

Development and Mechanical Characterization of Palmyra Fruit Fiber Reinforced Epoxy Composites

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ABSTRACT

In recent years, lingo cellulosic fibers are increasingly used as reinforcements in many thermoset and thermoplastic matrices for the production of low-cost and lightweight materials. Composites of Palmyra fruit fiber and epoxy have been prepared with various fiber volume fractions and tested. It is observed that with increase in fiber content there is considerable increase in strength. Similarly composites of different fiber weight fractions were prepared and epoxy as matrix material. Water absorption tests were performed to assess their performances. With the increase of fiber size water absorption capability of composites were increased due to the hydrophilic nature of fibers.

Keywords: Palmyra Fruit Fiber, Epoxy, Composites, Strength, Water Absorption

Razvoj i mehanička karakterizacija epoksi kompozita oja čanih palmira vlaknom. U poslednjih nekoliko godina, celulozna vlakna se sve više koriste za ojačanje mnogih termoset i termoplastičnih matrica za proizvodnju jeftinih i lakih materijala. Kompoziti od epoksi i Palmira vlakana su pripremljeni sa različitim jačinama frakcije vlakana i testirani. Primećuje se da sa povećanjem vlakana u sadržaju postoji značajno povećanje snage. Slično tome su pripremljeni kompoziti sa različitim težinama frakcije vlakana i epoksi kao materijala matrice. Za procenu njihovih performansi urađeni su testovi apsorpcije vode. Sa povećanjem veličine vlakana kompozita mogućnosti apsorpcije vode su povećane zbog hidrofilne prirode vlakana.

Ključne reči: palmira vlakno, epoksi, kompoziti, jačina, apsorpcija vode

I. INTRODUCTION

In today's engineering world many classes of composite materials have emerged, including fiber reinforced Plastics (FRP), natural fiber composites, metal matrix composites (MMC) and ceramic matrix composites (CMC). During the last few years, a series of works have been done to replace the conventional synthetic fiber with natural fiber composites. Sisal, jute, cotton, flax and broom are the most commonly fibers used to reinforce polymers. In addition, fibers like jute, oil palm, bamboo, wheat and flax straw, waste silk and banana have been proved to be good and effective reinforcement in the thermoset and thermoplastic matrices. A number of investigations have been conducted on several types of natural fibers such as kenaf, hemp, flax, bamboo and jute to study the effect of these fibers on the mechanical properties of composite materials. In recent composite technology research and development, efforts have

focused on new out-of-autoclave material forms, and automated processes that can markedly increase stiffness, toughness, ambient & high temperature strength production efficiencies.

A. Literature Review

In order to exploit the excellent attractive mechanical properties of Empty Fruit Bunch (EFB) fibers, enormous effort is being made by the researchers to develop the EFB-reinforced polymer matrix composites. Korenis et al. [1] assessed the performance where aspects of suitability for the candidate elements in terms of mechanical properties are analyzed. Ahmed et al [2] studied the physical and mechanical properties of oil palm empty fruit bunch fiber reinforced with polypropylene. They observed that tensile strength has considerably increased with oxidized fiber reinforcement and water absorption capacity is optimum

till 25 wt. % of fiber. Beyond this water absorption capacity has increased. Nicollier and Mutasher [3] investigated mechanical properties of banana-fiber-cement composites. Thermal, mechanical and morphological properties of fruit bunch fiber reinforced epoxy composites were examined by Jawaid et al. [4]. Fractures surfaces were also studied by scanning microscopy. Rao et al. [5] studied the wear behavior of coir fiber reinforced epoxy composites with the Taguchi method. Toutanji et al. [6] studied the fiber reinforced polymer composites (FRPC) and established an effective mean for the repair and rehabilitation of infrastructure. Razak and Kalam [7] studied the effect of OPEFB size on the mechanical properties and water absorption behaviour of OPEFB/PP nanoclay/PP hybrid Composites. The EFB laminates were tested for thermal and mechanical properties. Thermal shock and thermal insulation performance of the EFB laminates were evaluated under high powered IR heating lamps simulating a high heating rate and high heat flux environment for about 70⁰ C. Velumurugan et al. [8] conducted tensile tests and finite element analysis for palmyra fruit fiber reinforced epoxy composites to determine the tensile strength and fracture properties. The influence of fibre length on wear behavior of borassus fruit fibre reinforced epoxy composites was studied by Boopathi et al. [9]. It was seen that 5 mm length of fiber reinforced composite exhibited better wear properties sliding against steel. Ogbuagu et al. [10] investigated pulp and paper making potential of borassus fruit fibers in acidic and alkali media. Fibers treated in alkali medium had lower yield than treated in acidic medium. However better mechanical properties were observed from alkali treated fibers.

