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Develop and Investigate the Mechanical Properties of Natural Fiber Reinforced Polymer Composites

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***Abstract*— From recent few years, the role of natural fibers reinforced polymer composite materials are increasing in a faster rate in the field of engineering and commercial applications due to its constructive properties. The fibers from the natural sources provide unarguable advantages over synthetic reinforcement materials such as low cost, low density, high strength, and waste disposal problems. This study is to investigate the mechanical behaviors of natural fibre composite consists of Jute and Banana fibre as reinforcement and epoxy resin as matrix. The Banana fibres treated with acetone to improve its surface properties. The conventional hand layup technique is used to prepare different composite specimens samples. 16 numbers of different composite specimens are prepared with varying compositions of Banana fibres and epoxy resin. The objective of this study is to investigate the mechanical behavior of natural fiber composite material by using Experimental Technique. The nature of hybrid reinforcement with jute fiber at different composition is also studied. The samples are exposed to the mechanical testing like tensile test, hardness test and impact test and moisture absorption test. The results shows that the properties of hybrid banana-jute fiber composite shows better mechanical results as compare to individual banana fibre composite and which is sufficient to partly replacing currently used glass fibers composite reinforcement.**

Keywords: Mechanical properties, Hybrid composites, Banana fibers , Jute fibers ,Epoxy Resin.

I. Introduction

Use of natural fibers reinforcement in to Polymers has increasing day by day from last few years. While considering the surrounding aspects it is very remarkable if natural fibres could be used instead of glass fibres as reinforcement in some particular applications. Natural fibres have many advantages compared to glass fibres, for example they have low density, recyclable and decomposable also they are renewable raw materials and consist high strength and stiffness. Due to low density values producing composites that have good mechanical properties with a low specific mass.[1] The natural fibers are renewable, having a good calorific value, having good mechanical property. Due to its good eco-friendly nature makes the materials used in engineering markets such as the automotive industry and structural.[2] Natural fiber include Hemp, jute,.Banana,coir,sisal,kenf and many others. applicable for aerospace, sports, packing and automotive industries with use of natural fiber reduce weight of component by 10% , cost 5% than the fiber glass reinforced composite.[3] Due to good the mechanical properties of Ukam , sisal , hemp , coir , fiber reinforced composite asses the opportunity of some new material in engineering application.[4] in the comparatively study of the mechanical properties short chopped jute fiber epoxy and polyester composites the jute-epoxy have better mechanical properties as compared reinforced with jute-polyester composite[5].As comparing life cycle environmental performance of natural fiber composites with glass fiber composites found that natural fiber composites are biologically better in the some applications for the reasons as natural fiber production have lower environmental impacts as comparing to glass fiber production, these composites have higher fiber content for same performance, which reduces the amount of more environmental affected polymers, lower weight of NFR composites decrease the fuel consumption when used in auto industries applications[6]

Banana fibre is a waste product of banana cultivation so without including Extra input cost banana fibre can be used for industrial application purposes. The 40% banana fiber and 60% epoxy resin composite materials withstand the higher mechanical results when compared to the other combinations and used as an alternate materials for conventional fiber polymer reinforced composites. [2] Properties of the banana fiber composites are strongly depended on fibre length [1].Hemp-glass fiber reinforced hybrid composites and reported that The banana-glass fiber hybrid composites have more tensile strength than other composites. maximum flexural strength of 0.51kN obtained by the banana-hemp-glass fiber reinforced composites. And suggested that the banana-hemp-glass fibers reinforced hybrid epoxy composites can be used as a alternate material for synthetic fiber reinforced composite materials.[7] impact behavior jute fiber into resin like methacrylate soybean oil and reported that these materials present a better environmental sustainability than glass fibres recyclability and biodegradability, lower cost as well as higher mechanical properties because of their lower density than that of glass fibre.[8] The applications of jute polyester composites in manufacturing of suitcases, paper weights, helmets, electrical appliances, covers, pipes, post-boxes, roof tiles, panels for partition and bio-gas containers, and in the construction of mobile cover The jute fibers have a uniform cross section with micro fibrils having a multicellular structure. However, its mechanical properties are strictly not consistent and mainly depend on geographic origin, climatic growth conditions and processing techniques. [5].

