International Journal of Engineering and Advanced Research Technology (IJEART)
ISSN: 2454-9290, Volume-3, Issue-9, September 2017

A Study of Characteristics and Damage Assessment of Short Bamboo Fiber Based Polymer Composites

Preeti Singh, Mukesh Kumar Verma, Devvrat Verma

***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 (Al2O3) 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.

***Index Terms*— Polymer, Composite, Bamboo Fiber, Sem, Matrix Material**

I. INTRODUCTION

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. 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.

Mechanical properties of natural fiber based polymer composites are influenced by many factors such as fibers volume fraction, fiber length, fiber aspect ratio, fiber-matrix adhesion, fiber orientation, etc.. A great deal of work has already been done on the effect of various factors on mechanical behavior of natural fiber reinforced polymer composites. The post-impact Behavior of jute fiber reinforced polyester composites subjected to low velocity impact has studied by **Santulli** Effect of fiber content on tensile and flexural properties of pineapple fiber reinforced poly (hydroxybutyrate-co-valerate) resin composites has studied by **Luo and Netravali** The fracture energies for fibers such as sisal, banana, pineapple and coconut fiber reinforced polyester composites using Charpy impact tests has studied by **Pavithran et al.** They reported that, except for the coconut fiber, the fiber toughness is increases due to increase in fracture energy of the composites. The mechanical behavior of jute and kenaf fiber reinforced polypropylene composites has been studied by Schneider and **Karmaker** It is concluded from their study that jute fiber based composites provides better mechanical properties than kenaf fiber based composites. A systematic study on the properties of henequen fiber has made by **Cazaurang et al.** and reported that fibers have mechanical properties suitable for reinforcement in thermoplastic resins.

Various aspects of banana fiber reinforced polymer composites has studied by various investigators. The effect of various loading rate on mechanical properties of jute/glass reinforced epoxy based hybrid composites has studied by **Srivastav et al.** The mechanical properties of jute fiber reinforced polyester composites were evaluated by **Gowda et al.** It is reported from their study that they have better strengths as comparison to wood based composites.

Bamboo fiber reinforced composites with different polymers have been reported, including epoxy resin, **polypropylene (PP), polybutylenes succinct (PBS)**, and **polylactic acid (PLA)**. The mechanical properties and fracture mechanisms of bamboo fiber reinforced polymer composites under different loading conditions is studied by **Shin et al. Thwe and Liao** studied the effects of fiber content, fiber length, bamboo to glass fiber ratio, and MAPP content on mechanical properties of bamboo fiber reinforced plastics and bamboo-glass fiber reinforced plastics**.**

Jiang et al studied the mechanical behavior of poly (3-hydroxybutyrate-co-3- hydroxyvalerate)/bamboo pulp fiber composites. **Okubo et al.** studied the tensile strength and modulus of bamboo fiber reinforced polypropylene based composites. The mechanical properties of bamboo fiber reinforced polypropylene composites was studied and compared with those of commercial wood pulp by

Chen et al. The effect of bonding agent on mechanical properties of bamboo fiber reinforced natural rubber composites was studied by **Ismail et al.**The effect of fiber length on tensile properties of short bamboo fiber reinforced epoxy composites was studied by **Rajulu et al.** In another investigation, **Chen** studied the structure, morphology and properties of bamboo fiber reinforced polypropylene composites in details. The effect of environmental aging on mechanical properties of bamboo-glass fiber reinforced polymer hybrid composites was studied by **Thwe et al.**

II. KNOWLEDGE GAP

The literature survey presented above reveals the following knowledge gap in the research reported so far:

- Though much work has been done on a wide variety of natural fibers for polymer composites, very less has been reported on the reinforcing potential of short bamboo fiber in spite of its several advantages over others.
- A number of research efforts have been devoted to the mechanical and wear characteristics of either fiber reinforced composites or particulate filled composites. However, a possibility that the incorporation of both particulates and fibers in polymer could provide a synergism in terms of improved performance has not been adequately addressed so far.
- Studies carried out worldwide on erosion wear behavior of composites have largely been experimental and the use of statistical techniques in analyzing wear characteristics has been rare. Taguchi method, being a simple, efficient and systematic approach to optimize designs for performance, quality and cost, is used in many engineering applications. However, its implementation in parametric appraisal of wear processes has hardly been reported.

III. OBJECTIVES

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

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

IV. MATERIALS AND METHODS

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 thermo set. The most commonly used thermo set resins are epoxy, vinyl ster, 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 thermo set polymers as mentioned above, epoxy (LY 556) is chosen as the matrix material for the present research work. It chemically belongs to the 'epoxies' family and its common name of epoxy is Bisphenol-A-Diglycidyl-Ether.

