IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 5 Ver. IV (Sep. - Oct. 2017), PP 16-20
www.iosrjournals.org

Mechanical Behavior, Tribological Characterization and damage analysis of Short Fibers Reinforced Polymer Composites

Narendra Kumar[1], Anurag Pandey[2], Vijay Pratap Singh[3], Dr. S.M.Hussain [4]
[1,2,3] Student, Mechanical Engineering, Institute of Technology & Management Aligarh, U.P., India
[4] Prof. Mechanical Engineering Department, Institute of Technology & Management Aligarh UP India

Abstract: *Now-a-days, natural fiber reinforced polymer composites are increasingly being used for varieties of engineering applications due to their many advantages. Among natural fibers, bamboo has been widely used for many such applications due to its availability. Since these composites are finding wide applications in highly dusty environment which are subjected to solid particle erosion, a study of their erosion characteristics are of vital importance. Generally solid particle erosion, a typical wear mode leads to material loss due to repeated impact of solid particles. For a composite material, its mechanical behavior and surface damage by solid particle erosion depends on many factors. Attempts have been made in this paper to explore the potential utilization of bamboo fiber in polymer matrix composites. Therefore, the present research is focused on the mechanical and erosion wear behavior of short bamboo fiber reinforced composites filled with Alumina (Al_2O_3) particulate. It further outlines a methodology based on Taguchi's, Experimental design approach to make a parametric analysis of erosion characteristics. Finally, the morphology of eroded surfaces is examined using scanning electron microscopy (SEM) and possible erosion mechanisms are identified.*

Keywords - *Bamboo, Alumina, Tribological, Composite.*

Date of Submission: 02-10-2017 Date of acceptance: 18-10-2017

I. INTRODUCTION

When two or more materials with different properties are combined together, they form a composite material [1]. In general, the properties of composite materials are superior in many respects, to those of the individual constituents. This has provided the main motivation for the research and development of composite materials. There are two categories of constituent materials one is matrix and another is reinforcement. The primary functions of the matrix are to transfer stresses between the reinforcing fibers/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibers/particles in a composite improves its mechanical properties such as strength, stiffness etc. The objective is to take advantage of the superior properties of both materials without compromising on the weakness of either. The matrix material can be metallic, polymeric or can even be ceramic. When the matrix is a polymer, the composite is called polymer matrix composite. The properties of polymeric composite materials are mainly determined by three constitutive elements such as the resin, the reinforcement, such as particles and fibers, and the interface between them.

