strong for its size). Several thousand carbon fibers are bundled together to form a tow, which may be used by itself or woven into a fabric. Carbon fibers are usually combined with other materials to form a composite. When impregnated with a plastic resin and baked it forms carbon-fiber-reinforced polymer (often referred to as carbon fiber) which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. Carbon fibers are also composited with other materials, such as graphite, to form reinforced carbon-carbon composites, which have a very high heat tolerance

Fig.2 jute fiber

JUTE IS KNOWN AS THE 'GOLDEN FIBRE' DUE TO ITS GOLDEN BROWN COLOUR AND ITS IMPORTANCE. IN TERMS OF USAGE, PRODUCTION AND GLOBAL CONSUMPTION, JUTE IS SECOND ONLY TO COTTON. IT IS THE FIBRE USED TO MAKE HESSIAN SACKS AND GARDEN TWINE. JUTE IS ENVIRONMENTALLY FRIENDLY AS WELL AS BEING ONE OF THE MOST AFFORDABLE FIBRES; JUTE PLANTS ARE EASY TO GROW, HAVE A HIGH YIELD PER ACRE AND, UNLIKE COTTON, HAVE LITTLE NEED FOR PESTICIDES AND FERTILIZERS. JUTE IS A BAST FIBRE, LIKE FLAX AND HEMP, AND THE STEMS ARE PROCESSED IN A SIMILAR WAY.

Fig.3 glass fiber

Glass fiber (or glass fibre) is a material consisting of numerous extremely fine fibers of glass. Glassmakers throughout history have experimented with glass fibers, but mass manufacture of glass fiber was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass

fibers with the diameter and texture of silk fibers. Glass fibers can also occur naturally, as Pele's hair.

EPOXY RESIN:

Epoxy resin density of 1.15-1.20g/cm^3,mixed with hardener density of 0.97-0.99g/cm^3, is used to prepared the composite material resin from purchased local source

CATALYST (METHYL ETHYL KETONE PEROXIDE):

Methyl ethyl ketone peroxide, also known as 2-butanone peroxide, is a strongly oxidizing (caustic) organic peroxide that is commonly used in the manufacture of acrylic resins and as a room temperature hardening and curing agent for fiberglass-reinforced plastics and unsaturated polyester resins (HCN, 2002; NTP, 1993). At room temperature, it is a colorless to yellow liquid with a characteristic or mint-like odor (NIOSH, 2007; NTP, 2016). As MEKP is shock, sunlight, and heat sensitive, it is typically sold commercially in a solution of 30 – 60% MEKP mixed with diluents like dimethyl phthalate, cyclohexane peroxide, or diallyl phthalate to prevent explosions (HCN, 2002; NIOSH, 2007). It can also undergo spontaneous ignition or explosion if mixed with oxidizable organic, flammable, or chemical materials (HCN, 2002; NOAA, 2015). When MEKP is used as a hardening or curing agent, the duration of the reaction is dependent on both the type of resin being cured as well as the formulation of the MEKP solution. Typical reactions contain approximately 1 - 2% MEKP. In a series of experiments, the 'time to cure' was roughly 40 - 50 minutes for a commercial MEKP formulation (CI, 1999). The 'time to cure' is the time from the initiation of the reaction to when the peak temperature is reached (often in excess of 350°F), which is not necessarily the end of the reaction. Though it is sometimes incorrectly called a catalyst, MEKP is not a true catalyst as it is consumed in the reaction (Juska & Puckett, 1997). Studies of the health effects of MEKP are limited and primarily focus on short-term exposures to relatively large amounts of the chemical. Rats and mice exposed to MEKP (45% in dimethyl phthalate) on their skin for two and thirteen weeks developed a spectrum of necrotic, inflammatory, and regenerative lesions at the application site. Increased formation of red and white blood cells in the spleen and bone marrow was also observed (NTP, 1993). Direct exposure to the eyes of rabbits resulted in damage, with severe injury occurring with two drops of 40% MEKP. Three percent MEKP caused a more moderate reaction that improved after two days (Hathaway & Proctor, 2014). Several studies have examined inhalation exposure in mice and rats; the concentration needed to kill 50% of the animals (known as the LC50) in four hours was 170 parts per million (ppm) in mice and 200 ppm in rats.

ACCELERATOR (COBALT NAPHTHENATE):

Accelerators are material which help the decomposition of peroxides and produce free radicals which start the propagation reaction resulting in the gelation and ultimate cure of polyesters. Soaps of Cobalt and certain amines act as accelerators in the homolytic fission of peroxides generating from radicals. Therefore, the role of organic peroxides differ in their reactivity and response to accelerators depending upon their chemical constitution. The choice of accelerators very much depends on the type of organic peroxides selected for use.