Epoxy resin is thermosetting resin it is linked adhesive

polymer structure that are used in surface coating. For the fiber reinforced polymer Epoxy resin play role as the matrix to binding the fiber in place. For the matrix phase epoxy resin (Lapox HY 951) & Hardener (Lapox LY 556) used for bonding the fibers. [9] Epoxy resin is used for the composite as a binder with hardener, having the outstanding properties as good adhesion to dissimilar materials, high strength, toughness resistance , highly resistance to chemical attack and moisture, Odorless, tasteless and completely nontoxic , very less shrinkage. In application composite as part of structural unit, the major difficulty is low impact properties, which can be improved by integration of discrete layers of tough resin. As thermoplastic resins required a treating temperature which is higher than natural fibre, not used for natural fibre composites. as thermosetting resins cure in room temperature and they are widely used in natural fibre composites. Epoxy can shows better properties as a matrix.

Chemical treatment with NaOH removes moisture from the fibres which increase its strength, flexural rigidity of the fibres. this treatment removes all the impurities that are adjoining the fibre material and also give stability to the molecular orientation. [10] in this study acetone is used to clean the banana fibers. The surface modification by alkali treatment has improved the Mechanical properties than untreated fiber composites. The alkali treated banana fiber has improved the mechanical properties like tensile, flexural and impact strength of both the epoxy and vinyl ester composite. Define scope that use of various other natural reinforcing material mix with banana fiber to form a better hybrid composite which has a better mechanical properties and as well as cost effective.[11-14] hybrid coir – bagasse fiber with polymer resin he found that the 30% coir fiber 10% bagasse and 60% polyester resin shows the better mechanical properties compare to other combination .[12] Due to the challenges of petroleum based products like traditional reinforcing fibers glass and carbon fiber the need to find renewable resources. The combination of different natural fibers found to give better mechanical and physical properties.[13]The composite are made up by hand lay-up technique. The mould used for fabricating the composite is made up of two rectangular chromium plates size 300X300mm beading used to maintain thickness 3mm around mould plates.[15]In this study we compare the mechanical properties as tensile strength , impact strength, Hardness , % of Water absorption of Banana fiber and banana-jute hybrid fiber as matrix and epoxy as resin, conventional hand layup technique is used to fabricate desired composite .

II. METHODOLOGY

A. Materials

In this study the composite is prepared by Banana fibers and hybrid composite is prepared by banana-jute fibres and matrix used as epoxy resin with hardener due to its ease of availability and increasing demand in environmental friendly materials, significant importance in composite engineering.

2.1 Banana Fibers

The loose banana fibres are imported from Gujarat (India), Initially the fibre length is measured as 50 -60 cm as shown in fig.1 then this fibres are first sort out properly with same length after that the selected fibres are deeper in to the Acetone solution for 5-6 min. for cleaning purpose that the all moisture and dust particles removed from the fibres after removed from Acetone solution and this clean fibres are kept for soaking for 24 hours at room temperature, then this acetone treated fibres are cut in 30cm pieces with this fibres we made a banana fiber mat as (almost unidirectional continues mat) shown in fig. 2 this mats used as a laminate during the preparation of composite reinforcement.

Figure 1 loose banana fibers

Figure 2 Banana fiber mat

2.2 Jute Fibres

Mostly two types of jute fibers are available in the market Capsularies jute fiber is whitish in nature and Olitorious fibers comes in yellow, gray, brown colors the jute used for this study is Olitorious jute it was gray in color this jute fiber is purchased in the form of bi-directional mat as shown in fig.3 These mat purchased by local dealer from pune, India.

Figure 3 Jute fiber mat

Table1 Physical properties of Banana and jute fiber[2,4,16]

Property	Banana fiber	Jute fiber
Density	1.35	1.46
Cellulose	62-64	45-64
Hemi-Cellulose	19	12
Lignin	5	21-26

2.3 Matrix Preparation

In this study we used the Epoxy resin (Grade – L-12 (3202) Density 1.15-1.20 g/cm^3 for the composite as a binder with hardener Lapox (K6) Density 0.97-0.99 g/cm^3 as shown in The epoxy and hardener used in ratio 2:1 as directed by supplier and mix properly with help of stirrer in this study we use epoxy resin as matrix because such outstanding properties as Excellent adhesion to different materials, Great strength, toughness resistance etc.

2.4 Release Agent

Two A3 size plastic paper sheet used as the release agent in

this study which avoided the sticking of the composite with the mould. Plastic paper placed over the base plate another is on top of the composite to avoid the sticking with upper plate.

