BNUT

Iranian (Iranica) Journal of Energy & Environment
Journal Homepage: www.ijee.net
IJEE an official peer review journal of Babol Noshirvani University of Technology, ISSN:2079-2115

Short Communication

Experimental Study on Mechanical Properties of Randomly Oriented Natural Fiber Hybrid Composites

S. Om Prakash[1]*, T. Mathavaraj Ravikumar[2], M. Arulraj[3]

[1] *Department of Mechanical Engineering, Sri Ranganathar Institute of Engineering and Technology, Athipalayam, Coimbatore, India*
[2] *Department of Mechanical Engineering, Vidya Academy of Science and Technology Technical Campus, Kilimanoor, Kerala, India*
[3] *Department of Mechanical Engineering, Coimbatore Institute of Engineering and Technology, Coimbatore, India*

P A P E R I N F O

Paper history:
Received 02 January 2020
Accepted in revised form 23 February 2020

Keywords:
Hybrid Composite
Mechanical Properties
Modulus
Natural Fiber
Polyester
Strength

A B S T R A C T

Natural fibers such as banana, sisal, snake grass, coir, hemp, jute and so on are armed with enormous advantages like less weight, reliability, recyclability and environmental friendly nature. Such fibers may enhance the system's performance by acting as additives with the thermoplastics in different perspectives. Besides the natural composites, hybrid composites facilitate the design of material with specific property matched to an application. In the present work an attempt has been made to manufacture and test the banana and snake grass short fiber reinforced hybrid polyester composites in random orientation and random lay-up. Methyl Ethyl Ketone Peroxide was used as the coupling agent and Cobalt Naphthalene as the catalyst. Hand layup technique was used to manufacture the composites. Relative volume fraction of the fibers was varied between 2.5-12.5% in the ratio 1:1. Properties like tensile strength and modulus, flexural strength and modulus are measured for the composites by conducting the appropriate tests according to ASTM standards.

***doi**: 10.5829/ijee.2020.11.01.11*

INTRODUCTION

Composites are the tailor-made materials whose properties can be modified according to the application. Composites generally consist of fibers of high strength 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 combination of properties that cannot be achieved with either constituent acting alone. Composites provide room to tailor the variables such that numerous alternatives arise to achieve the required strength of the structures. The potentials of composite materials are visibly clear from the various opportunities and channels thrown open by their remarkably diverse properties and characteristics. The renewed interest in composites may be attributed to their potential advantages of weight saving, low price per unit volume, renewable and recyclable properties [1]. The availability of natural fibers abundant and is relatively cheaper than man-made fibers. They possess some advantages like low density, low cost and some disadvantages like low impact strength, high moisture absorption [2]. The usage areas of natural fibers are mostly in automotive sector, both for interior and exterior components. Suitable hybrid composites may be also used for many specific applications like piping industry, passenger car bumper beam and so on [3, 4]. Hybrid composites facilitate the design of material with specific property matched to an application. Specific properties like the impact strength at lower velocities was tested for the natural fiber composites and was compared with the standard synthetic fiber reinforced composites [5]. Fiber characteristics were considered in determining the extent of fiber reinforcement in a thermoplastic matrix. The characteristics of the interphase in a fiber reinforced hybrid composite were also studied as it is important in transferring the load from the fiber to the surrounding matrix [6]. In the present communication the properties of banana and snake grass fiber reinforced polyester hybrid composites is reported. Properties like tensile strength, tensile modulus, flexural strength and flexural modulus are determined and Scanning Electron Microscope pictograph is used to analyze the failure cross section of the specimen. Some studies had been previously carried out for finding out the chemical and physical modification of the matrix by the introduction of fiber [7]. The factors like cellulose content, microfibrillar angle, diameter of the fiber enhance the chance of using banana fibers and the factors like spiral angle and lumen size

*Corresponding Author Email: *pingingprakash@gmail.com* (O. M. Prakash)

in the fibers facilitate the inclusion of the snake grass fibers [8]. All these factors resulted in properties like high tensile strength, strain compatibility, better stress transfer and high impact strength. Hence in this work randomly oriented and randomly laid up short banana and snake grass fibers reinforced polyester hybrid composites manufactured and their mechanical properties are evaluated. Some studies had been also carried out in determining the hygrothermal aging and fatigue behaviour under cyclic tensile load [9]. Studies on the interlaminar fracture toughness, which influences the flexural behaviour of a natural and synthetic fiber reinforced polypropylene composites was also reported in literature [10].