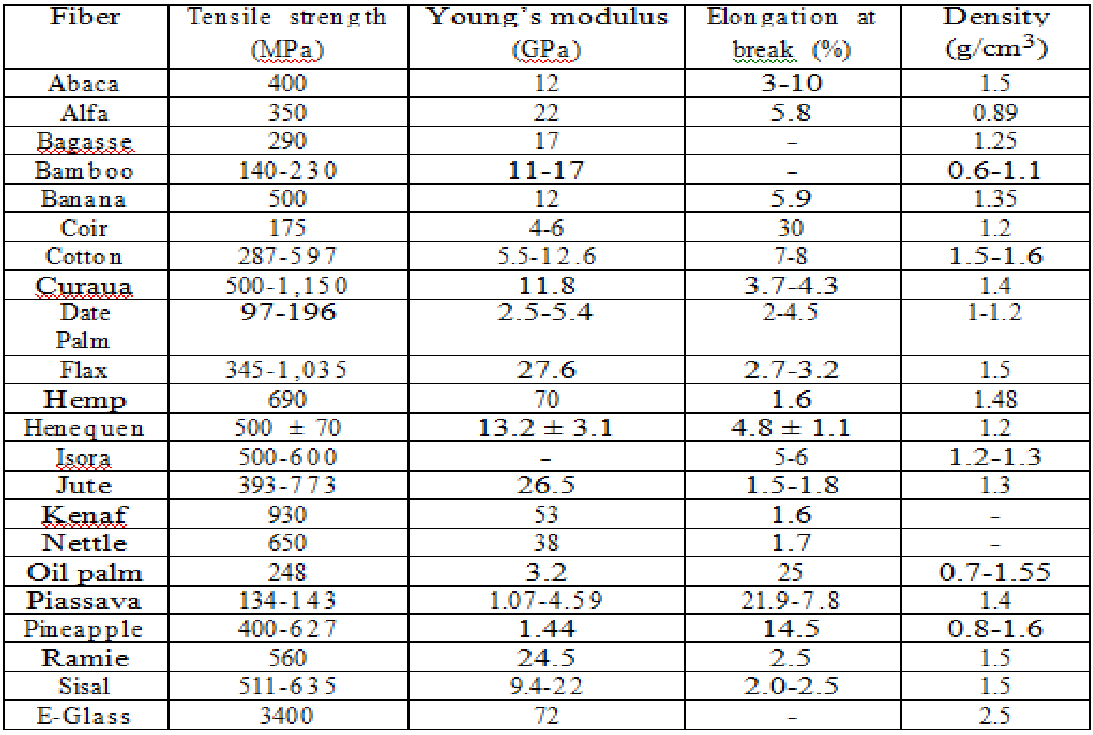
II. BACKGROUND

As far as the reinforcement is concerned, extensive use has been made of inorganic man-made fibers such as glass and organic fibers such as carbon and aramid. Recently, the rapidly increasing environmental awareness, geometrically increasing crude oil prices, growing global waste problem and high processing cost trigger the development concepts of sustainability and reconsideration of renewable resources. The use of natural fibres, derived from annually renewable resources, as reinforcing fibres in both thermoplastic and thermoset matrix composites provides positive environmental benefits with respect to ultimate disposability and raw material utilization [2]. The advantages associated with the use of natural fibers as reinforcement in polymers are their availability, non-abrasive nature, low energy consumption, biodegradability and low cost. In addition, natural fibers have low density and high specific properties. The specific mechanical properties of these fibers are comparable to those of traditional reinforcements. A number of investigations have been carried out to assess the potential of natural fibres as reinforcement in polymers

III. Literature Survey

This study provides the background information on the issues to be considered in the present research work and to focus the relevance of the present study. The purpose is also to present a thorough understanding of various aspects of short bamboo fiber reinforced polymer composites with a special attention to their erosion wear behavior.

In fiber reinforced polymer composites, the fibers can be either synthetic fibers or natural fibers. Advantages of natural fibers over synthetic fibers include low density, availability, low cost, recyclability and biodegradability [3-5]. Due to their many advantages they are comparable to those of synthetic fibers used as reinforcements. It is also known that natural fibers are non-uniform with irregular cross sections, which making their structures quite unique and much different from synthetic fibers. Generally, the natural fibers are consisting of cellulose, hemi-cellulose, lignin, pectin, waxes and water soluble substances. The chemical composition of natural fibers may differ with the growing condition and test methods even for the same kind of fiber. The physical mechanical properties of natural fibers are greatly influenced by their chemical compositions. The properties of some of these fibers are presented in Table 1. It is evident from Table 1. That, the tensile strength of glass fiber is substantially higher than that of natural fibers even though the modulus is of the same order. However, when the specific modulus of natural fibers is considered, the natural fibers are better as compared to glass fibers. Therefore, these higher specific properties are the major advantages of natural fiber as reinforcement in polymer composites for weight sensitive applications.



Fiber	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)	Density (g/cm^3)
Abaca	400	12	3-10	1.5
Alfa	350	22	5.8	0.89
Bagasse	290	17	-	1.25
Bamboo	140-230	11-17	-	0.6-1.1
Banana	500	12	5.9	1.35
Coir	175	4-6	30	1.2
Cotton	287-597	5.5-12.6	7-8	1.5-1.6
Curaua	500-1,150	11.8	3.7-4.3	1.4
Date Palm	97-196	2.5-5.4	2-4.5	1-1.2
Flax	345-1,035	27.6	2.7-3.2	1.5
Hemp	690	70	1.6	1.48
Henequen	500 ± 70	13.2 ± 3.1	4.8 ± 1.1	1.2
Isora	500-600	-	5-6	1.2-1.3
Jute	393-773	26.5	1.5-1.8	1.3
Kenaf	930	53	1.6	-
Nettle	650	38	1.7	-
Oil palm	248	3.2	25	0.7-1.55
Piassava	134-143	1.07-4.59	21.9-7.8	1.4
Pineapple	400-627	1.44	14.5	0.8-1.6
Ramie	560	24.5	2.5	1.5
Sisal	511-635	9.4-22	2.0-2.5	1.5
E-Glass	3400	72	-	2.5

Table:-1. Properties of natural fibers [A]

IV. SCOPE

The knowledge gap in the existing literature review has helped to set the objectives of this research work which are outlined as follows:

Fabrication of unfilled and alumina filled short bamboo fiber reinforced epoxy composites. Evaluation of mechanical properties of both unfilled and particulate filled composites such as tensile strength, impact strength flexural strength, and micro-hardness etc.Study of solid particle erosion behavior of unfilled and filled composites both in steady state condition and by Taguchi orthogonal array design.To study the fracture surface morphology using SEM study for mechanical properties samples and eroded samples.

