Nano World Journal

https://doi.org/10.17756/nwj.2023-s1-102

Research Article

Open Access

Mechanical Characterization of Fiber Reinforced Epoxy Composite: *Ziziphus oenoplia* Fiber

P. Arunkumar[1], S.R. Surender[2*], G. Suganya Priyadharshini[3], M. Makeshkumar[1], M. Sasi Kumar[4], R. Sanjiv[1] and B. Balachander[1]

[1]*KPR Institute of Engineering and Technology, Coimbatore, Tamil Nadu, India*
[2]*Park College of Engineering and Technology, Coimbatore, Tamil Nadu, India*
[3]*Coimbatore Institute of Technology, Coimbatore, Tamil Nadu, India*
[4]*KIT - Kalaignar Karunanidhi Institute of Technology, Coimbatore, Tamil Nadu, India*

***Correspondence to:**
S.R. Surender
Park College of Engineering and Technology,
Coimbatore, Tamil Nadu, India.
E-mail: srsurender.mech@gmail.com

Received: November 24, 2022
Accepted: May 07, 2023
Published: May 10, 2023

Citation: Arunkumar P, Surender SR, Priyadharshini GS, Makeshkumar M, Kumar MS, et al. 2023. Mechanical Characterization of Fiber Reinforced Epoxy Composite: *Ziziphus oenoplia* Fiber. *NanoWorld J* 9(S1): S529-S533.

Published by United Scientific Group

Abstract

The recent developments in Polymer Matrix Composites (PMC) are enormous to enhance the mechanical attributes and to overcome the challenges incurred during the fabrication process. Furthermore, natural fibers are getting great attention in fabrication of PMC composites due to their sustainability and green manufacturing process. However, synthetic fiber material used in PMC composite causes environmental pollution and its material cost is high. In this study, natural fiber of *Ziziphus oenoplia* is utilized for the fabrication of PMC using Hand Lay-up process. For Fiber Reinforced Polymer composite materials, it can also be employed as an alternate reinforcement method. The composition of epoxy and *Z. oenoplia* fiber in wt% are varied as 70:30, 60:40, and 50:50. *Z. oenoplia* fiber reinforced polymer composite mechanical parameters like tensile strength, flexural load, and impact energy are measured. It is found that the maximum mechanical properties such as tensile strength (10.31 MPa), flexural load (1.11 kN), and impact energy (4 Joules) are obtained at composition of 60:40 in wt%.

Keywords

Polymer matrix composites, *Ziziphus oenoplia*, Fiber reinforced epoxy composite, Hand Lay-up method

