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Evaluation of Mechanical Properties of Fishtail palm fiber composite reinforced with polyester matrix, by an innovative approach

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***Abstract*— This paper presents the results of a current research of the mechanical properties like ultimate strength and stiffness modulus in composites using natural fiber reinforcements. Fish tail palm fibers were selected to this study, in order to get good surface morphology and better bonding of fiber surface with matrix, fibers were processed for mercerization and then followed by alkaline treatment. The cross section and diameter of fish tail palm fiber was investigated by using laser beam equipment and tensile strength of single fiber was investigated by Electronic Tensometer of 2 ton capacity. Fish tail palm fibers of almost circular cross section were selected to this study to investigate mechanical properties these fibers are randomly distributed in polyester matrices to produce composite specimens in the form of rectangular strips of 160 mm x 12.5 mm x 3 mm thick are prepared by innovative approach of hand lay-up process . Five sets of specimens were molded at three different fiber volume fractions. Tensile test was performed all these sets of specimens. The average ultimate tensile strength, tensile modulus was determined. Impact strength of composites also investigated by moulded 15 samples of each in 4 different volume fractions.**

***Index Terms*— Mechanical properties, Natural fiber reinforcements, ultimate tensile strength, Surface morphology ,Mercerization, Alkaline treatment, Impact strength, composite, etc.**

I. INTRODUCTION

Natural fiber reinforced composite materials consists of fibers of high strength modulus embedded in or bonded to a matrix with distinct interfaces between them. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved either of the constituents acting alone. In general fibers are principal load carrying members, while the surrounding matrix keeps them in desired location and orientation, acts as a load transfer medium between them, and protects them from environmental damages due to elevated temperatures, humidity, etc. natural fiber reinforced polymer matrix composites have attracted more and more research interests owing to their potential as an alternative for synthetic fiber composites such as glass or carbon fiber composites.

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Natural fiber composites posses the advantage such as easy availability, renewability of raw materials, low cost, light weight, high specific strength, and stiffness. Polymers used as matrix materials are commonly referred to as resins. The matrix resin generally accounts for 40 to 50 percent, by volume, of a composite material. Matrix maintains the shape of the composite structure, aligns the reinforcements, and acts as a stress transfer medium. In addition the matrix protects the fiber from abrasion and corrosion. More importantly the limitation of a composite may well be a function of matrix properties. For example thermal stability and maximum working temperature of a composite are largely determined by the matrix properties.

Fishtail palm tree contains divided leaves and triangular leaflets and got scientific name "caryotos urens" . This is a member of the "Arecaceace family" and this is also a member of the family named "palmae" this is known as "man" in hindi and supari in Bengali. The fiber that is extracted from the fishtail is undoubtedly the most unimportant product of the tree, the fiber is very strong. Fishtail flowering begins at the tree summit and then works its way downward to the bottom of the trunk.

II. MATERIALS AND METHODS:

A. *Collection and preparation of fibers*

Fishtail palm fiber was extracted by a process called retting. The base of the palmyra stack that sticks on to the trunk of tree by means of fibers they are in the form of long strips. when the tree grows up the bottom most stems are weighed enough tends to separated from the trunk of the tree in their way of bending towards the ground. These stems are separated along the fiber straps from the trunk of fishtail palm tree. These separated fiber straps as shown in fig 2.1(a) are allowed to submerged in the stagnant water. After 15 to 20 days the top layer loosens then these loosened layers are cleaned with sufficient water and kept them in the second retting tank for 3 days . After keeping the fiber straps in second retting tank for 3 days they are removed and rubbed with hands and rinsed in sufficient water. Then the fibers are graded and separated to have same size and length. Fibers are soaked initially in mild detergent soap solution for an hour and are thoroughly agitated and combed within the soap bath to remove larger part of associated dirt and pith (7). Wet fibers are pulled through a tight cotton cloth two to three times to remove the remaining dirt from fibers. Cleaned fibers are shown in fig. 2.1(b).