B. Scope

The objective of the present research is to explore the possible use of Palmyra fruit fiber wastes as reinforcement in a polymer matrix for making composites and

- a. The fibers are to be cut and crushed to micron sizes for proper mixing with the matrix of epoxy to develop composites
- b. Hand moulding technique is employed to fabricate the tensile test bars etc. by developing suitable dies in house
- c. Mechanical characterization of these specimens in terms of tensile strength, tensile modulus etc. by

standard methods using Tensometer or available equipments.

- d. Water absorption capacity of the specimens by weight gain method as per ASTM standards
- e. Out of different types of composites so prepared the best one under above tests may be found out.

II. METHODS AND MATERIAL

A. Palmyra Fruit Fiber (PFB)

Palmyra fruit bunch fiber is a lingo cellulosic source which is available as substrate in cellulose production. The application of cellulose to produce bio-ethanol (alternative source of fuel) is handicap by high cost. The use of fruit bunch, wastage from Palmyra will reduce the cost of enzyme production comparable to other sources. Advantages of Palmyra fruit bunch fibers are its availability, renewability, low cost and high strength. These materials have been collected from local areas available in plenty in Odisha at Talcher in Angul district (Fig.1)

B. Epoxy Resin

Epoxy resin (CY-230 and Hardener-HY 951 were collected from Hindustan Ceiba Geigy Ltd, India) for preparation of the composite and investigation.

Properties of epoxy resin in use are, Density = 1200 kg/m³, Young's modulus of elasticity = 20 GPa, Tensile strength = 75 MPa.

C. Preparation of Composite

• Alkali Treatment of Fibers

The PFB fibers were taken out with specified dimensional size as mentioned earlier. The fibers were soaked in 1% NaOH solution at room temperature for 24 hours. Then, the fibers were taken out and washed with distilled water for 7 times to remove excessive alkaline solution. The fibers were dried in an oven at 80°C for 8 hours. This has been done for proper wetting of fibres with polymer matrix and has better strength than untreated fibers.

• Specimen preparation

Palmyra fibers of 2-3 mm length and 0.5 mm diameter were cut for mixing with epoxy to prepare test bars of ASTM D 638 standards for tensile test. These fibers were further crushed to particle sizes. The particles of different diameters have been selected passing it through sieve shaker. Particulate composites of different weight fractions i.e 5, 10 and 15 % respectively for three

different fiber sizes (106 μ m, 150 μ m, and 212 μ m) (Fig.2,3 and 4) were prepared.

The compounding process was performed in a dispersion mixer at 180°C which follows the standard of thermoplastic temperature with rotating speed of 50 rpm and PFB particles were poured into the mixer after 20 min. Compounding process is continued further at same speed for 10 to 15 min, to ensure the PFB particles mix thoroughly with the matrix before the compound was poured in a box type steel die for making sheets. The composite sheet was prepared after curing at room temperature for three days. Further these sheets were cut into 50x13x5 mm rectangular sizes for water absorption tests.

D. Die Design for Tensile Testing

A wooden die (Acacia wood) has been prepared suiting to the requirements of ASTM D 638 Standard as shown in Fig. 5. The limiting dimensions have been given in Table 1. The photograph of the mould is also shown in Fig.6.

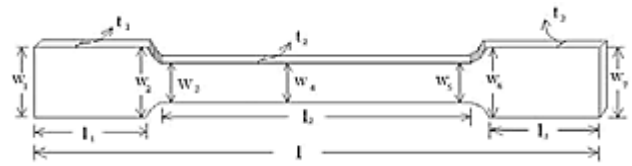


Figure 5 : Standard tensile test specimen



Figure 6 : Wooden Die block for tensile test

III. RESULTS AND DISCUSSION

A. Tensile Test

A standard specimen is prepared as shown in figure 5. The test process involves placing the test specimen in the Tensometer and applying tension to it until it fractures. During the application of tension, the elongation of the gauge section is recorded against the applied force. The Tensometer and the specimens under test have been shown in Fig.7 and 8 respectively. Tensometer has been supplied by MIKROTECH (A Kudale Enterprise based at Pune, India) in the year 1992. Capacity – 2000 Kgf (20 KN), Loading ranges are 2000,1000, 500, 250,125,62.5,31.25, 16 and 8 Kgf, Vice type grips were used. Overall dimension-965x235x230 mm. A load range of 16 Kgf was set for the experiment.