FIBER MATERIAL:- Fiber is the reinforcing phase of a composite material. The present research work, bamboo fiber is taken as the reinforcement in the epoxy matrix to fabricate composites. In general, bamboo is available everywhere around the world and is an abundant natural resource. It has been a conventional construction material since ancient times. The scientific name of the type of bamboo used for this work is **Dendrocalamus strictus** [73]. This is one of the predominant species of bamboo in Orissa, Uttar Pradesh, Madhya Pradesh and Western Ghats in India. This species occupies approximately 53% of total bamboo area in India. Bamboo is an orthotropic material with high strength along and low strength transversal to its fibers. The structure of bamboo itself is a composite material, consisting of long and aligned cellulose fibers immersed in a ligneous matrix. In this work, short bamboo fiber is used as the reinforcement in the composites. The fiber mats are dried in an oven at a temperature of 105°C for 72 h to remove moisture prior to composite making. The average thickness of each bamboo fiber is about 1.5 mm. Figure 1 shows short bamboo fibers and bamboo fiber reinforced epoxy composite.

Figure 1 Short bamboo fiber and bamboo based composite

Table 1 Orthogonal array for L16 (4^5) Taguchi Design

Sl. No.	Impact Velocity (m/sec)	Fiber/ filler Content (wt %)	Impingement Angle (Degree)	Stand-off distance (mm)	Erodent Temperature (°C)
1	1	1	1	1	1
2	1	2	2	2	2
3	1	3	3	3	3
4	1	4	4	4	4
5	2	1	2	3	4
6	2	2	1	4	3
7	2	3	4	1	2
8	2	4	3	2	1
9	3	1	3	4	2
10	3	2	4	3	1
11	3	3	1	2	4
12	3	4	2	1	3
13	4	1	4	2	3
14	4	2	3	1	4
15	4	3	2	4	1
16	4	4	1	3	2

ISSN: 2454-9290, Volume-3, Issue-9, September 2017

V. RESULTS

Bamboo fiber reinforced epoxy composites without filler
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 1. It is evident from the Table 1 that at 45wt% of fiber loading the composites show better mechanical properties as compared to others.

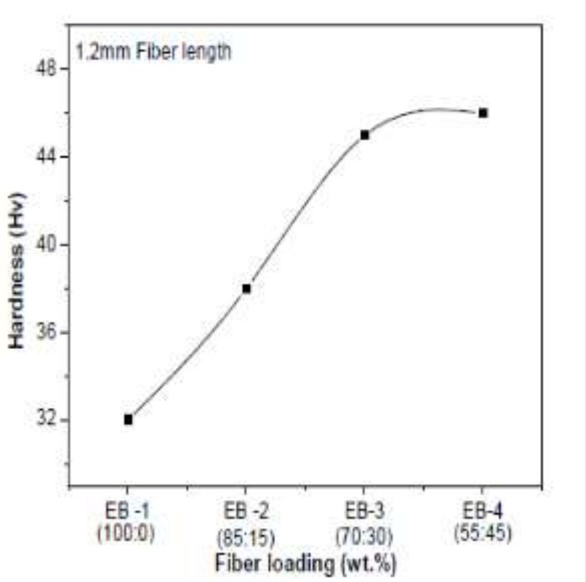

Figure 2 Effect of fiber loading on tensile strength of composites

Effect of fiber loading on flexural strength of composites

Figure shows the effect of fiber loading on flexural strength of composites. Adversely, as shown in Figure 3, the flexural strength increased by the increase of fiber loading up to 30wt%. For instance, flexural strength of bamboo-epoxy composite is increased from 16.41MPa to 31.27MPa i.e. up to 30wt% and then decreased from 31.27MPa to 19.93MPa i.e. up to 50wt% respectively (Figure 3).

It is also observed from Figure 3 that a linearly increasing trend up to a certain value of fiber loading (30wt%) and suddenly drops due to failure of specimens and the arrest points correspond to breakage and pull out of individual fibers from the resin matrix.

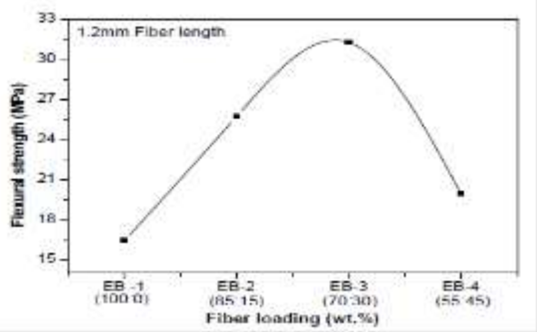

Fig 3 Effect of fiber loading on flexural strength of composites

This is due to higher flexural stiffness of bamboo composite and the improved adhesion between the matrix and the fiber. The effect of weight fraction of fiber on mean flexural strength for other fiber reinforced composites in comparison to bamboo composites are more. According to Ismail et al. [82] and Yao and Li [83], this decrease is attributed to the inability of the fiber, irregularly shaped, to support stresses transferred from the polymer matrix and poor interfacial bonding generates partially spaces between fiber and matrix material and as a result generates weak structure .As flexural strength is one of the important mechanical properties of the composites. For a composite to be used as the structural application it must possess higher flexural strength.