Fig. 2.1(a) Raw fibers

Fig. 2.1(b) processed fibers

B. Mercerization of fibers

Mercerization process changes in the fiber structure, dimension, morphology and mechanical properties'[1]. This process is believed to remove natural and artificial impurities away from fibres, create a rough fibre surface topography, and reduce fibre bundles into smaller fibres[6].The result is increased adhesion due to increased fibre surface area and mechanical interlocking between fibre and matrix. Mercerization also activates hydroxyl groups in natural fibre. Further, mercerization improves fibre tensile strengths. This treatment possibly orients fibrils along the direction of tensile forces by removing hemicelluloses from fibre, resulting in better load sharing between the fibrils. However, improving the fibre tensile strength is limited by a maximum duration of treatment [4] Studies by Prasad *et al*. showed that in 5% aqueous solution of NaOH at 28^0C, for 48 h duration fibre tensile strength increases but begins to decrease gradually after 72–76 h duration. The alkali modified surface, improved fibre tensile strength and fibre thermal stability help to improve properties of composites .

C. Investigation of Diameter and cross sectional shape of the Fibers

Laser beam equipment supplied by spectra-physics, USA is used to investigate the cross-sectional shape of the natural fibers considered. The laser equipment consists of a tiny hole through which a Ne-He beam emits. The wavelength of the light beam is 6323 A^0. Where A^0 is 10^{-10} m. The beam of light gets diffracted when falls on the slender wire. The equipment measures diffraction patterns of single slit, thin hair, optical gating, and diameter of thin wire etc.

A stand for folding the fiber across the laser beam light and having facility to rotate the fiber in its axis is fabricated. It consists of two vertical cardboard sheets attached to a flat wooden plank facing each other. At the centre of each vertical sheet a rotary thin disc is supported such that the disc rotates about its axis. The axes of these discs are collinear. The fiber is aligned and attached to the center of the discs. Rotating the two discs rotates the fiber about its axis.

The laser beam is focused on to the screen at a distance of about 2m from the fiber. The discs which holds the ends of the fiber, are placed between the screen and laser equipment. The laser beam is adjusted such that the beam intersects the axis of the fiber at right angles. The fibre twist is removed by rotating the one of the rotary discs attached to the vertical plate of the fiber stand. Then the laser light focused on the fiber diffracts and the pattern falls on the screen. Fine adjustment is made to view the bright and dark bands of different order. The distance between the middle and the first bright fringe represents the diameter of the fiber. This measurement is noted for every angular increment of 45^o of the fiber about its axis. The diameter of the fiber at steps of 45^o is found. The average diameter of the fiber at 0^o, 45^o, 90^o, and 135^o, is calculated. These values are magnified to 10000 times so to plot the on a graph sheet. The plot is clearly the periphery of the fiber. The cross section of the fiber is decided whether circular or not. Fish tail palm fibers having circular cross section are considered for tensile testing.

D. Determination of density of fishtail palm fiber

Density of fishtail palm fiber was determined by pyconometric procedure. A Pycnometer is a vessel with a precisely known volume, is filled with a canola oil , weighed on a digital balance of 1 mg sensitivity say, (w1). Similarly fishtail palm fiber was weighed was(w2) then the fiber was immersed in vessel contains canola oil. Again weighed the vessel along with canolaoil and fiber was (w3) , now determine weight of the fiber in canola oil was (w3-w1) .

We know, Specific gravity = Weight of the body in air / weight in equal volume and,

Specific gravity = Density of fiber/ Density of canola oil (0.92 g/cc).

III. MECHANICAL TESTING

A. Testing of tensile strength of single fiber

In order to find the tensile strength of single fibers, fibers are graded according to diameter and cross sectional shape of the fibers. Fibers of same diameter, circular cross sectional shape were selected for testing. In accordance with ASTM D 3379-89, [8] the tensile test samples of fish tail palm fiber were fabricated by mounting single fiber on a piece of stiff card board with a gauge length of 50 mm as shown in Fig.3.1. The ends of the fibers were glued on to the card board with polyester resin and tested at cross head speed of 5mm/min. in order to get valid results 20 samples were tested.

