

Enhancement of Mechanical Properties of Banana Fiber Reinforced Vinyl Ester Composites

Rajesh Ghosh

Associate Professor

Department of Mechanical Engineering

Anil Neerukonda Institute of Technology and Sciences, Visakapatnam, AP, India

Corresponding Author's email: *rajesh_ghosh@yahoo.com*

Abstract

The effect of ultrasonic treatment on the mechanical properties of banana fiber reinforced vinyl ester resin composites has been experimentally determined. Banana fibers were initially mercerized. These were then subjected to ultrasonic treatment while preparing the composites. Similar method was followed earlier to study the effect on water absorption property of the composites which showed encouraging results (Ghosh et al, 2013) [1]. Hence these composites were tested for their mechanical strengths. The mechanical strengths were found to be better than the composites made in the general procedure.

Keywords: *Alkali treatment, sonication, mechanical strength, banana fiber composites*

INTRODUCTION

Bio-fiber reinforced composites are being worked upon for various engineering applications. The interest in the development of plant-fiber composites has grown vastly during the recent years

because of their inherent advantages over mineral based fiber reinforced composites. Glass fiber composites have forayed into many applications but they have a detrimental effect on the environment and hence researchers are working on the

possibility of replacing these composites. These composites are being used in marine applications but prolonged exposure to humid conditions has caused degradation in flexural strength and modulus (kootsokoos, gellert ep) [2], [3]. Bio fibers are hard cellulose fibers which are environment friendly being degradable, renewable and inexpensive materials. The different fibers that are used in this segment are jute, flax, banana, sisal and pineapple (s padma priya, sk rai) [4]. These fibers possess good mechanical properties and they also offer good electrical resistance and acoustic insulation (s padma priya, sk rai; WD brower) [4], [5]. Composites from enzyme treated fibers have shown better mechanical properties when compared to untreated fiber composites owing to the increased immobilization of the polymer matrix at fiber matrix interface (karaduman) [6]. Hybrid composites were worked with and reported to have significant increase in the tensile, flexural and compressive strengths (noorunnisa) [7].

Adekunle et al [8] have observed that hybridization of flax fabric with lyocell fiber reduced the water uptake (adenkule). Alkaline treatment improved the tensile properties of sisal fiber/PU composites (RV

Silva et al) [9]. In this paper, the mechanical strengths of banana fiber reinforced vinyl ester composites were experimentally found for specimens made in different procedures and mechanical strengths were compared for these specimens after these are immersed in distilled water and sea water upto saturated condition.

EXPERIMENTAL

Materials and Fabrication process

Banana fibers were taken as thin bunches and weaved into mats using a wire frame support. These were then divided into batches and few mats were mercerized in 5% NaOH solution in a normal way while few mats were treated with 5% NaOH solution in combination with air bubbling. Bisphenol epoxy based vinyl ester resin is obtained from ECMAS Resin Pvt Ltd, India and is used as the matrix material. The detailed fabrication procedure is explained in another journal paper by the same author (ghosh et al) [1].

Mechanical strengths test

The tensile strength is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contract. Tensile tests measure

the force required to break a polymer composite sample specimen and the extent to which the specimen stretches or elongates to that breaking point.

Tensile tests of the composite specimens were done according to ASTM D638. The tests were carried out in a Hounsfield tensometer - model H20KW. The cross head speed was 1mm/min.

The flexural strength is a mechanical parameter and is defined as the material's ability to resist deformation under load. The flexural test was done according to ASTM D790 in a universal testing machine by UNITED calibration corp. with a cross head speed of 0.5mm/min.

The sonication process on the fiber mats

The composites specimens were made following the general procedure of hand lay-up technique. Specimens were also made by the sonication processing of the fiber mats in resin. The sonication process is detailed in earlier published paper (ghosh et al) [1]. The specimens subjected to different environmental conditions were tested for tensile and flexural tests. The strengths are compared between the following cases.

- i.** when the fibres are treated with 5% NaOH normally.
- ii.** when the fibres are treated with 5% NaOH and subjected to sonication process.
- iii.** when the fibres are treated with 5% NaOH and the composite specimens are immersed in sea water.
- iv.** when the fibers are treated with 5% NaOH and the composite specimens are immersed in distilled water.
- v.** when the fibers are treated with 5% NaOH and subjected to sonication process, and then the composite specimens are immersed in sea water.
- vi.** when the fibers are treated with 5% NaOH and subjected to sonication process and the the composite specimens are immersed in distilled water.

