CHARACTERIZATION OF JUTE FIBER REINFORCED PHENOLIC RESIN WITH SIC FILLER

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Abstract: Composite materials are commercially recognized since last three decades due to their excellent mechanical properties. The literature review has showed the poor wear characteristics of natural fibers. The present work is to make an attempt to improve the mechanical properties. The aim of the research is to determine the optimum concentration of constituents to have best set of properties. In the present work the effect of addition of Silicon carbide on mechanical properties of jute fiber reinforced phenolic resin is studied. The woven jute fabric reinforced phenolic resin is fabricated by conventional hand lay-up technique. The SiC in powder form was used as filler material. The concentration of the filler material i.e. SiC in the matrix is varied to have clear understanding about the effect on properties of the composite. The fabric g.s.m. and the resin concentration is kept constant throughout. Tensile tests, flexural tests, compression and impact tests were conducted. The result data thus obtained from the tests is useful in assessing the feasibility of jute fiber reinforced phenolic composite in mechanical applications.

IndexTerms - jute fiber, SiC, ceramic filler, phenolic, natural fiber.

I. INTRODUCTION

Polymer matrix composites are very popular amongst the wide range of composite materials. The reason is that it is relatively cheaper and the manufacturing method is simpler. The mechanical properties of thermoset polymers such as tensile strength, compressive strength and impact properties are found to be very low as compared to the conventional materials. [1] This disadvantage can be overcame by incorporating a secondary phase in the polymer. In this way a polymer matrix composite (PMC) is formed.[2] A wide range of applications are provided by the polymer matrix composites from civil engineering, sport goods, medical supplies to aerospace industry in making the airplane fuselage. Composite materials are also useful in marine applications where the metals fails due to corrosion.[3] Composite materials also have good fatigue properties when compared to steels. [4]Manufacturing processes of metals results in accumulation of harmful gases such as Sulphur dioxide, nitrogen dioxide etc. These gases are responsible for acid rain which causes a no. of health as well as environmental issues. Taking the pollution caused due to manufacturing of conventional metallic and alloy materials the composites are the need for tomorrow. The composite materials are used as a substitute to metals in many applications. [5-6] One of the most common example that we can see in our day to day life is roofing made up of PMC(polymer matrix composites) consisting of glass fiber or natural fibers, which was conventionally made by using iron sheets or concrete.[7]
Another example would be the doors. From ancient times the doors are used to be made of cast iron plates or wooden plates. Considering the continuously growing civil industry there is huge demand for building materials. The composite materials can effectively serve this purpose. [8]
There is a wide variety of reinforcement material that is available to use with PMC.[1,4] The main categories are natural fibers and synthetic fibers. The common synthetic fibers are glass, carbon and aramid etc. The common types of natural fibers available are jute, hemp, banana etc. [9]Although the mechanical properties of synthetic fibers are good than that of natural fibers, the main problem is with manufacturing and availability of raw materials for synthetic fibers.[10,11]The synthetic fibers are relatively costlier in production than the natural fibers. In recent years the research is being carried out to produce cheaper composites by using jute fibers and thermoset blends to have a desirable set of properties.[12]
Jute fiber is composed of cellulose and lignin.Both types of reinforcements viz. synthetic and natural fibers have their advantages and disadvantages. Jute fiber is pretreated before manufacturing the composite material because jute fibers are hydrophilic in nature i.e.

they tend to absorb water present in surrounding even in the form of humidity.[3-6] Jute fiber is treated with alkaline solution generally NaOH to increase its strength by making it hydrophobic in nature. The alkaline pretreatment also helps in improving adhesion between the fiber and matrix. [13] Which will then help in effective transfer of load to the reinforcements. Jute is one of the most affordable natural fibers. Production of natural fibers have a substantially less impact on environment when compared to glass and carbon fibers. And jute fibers are biodegradable. The advantages possessed by the composite materials prove their feasibility by replacing the conventional metallic materials used in industries. [14]

The properties of composite material also depends on the manufacturing technique used. The orientation of reinforcement of fibers in matrix also plays a major role in load carrying capacity of the material. [13-15]

Jute fiber is naturally grown by using renewable energy sources i.e solar energy. In jute fiber composites, the volume of fiber used is much larger for developing equal strength as that in case of glass fiber composites. [11] Which results in less fraction of polymer matrix. The less the fraction of thermoset used reduces the use of plastic.

Cost is also a major controlling factor in designing a material. As jute fiber is available naturally, jute fiber reinforced composites finds it uses as a cheap material and as a substitute to wood. [8]

Phenol is one of the most important thermosetting polymer. Phenolic resin exhibits desired properties like high stiffness, good electrical insulation, dimensional stability and good corrosion resistance.[1-4]Phenolics are flame resistant, low smoke producing compounds which makes them an effective material as a matrix for high temperature applications.[1-4] Phenols are also suitable for wear resistant applications.[1]

II. EXPERIMENTAL

Selection of the materials

As day by day the research is being shifted towards finding cleaner and cheaper materials in manufacturing applications. Natural fibers are cheap in production and most importantly are eco-friendly. The jute fiber woven fabric is selected as the secondary phase of the composite. Fig. 1 describes the consistency in the woven pattern of the jute fabric. Which will effect the directional properties of the compositei.e. isotropic properties.