Introduction

Due to its superior dielectric characterization, durability to a variety of stress circumstances, and sustainability, natural fiber-reinforced polymer composites have recently attracted significant attention in the fields of civil construction, automotive, and aircraft [1]. Research has been done by Dhal et al. [2] on the creation of a novel, inexpensive polymer composite reinforced with brown grass flower broom. The physio-mechanical characteristics of the composite were studied while the reinforcement was manufactured with various weight percentages. According to the findings, the interface between the fiber and reinforcement in a composite material is robust, and the material has the lowest porosity possible. The increase in reinforcement weight percentage also caused a drop in density, an increase in hardness, and an increase in flexure strength. Abdullah et al. [3] worked in the mechanical property study of hybrid composite of kenaf/PET fiber reinforced. They observed that the composite's reinforcing generates a noticeable improvement in its mechanical properties. As a result, they suggested that hybrid composite would be appropriate for automobile exterior applications. Atiqah et al. [4] studied the influence of chemical treatments on SPF with Thermoplastic Polyurethane to identify its characterization and fiber-matrix adhesive bonding. Ali et al. [5] reviewed the effect of various natural fibers treatments on moisture absorption, fiber degradation, compatibility, and mechanical properties. Athith et al. [6] studied tri and mechanical properties of natural fiber under different proportions of tungsten carbide powder. They identified that adding filler materials with the fiber-matrix enhanced its mechanical characteristics and lowered its rate of wear. Several studies have dealt with aerospace applications of various natural fiber-based PMC [7-12]. Abdellaoui et al. [13] utilized nanocomposite and hybrid reinforcements in the same polymer matrix. Girijappa et al. [14] conducted comprehensive review to identify the sustainability and renewability of natural fiber materials in order to develop eco-friendly composite materials. They suggested that the natural fiber obtained directly from the natural sources has poor resistance to moisture. Hence chemical treatments can be a possible approach to improve the adhesiveness of fiber and matrix which is further used to increase its mechanical properties. The tensile and flexure characteristics of Kenaf fiber reinforced polypropylene composites after various chemical treatments were investigated by Asumani et al. [15]. The outcome demonstrated that alkali-silane treatment is employed to strengthen the adhesive bonding between fiber and matrix as well as its mechanical qualities. Alawar et al. [16] utilized date palm tree fiber to study mechanical properties and chemical analysis at various alkali treatments and acid treatments. Anuar et al. [17] have worked in the fabrication of thermoplastic elastomer reinforced kenaf bast fiber composite. Aslan et al. [18] dealt with hybrid composite materials and determined the tribological, and mechanical properties of waste composite materials. The results suggested that waste sisal/glass PP composites have better performance compared to sisal/carbon PP composites. Al-Oqla et al. [19] established a feasibility of natural fiber composites to sustain in the field of automotive industries. They found that date palm fiber is suitable among other commonly used in industries in the form of technical properties and performance, sustainability, cost, and societal aspects. The potential use of intrinsically conductive polymers and conductive polymer composites loaded with natural fibers in various technologies and industrial applications was also covered by Al-Oqla et al. [20]. The present research is focused on the fabrication of PMC composites by utilizing the natural fiber of *Z. oenoplia*. The composite is built using the Hand Lay-up technique. An investigation is conducted into the mechanical behavior of *Z. oenoplia* fiber reinforced epoxy composite, including tensile strength, flexure strength, and impact strength.

Materials and Methods

Materials

The natural fiber is extracted from the stem bark of Z. oenoplia which is a shrub belonging to the family called Rhamnaceae. This Z. oenoplia is a thorny shrub which can spread, climb, and grow up to a height of 1.5 m. This thorny shrub shown in figure 1 is found near Yecaud forest, near Salem, Tamil Nadu, India. Thus, the extracted Z. oenoplia natural fiber shown in figure 2 is used as reinforcement in composite material. In composite materials, epoxy resin acts as the matrix.

Figure 1: *Z. oenoplia* **(a)** thorny shrub and **(b)** stem.

Figure 2: *Z. onenoplia* fiber.

Methods

The *Z. oenoplia* bark is removed from the stem and it is immersed in water for 10 days to so that microbial degradation can take place. The immersed bark is taken out from the water, and it is cleaned with the help of fresh water. Now the fiber is extracted from the bark by the combing process with a help of metal comb [21-23]. The extracted *Z. oenoplia* natural fiber is shown in figure 2. Now, the *Z. oenoplia* fiber and epoxy are used to fabricate a composite material using Hand Lay-up process with a help of die mold as shown in figure 3. The die specifications are Cavity Size of 200 x 125 x 20 mm; Base Plate of 200 x 125 x 15 mm; Top Cover Plate of 200 x 125 x 15 mm; Side Cover Plates of 200 x 50 x 15 mm; and the material used is Mild Steel (Fe-250). Three composite material samples are made of different compositions as shown in the following table 1. Figure 4 shows the different composite specimens.

Figure 3: Die.

Table 1: Different composition of *Z. onenoplia* – Epoxy Composite.

Specimen	Epoxy		*Z. oenoplia*	
	Wt%	Gms	Wt%	Gms
1	70	420	30	180
2	60	360	40	240
3	50	300	50	300

Figure 4: Fabricated *Z. oenoplia* - Epoxy Composite **(a)** Specimen 1, **(b)** Specimen 2, and **(c)** Specimen 3.