Effect of fiber loading on impact strength of composites

Since fiber reinforced polymer composites are mainly used in structural applications, their impact resistance is also one of the important concerns. The improvement in impact strength of composites with respect to fiber loading is shown in Figure 4. The impact strength of the composites increases slightly with increase of fiber loading up to 15wt% and on further increase in fiber loading the strength increases drastically. The decrease in impact strength or smaller

Variation in strength may be due to induce micro-spaces between the fiber and matrix polymer, and as a result causes numerous micro-cracks when impact occurs, which induce crack propagation easily and decrease the impact strength of the composites [84, 85].

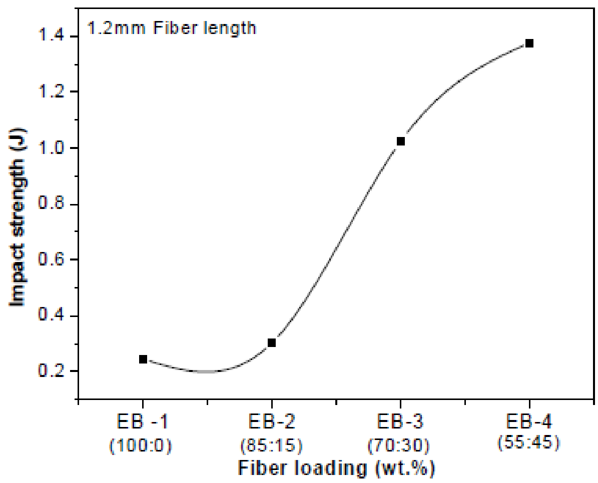

Figure 4 Effect of fiber loading on impact strength of composites

VI. CONCLUSIONS

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:

1. The successful fabrications of a new class of epoxy based composites reinforced with short bamboo fibers have been done.
2. 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.

3. 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.
4. 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.
5. Possible use of these composites such as pipes carrying coal dust, industrial fans, helicopter fan blades, desert structures, low cost housing etc. is recommended. However, this study can be further extended in future to new types of composites using other potential natural fibers/fillers and the resulting experimental findings can be similarly analyzed.

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to all those who provided me the possibility to complete this paper. A special gratitude I give to our M.Tech Heat Power and thermal engineering project co-coordinator, **MRS JYOTI KALE** whose contribution in stimulating suggestions and encouragement, helped me to coordinate my project students especially in writing this paper.

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 Thermo set 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] Saheb D.N., Jog J.P., (1999). Natural fiber polymer composites: a review. Adv Polym Technol; 18(4):351–63.
[7] 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.
[8] Sgriccia N., Hawley M.C. and Misra M., (2008). Characterization of natural fiber surfaces and natural fiber composites, Composites: Part A 39 1632–1637.
[9] 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.
[10] Kahraman R., Abbasi S. and Abu-Sharkh B., (2005). Influence of Epolene G- 3003 as a Coupling Agent on the Mechanical Behavior of Palm Fiber- Polypropylene Composites, International Journal of Polymeric Materials,54(6), pp. 483-503.
[11] Santulli C., (2001). Post-impact damage characterisation on natural fibre reinforced composites using acoustic emission. NDT & E International, 34(8), pp. 531-536.
[12] Luo S. and Netravali A.N., (1999). Mechanical and thermal properties of environmentally friendly green composites made from pineapple leaf fibers and poly (hydroxybutyrate-co-valerate) resin, Polymer Composites, 20(3), pp. 367-378.
[13] Pavithran C., Mukherjee P.S., Brahmakumar M. and Damodaran A.D., (1987).Impact properties of natural fibre composites, Journal of Materials Science Letters, 6(8), pp. 882-884.
[14] Karmaker A.C. and Schneider J.P., (1996). Mechanical Performance of Short Jute Fiber Reinforced Polypropylene, Journal of Materials Science Letters, 1996, 15(3), pp. 201-202.
[15] Cazaurang-Martinez M.N., Herrera-Franco P.J., Gonzalez-Chi P.I. and Aguilar-Vega M., (1991). Physical and mechanical properties of henequen fibers, Journal of Applied Polymer Science, 43(4), pp. 749-756.
[16] Joseph S., Sreekala M.S., Oommen Z., Koshy P. and Thomas S., (2002). A Comparison of Mechanical Properties of Phenol Formaldehyde Composites Reinforced with Banana Fibers and Glass Fibers, Composites Science and Technology, 62(14), pp. 1857-1868.
[17] Pothan L.A., Oommen Z. and Thomas S., (2003). Dynamic Mechanical Analysis of Banana Fiber Reinforced Polyester Composites, Composites
[18] Science and Technology, 63(2), pp. 283-293.
[19] Corbière-Nicollier T., Laban B.G., Lundquist L., Leterrier Y., Månson J.A.E. and Jolliet O., (2001). Life Cycle Assessment of Biofibers Replacing Glass Fibers as Reinforcement in Plastics, Resources, Conservation and Recycling, 33(4), pp. 267-287.
[20] Pothan L.A., Thomas S. and Neelakantan N.R., (1997). Short Banana Fiber Reinforced Polyester Composites: Mechanical, Failure and Aging

Preeti Singh, M Tech Student, VITS Jabalpur (MP.)
Mukesh Kumar Verma, M Tech Student, VITS Jabalpur (MP.)
Devvrat Verma, M Tech Student, VITS Jabalpur (MP.).