MATERIALS AND METHODS

Selection of Material

Banana fibers were obtained from M/s vibrant nature industries, Chennai. Snake grass fibers were obtained by the manual extraction fibers from the natural plant grown around the urban areas of Perundurai. The physical properties of banana fibers are summarized in Table 1. Isophthallic Polyester resin was obtained from M.N Polyesters Coimbatore, India. The specific gravity of the resin at 25°C was 1.46. The properties of isophthallic polyester resin is listed in Table 2.

Preparation of composite

Good quality plagiarism software/ tool (Turnitin / Procured Banana fibers and extracted Snake grass fibers are initially air dried for about 2 hours and were chopped to a length of 10 mm. Hand lay-up technique was used to prepare the composite specimen. Polyester resin was cured by one volume percent of methyl ethyl ketone peroxide (catalyst). One volume percent of Cobalt Naphthalene (accelerator) was also added while curing. Random lay-up technique was used to prepare the laminates and those layers consist of the resin, banana fiber and snake grass fiber consecutively. Fibers are laid in random orientation and homogeneity was ensured by using a roller. Air bubbles were also removed when a roller was used. Fiber volume fraction was varied in between 5 to 25% and the relative volume fraction of fibers was maintained at 1:1 for all volume fractions of fibers. The fibers are reinforced with the polyester resin within a mould cavity of dimensions 230 mm X 200 mm X 4 mm. curing was done for about 10 hours under 25°C. Composite specimen resulting after all these stages was edge prepared for further stages like cutting, testing etc.

TABLE 1. Properties of banana fiber

Sl. No.	Properties Description	Values
1	Density (g/cm^3)	1.40
2	Elongation (%)	3.1±1.1
3	Maximum Stress (MPa)	270±8.7
4	Modulus (MPa)	10855±1510

TABLE 2. Properties of banana fiber

Sl. No.	Properties	Unit	Range
1	Specific Gravity	No unit	1.1 - 1.46
2	Hardness (Rockwell	No unit	70 - 115
3	Tensile Strength	MN/mm^2	42 - 91
4	Tensile modulus	GN/mm^2	2 - 4.5
5	Compressive strength	MN/mm^2	90 - 250
6	Shrinkage	%	0.004 - 0.008

Mechanical testing

The composite sheet of dimension 230 mm X 200 mm X 4 mm was cut according to ASTM standards for various tests. Tensile test as carried out in an Electronic Tensometer according to the standard ASTM D 638 – 03. Three point flexural test as being carried out in a spring testing machine with a suitable attachment according to the standard ASTM D 790 – 03.

Scanning electron microscopy

The shear surfaces of the specimen are used to observe the effects of various fiber-matrix characteristics upon the properties of the composites. Failed composites specimen was examined using Scanning Electron Microscope model Jeol JSM 35-C. Surfaces that are analyzed were coated with suitable solvent.

RESULT AND DISCUSSION

Effect of fiber volume fraction upon tensile strength and modulus

Mechanical properties of the composites generally rely upon matrix nature, fiber orientation and fiber-matrix interface [2]. Tensile test was conducted according to American Society of Testing Method standard D 638 – 03 for plastics. Five dog bone shaped specimen were obtained from the composite sheet and were tested in an Electronic Tensometer with a maximum gauge length of 180mm. The average values of these five samples were taken as the strength and modulus of the composite. Curves, as shown in Figures 1 and 2, were plotted for stress against the strain and tensile strength and tensile modulus were determined from the breaking parameters. For 10%, 15% and 20% volume fraction of the fibers the average maximum tensile strength of the specimen was found to be 32MPa, 38MPa and 46MPa, respectively. The average maximum tensile modulus was found to be 455GPa, 487GPa and 507Gpa, respectively. Average peak load was found to be 750N, 920N and 1048N and average displacement was 3.20mm, 3.85mm and 4.30mm, respectively. Tensile strength was found to increase by 16% and 18% from 0.10 V_f to 0.20 V_f of the fiber and the tensile modulus increased by 19% and 13% in between the same volume fractions. Tests for 5% and 25% volume fraction of fibers are yet to be conducted.

The Scanning Electron Micrograph of the tensile fractured specimen for the volume fraction of 0.10 and 0.20 are shown in the Figures 3 and 4, respectively. The fiber breakage at the interphase of the 0.20 V_f is evident and the interaction between the fiber and matrix phases was much better. But in 0.10 V_f fiber pull out and fiber matrix debonding is clearly seen. The reason for this is that there is a shortage of fiber for the effective stress transfer. But as the volume fraction increases agglomeration of fiber occurs and as a result the strength of the composite decreases due to less fiber-fiber interaction.