Experimentation

Hand Lay-up process is a simple and economical method in manufacturing a composite material. The *Z. oenoplia* epoxy composite specimens a, b, and c are prepared by using this technique. To prevent the composite material from adhering to the surface, a releasing anti-adhesive substance is applied on the surface of the mold die. After that, a plastic sheet is adhered to the bottom and top of the mold plate to improve the composite's surface finish. Now, according to the specimen a, b, and c material composition, *Z. oenoplia* fiber and epoxy are mixed in a vessel and it is poured into the die mold and then it is allowed to cure in room temperature for about 48 hours. The specimen of the composite material is taken out of the mold after curing and prepared for the tensile test, flexural test, and impact test in accordance with ASTM standards. According to figure 5, the Aimil Universal Testing Machine is used to conduct the tensile and flexure test. As seen in figure 6, the impact test is carried out using an Izod impact tester.

Results and Discussion

In this article, the tensile strength, flexure strength, and impact strength of an epoxy composite reinforced with *Z. oenoplia* fiber are examined.

Tensile test

To evaluate the tensile strength under various reinforcement settings, the specimen is subjected to the tensile test in accordance with ASTM D638 standard. The reinforcement of *Z. oenoplia* fiber is chosen as 30%, 40%, and 50% of total weight of composite, respectively. Figure 7 shows the tensile specimen before and after tensile testing. From the results, it is found that specimen 2 (60 wt% Epoxy and 40 wt% *Z. oenoplia* fiber) experienced maximum tensile strength of 10.31 MPa compared to the other two specimens. The obtained tensile test results of present study are moderately correlated with various other fibers such as phoenix (39.22 MPa), kenaf (31.3 MPa), sisal (8.37 MPa), oil palm (29.9 MPa), banana (16 MPa), lantana camara (19 MPa), and *Sansevieria trifasciata* (75.22 MPa) [24].

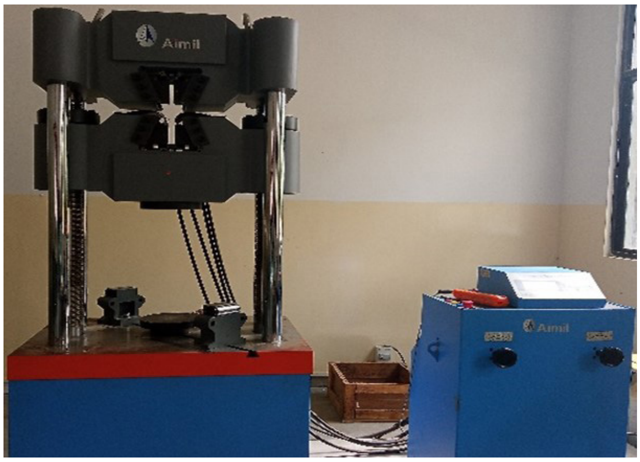


Figure 5: Tensile and flexure testing machine.

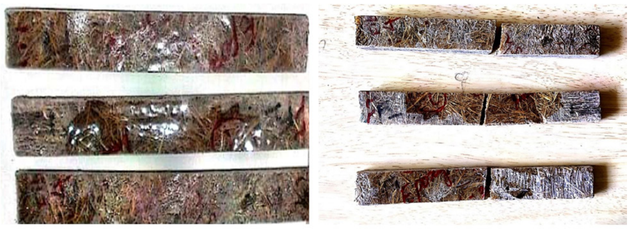
Figure 6: Impact testing machine.

(a) (b)

Figure 7: Specimen **(a)** before and **(b)** after tensile test.