V. MATERIAL AND METHOD

5.1 Materials

5.1.1 Matrix Material

Among different types of matrix materials, polymer matrices are the most commonly used because of cost efficiency, ease of fabricating complex parts with less tooling cost and they also have excellent room temperature properties when compared. Polymer matrices can be either thermoplastic or thermoset. The most commonly used thermoset resins are epoxy, vinyl ester, polyester and phenolics. Among them, the epoxy resins are being widely used for many advanced composites due to their many advantages such as excellent adhesion to wide variety of fibers, good performance at elevated temperatures and superior mechanical and electrical properties. In addition to that they have low shrinkage upon curing and good chemical resistance. Due to several advantages over other thermoset polymers as mentioned above, epoxy (LY 556) is chosen as the matrix material for the present research work. It chemically belongs to the 'epoxide' family and its common name of epoxy is Bisphenol-A-Diglycidyl-Ether.

Figure 5.1 Short bamboo fiber and bamboo based composite

5.2 Composite Fabrication

In this study, short bamboo fiber is taken as reinforcement is collected from local sources. The epoxy resin and the hardener are supplied by Ciba Geigy India Ltd. Al_2O_3 powders are obtained from NICE Ltd India in a range of 80-100 µm. A stainless steel mould having dimensions of 210 × 210 × 40 mm^3 is used for composite fabrication. The short bamboo fiber and Al_2O_3 particulates are mixed with epoxy resin by the simple mechanical stirring and the mixture is poured into various moulds conforming to the requirements of various testing conditions and characterization standards. The composite samples of four different compositions (EB-1 to EB-4), in which no particulate filler is used. The other composite samples EBA-1 to EBA-4 are prepared in four different percentages of alumina particulates (0wt%, 5wt%, 10wt% and 15wt% of alumina) is used keeping bamboo fiber at a fixed percentages (i.e. 45wt%). A releasing agent is used to facilitate easy removal of the composite from the mould after curing.

5.3 Mechanical testing of composites

The tension test was performed on all the three samples as per ASTM D3039-76 test standards. The tension test is generally performed on flat specimens. A uni-axial load is applied through the ends. The ASTM standard test recommends that the length of the test section should be 100 mm specimens with fibers parallel to the loading direction should be 11.5 mm wide and.

To find out the flexural strength of the composites, a three point bend test is performed using Instron 1195. The cross head speed was taken as 10 mm/min and a span of 30 mm was maintained. The strength of a material in bending is expressed as the stress on the outermost fibers of a bent test specimen, at the instant of failure. In a conventional test, flexural strength expressed in terms of MPa is equal to

VI.

$$\text{Flexural Strength} = 3PL / 2bd^2 \qquad (5.1)$$

Where, P= applied central load (N)
L= test span of the sample (m)
b= width of the specimen (m)
d= thickness of specimen under test (m), Leitz micro-hardness tester is used for micro-hardness measurement on composite samples. A diamond indenter in the form of a right pyramid of a square base of an angle 136° between opposite faces is forced under a load F into the sample. After removal of the load, the two diagonals of the indentation (X and Y) left on the surface of the sample are measured and their arithmetic mean L is calculated. The load considered in the present study is 24.54N and Vickers hardness is calculated using the following equation:

$$H_V\ 0.1889\ \frac{F}{L^2} \quad \text{and} \quad L \quad \frac{X\ Y}{2} \qquad (5.2)$$

Where F is the applied load (N), L is the diagonal of square impression (mm), X is the horizontal length (mm) and Y is the vertical length (mm).

Finally, impact tests are carried out on composite specimens as per ASTM D 256 using an impact tester. The pendulum impact testing machine ascertains the notch impact strength of the material by shattering the V-notched specimen with a pendulum hammer, measuring the spent energy, and relating it to the cross section of the specimen. The standard specimen for ASTM D 256 is 64 × 12.7 × 3.2 mm and the depth of the notch is 10.2 mm.

5.4 Scanning electron microscopy (SEM)

Scanning electron microscope of Model JEOL JSM-6480LV was used for the morphological characterization of the composite surface. The samples are cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and observed SEM at 20 kV.