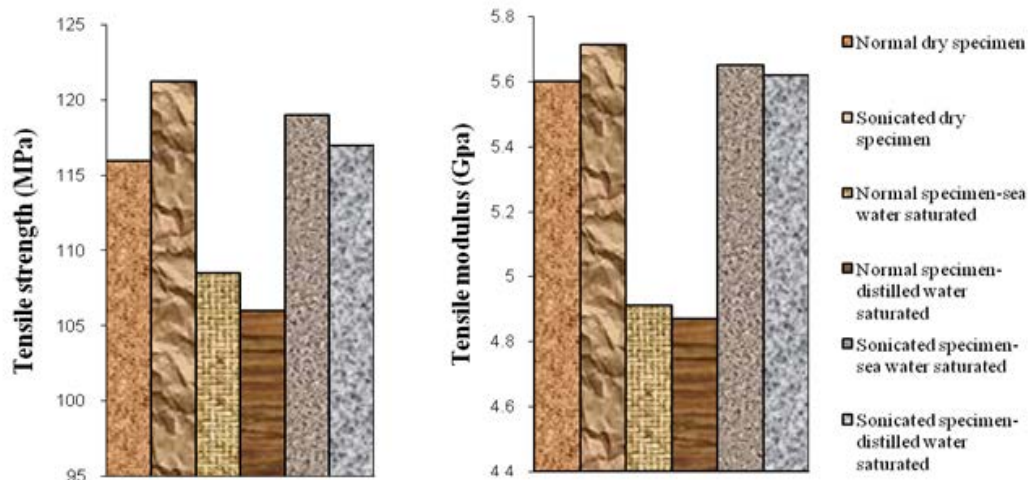


Fig. 1 Comparison of mechanical properties

The tensile strength and tensile modulus of the composite specimens prepared by different procedures are plotted as shown in fig. 1. The tensile strength of the normal dry specimens and strengths of specimens that were water saturated by distilled water or sea water are also shown. It can be seen that the composites that were prepared with fibres subjected to sonication process showed improved mechanical strengths.

The tensile strength of the sonicated composite specimen has increased by 4.52% over the specimens prepared in the normal process. There is a heavy reduction in the tensile strength of specimens prepared in the normal process that were either sea water immersed or distilled water immersed. But the tensile strength of the specimens that

were prepared by sonication process was marginally reduced when they were immersed in either sea water or distilled water.

The flexural strength and flexural modulus of the different composite specimens are plotted and shown in fig. 2. The specimen made with sonication process is found to have flexural strength of 6.62% more than the normal specimens. The flexural strength of the normal specimens has reduced heavily when they were immersed in distilled water and sea water. But marginal reduction in the flexural strength is recorded by the specimens that were made by sonication process and immersed in either distilled water or sea water. This can be attributed to the increased wettability and adhesion of the fibres with the resin as the

ultrasonic waves force the resin to better penetrate and adhere strongly to the fibres. The micro-gaps in the fiber-matrix interface is eliminated by the sonication process leaving very few voids. Hence the capillary action of water ingress is reduced drastically. Therefore the effect of moisture absorption and the effect of moisture on the mechanical strengths are reduced. See figure: 2

Discussion: Effect of mercerization, air bubbling and sonication on the fiber

Banana fiber is composed of cellulose, hemicelluloses, lignin and pectin. Cellulose is a heterogenous material composed of alpha, beta and gamma cellulose which

contain 200 sugar residues of d- glucose linked to each other via glycosidic bridges. Since d-glucose is rich in hydroxyl groups, two adjacent cellulose chains are firmly bonded along their length by multiple hydrogen bonds and confer substantial mechanical rigidity and strength to the resultant cellulosic fiber. The NaOH treatment converts the alpha glucose into more favorable beta glucose which is the monomer unit of cellulose. Hemicellulose is a branched chain molecule composed of sugar residues of glucose, xylose and arabinos.