Cobalt naphthenate is widely used in polyester resins and paint driers. It is used as a curing accelerator, cross linker catalyst for unsaturated polyester resins. It is also used in the production of adhesives, varnishes and waterproofing agents for textiles. Further, it is used as corrosion inhibitors, lubricants, and fuel additives. It plays an important role as oil drying agents.

FABRICATION OF COMPOSITES

The fabrications of composite slab are carried out by conventional hand layup technique. **Kenaf fiber, sisal fiber** are used as **reinforcement** and **epoxy resin** is taken as **matrix material** with natural fillers **(kenaf fiber, sisal fiber).** This mix consists of the resin, accelerator, fillers, and additives if any. The addition of accelerator to resin will not cause any cross linking until catalyst is added. The low temperature curing epoxy resin, catalyst and accelerator are mixed in a ratio of **1.0:0.5:0.5** by weight percentage. A plywood mould having dimension of **(310 ×210× 20)** mm3 is used for composite fabrication. The natural fillers are mixed with epoxy resin by the simple stirring and the mixture is poured into various moulds conforming to the requirements of various testing conditions and characterization standards. The mould should be thoroughly cleaned and free from dirt's before the releasing agent is applied. Then, the mould surface is coated with silicone free wax (e.g. mansion polish). After some time the wax has to be removed to have a glassy finish on the mould surface. In certain cases release of the product is difficult with wax alone. So, a layer of poly vinyl alcohol (PVA) is applied. Since, PVA is water soluble material, 15% solution in water is applied with sponge. The brush application will leave the prints of brush lines so, sponge is preferable. After the water evaporates, a thin layer of PVA forms on the mould surface. The PVA layer must be completely dry before the gel coat is applied perhaps it will create wrinkles called 'elephant skin'. MEK or cellulose acetate, casein, carboxyl-methyl cellulose and methyl cellulose are the other film formers used as releasing agents. A releasing agent is used for facilitate easy removal of the composite from the mould after curing. If any entrapped air bubbles are there, then they are removed by a sliding roller and the mould is closed for curing at a room temperature for 24 h at a constant load of 25-30kg. After curing the specimens of suitable dimensions are cut for mechanical test as ASTM standard. The composition and designation of the composites prepared for this study are listed in the below table,

DETAILED DESIGNATION AND COMPOSITION OF COMPOSITES.

S.NO	COMPOSITES	COMPOSITION
1	C1	Carbon fiber (10 WT%) + jute fiber (10WT%) + Epoxy Resin(80%WT)
2	C2	Glass fiber(20%WT) +epoxy resin(80%wt)

***Fig.4* DETAILED DESIGNATION AND COMPOSITION OF COMPOSITES.**

3. Test

Various mechanical test is carried out in order to understand and compare the mechanical property of the isophthalic based Carbon Jute fabric and Glass fabric. All the mechanical test is carried out according to the ASTM D standards. The following are mechanical test carried out:

3.1 Tensile Test

UNIAXIAL TENSILE TESTING :

Uniaxial tensile test is known as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus. These important parameters obtained from the standard tensile testing are useful for the selection of engineering materials for any applications required. The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross sectional area perpendicular to the load direction) till failure. The applied tensile load and extension are recorded during the test for the calculation of stress and strain. A range of universal standards provided by Professional societies such as American Society of Testing and Materials (ASTM), British standard, JIS standard and DIN standard provides testing are selected based on preferential uses. Each standard may contain a variety of test standards suitable for different materials, dimensions and fabrication history. For instance, ASTM E8: is a standard test method for tension testing of metallic materials and ASTM B557 is standard test methods of tension testing and cast aluminium and magnesium alloy products A standard specimen is prepared in a round or a square section along the gauge length as shown below, depending on the standard used. Both ends of the specimens should have sufficient length and a surface condition such that they are firmly gripped during testing. The initial gauge length Lo is standardized (in several countries) and varies with the diameter (Do) or the cross-sectional area (Ao) of the specimen as listed in table 1. This is because if the gauge length is too long, the % elongation might be underestimated in this case. Any heat treatments should be applied on to the specimen prior to machining to produce the final specimen readily for testing. This has been done to prevent surface oxide scales that might act as stress concentration which might subsequently affect the final tensile properties due to premature failure. There might be some exceptions, for examples, surface hardening or surface coating on the materials. These processes should be employed after specimen machining in order to obtain the tensile properties results which include the actual specimen surface conditions.