Figure 1 : Palm Fiber (0.5 mm)



Figure 2 : 212 μ m fiber



Figure 3: 150 μ m fiber



Figure 4 : 106 μ m fiber

Table 1 Specimen dimensions as per ASTM Standard

Specimen	l_1	l_2	l_3	l	w_1	w_2	w_3	w_4	w_5	w_6	w_7	t_1	t_2	t_3
Standard	42	100	42	204	25	25	13	13	13	25	25	-	-	-



Figure 7 : The Tensometer



Figure 8 : Test specimens

Figures (9-12) show the effect of volume fraction of Palmyra fiber on mean tensile strength, mean tensile modulus, specific tensile strength and specific tensile modulus respectively. In Fig. 9, mean tensile strength decreases up to volume fraction of 0.18 and then increases. In Fig. 10, mean tensile modulus increases with the increase in volume fraction. Specific tensile strength decreases up to 0.11 and then increases with the increase in volume fraction in Fig. 11. Specific tensile modulus increases with the increase in volume fraction in Fig. 12.

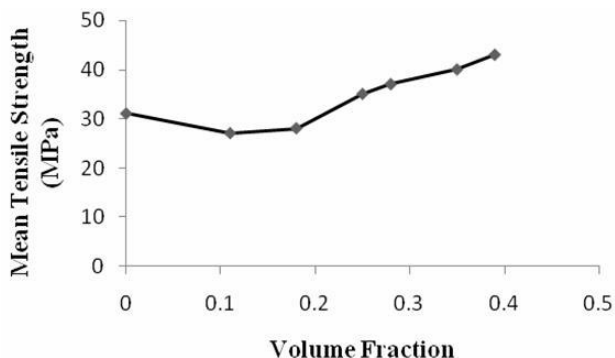


Figure 9 : Vol. Fraction vs. Mean Tensile Strength

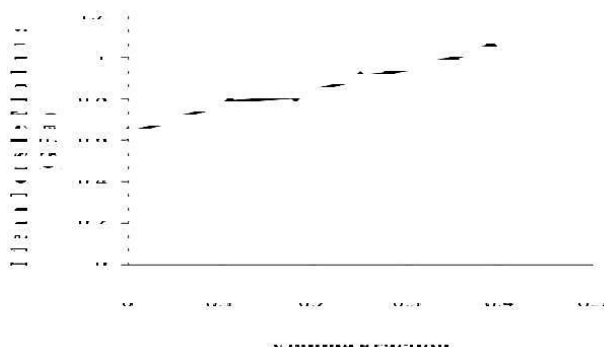


Figure 10 : Vol. Fraction vs. Mean Tensile Modulus

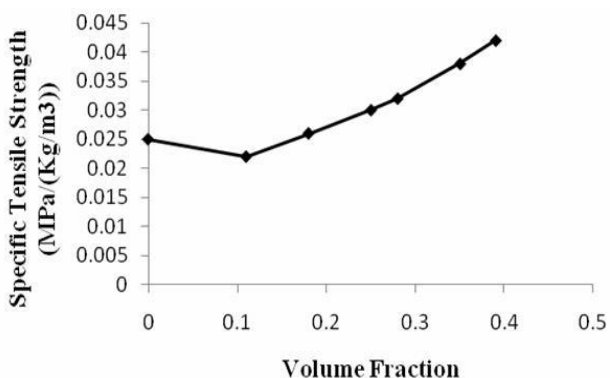


Figure 11 : Vol. Fraction vs. Specific Tensile Strength

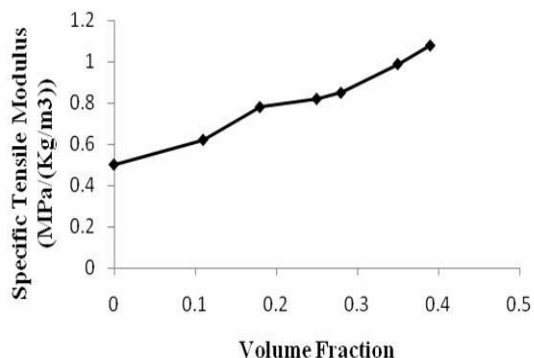


Figure 12 : Vol. Fraction vs. Sp. Tensile Modulus

B. Water Absorption Test

Water absorption (ASTM D570) is used to determine the amount of water absorbed under specified conditions. For this test, the specimens prepared are (50 mm x 13 mm with thickness of 5 mm) dried in an oven for a specified time and temperature and then placed in desiccators to cool. The specimens are weighed in electronic balance having least count of 0.001gm. The material is then soaked in water, often at room temperature for 24 hours. The final weight is taken in electronic balance and thus the difference between initial weight and final weight gives the water absorption capacity of the material. This test is necessary because various polymeric materials are susceptible to water absorption during its life exposure. The specimens tested under such conditions exhibited the gain in weight as indicated in Table 2.