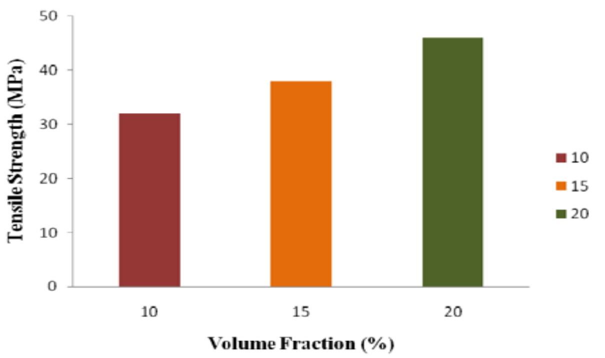

Figure 1. Variation of Tensile strength

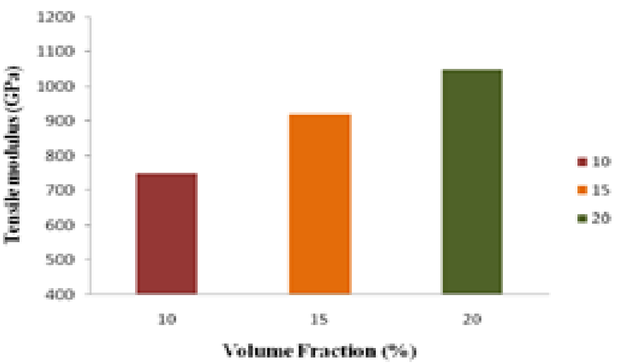

Figure 2. Variation of Tensile modulus

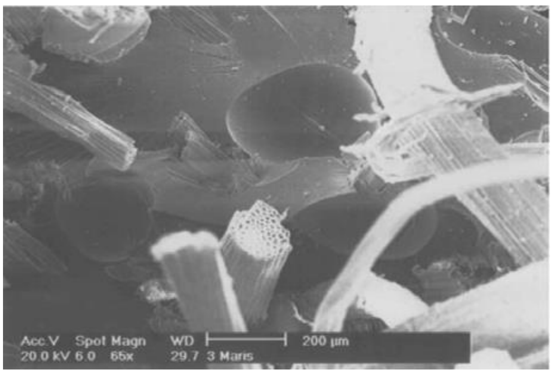

Figure 3. SEM micrograph of 0.10 Vf

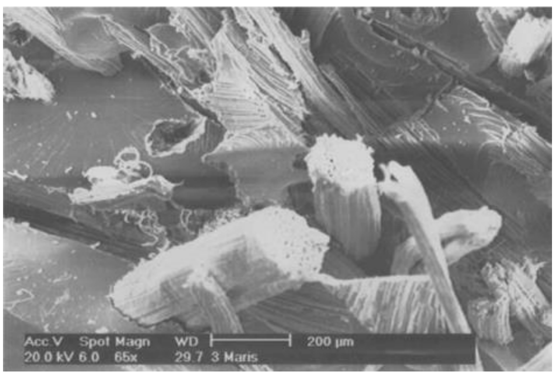

Figure 4. SEM micrograph of 0.20 V_f

Effect of fiber volume fraction upon flexural strength and modulus

Another most important property that is measured for the composite used in the structural applications is the flexural strength and modulus. Flexural test was carried out according to the standard ASTM D 790 – 03 for plastics. Three point flexural test was used to measure the flexural strength of the composite. Five rectangular shaped specimens were obtained from the composite laminate and the strength was measured in a spring testing machine with suitable attachment for carrying out the test. The average values of these five samples were taken as the strength and modulus of the composite. For 10%, 15% and 20% volume fraction of the fibers the average flexural strength was found to be 42 MPa, 58MPa and 87MPa, respectively. The average flexural modulus was 10GPa, 11Gpa and 9GPa, respectively. Average load applied was found to be 70N, 96N and 144N, respectively and the deflection was found to be 24.5mm, 21mm and 17mm, respectively. Flexural strength was found to be increased by 28% and 33% from 0.10 volume fraction of fiber to 0.20 volume fraction of fiber and the flexural modulus of the specimen was increased by 9% from 0.10 to 0.15 volume fractions and dropped by 18% from 0.15 to 0.20 volume fraction of fiber. Tests for 5% and 25% volume fraction of fibers are yet to be conducted.