5.5 Erosion testing of composites

The erosion testing of composite specimens is performed on a standard erosion test rig as per ASTM G76 standard. The test rig consisting of an air compressor, a conveyor belt-type particle feeder, an air drying unit, an air particle mixing and an accelerating chamber. The dried and compressed air is mixed with the silica sand which is then fed constantly into the mixing chamber by a conveyor belt feeder and accelerated by passing the mixture through a convergent brass nozzle of internal diameter of 3 mm. The set-up is capable of creating erosive situations for assessing solid particle erosion wear resistance of the composite samples

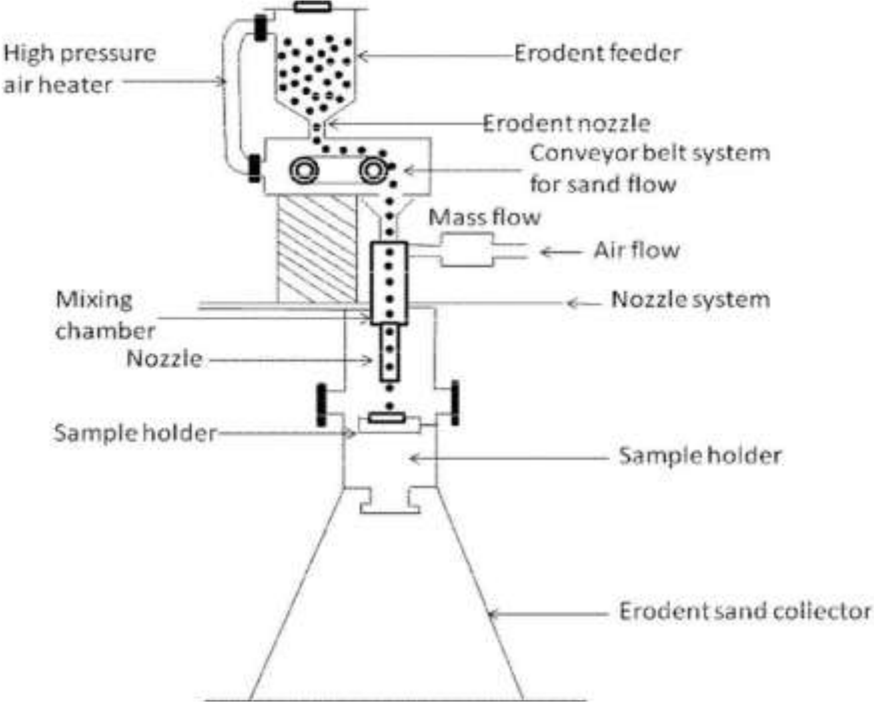


Fig 5.5 a schematic diagram of the erosion test rig

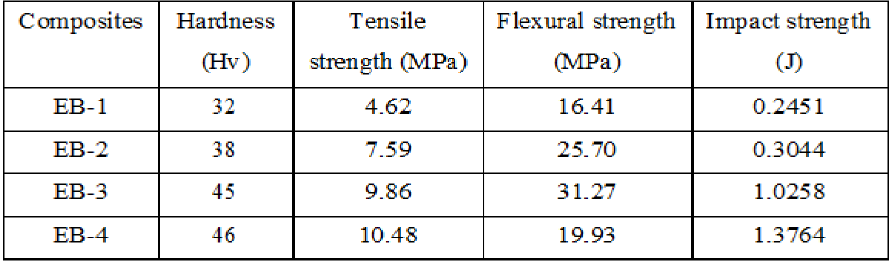
5.6 Taguchi Method

Taguchi's parameter design is an important tool for robust design. It offers a simple and systematic approach to optimize the design parameters because this systematic approach can significantly minimize the overall testing time and the experimental costs. Two major tools used in robust design are signal to noise ratio (S/N), which measures quality with emphasis on variation, and orthogonal array, which accommodates many design factors simultaneously. In design of experiment, the most important stage lies in the selection of the control factors.

Bamboo fiber reinforced epoxy composites without filler

5.7 Mechanical characteristics of composites without filler

The mechanical properties of the short bamboo fiber reinforced epoxy composites with different fiber loading under this investigation are presented in Table 4.1. It is evident from the Table 2 that at 45wt% of fiber loading the composites show better mechanical properties as compared to others.



Composites	Hardness (Hv)	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (J)
EB-1	32	4.62	16.41	0.2451
EB-2	38	7.59	25.70	0.3044
EB-3	45	9.86	31.27	1.0258
EB-4	46	10.48	19.93	1.3764

VII. CONCLUSION

The experimental investigation on the effect of fiber loading and filler content on mechanical and erosion behavior of short bamboo fiber reinforced epoxy composites leads to the following conclusions obtained from this study are as follows:

The successful fabrications of a new class of epoxy based composites reinforced with short bamboo fibers have been done.