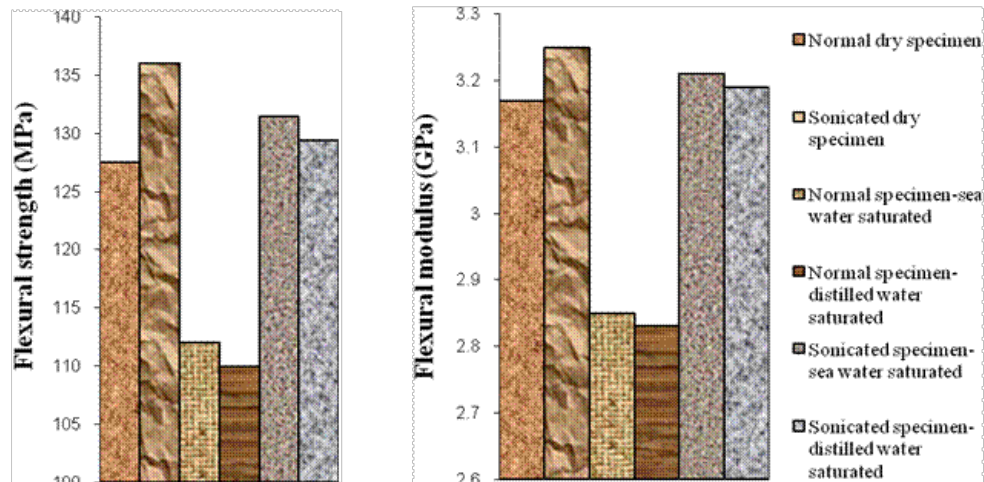


Fig. 2 Comparison of mechanical properties

Natural fiber is primarily hydrophilic while resin is hydrophobic. NaOH treatment improves the chemical bonding between the fiber mat and resin, by partial removal of lignin from the surface of the mat. The resultant increase in surface roughness increases the area of contact between resin and the mat. NaOH substantially removes the hemicelluloses of the mat.

Removal of hemicelluloses will greatly facilitate effective contact area, aiding in a better chemical bonding. Treatment of natural fiber increases the number of crystalline domains called crystallites and thereby improves the mechanical strength.

The ultrasonic waves emanated in the sonication procedure helps to disperse the resin in an aggressive manner in to the fiber micro-pores thus leading to better fiber resin bond.

SEM Image of the fractured specimens

Fig. 3 and Fig. 4 show the SEM images of the fractured specimens. The SEM image shows the porous nature of the mercerized fiber. Alkali treatment cleans the fiber surface and develops micro-porosity with many pits and holes on the fiber. The resin can get absorbed through the surface pores into the micro-fibrillar bundles of the fiber so that the composite failure can be prevented by simple interfacial debonding.