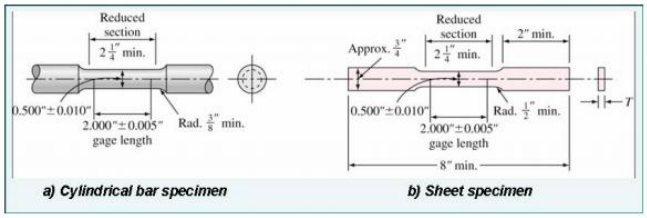

Fig.5 Specimen

PROCEDURE

1. The specimens provided are made of composite materials. Measure and record specimen dimensions (diameter and gauge length) in a table provided for the calculation of the engineering stress and engineering strain. Marking the location of the gauge length along the parallel length of each specimen for subsequent observation of necking and strain measurement.
2. Fit the specimen on to the universal Testing Machine (UTM) and carry on testing. Record load and extension for the construction of stress-strain curve of each tested specimen.
3. Calculate Young's modulus, yield strength, ultimate tensile strength, fracture strain, % elongation and % area of reduction of each specimen and record on the provided table.
4. Analyse the fracture surfaces of broken specimens using stereoscope, sketch and describe the results.
5. Discuss the experimental results and give conclusions.

3.2 Flexural Test

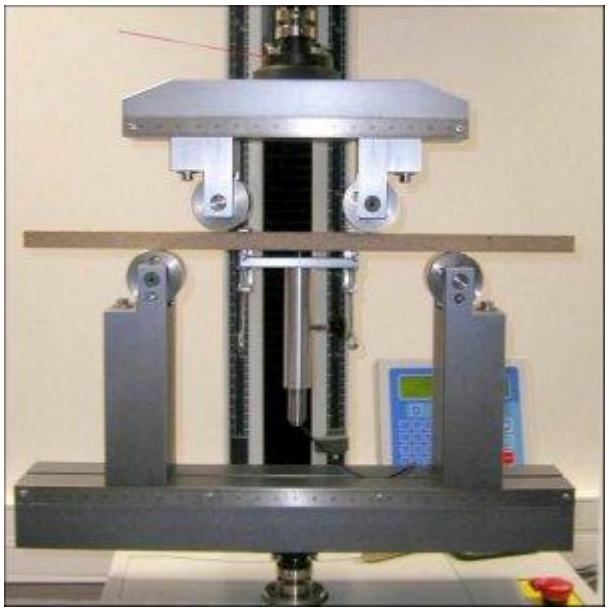

Fig.6 Flexural Test machine

Flexure tests are generally used to determine the flexural modulus or flexural strength of a material. A flexure test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is the flexural strength of that particular sample. Unlike a compression test or tensile test, a flexure test does not measure fundamental material properties. When a specimen is placed under flexural loading all three fundamental stresses are present: tensile, compressive and shear and so the flexural properties of a specimen are the result of the combined effect of all three stresses as well as (though to a lesser extent) the geometry of the specimen and the rate the load is applied.

The most common purpose of a flexure test is to measure flexural strength and flexural modulus. Flexural strength is defined as the maximum stress at the outermost fiber on either the compression or tension side of the specimen. Flexural modulus is calculated from the slope of the stress vs. strain deflection curve. These two values can be used to evaluate the sample materials ability to withstand flexure or bending forces.

FLEXURE TEST TYPES:

The two most common types of flexure test are three point and four point flexure bending tests. A three point bend test consists of the sample placed horizontally upon two points and the force applied to the top of the sample through a single point so that the sample is bent in the shape of a "V". A four point bend test is roughly the same except that instead of the force applied through a single point on top it is applied through two points so that the sample experiences contact at four different points and is bent more in the shape of a "U". The three point flexure test is ideal for the testing of a specific location of the sample, whereas, the four point flexure test is more suited towards the testing of a large section of the sample, which highlights the defects of the sample better than a 3-point bending test.

A bend test is similar to a flexure test in the type of hardware and test procedure involved. Bend tests are used with ductile materials whereas flexural tests are used with brittle materials.

PROCEDURE:

1 Prepare the test specimen
2 Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
3 Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be **3d** and the distance between the inner rollers shall be **d**. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.
4 The test specimen shall be placed in the machine correctly centred with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.
5 The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

3.4 Impact Test

Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force. The test measures the impact energy, or the energy absorbed prior to fracture. The most common methods of measuring impact energy are the:

- Charpy Test
- Izod Test

IMPACT ENERGY:

Impact energy is a measure of the work done to fracture a test specimen.

When the striker impacts the specimen, the specimen will absorb energy until it yields. At this point, the specimen will begin to undergo plastic deformation at the notch. The test specimen continues to absorb energy and work hardens at the plastic zone at the notch. When the specimen can absorb no more energy, fracture occurs.

THE CHARPY TEST

While most commonly used on metals, it is also used on polymers, ceramics and composites. The Charpy test is most commonly used to evaluate the relative toughness or impact toughness of materials and as such is often used in quality control applications where it is a fast and economical test. It is used more as a comparative test rather than a definitive test.

Charpy Test Specimens

Charpy test specimens normally measure 55x10x10mm and have a notch machined across one of the larger faces. The notches may be:

V-notch – A V-shaped notch, 2mm deep, with 45° angle and 0.25mm radius along the base.