Table 2 Percentage of water absorption by various composites

Fiber size in micron	Fiber Weight fractions of the composite	Initial weight in gms	Final weight in gms	Percentage absorption
106	5	4.312	7.532	74.68
	10	5.102	7.005	37.31
	15	5.450	7.512	37.83
150	5	5.212	7.023	38.20
	10	4.823	6.80	40.99
	15	4.684	6.223	32.86
212	5	4.003	6.543	63.45
	10	5.220	6.450	23.56
	15	5.231	7.231	38.23

IV. CONCLUSION

It is observed from the tensile tests that the tensile strength and modulus increases with the increase in volume fraction of fibers. Of course with less fiber reinforcement (10% or so) there is slight decrease in strength which might have occurred due to higher amount of matrix material. Further it is seen that at around 40 % of fiber content highest strength and modulus has been achieved for this type of composite. This is in near agreement with the work of earlier researchers [8] where 5 mm length of fibers showed tensile strength around 22 MPa whereas in this case it is found to be around 40 MPa. This might have been obtained due to lesser length of fibers i.e. 2-3 mm. The water absorption tests indicate that for 106 micron and 212 micron sizes of fibers with 10% weight fraction of fibers are less susceptible to moisture absorption than for 150 micron size of fibers. However it can be concluded that these composites absorb water much more than specified as per standard and not suitable for application in wet environment. Probably the hydrophilic nature of these fibres contributes to such properties. But these composites can be very well suitable for structural applications in dry environment due to higher strength.

V. REFERENCES

- [1] Koronis. G., Silva. A., Fontul. M. "Green composites. A review of adequate materials for automotive applications," *International Journal of Mechanical Sciences*, Vol.52 (2010), pp.874–891.
- [2] Ahmed, A.S., Alam, M.A., Piee, A., Rahman, M.R. and Hamdan, S. "Study of Physical and Mechanical Properties of Oil Palm Empty Fruit Bunch Fiber Reinforced Polypropylene Composites," *Jou. of Energy and Environment*, Vol.2, (2010) , pp.16-21
- [3] Nicollier, C., and Mutasher, S.A. "Failure prediction on advanced grid stiffened composite cylinder under axial compression," *Composite Structures*, Vol.93 (2011), 1939–1946.
- [4] Jawaid, M., Abdul Khalil, H.P.S., Bhat, A.H., and Abu Baker, A. " Impact Properties of Natural Fiber Hybrid Reinforced Epoxy Composites," *Advanced Material Research*, Vol.264-265, (2011) , pp.688-693.
- [5] Rao. C.H., Kundalwal. S.I. and Ray, M.C. "Sensing of Damage and Healing in Three-dimensional Braided Composites with Vascular Channels," *Composites Science and Technology*, Vol.72 (2012), pp. 1618–1626.
- [6] Toutanji. H, Li. F. and Cheng. H.M. "Effective Properties of a Novel Continuous Fuzzy-fiber Reinforced Composite Using the Method of Cells and the Finite Element Method," *European Journal of Mechanics of Solids*, Vol. 36 (2012), pp. 191-203.
- [7] Razak, N. W. A. and Kalam, A. "Effect of OPEFB Size on the Mechanical Properties and Water Absorption Behaviour of OPEFB/PP nanoclay/PP Hybrid Composites," *Procedia Engineering* Vol.41 (2012) pp.1593 – 1599.
- [8] Velumurugan, G., Vadivel, D., Aravind, R., Vengatesan, S.P. and Mathizhagan, A. "Tensile Test Analysis of Natural Fibre Reinforced Composites," *Int. Jou. of Mechanical and Industrial Engineering*, Vol.2, Issue-4, 2012, pp.56-60.
- [9] Boopathi, L, Sampath, P.S., Mylsamy, K. " Influence of Fiber Length in the Wear Behaviour of Borassus Fruit Fibre Reinforced Epoxy Composites," *Int. Jou. of Engineering Science and Technology*, Vol.4, Sept. 2012, pp. 4119-4129.
- [10] Ogbuagu, A.S., Ekpunobi, U.E., Onwuka, T.N., and Okeye, N.H., "Pulp and Paper Making Potential of Palmyra Fruit Fiber Borassus Flabelifar," *Der Chemica Sinica*, Vol. 4, (2013), pp. 19-24.