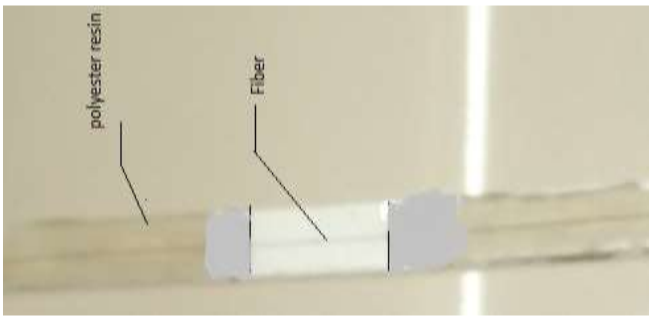

Fig.3.1 Single fiber specimen

B. Tensile testing of composites

a) Computation of volume fraction

In order to specify any composite material, we must have a quantitative description of the proportions of the constituents it contains. In manufacture, it is natural to describe the constituents of a composite in terms of their proportions by volume. Constituents (reinforcement, matrix, fillers, etc) are routinely calculated their volume before processing. To determine number of fibers incorporated in the mould cavity designers need the constituents to be quantified in terms of their volume fraction.

A sample calculation for achieving 10% volume fraction was given below.

$$V_f = \frac{\rho_m w_f}{\rho_f w_m + \rho_m w_f}$$

Dimensions of the specimen mould : 160 mm x 50 mm x 3 mm

Volume of the mould : 24 cc

V_f – *Target volume fraction* 10%

ρ_m – Density of matrix 0.54 g/cc

w_f – Weight of the fiber for 10 % Vf

w_m –
Weight of the matrix incorporated in the specimen mould

ρ_f – Density of the fibers is 1.65 g/cc

Linear density of fibers : 0.22 g/m

According to the calculations weight of the fibers required : 3.96 g

Number of fibers to be incorporated : 112 to 113

b) Preparation of mould

Natural fibers are tend to curl and wrinkled in their own way and it is difficult to align the fibers in longitudinal direction, that are parallel to each other in the mould. All conventional methods are fail to keep the fibers in pre tension in the mould. However a new approach can overcome the sited problem by Srihari Prasad et al [7]

To prepare mould a Vitrified ceramic tile was used. These tiles are nonstick, mirror like polished surface and are tough enough. The cured specimens are easily eject from the mould. Mould cavity was prepare by pasting 2-way glue tape along the pencil marked lines. These lines were marked according to the dimensions of the specimen and number of specimens to be moulded for one particular volume fraction. Peripheral 3 mm thick bank can be made by pasting second layer of 2-way glue tape over the first layer, it can stick together with tile surface hence leakage can be prevented while pouring the resin to during the gel formation as shown in fig.(2). This 2-way glue tape also helps to stick the fibers in tension between the layers at longitudinal ends. so that fibers are not wrinkled in the mould and they are aligned properly. this is the most flexible method can alter size of the mould whenever required.

A 3 mm thick laminate used to prepare was made from the polyester resin (mixed with styrene monomer), catalyst (methyl ethyl ketone peroxide) and accelerator (cobalt naphthanate) taken in the ratio of 100,1.5, and 1.5 parts by weight respectively. Then the mould was loaded with the matrix mixture and fishtail palm fibers in random orientation as shown in fig.2(b) and fig.2(c) (with varying fiber content) and was placed at room temperature for 24 hours. The cured laminates were removed from the mould, test samples were cut by laser cutting machine, edges are neatly cleaned with emery paper. Mechanical tests are performed by using an Instron universal testing machine, equipped with controller and recorder system according to ASTM D638 for tensile properties, with a loading rate of 1mm/min. The load verses displacement curves were obtained directly and the stress were calculated by using the relationships for tension bars and linear bending beams.