The mechanical properties of the composite material depends on the interaction between the different constituent phases. [1] Jute fibers have good affinity towards phenolic resin. [3] Phenolic resin of grade 7802 is selected as the matrix material.

The filler is added to the composite material to introduce properties such as wear characteristics which cannot be achieved through the reinforcement or matrix phase. [14,15] Use of ceramic materials have shown good results in improving wear characteristics of composite material. [14] Silicon carbide (SiC) in powder form with particle size as 5µm approx.

Procurement of materials and equipments

Raw materials needed are jute fiber woven fabric, particulate SiC filler, phenolic resin, sulphonic acid, ethanol for pretreatment of jute fabric. Equipments needed are brush, sponge roller, measuring jar, tray, polyethylene sheets. Raw material for fabrication of composite is procured from local industrial sources. Raw jute fiber woven fabric is obtained readily from RanganathanChettiar Traders, Parry's, Chennai, Tamilnadu. Phenolic resin of grade 7802, as a matrix material is obtained from Linear Polymers Pvt. Ltd. Panicheri, Chennai. SiC particulate filler of 5µm particle size is purchased from parry's. The basic hand lay up technique at room temperature is followed. ParatolueneSulphonic acid is used as a catalyst hardener to facilitate solidification at room temperature.

Fig. 1 Consistency in woven pattern of Jute fabric

Preparation of samples

Samples are to be prepared for performing tensile tests, flexural test,impact and compression tests to compare results before and after adding SiC.For this purpose the jute fabric is cut into uniform area of 30*30cm^2,as shown in Fig. 2. After manufacturing these prepared samples are cut in specific measurements as specified in standards.

Fig. 2 Jute fabric cut in sheets of 30*30cm^2

Pretreatment

The fabric still contains a small amount of water content and starch. This may affect the properties of jute fiber such as decrease in tensile strength. To avoid this problem the jute fabric is treated with ethanol solution to remove starch. The ethanol is varnished on jute fabric with the help of nylon brush. It was allowed to dry at room temperature. To remove the moisture content from the fibers heat treatment is used. The jute samples were heated in oven at 100°C for about 1 hr.

Manufacturing

The manufacturing process is done by conventional hand lay-up technique. Manufacturing of samples is done on polyethylene sheets. The paratoluene sulphonic acid is used as hardener with concentration of 5%wt of resin. SiC in particulate form with 5µm is used in manufacturing. The SiC in particulate form is mixed in phenolic resin in beaker. For manufacturing of one specimen 600 gm of phenolic resin was used. Six layers of jute fabric were used in manufacturing of one specimen. While manufacturing of SiC filled composite, the SiC powder was mixed with liquid phenol thoroughly. The mixture is stirred well to have homogeneity in SiC distribution as SiC powder may get settled down in beaker. The SiC concentration used is 0, 5%wt.

Fig. 3 Manufactured specimen of Jute fiber reinforced phenolic composite with 0% of SiC

The pre-treated sheets of pre-cut jute fabric is placed on polyethylene sheet and phenolic resin mixture is applied on it evenly using brush. Multiple numbers of sheets are used in manufacturing with one above another to achieve required thickness of 8mm. Fig. 3 shows the manufactured sample with 0% of filler.

A uniform pressure of roller should be employed while manufacturing successive layers. This is done to remove any trapped air bubble in between two successive layers. As greater pressure may cause the phenol applied in fabric to come out from sides, sufficient and uniformity in pressure was maintained.
Characteristic gray color can be seen in the sample with 5% SiC. The specimen is shown in Fig. 4.

Fig. 4 Manufactured specimen of Jute fiber reinforced phenolic composite with 5% of SiC

Curing

The manufactured samples were first allowed for drying at atmospheric temperature. Later the samples were heated in oven at 80°C for about 1hr. The manufactured samples are allowed to cure at room temperature.

Tests

1. **Tensile test**

The ratio of maximum load on an engineering material to the initial cross section is known as ultimate tensile strength. The tensile properties a composite material depend on the adhesion between the constituent phases in the composite material.[2] The samples with different set of concentration in terms of SiC %weight were tested on universal testing machine.

The specimen size is 250*25mm^2.

2. **Flexure test**

In flexural test the specimen is simply supported at two ends and the load is applied on the top of the specimen. The specimen is subjected to bending. During the test the top layers are subjected to the compressive stress whereas the bottom layers are subjected to tensile stress. [2] Flexural strength increases with increase in bonding between the phases of composite i.e. fibers and matrix. The specimen size is 250*25mm^2.

3. **Compression test**

The procedure followed was similar to that of tensile test. Whereas the load applied on the specimen in compression test is in inward direction, opposite to that in tensile test. The specimen size is 24*12mm^2.

4. **Impact test**

For checking the impact strength the CHARPY test is employed. CHARPY test gives the amount of energy absorbed during the fracture. The sample size used is 55*12mm^2.