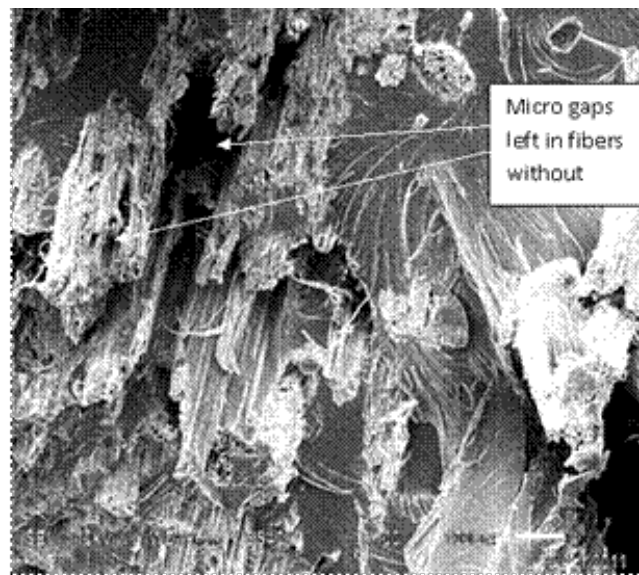


Fig. 3 SEM image of fractured specimen

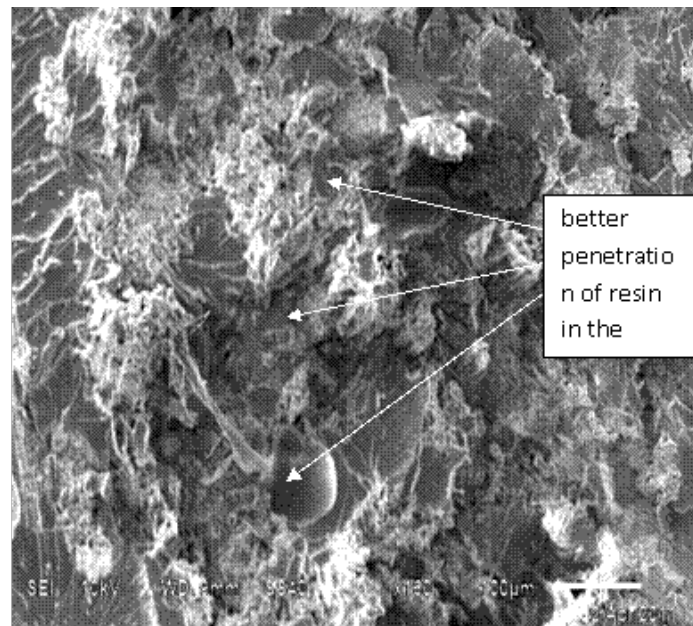


Fig. 4 SEM image of fractured specimen

The morphology of the fractured specimen in which the fiber mats were not subjected to sonication treatment show more fiber pull-outs, many micro-gaps are left which indicates weak adhesion of resin to the fibers, more affinity towards moisture and lower mechanical strengths. The SEM image of the specimens in which the fiber mats were subjected to sonication process show that resin has penetrated deeper into the fibers.

Hence better adhesion is obtained. This increased the compatibility between fiber and matrix. The fiber pullout is of shorter

length. This suggests better strength of the composite specimen. This also suggests more water resistant phenomenon of the composite specimens.

CONCLUSION

Sonication process helps the resin to disperse aggressively deep into the pores of the fiber. The ultrasonic waves emanated from the sonicator force the resin to penetrate more into the fiber, resulting in better bonding of resin and the fiber. The resin fills the micropores of the fiber and reduces the capillary action of water uptake. This improves the mechanical properties of the composites as well as higher resistant towards moisture absorption. Sea water

ageing reduces the mechanical properties of the composites.

Industrial Textiles, vol. 35, no. 3, pp. 217–226, Jan. 2006.

REFERENCES

- 1) R. Ghosh, A. Ramakrishna, and G. Reena, “Effect of air bubbling and ultrasonic processing on water absorption property of banana fibre-vinylester composites,” *Journal of Composite Materials*, Jun. 2013.
- 2) A. Kootsookos and A. P. Mouritz, “Seawater durability of glass- and carbon-polymer composites,” *Composites Science and Technology*, vol. 64, no. 10–11, pp. 1503–1511, Aug. 2004.
- 3) E. P. Gellert and D. M. Turley, “Seawater immersion ageing of glass-fibre reinforced polymer laminates for marine applications,” *Composites Part A: Applied Science and Manufacturing*, vol. 30, no. 11, pp. 1259–1265, Nov. 1999.
- 4) S. P. Priya and S. K. Rai, “Mechanical Performance of Biofiber/Glass-reinforced Epoxy Hybrid Composites,” *Journal of*
- 5) W. D. Brouwer, “Natural fiber composites in structural components: alternative applications for sisal?,” in *Common Fund for Commodities - Alternative Applications for Sisal and Henequen*, Rome, Italy, 2000, vol. paper no. 14.
- 6) Y. Karaduman and L. Onal, “Dynamic mechanical and thermal properties of enzyme-treated jute/polyester composites,” *Journal of Composite Materials*, Aug. 2012.
- 7) P. N. Khanam, M. M. Reddy, K. Raghu, K. John, and S. V. Naidu, “Tensile, Flexural and Compressive Properties of Sisal/Silk Hybrid Composites,” *Journal of Reinforced Plastics and Composites*, vol. 26, no. 10, pp. 1065–1070, Jul. 2007.
- 8) K. Adekunle, S.-W. Cho, C. Patzelt, T. Blomfeldt, and M. Skrifvars, “Impact and Flexural Properties of Flax Fabrics and Lyocell Fiber-Reinforced bio-based Thermoset,”

Journal of Reinforced Plastics and Composites, May 2011.

- 9) R. V. Silva, M. M. Ueki, D. Spinelli, W. W. B. Filho, and J. R. Tarpani, “Thermal, Mechanical, and Hygroscopic Behavior of Sisal Fiber/Polyurethane Resin-based Composites,” Journal of Reinforced Plastics and Composites, vol. 29, no. 9, pp. 1399–1417, May 2010.