Variation in flexural strength and flexural modulus for a set of five specimen obtained from each composite sheet of different volume fraction are shown in the Figures 5 and 6. The following figure shows the SEM micrograph of a flexural

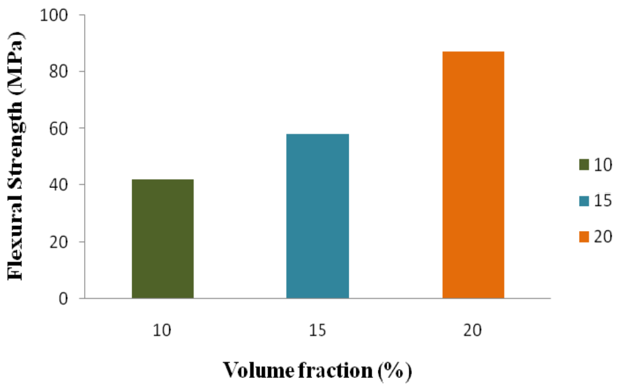

Figure 5. Variation of Flexural strength

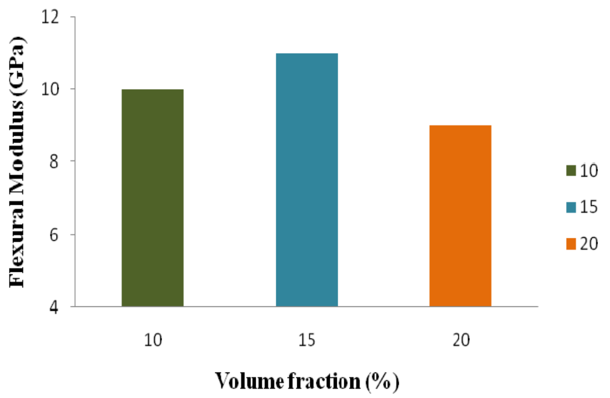

Figure 6. Variation of Flexural Modulus

fractured specimen (Figure 7). It was observed that the crack due to bending initiated at compression region of the load. Also, the major factors that contribute to the failure were fiber-matrix adhesion and fiber matrix interphase, debonding and fiber breakage.

Effect of fiber volume fraction upon compressive strength

Compression test was carried out according to the standard ASTM D 4762 – 08 for plastics. Five specimens according to the standards are obtained from the composite laminate and are tested in a UTM to determine the compressive properties. For 10%, 15% and 20% the average compressive strength was found to be 74MPa, 114MPa and 142MPa, respectively. As the fiber volume fraction increases, the compressive strength also increases. In between 0.10 and 0.15 volume fraction the increase was 36% and similarly in between 0.15 to 0.20 volume fraction the increase was 20%. The failure of the specimen initiated and then propagated through the axis parallel to the load and the pattern of failure was shear failure. Figure 8 shows the variation of compressive strength with respect to the volume fraction of fibers.

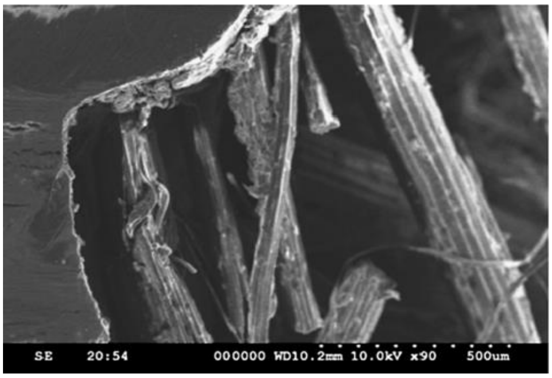

Figure 7. SEM micrograph of 0.20 V_f

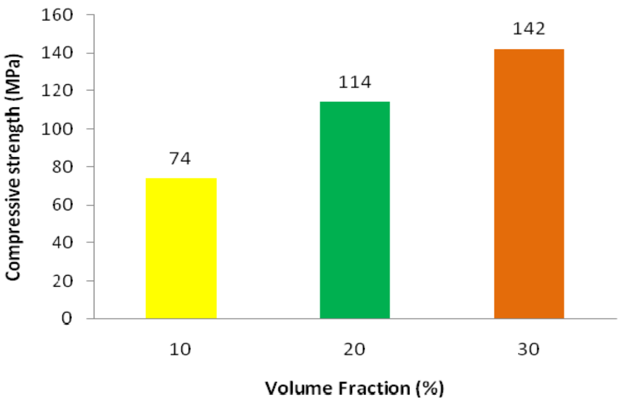

Figure 8. Variation of Compressive Strength

CONCLUSION

Static mechanical properties like tensile strength, tensile modulus, flexural strength and flexural modulus were investigated for the banana and snake grass fiber reinforced polyester composites with reference to the relative volume fraction both the fibers being 1:1. It was found that the variation of the tensile strength of the composite increased from 0.05 V_f to 0.20 V_f by 30% and tensile modulus also behaved in the same way by increasing 11% from 0.10 to 0.20 volume fraction of fibers. This behaviour was due to the usage of critical fiber fragment length in the manufacturing of composite. This factor was also facilitated by the good adhesion between the fiber and matrix and as a result the fiber damage at this critical length became rare, thus increasing the strength of the composite and render the variation in stress distribution of the hybrid composite. In the case of the flexural strength the failure was found to be initiated at the compression region and fiber breakage started at the tension region. The 40% increase in flexural strength and 10% drop in flexural modulus of the hybrid composite were due to the fiber-matrix behaviour in the interphase and influenced greatly by the shear and normal stresses induced at the fiber-matrix contact.