III. RESULT AND DISCUSSIONS

1. Effect of pretreatment-

The natural fibers are often pretreated before being used manufacturing. The pre-treatment is done primarily to increase the mechanical properties of the fibers. Unlike the synthetic fibers natural fibers contain a substantial amount of water content.[13] Which have to be removed before manufacturing. The jute fibers also contain starch. The starch is mainly responsible for the hydrophilic nature of the jute fiber. The starch is removed by the ethanol treatment on the jute fabric. The studies have shown that the pre-treatment enhances the mechanical properties of the natural fibers. [8,13] As stated in previous section the moisture present in Jute fibers is removed by heat treatment in oven at 100°C for 1hr.

2. Mechanical properties without filler

The mechanical properties of the composite manufactured without using silicon carbide are tested on UTM for tensile and compressive strength. Charpy test is employed to have impact strength. Whereas the three point bending test is used to get flexural strength. [14] The test results are tabulated in Table 1.

3. Effect of addition of filler on mechanical properties

Tests are carried out in same manner as in the non-filler containing composites. The test results gave a clear understanding of the effect of addition of the filler. [14]

TESTS	0%SiC	5%SiC
Tensile (N/mm^2)	40	52
Compression(N/mm^2)	25	32
Flexural(N/mm^2)	47	60
Impact(Joules)	3.5	5

Table 1

The mechanical properties of the composite material depend on the interaction between constituent phases i.e. fibers and the matrix. Tensile test resulted in brittle fracture. Compression test showed the delamination effect. Flexural properties are satisfactory due to the brittle behaviour of the matrix phase. As evident from the results the impact properties of the specimens were very less.

IV. CONCLUSION

Comparing the results obtained in similar research improvement in mechanical properties is observed. [13] The ethanol treatment and mild heating in oven results in better mechanical properties.

The influence of SiC filler on characteristics of jute-phenolic composites is observed. Incorporation of the SiC has shown a significant improvement in mechanical properties of the composite material.

The damage occurred to fibers in unfilled specimen is overcame in SiC filled jute-phenolic composite. The reduction in fiber breakage was due to the increase in density of the SiC filled matrix phase.

25 to 30% increase in tensile, flexural and compression strength is observed from test results.

The mechanical properties are greatly influenced by manufacturing technique used. The adhesion between the laminates is the most influencing parameter.

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VI. REFERENCES

[1] Sanjay K. Mazumdar; Composite manufacturing; CRC press; 2002 edition.

[2] Gaurav Agarwal, Amar Patnaik and Rajesh Kumar Sharma, Thermo-mechanical properties of silicon carbide-filled chopped glass fiber-reinforced epoxy composites; 2013, 5:21

[3] B. Singh, M. Gupta, AnchalVerma;The durability of jute fiber-reinforced phenolic composites;60 (2000) 581-589

[4] Mallick, P.K., Fiber–Reinforced Composites: Materials, Manufacturing and Design", Marcel Dekker Inc, 1993.

[5] M. Boopalan&M.J.Umapathy&P.Jenyfer; Comparative study of mechanical properties of jute reinforced polymer composites and sisal fibre reinforced polymer composites. 10.1007/s12633-012-9110-6

[6] Navin Chand, U.K. Dwivedi; Effect of coupling agent on abrasive wear behaviour of chopped jute fibre-reinforced polypropylene composites. Wear 261 (2006) 1057–1063

[7] B. Suresha, G. Chandramohan;Three-body abrasive wear behaviour of particulate-filled glass–vinyl ester composites; 200 (2008) 306–311

[8] B. Singh, M. Gupta;Performance of Pultruded Jute Fibre Reinforced Phenolic Composites as Building Materials for Door Frame;DOI: 10.1007/s10924-005-2944.

[9] Agarwal, B.D., and Broutman L.J., "Analysis and Performance of Fiber Composites"

[10] BülentÖztürk; Hybrid Effect in the Mechanical Properties of Jute/Rockwool Hybrid Fibres Reinforced Phenol Formaldehyde Composites. 10.1007/s12221-010-0464-3.

[11] K. Sabeel Ahmed, S.Vijayarangan; Tensile, Flexural and interlaminar shear properties of woven jute and jute-glass fabric reinforced polyester composites. 207(2008)330–335.

[12] M. Boopalan, M. Niranjanaa, M.J. Umapathy; Study on the mechanical properties and thermal properties of jute and banana fiber reinforced epoxy hybrid composites. Part B 51 (2013) 54–57.

[13] Dipa Ray, B.K. Sarkar, S. Das, A.K. Rana ;Dynamic mechanical and thermal analysis of vinylester-resin-matrix composites reinforced with untreated and alkali-treated jute fibres. 62 (2002) 911–917

[14] K. Sabeel Ahmed, Syed Sha Khalid, V. Mallinatha, S.J. Amith Kumar; Dry sliding wear behaviour of SiC/Al_2O_3 filled jute/epoxy composites;36 (2012) 306–315.

[15] Subramanian, Asaithambi P, Kishore. Friction and wear of epoxy resin containing graphite; J ReinfPlast Compos 1986;5:200–8.