Flexure test

The flexure test is carried out on the specimen as per ASTM D790 standard to determine the flexure strength at different reinforcement conditions. Figure 8 shows the flexure specimen before and after flexure testing. From the results, it is found that specimen 3 (50 wt% Epoxy and 50 wt% *Z. oenoplia* fiber) experienced maximum flexure strength of 1.11 kN compared to the other two specimens. The flexure test results



(a) (b)

Figure 8: Specimen **(a)** before and **(b)** after flexural test.

of present study are greatly dominating the previous works of various glass fiber composites such as 0.4% Co + GF (257.305 N), 0.6% Co + GF (348.008 N), 0.8% Co + GF (243.535 N), and 1% Co + GF (319.070 N) [25].

Impact test

To determine the toughness of the composite under various reinforcement circumstances, the specimen is subjected to an impact test in accordance with ASTM D256. Figure 9 shows the impact specimen before and after impact testing. From the results, it is found that specimen 3 (50 wt% Epoxy and 50 wt% *Z. oenoplia* fiber) experienced maximum impact strength of 4 J compared to the other two specimens.

The comparative study has been made for tensile, flexure, and impact strength of *Z. oenoplia* reinforced PMC composites for three specimens (1, 2, and 3) and it is shown in figure 10. It is clearly identified that specimen 2 yields maximum mechanical properties (4 J) compared to the other two specimens. The impact test results of present study are greatly dominating the previous works of various composites such as Epoxy (0.14 ± 0.01 J), J15 (0.28 ± 0.02 J), J20 (0.29 ± 0.03 J), J25 (0.34 ± 0.03 J), and J30 (0.35 ± 0.02 J) [26].

(a) (b)

Figure 9: Specimen **(b)** before and **(b)** after impact test.

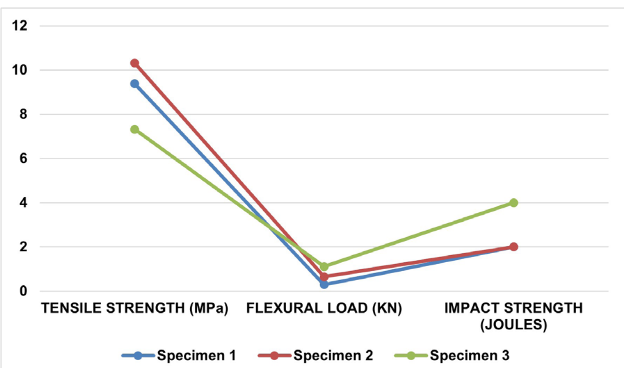


Figure 10: Comparison of tensile, flexural and impact strength for specimen 1, 2, and 3.

Conclusions

The goal of the current work is to fabricate PMC composites reinforced with *Z. oenoplia* in three distinct reinforcement fractions. Following experimental characterization of the mechanical parameters, including tensile strength, flexure strength, and impact strength, the following results are represented:

- Specimen 2 (60 wt% Epoxy and 40 wt% *Z. oenoplia* fiber) experienced maximum tensile strength of 10.31 MPa compared to the other two specimens.
- Specimen 3 (50 wt% Epoxy and 50 wt% *Z. oenoplia* fiber) depicts a high impact strength of 4 J compared to the other two specimens.
- Maximum impact strength of 4 J is obtained in Specimen 3 (50 wt% Epoxy and 50 wt% *Z. oenoplia* fiber).

Acknowledgments

Authors sincerely acknowledge the experimental facilities rendered by the Centre of Machining and Materials Testing, KPR Institute of Engineering and Technology.

Conflict of Interest

The authors declare that they have no known conflict of interests that could have appeared to influence the work reported in this paper.

Credit Author Statement

P. Arunkumar: Conceptualization, Methodology; S.R. Surender: Writing - original draft preparation, Supervision; G. Suganya Priyadharshini: Resources, Investigation, Writing - original draft preparation; M. Makeshkumar: Visualization, Software; M. Sasi Kumar: Formal analysis; R. Sanjiv: Validation; B.Balachander: Data curation. All the authors read and approved the manuscript.