U-notch or keyhole notch – A 5mm deep notch with 1mm radius at the base of the notch.

PROCEDURE:

The Charpy test involves striking a suitable test piece with a striker, mounted at the end of a pendulum. The test piece is fixed in place at both ends and the striker impacts the test piece immediately behind a machined notch.

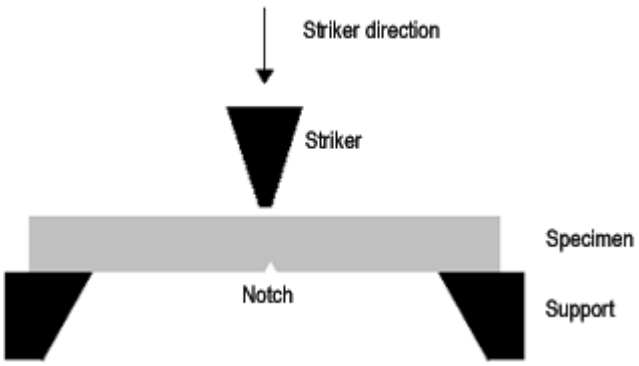

Fig.6 Schematic of Charpy impact test.

Barcol Hardness

The Barcol hardness test characterizes the indentation hardness of materials through the depth of penetration of an indentor, loaded on a material sample and compared to the penetration in a reference material. The method is most often used for composite materials such as reinforced thermosetting resins or to determine how much a resin or plastic has cured. The test complements the measurement of glass transition temperature, as an indirect measure of the degree of cure of a composite. This is an indentation-type of hardness, where pressure is uniformly applied on the surface of a specimen to the dial indicator maximum reading. The depth of penetration or indentation is then converted into an absolute Barcol number. The Barcol number is automatically generated by the measuring equipment.

III. RESULT AND DISSUCION

The results are drawn from the average value obtained from the following test mention. Minimum of five samples are used for the testing. The average value is calculated and the results are tabulated are provided. The samples are given the tag A and B as mention below

A- Carbon Jute fabric composite
B- Glass fabric composite

1. Mechanical properties

Considering the Mechanical aspect such as Tensile, Flexural, Hardness and Impact Values which is tabulated below in Table 1 it could be inferred that Glass Fibre has comparatively greater Mechanical properties than Carbon Jute fabric, but the difference is much negligible.

Table 1: *Mechanical properties readings*

SPECIMEN	TENSILE STRENGTH	FLEXURAL LOAD	IMPACT VALUES
UNITS	(MPa)	(KN)	JOULES X 10 [1]
A	187	26.37	80
B	59.64	0.37	4

Fig.7. *Comparison of Mechanical Properties.*

2. Barcol Hardness

Based on Barcol Hardness, carbon jute fabric has an average hardness of 83 and Glass Fibre having 40. This shows that Carbon Jute fibre is comparatively a bit harder than Glass fabric.

Table 2: *Barcol Hardness readings*

SPECIMEN	BARCOL HARDNESS		
A	82	85	84
B	39	42	38

Fig.8. *Comparison of specimens based on Barcol Hardness*

IV. CONCLUSION

On the upcoming study the natural fillers are added with the prescribed weight ratio to the carbon and jute fiber composite and Glass fiber and its mechanical characteristics are analysed by the same testing

procedure and by comparing the obtained results, the better material composition is finalized.

V. REFERENCES

- Oksman K and Clemons C 1997 Mechanical properties and morphology of impact modified polypropylene–wood flour composites Journal of Applied Polymer Science pp 1503-1513
- Ismail H, Salmah M and Nasir 2001 Dynamic vulcanization of rubber wood-filled polypropylene/natural rubber blends Polymer Testing pp 819-824
- Bisht N and Gope P C 2015 Mechanical properties of rice husk flour reinforced epoxy bio- composite. Int Journal of Engineering Research and Applications 5 Issue 6 (Part -3) pp 123- 128
- Begum K and Islam M A 2013 Natural fiber as a substitute to synthetic fiber in polymer composites: A review, Res. J. Eng. Sci. pp 46–53
- De Sousa M V, Monteiro S N J and D'Almeida J R M 2004 Evaluation of pre-treatment, size and molding pressure on flexural mechanical behavior of chopped bagasse polyester composites, Polym. Test. pp 253–258
- Yadav S , Gupta G and Bhatnagar R 2015 A Review on Composition and Properties of Bagasse Fibres International Journal of Scientific & Engineering Research 6, Issue 5 pp 143-148
- Swain P T R and Biswas S 2014 Physical and mechanical behavior of Al2O3filled jute fiber reinforced epoxy composites Int J Current Engg Tech pp 67-71
- Mishra A 2013 Strength and corrosion testing of jute/ glass- epoxy hybrid composite laminates Plastic and Polymer Technology pp 48-54