2.5 Mould Preparation

Hand layup Manufacturing Technique is used to prepare Natural fiber reinforced composite for this purpose Two stainless steel plates of size 30cm X 10cm and Thickness 10 mm is used as Bottom or Base plate and Top plate of the mould, each corner of plate 7mm hole is drilled and M6 Nut-Bolt assembly use for Tightening purpose as per pressure requirement on two plates, 4mm slot provided at base plate maintain through-out thickness of composite sheet. The mold is shown in fig.5 as below.

Figure 4 Mould for composite preparation

2.6 Fabrication of Composite

First take the natural fibre and matrix solution in ratio of 40:60 by weight. Then two stainless steel plates pattern is used to prepare natural fiber reinforced composite base plate is covered with a plastic sheet to avoid any sticking action of the mixture of the natural fiber and matrix solution then fibres mat kept above the base plate or bottom plate which covered with the plastic paper .Then the matrix solution of epoxy resin and hardener is applied directly on the layer of fibre mat with the help of brush by hand. The care to be taken while applying the solution that it should be uniformly spread all over the layer After confirming uniform distribution of layer the second layer of the mat fibre is placed properly on previous layer. Again the solution of matrix is applied on this layer uniformly with hand brush. Similarly, next thread layer of the mat fibre is kept gradually on previous layers properly and matrix solution is applied continuously over it by hand brush. After keeping the layers one over another the plastic sheet is covered over it The roller is used for rolling purpose. The roller is rolled over layers of laminates smoothly and continuously removes interrupted bubbles during manufacturing, After that keep the upper plate over the plastic paper & tighten two plates with nut bolt assembly to get desired thickness of composite that is 4mm.Finally composite is kept for curing for 48 hours at atmospheric temperature with same setup as shown in fig. 5 .After 48 hours the natural fiber reinforced composite is take out as shown in fig.6

Figure 5 Sample for curing

Figure 6 Composite sheet

Finally we cut the samples from unfinished Banana composite sheet through hacksaw and finished by paper as shown in Figure 6 and Produce desired sample for testing as per respective ASTM standards. As shown in fig.7

Figure 7 Finished composite testing speciman

B. Mechanical Testing

3.1 Tensile test

The testing sample specimen prepared according to ASTM standard D3039 (250X25X4mm) is using a hand cutter and the edges are finished using an salt paper. The measurements, gauge length are chosen according to the ASTM D3039 standard. The tensile test is performed on the Universal Testing Machine. The process involves placing the test sample in the UTM and applying tension to it till the material is fracture. Then the force is recorded as a the increase in gauge length. During the application of force, the elongation of the gauge section is recorded against the applied force.in this study two different types of samples prepared according to the ASTM standards and the experiments are repeated for three times per sample and the average values are record for discussion.

Ultimate tensile strength calculated as

$\sigma t = P/bh$ (1)

Where,

P= Ultimate load on the specimen.

b= width of the specimen =25mm

h= thickness of the specimen=4.2mm

L= Initial Length of specimen =250

Table. 2 Experimental tensile strength result

Sample	Trial 1	Trail 2	Trial 3	Avg. MPa
40% Banana fiber + 60% Epoxy Resin	59.22	61.22	58.22	59.55
20% Jute fiber +20% Banana fiber +60% Epoxy	68.56	69.52	70.12	69.4

3.2 Hardness test

The hardness test is carried out on the Rockwell M Scale testing machine the higher load is applied 100 kg and ball indicator 1/16" the M scale testing commonly used to measurer hardness of soft and plastic materials. The hardness test results directly obtained from machine and recorded as in table no.3.

Table. 3 Experimental Hardness scale results

Sample	Trial 1	Trail 2	Trial 3	Avg. L scale
40% Banana fiber + 60% Epoxy Resin	42.42	42.5	41.92	42.28
20% Jute fiber +20% Banana fiber +60% Epoxy	46.12	46.22	46.28	46.2

3.3 Impact Test

The impact test specimens samples are prepared according to the required dimension as per ASTM- D256 (12.7X63.5X4) standard and V notch is created at the center of specimen ,notch depth 2.54mm, angle 45^0 During the testing the specimen loaded in the testing machine and allows the pendulum till it breaks. Using the impact test, the amount of energy absorbed by sample before fracture is determined easily by charpy impact test and this result is used to measure the toughness of material the effect of strain rate on ductility of material will be analyzed by using this test .in this study two different sample tested three times and results taken for discussion.

Table. 4 Experimental Impact energy of the composites.