References

1. Pickering KL, Efendy MA, Le TM. 2016. A review of recent developments in natural fibre composites and their mechanical performance. *Compos A Appl Sci Manuf* 83: 98-112. https://doi.org/10.1016/j.compositesa.2015.08.038
2. Dhal JP, Mishra SC. 2013. Processing and properties of natural fiber-reinforced polymer composite. *J Mater* 2013: 297213. https://doi.org/10.1155/2013/297213
3. Abdullah MZ, Dan-mallam Y, Yusoff PSMM. 2013. Effect of environmental degradation on mechanical properties of kenaf/polyethylene terephthalate fiber reinforced polyoxymethylene hybrid composite. *Adv Mater Sci Eng* 2013: 671481. https://doi.org/10.1155/2013/671481
4. Atiqah A, Jawaid M, Ishak MR, Sapuan SM. 2018. Effect of alkali and silane treatments on mechanical and interfacial bonding strength of sugar palm fibers with thermoplastic polyurethane. *J Nat Fibers* 15(2): 251-261. https://doi.org/10.1080/15440478.2017.1325427
5. Ali A, Shaker K, Nawab Y, Jabbar M, Hussain T, et al. 2018. Hydrophobic treatment of natural fibers and their composites—a review. *J Ind Textiles* 47(8): 2153-2183. https://doi.org/10.1177/1528083716654468
6. Athith D, Sanjay MR, Gowda TGY, Madhu P, Arpitha GR, et al. 2018. Effect of tungsten carbide on mechanical and tribologi-

cal properties of jute/sisal/E-glass fabrics reinforced natural rubber/epoxy composites. *J Ind Textiles* 48(4): 713-737. https://doi.org/10.1177/1528083717740765