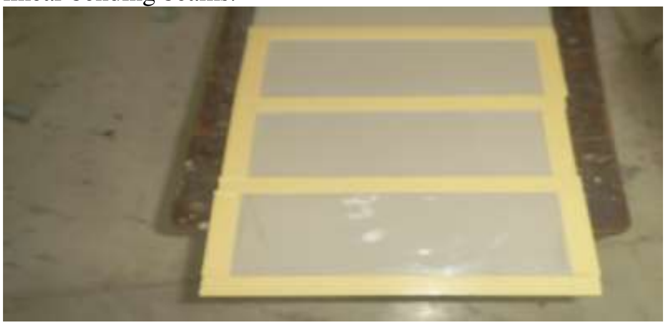

Fig. 3.2.2(a) Mold cavity

Fig. 3.2.2(b) Fibers kept in straight alignment

Fig.2.2.2(c) Composite at curing

c) Tensile testing of composites

A 2 ton capacity- Electronic tensometer of METM 2000 ER-I model, supplied by M/S Microtech, Pune, is used to find the tensile strength of individual fibers. Disc chucks are provided for gripping small, soft , fine fibers. A load cell of 20kg is used. A crosshead speed of 0.2mm/min. is set by installing suitable pulleys on the testing machine. Then the power supply is given to the testing machine to load the fiber till it breaks. A number of load-extension readings are recorded until the specimen failed. For every 0.1mm of crosshead movement, load readings are recorded. Tensile strength at failure and tensile modulus are calculated from the load-elongation data knowing cross sectional area of the specimen and gauge length. Five specimens are selected randomly from the bulk of the specimens and the average values of the tensile strength and modulus are calculated. The test was conducted for three different volume fractions (as shown in fig.2(d)) at 24^{0}c and 50% relative humidity at the laboratory conditions.

Fig.3.2.3 30% Vf 20% Vf 10% Vf

C. Impact strength

Test samples were prepared in accordance with ASTM D 256-88, [11] to carryout impact test. Specimens of 63.5 mm long, 10mm wide and 12.7 mm thick were prepared. A notch of 45^0 included angle was cut at the centre of the 10mm wide face by Hacksaw. Inorder to get valid evidence, 15 samples each were tested for four different volume fractions, under plastic impact testing machine , supplied by M/s international equipment pvt.Ltd, Mumbai, India

IV. Results and discussions.

A. Tensile properties of single fiber

It is very important that, one can find the properties of natural fiber reinforced composites, should find the properties of single fiber. Hence the authors investigated properties of single fiber. Table 1. Shows the properties of some of natural fiber along with fishtail palm fiber and E-glass fiber[12]. It is more evident that the tensile strength of fishtail palm fiber is more, compare to the other natural fibers but the density of fishtail palm fiber was little higher . Fig.4.1(a), Shows stress strain behavior of the fishtail palm fiber that, its resultant strain is directly proportional to the corresponding stress up to certain limit and beyond that the relation is not linear.

B. Tensile properties of composite

Load vs elongation graph shown in fig.4.2(a). The results shows that Fibers of 30% volume fraction composite bearing more load compare with 10% and 20% volume fractions of fibers. Fig .4.2 (b) shows that 30% volume fraction of the fibers have more tensile strength with corresponding strain. Variation of tensile modulus and specific modulus were presented in fig 4.2 (c) and fig. 4.2 (e) respectively. It is evident that tensile modulus increases with increase in volume fraction of the fibers where as specific modulus decreases with increase in volume fraction of the fibers.

C. Impact strength of composite

Fig.6 shows the results of impact strength of the fishtail palm fiber composites at different volume fractions. It is evident that impact strength increases with increasing fiber volume fraction and it has maximum value 410 j/m at 40% fiber volume fraction.

V. Conclusions

In this study, fishtail palm fiber reinforced polymer matrix composites were fabricated by hand lay- up method with an innovative approach proposed by A. Srihari Prasad [7]. Composites were prepared in three different (10%,20% and 30%) volume fractions. Before the study of composite the authors were study the properties of single fiber, from that the following conclusions were drawn

- Density of fishtail palm fiber was nearly equal to the other natural fibers such as Sisal, Cotton, Hemp, jute , ramie etc. Hence it can be consider light weight material.
- Tensile strength of fishtail palm fiber was more than that of other natural fibers. Hence strength to weight ratio is more.
- Tensile strength of composites were increased with an increasing of fiber volume fraction 0% to 30 %.
- Tensile modulus of composites were increased with an increasing of fiber volume fraction 0% to 30%.

Hence fishtail palm fiber composites are become versatile materials in automobile industries, Aerospace applications, construction applications and sports industries.