Sample	Trial 1	Trail 2	Trial 3	Avg. Joule
40% Banana fiber + 60% Epoxy Resin	9.43	8.15	8.12	8.56
20% Jute fiber +20% Banana fiber +60% Epoxy	9.98	10.2	10.42	10.2

3.4 Water absorption test

The water absorption test was performed as per ASTM standard D 570. The testing sample size was taken as 25mm X25mmX4mm in this study the test is performed on two types of water as on availability of water that is ordinary water and distilled water **.**Initially samples completely dried . Then these samples were initially weighted on weight machine whose accuracy is 0.001g then this specimen is dipped in water containing plastic tub for next 14 Days at room temperature. After the 14 days span is completed samples are taken out from the tub and weighted on weight machine. The amount of moisture absorption is directly calculated by weight difference between the measured weight and initially measured weight. The percentage of water absorption is calculated through formula as.

Water absorption % ={(MW-MD)/MD}X100

Table 5 water absorption test results

Sample	% Ordinary water absorption	% Distilled water absorption
40% Banana fiber + 60% Epoxy Resin	3.72	3.42
20% Jute fiber +20% Banana fiber +60% Epoxy	4.34	4.12

III. RESULT AND DISCUSSIONS

In this presented experimental study the individual banana fiber composite laminate and Hybridized Banana-Jute Fiber composite laminate with epoxy resin as matrix is prepared with hand layup manufacturing technique. And the 16 no. testing sample is prepared according to respective ASTM standard for Mechanical property testing as Tensile test , Impact test and hardness text ,samples are tested on the Universal testing machine for Tensile and on Impact test machine for impact energy, the average values of each test is considered as a final results, Results indicate that the hybrid banana-jute fiber and epoxy resin composite shows better mechanical properties compare to banana fiber epoxy resin composite . the tensile strength, hardness, impact energy and % of water absorption of banana and banana-jute fiber composite fiber are listed in table 6.

Table no.6 Experimental results of composite tested samples

Sample	Tensile strength MPa	Hardness scale reading	Impact Energy Joule	% water absorption
40% Banana +60% Epoxy Resin	59.55	42.28	8.56	3.42
20% Jute +20%Banana fiber +60% Epoxy resin	69.4	46.2	10.2	4.12

4.1 Tensile Testing Analysis

The banana fiber and hybridized banana-jute fiber reinforced composite specimen are prepared with different volume fractions and tested on the universal testing machine (UTM). The tensile strength comparison of the different combinations of the banana-Jute fiber epoxy composites are presented in Fig.8. From the figure it has been clearly indicated that the hybridized banana-jute fiber reinforced composite shows higher tensile strength 69.4Mpa as compare to banana fiber composite.

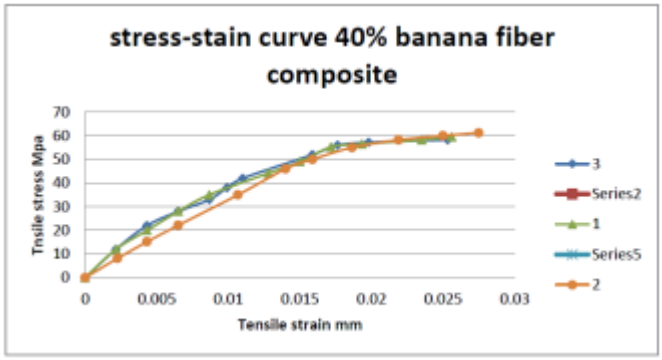

Figure 8 Stress vs strain curve 40% banana composite fiber.

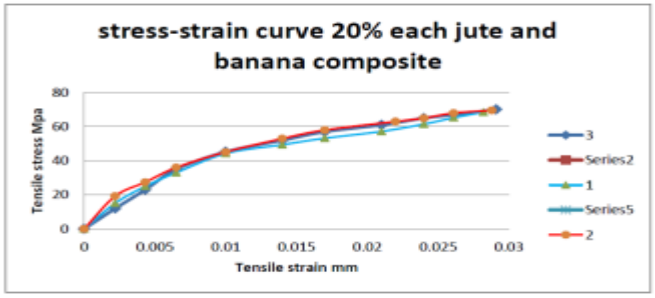

Figure 9 Stress vs strain curve 20% Jute fiber and 20% banana fiber composite.