7. Al-Furjan MSH, Shan L, Shen X, Zarei MS, Hajmohammad MH, et al. 2022. A review on fabrication techniques and tensile properties of glass, carbon, and Kevlar fiber reinforced polymer composites. *J Mater Res Technol* 19: 2930-2959. https://doi.org/10.1016/j.jmrt.2022.06.008
8. Harris CE, Starnes Jr JH, Shuart MJ. 2002. Design and manufacturing of aerospace composite structures, state-of-the-art assessment. *J Aircraft* 39(4): 545-560. https://doi.org/10.2514/2.2992
9. Lasri L, Nouari M, El Mansori M. 2011. Wear resistance and induced cutting damage of aeronautical FRP components obtained by machining. *Wear* 271(9-10): 2542-2548. https://doi.org/10.1016/j.wear.2010.11.056
10. McIlhagger A, Archer E, McIlhagger R. 2020. Manufacturing Processes for Composite Materials and Components for Aerospace Applications. In Irving P, Soutis C (eds) Polymer Composites in the Aerospace Industry. Woodhead Publishing, pp 59-81.
11. Balakrishnan P, John MJ, Pothen L, Sreekala MS, Thomas S. 2016. Natural fibre and polymer matrix composites and their applications in aerospace engineering. In Rana S, Fangueiro R (eds) Advanced Composite Materials for Aerospace Engineering. Woodhead Publishing, pp 365-383.
12. Asim M, Saba N, Jawaid M, Nasir M. 2018. Potential of Natural Fiber/Biomass Filler-Reinforced Polymer Composites in Aerospace Applications. In Jawaid M, Thariq M (eds) Sustainable Composites for Aerospace Applications. Woodhead Publishing, pp 253-268.
13. Abdellaoui H, Raji M, Essabir H, Bouhfid R. 2019. Mechanical Behavior of Carbon/Natural Fiber-based Hybrid Composites. In Jawaid M, Thariq M, Saba N (eds) Mechanical and Physical Testing of Biocomposites, Fibre-Reinforced Composites and Hybrid Composites. Woodhead Publishing, pp 103-122.
14. Girijappa YGT, Rangappa SM, Parameswaranpillai J, Siengchin S. 2019. Natural fibers as sustainable and renewable resource for development of eco-friendly composites: a comprehensive review. *Frontiers Mater* 6: 226. https://doi.org/10.3389/fmats.2019.00226
15. Asumani OML, Reid RG, Paskaramoorthy R. 2012. The effects of alkali–silane treatment on the tensile and flexural properties of short fibre non-woven kenaf reinforced polypropylene composites. *Compos A Appl Sci Manuf* 43(9): 1431-1440. https://doi.org/10.1016/j.compositesa.2012.04.007
16. Alawar A, Hamed AM, Al-Kaabi K. 2009. Characterization of treated date palm tree fiber as composite reinforcement. *Compos B Eng* 40(7): 601-606. https://doi.org/10.1016/j.compositesb.2009.04.018
17. Anuar H, Zuraida A. 2011. Improvement in mechanical properties of reinforced thermoplastic elastomer composite with kenaf bast fibre. *Compos B Eng* 42(3): 462-465. https://doi.org/10.1016/j.compositesb.2010.12.013
18. Aslan M, Tufan M, Küçükömeroğlu T. 2018. Tribological and mechanical performance of sisal-filled waste carbon and glass fibre hybrid composites. *Compos B Eng* 140: 241-249. https://doi.org/10.1016/j.compositesb.2017.12.039
19. Al-Oqla FM, Sapuan SM. 2014. Natural fiber reinforced polymer composites in industrial applications: feasibility of date palm fibers for sustainable automotive industry. *J Cleaner Prod* 66: 347-354. https://doi.org/10.1016/j.jclepro.2013.10.050
20. Al-Oqla FM, Sapuan SM, Anwer T, Jawaid M, Hoque ME. 2015. Natural fiber reinforced conductive polymer composites as functional materials: a review. *Synth Met* 206: 42-54. https://doi.org/10.1016/j.synthmet.2015.04.014
21. Saravanakumar SS, Kumaravel A, Nagarajan T, Sudhakar P, Baskaran R. 2013. Characterization of a novel natural cellulosic fiber from Prosopis juliflora bark. *Carbohydr Polym* 92(2): 1928-1933. https://doi.org/10.1016/j.carbpol.2012.11.064
22. Aravindh M, Sathish S, Raj RR, Karthick A, Mohanavel V, et al. 2022. A review on the effect of various chemical treatments on the mechanical properties of renewable fiber-reinforced composites. *Adv Mater Sci Eng* 2022: 2009691. https://doi.org/10.1155/2022/2009691
23. Prabhu L, Krishnaraj V, Sathish S, Gokulkumar S, Sanjay MR, et al. 2020. Mechanical and acoustic properties of alkali-treated *Sansevieria ehrenbergii/Camellia sinensis* fiber–reinforced hybrid epoxy composites: incorporation of glass fiber hybridization. *Appl Compos Mater* 27: 915-933. https://doi.org/10.1007/s10443-020-09840-4
24. Rajeshkumar G, Hariharan V, Sathishkumar TP, Fiore V, Scalici T. 2017. Synergistic effect of fiber content and length on mechanical and water absorption behaviors of *Phoenix* sp. fiber-reinforced epoxy composites. *J Ind Textiles* 47(2): 211-232. https://doi.org/10.1177/1528083716639063
25. Rajak DK, Wagh PH, Moustabchir H, Pruncu CI. 2021. Improving the tensile and flexural properties of reinforced epoxy composites by using cobalt filled and carbon/glass fiber. *Forces Mech* 4: 100029. https://doi.org/10.1016/j.finmec.2021.100029
26. Gupta MK. 2018. Thermal and dynamic mechanical analysis of hybrid jute/sisal fibre reinforced epoxy composite. *Proc Inst Mech Eng L J Mater Des Appl* 232(9): 743-748. https://doi.org/10.1177/1464420716646398