Table -1 : Properties of natural fibers

Properties	Fibers: E-glass	Hemp	Jute	Ramie	Coir	Sisal	Flax	Cotton	Fishtail Palm
Density(g/cc)	2.55	1.48	1.46	1.5	1.25	1.33	1.4	1.51	1.65
Tensile Strength(MPa)	2400	550-900	400-800	500	220	600-700	800-1500	400	700-800
E-Modulus (GPa)	73	70	10-30	44	6	38	60-80	12	45
Specific modulus	29	47	7-21	29	5	29	26-46	8	27
Elongation at failure(%)	3	1.6	1.8	2	15-25	2-3	1.2-1.6	3-10	1.5-3

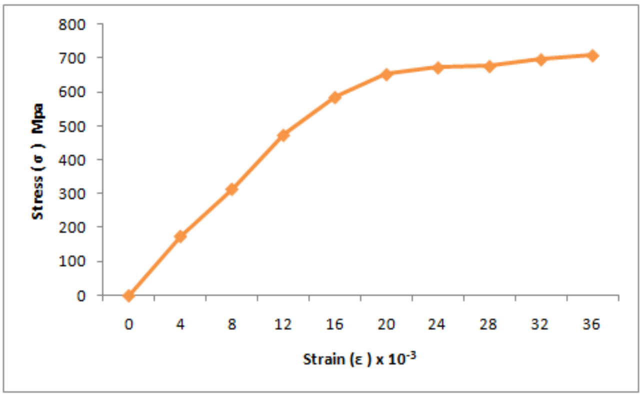

Fig.4.1(a) Stress Vs Strain curve for single fiber

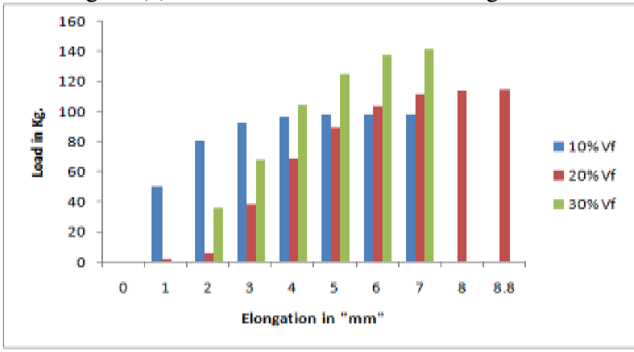

Fig.4.2(a) Load Vs Elongation of composites

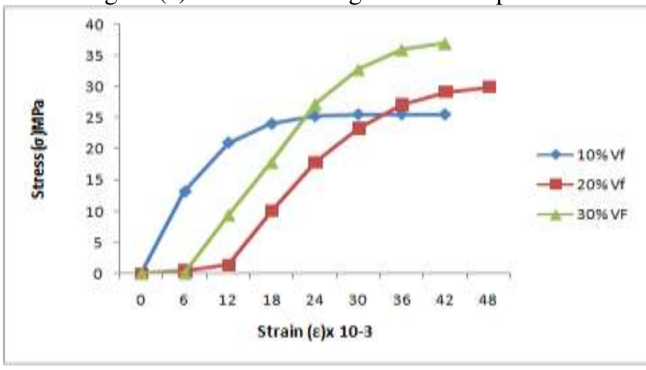

Fig.4.2(b) Stress Vs Strain curves of Composites

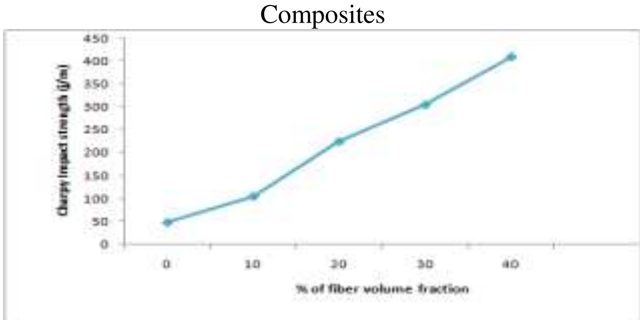

Fig.4.2(c). Impact strength Vs % of fiber volume fraction

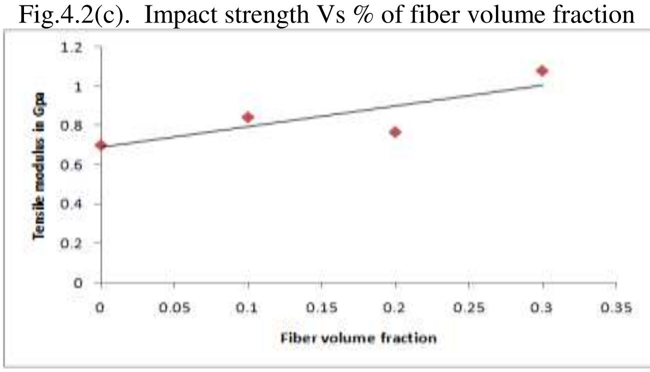

Fig. 4.2 (d). Tensile modlus Vs Fiber volume fraction

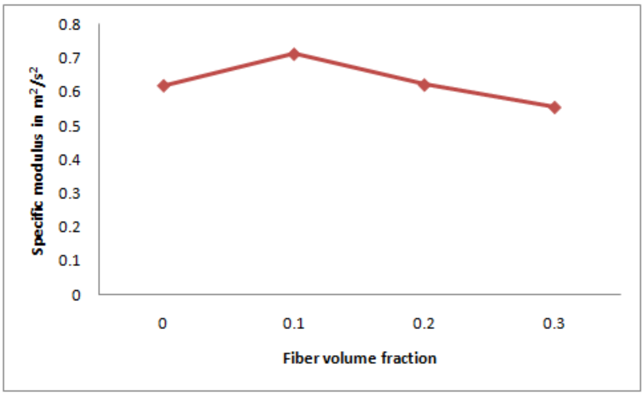

Fig.4.2 (e) Specific modulus Vs fiber volume fraction

REFERENCES :

[1] Bledzki and J. Gassan, Composites reinforced with cellulose based fibres, Prog. Polym. Sci. 24, 221–274 (1999).

[2] Y. Li, Y. W. Mai and L. Ye, Sisal fibre and its composites: a review of recent developments, Compos. Sci. Technol. 60, 2037–2055 (2000).

[3] K. Joseph, S. Thomas and C. Pavithran, Effect of chemical treatment on the tensile properties of short sisal fibre-reinforced polyethylene composites, Polymer 37, 5139–5149 (1996).

[4] S. V. Prasad, C. Pavithran and P. K. Pohatgi, Alkali treatment of coir fibres for coir–polyester composites, J. Mater. Sci. 18, 1443–1454 (1983).