Table no.7 Experimental Result from test as

40% banana fiber composite		
Max.load (KN)	Max.defection (mm)	Young's modulus E (GPa)
6.33	5.92	2.29
6.87	6.18	2.27
6.42	5.91	2.38
20% Jute and 20% banana fiber composite		
7.6	6.98	2.43
7.2	7.12	2.41
7.27	7.0	2.40

E= ultimate tensile stress/tensile strain(2)

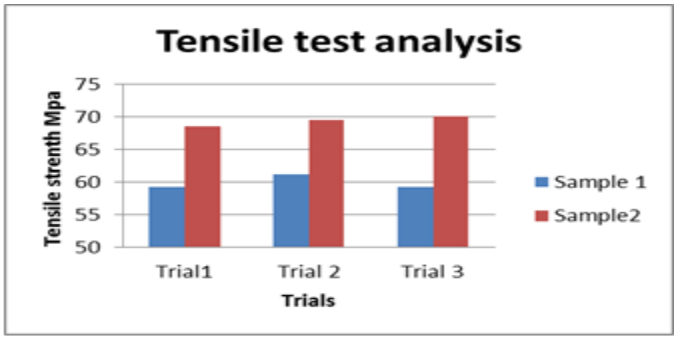

Figure 10 . Tensile test Results

4.2 Hardness Test analysis

The carried out on the Rockwell hardness machine the hardness of the sample measured directly from Rockwell M scale readings. Maximum load 100kg is applied then results was found in close conjunction with each other. Hybridized composite sample shows result as 46.2 and banana fiber composite shows result 42.28 after calculating the average result as shown in fig.11

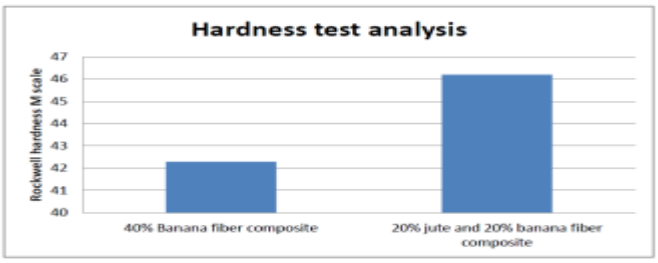

Figure no. 11 Hardness test results

4.3 Impact Test analysis

The banana fiber and hybridized banana-jute fiber reinforced composite specimen are prepared with different volume fractions and tested on the Impact testing machine . The Impact energy comparison of the different combinations of the banana-Jute fiber epoxy composites are presented in Fig.12 From the figure it has been clearly indicated that the hybridized banana-jute fiber reinforcing composite shows higher energy absorption capacity as compared to banana fiber reinforcing composite measured as 10.2 vs 8.56

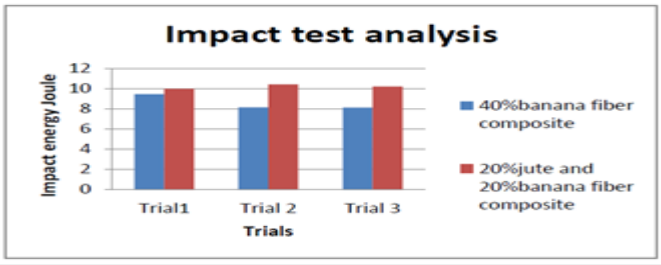

Figure 12. Impact Test results

IV. CONCLUSIONS

In this experimental work, the banana and jute fibers are used as a reinforcing material with epoxy resin as a matrix, the composites are fabricated and mechanical characteristics of these materials are examined. From the experiment the following conclusions has been found.

1.The maximum tensile strength is 69.4MPa which is obtained by the 20% Jute fiber and 20% banana fiber and 60% epoxy resin composites

2. The maximum Impact energy is also obtained by the same combination of the composite samples that is 10.2 joules.as compare to 40% banana fiber and 60% epoxy resin composite 8.56 Joules.

3. Hardness test proved that the hybridized banana-jute sample withstands with higher impact load as compare to only banana fiber sample.

4. Banana fiber composite shows better result as compared to Hybridized banana-jute fiber composite in both ordinary and distilled water conditions.

From the experimental study it can be suggested that, the hybridized Jute-Banana fiber 20% each and 60% epoxy resin composite materials can withstand the higher loads, High tensile strength, high impact strength when compared to the 40% banana fiber and 60% epoxy combinations and used as an alternate materials for conventional fiber reinforced polymer composites and application suggested as rear view mirror cover, visor in two wheeler, seat cover, indicator cover, cover L –side, writing pen, name plate has been fabricated and it can be replaced with the existing glass fibers. Finally this paper concluded that one of the best materials is Banana and jute hybrid fiber composite can be used to make the variety of products in automobile accessories.

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