The present investigation revealed that 45wt% fiber loading shows superior hardness, tensile strength and impact strength. Whereas, for flexural strength show better in 30wt% of fiber loading. As far as inclusion of filler content in the bamboo-epoxy composites, the mechanical properties are inferior as compared to unfilled composites.

Study of influence of impingement angle on erosion rate of the composites filled with different weight percentage of particulates reveal their semi-ductile and semi-brittle nature with respect to erosion wear. The result shows the peak erosion taking place at an impingement angle of 60° for the neat epoxy resin and for unfilled bamboo-epoxy composites the peak erosion rate is around 75° impingement angle, whereas composite samples filled with alumina, the maximum erosion rate is recorded at an impingement angle of 60° under similar experimental conditions. This clearly indicates that these composites respond to solid particle impact neither in a purely ductile nor in a purely brittle manner. This behavior can be termed as semi-ductile in nature. The erosion rate is also greatly affected by the erodent temperature.

The fracture surfaces study of short bamboo fiber reinforced epoxy composite after the tensile test has been done. From this study it has been concluded that the poor interfacial bonding is responsible for low mechanical properties..

Acknowledgements

It gives me immense pleasure to express my deep sense of gratitude to my supervisor **Dr. S.M. Hussain** for her invaluable guidance, motivation, constant inspiration and above all for her ever co-operating attitude that enabled me in bringing up this thesis in the present form.

REFERENCES

[1] Herakovich C.T., (1998). Mechanics of fibrous composites. New York: Wiley; p. 1–27.
[2] Narayan R., (1992). Biomass (renewable) resources for production of materials, chemicals and fuels – a paradigm shift, ACS Symp Ser 476.
[3] Pool K.V., Dharan C.K.H. and Finnie I., (1986). Erosion wear of composite materials, wear, vol. 107, 1-12.
[4] Aglan H.A. and Chenock T.A. Jr., (1993). Erosion damage features of polyimide Thermoset composites, SAMPE Quartery, 41-47.
[5] Rao P.V., (1995). Characterization of optical and surface parameters during particle impact damage, ASME/Fluids engineering publications, 23:87-96.
[6] Maldas D., Kokta B.V., Raj R.G. and Daneault C., (1988). Improvement of the mechanical properties of sawdust wood fibre-polystyrene composites by chemical treatment. Polymer 1988; 29(7):1255–65
[7] Sgriccia N., Hawley M.C. and Misra M., (2008). Characterization of natural fiber surfaces and natural fiber composites, Composites: Part A 39 1632–1637.
[8] John M.J. and Anandjiwala R.D., (2008). Recent Developments in Chemical Modification and Characterization of Natural Fiber-Reinforced Composites, Polymer Composites, 29(2), pp.187-207.
[9] Kahraman R., Abbasi S. and Abu-Sharkh B., (2005). Influence of Epolene G- 3003 as a Coupling Agent on the Mechanical Behavior of Palm FiberPolypropylene Composites, International Journal of Polymeric Materials, 54(6), pp. 483-503.
[10] Santulli C., (2001). Post-impact damage characterisation on natural fibre reinforced composites using acoustic emission. NDT & E International, 34(8), pp. 531-536
[11] Kishore debnath , A STUDY ON MECHANICAL BEHAVIOR AND DAMAGE ASSESSMENT OF SHORT BAMBOO FIBER BASED POLYMER COMPOSITES 2011
[12] Tobias B.C., (1993). Tensile and impact behaviour of natural fibre-reinforced composite materials, In Proceedings of Advanced Composites 93: International Conference on Advanced Composite Materials; Wollongong; Australia; 15-19 Feb. 1993. pp. 623-627.
[13] Srivastav A.K., Behera M.K. and Ray B.C., (2007). Loading Rate Sensitivity of Jute/Glass Hybrid Reinforced Epoxy Composites: Effect of Surface Modifications, Journal of Reinforced Plastics and Composites, 26(9), pp. 851- 860.
[14] Gowda T.M., Naidu A.C.B., and Chhaya R., (1999). Some Mechanical Properties of Untreated Jute Fabric-Reinforced Polyester Composites, Composites Part A: Applied Science and Manufacturing, 30(3), pp. 277-284.
[15] Saheb D.N., Jog J.P., (1999). Natural fiber polymer composites: a review. Adv Polym Technol; 18(4):351–63.