[5] Mohd Yussni Hashim, Mohd Nazrul Roslan, Azriszul Mohd Amin , Mercerization treatment parameter effect on Natural Fiber Reinforced Polymer Matrix Composites: A brief review , World Academy of science and technology 68, 2012

[6] G.W.Beckermann and K.L. Pickering " Engineering and evaluation of hemp fiber reinforced polypropylene composites: Fiber treatment and matrix modification" Composites part A: Applied science and manufacturing, 39, 979-988,2008

[7] Srihari Prasad A., Balakrishna murthy, ramana k.v. and sambasiva rao G." Preparation of transversely isotropic test specimen of glass FRP composite –an innovative approach-I"journal of experimental sciences 2012,3(2): 64-67

[8] ASTM D 3379-89, standard test method for tensile strength and youngs modulus for high modulus single filament materials . ASTM International, 1975-2-28.

[9] Murali mohan Rao K, Ratnaprasad A.V., Mohan Rao K. Fabrication and testing of natural fiber composites: Vakka, sisal, bamboo and banana. Material Science 2010;31:508-13

[10] Q.T.H.Shubhra,A.K.M.M.alam,M.A.Gafur,Mubarak A.Khan et .,al characterization of plant and animal based natural fiber reinforced polypropylene Composites and their comparative study ; Fibers and polymers, 2010,Vol.11,No.5,725-731.

[11] ASTM D 256-88, standard test method for impact resistance of plastics and insulating materials, ASTM international; 1988-3-25.

[12] Paul wambua, Jan Ivens, Ignaus Verpoest, Natural fibers: Can they replace glass in fiber reinforced plastics? Composites Science and technology.