REFERENCES

1. Rajesh, M. and Pitchaimani, J., 2017. Mechanical properties of natural fiber braided yarn woven composite: comparison with conventional yarn woven composite. ***Journal of Bionic Engineering***, 14(1), pp.141-150.
2. Srinivas, K., Naidu, A.L. and Bahubalendruni, M.R., 2017. A review on chemical and mechanical properties of natural fiber reinforced polymer composites. ***International Journal of Performability Engineering***, 13(2), pp.189-200.
3. Khalil, H.A., Bhat, I.U.H., Jawaid, M., Zaidon, A., Hermawan, D. and Hadi, Y.S., 2012. Bamboo fibre reinforced biocomposites: A review. ***Materials & Design***, 42, pp.353-368.
4. Musalaiah, G.,Suresh, B.V.,Tanniru, M.,Ramakrishna Reddy, P., 2017. Development and mechanical characterisation of glass fibre reinforced polymer composite. ***International Journal of Mechanical Engineering and Technology***, 8(7), 231-239.
5. Swolfs, Y., Gorbatikh, L. and Verpoest, I., 2014. Fibre hybridisation in polymer composites: a review. Composites ***Part A: Applied Science and Manufacturing***, 67, pp.181-200.
6. Arthanarieswaran, V.P., Kumaravel, A. and Kathirselvam, M., 2014. Evaluation of mechanical properties of banana and sisal fiber reinforced epoxy composites: Influence of glass fiber hybridization. ***Materials & Design***, 64, pp.194-202.
7. Mishra, V. and Biswas, S., 2013. Physical and mechanical properties of bi-directional jute fiber epoxy composites. ***Procedia Engineering***, 51, pp.561-566.
8. Mylsamy, K. and Rajendran, I., 2011. The mechanical properties, deformation and thermomechanical properties of alkali treated and untreated Agave continuous fibre reinforced epoxy composites. ***Materials & Design***, 32(5), pp.3076-3084.
9. Sapuan, S.M., Leenie, A., Harimi, M. and Beng, Y.K., 2006. Mechanical properties of woven banana fibre reinforced epoxy composites. ***Materials & Design***, 27(8), pp.689-693.
10. Jindal, U.C., 1986. Development and testing of bamboo-fibres reinforced plastic composites. ***Journal of Composite Materials***, 20(1), pp.19-29.

Persian Abstract

DOI: 10.5829/ijee.2020.11.01.11

چکیده

الیاف طبیعی مانند موز، سیزال، چمن مار، کویر، کنف، جوت و غیره دارای خواص و مزایای عظیمی مانند وزن کم، قابلیت اطمینان، بازیافت و با طبیعت دوستانه و سازگار با محیط زیست هستند. چنین الیاف ممکن است با عملکرد به عنوان مواد افزودنی با ترموپلاستیک در چشم‌اندازهای مختلف عملکرد سیستم را بهبود بخشند. علاوه بر کامپوزیت‌های طبیعی، کامپوزیت‌های ترکیبی، طراحی مواد با خاصیت خاص را مطابق با کاربرد تسهیل می‌کنند. در پژوهش حاضر تلاش شده است موز و چمن مارها کامپوزیت‌های پلی‌استر ترکیبی تقویت شده با الیاف کوتاه به صورت تصادفی و تخمگذار تصادفی تولید و آزمایش شوند. متیل اتیل کتون پراکسید به عنوان عامل اتصال‌دهنده و کبالت نفتالین به عنوان کاتالیزور مورد استفاده قرار گرفته است. برای ساخت کامپوزیت‌ها از تکنیک آماده‌سازی دست استفاده شد. کسر حجمی نسبی الیاف در نسبت ۱: ۱ بین ۵/۵ تا ۵ درصد متغیر بود. خواصی مانند استحکام کششی و مدول، استحکام خمشی و مدول برای انجام کامپوزیت‌ها با انجام آزمایشات مناسب طبق استانداردهای ASTM اندازه‌گیری می‌گردد.