

Erosion Wear Behaviour of Bamboo-Glass Hybrid Fiber Reinforced Polymer

P.Sneha Latha¹, M.Venkateswara Rao²PhD Scholar, Department of Mechanical Engg, Acharya Nagarjuna Engg College, Andhra Pradesh, India¹Professor, Department of Mechanical Engg, Bapatla Engg College, Bapatla, Andhra Pradesh, India²

ABSTRACT: Effect of stacking sequence of tribological properties woven bamboo-glass fabric reinforced polymer hybrid composites has been investigated experimentally. Composites are fabricated by hand layup technique. Hybrid composites are fabricated with a total of 4 plies, by varying the number and position of glass layers. Four layer glass and bamboo fibers are fabricated to compare the hybrid effect. Specimen preparation and testing was carried out as per ASTM standards. The results indicated that the bamboo composite are more erosion resistance when compared to glass fiber when hybridized with glass fiber the erosion rate is less when compared to pure glass fiber..

KEYWORDS: Erosion, Bamboo, Glass, Epoxy.

I. INTRODUCTION

Natural waste fibers are cheaper and substitute for man-made fibers, like glass and carbon fiber. Among the assorted natural fibers, bamboo has completely different properties and qualities and it is one amongst the naturally occurring composite material which may be exploited for the design and development of polymer composite. Presently bamboo is taken into account vital natural plant fiber and includes a nice potential to be utilized in polymer composite industry. In recent decades natural fibres such as Jute [1], rice husk [2], sisal [3], wood apple [4], coconut shell [5], Pineapple [6], Kenaf [7] etc. have attracted the attention of the researchers for applications in the field of automobiles parts, households, windows Frame, civil structure and low cost housing. Compared with synthetic fibres, natural fibres have many advantages like low density, cheaper, high strength, high stiffness and biodegradable properties. Presently bamboo is taken into account vital natural plant fiber and includes a nice potential to be utilized in polymer composite industry. Its structural variation, mechanical properties, extraction of fibers, chemical modification, and thermal properties had created it versatile for the utilization in composite trade [8]. Bamboo or genus Bambusa is profusely obtainable in a geographical area like South America, and also the rest comes from Africa and Oceania. The obtainable literature of bamboo and bamboo-polymer based mostly composites attests to its importance. Based on the literature bamboo can be used in different forms, including water bamboo husk [9], bamboo strip [10] and bamboo fibers [11] etc. Previous analysis has been studied the effects of bamboo fibers reinforced polyester matrix towards varied testing for example tensile and flexural properties [12] and fracture properties [13]. Slawomir Borysiak [14] prepared the wood/polypropylene (PP) composites for structural characterization by using compression moulding method and injection technique. Further, investigated the effect of chemical modifications of wood and also studied the processing parameters on the super molecular structure and morphology of composite by using Wide-angle X-ray scattering (WAXS) and scanning electron microscopy (SEM). It was found that, the amount of hexagonal phase of PP matrix slightly decreases due to modification of wood. A.V Ratna Prasad and K. Mohana rao [15] conducted the experiments of the tensile and flexural tests on the composites prepared by reinforcing jowar, sisal and bamboo as a new natural filler into a polyester resin matrix. The studied shows that jowar fibers as reinforcement in polyester matrix have high strength and rigidity for light weight applications compared to conventional sisal and bamboo composites. Seyed Majid Zabihzade [16] prepared the filler materials from wheat straw, hybrid Euro-American poplar, and loblolly pine were mixed with high density polyethylene (HDPE) at 35 wt%. And also investigated the effect of maleic anhydride grafted polyethylene (MAPE) (0 and 2wt. %) as compatibilizer in the composite. Xue Li et al. [17] studied the different chemical treatments of natural fiber- reinforced composites. Due to the chemical treatments decreases the adhesion

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interaction problem between the fiber surface and the polymer matrix, increase fiber strength and decrease the water absorption of natural fibers.

Ray et al [18] and Mishra et al. [19] performed a alkaline chemical treatment on sisal fibers and jute fibers. Fibers are submerged in aqueous sodium hydroxide (NaOH) solution (5%) for 2 h up to 72 h at room temperature. They observed that, better mechanical interlocking due to increases surface roughness of natural fibers. Based on the literature very few people worked on the bamboo fiber composites to this end, an effort has been made to fabricate bamboo-glass fiber laminate hybrid composite and study their tribological behaviour of both bamboo and glass fiber reinforced epoxy based hybrid composites.

II. MATERIALS AND METHODS

A. RAW MATERIALS USED

Raw materials used in this experimental work are listed below:

1. Bamboo fiber
2. E glass fiber
3. Epoxy resin and Hardener

2.1.1 Bamboo fiber

The bamboo fiber in the shape of mats which are collected from the local sources is shown in Figure 1. Bamboo or genus Bambusa is profusely obtainable in a geographical area like South America, and also the rest comes from Africa and Oceania. Bamboo contains about 35-65% cellulose, 30-35% hemicellulose, and 15-31% lignin. The fiber has a high aspect ratio, high strength to weight ratio, is low in energy conversion, and has good insulation properties.



Fig. 1 Bamboo fiber mat [20]

2.1.2 E glass fiber

A Glass fibre is a material consisting of numerous extremely fine fibres of glass. Glass fibers are useful thermal insulators because of their high ratio of surface area to weight. However, the increased surface area makes them much more susceptible to chemical attack. By trapping air within them, blocks of glass fiber make good thermal insulation, with a thermal conductivity of the order of $0.05\text{W}/(\text{m}\cdot\text{K})$. Its advantages are low cost, high strength, good insulation and high chemical resistance. E glass fiber is shown in Figure 2,



Fig. 2 E-Glass fiber mat [20]

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2.1.3 Epoxy Resin and Hardener

The type of epoxy resin used in the present investigation is Araldite LY-556 which chemically belongs to epoxide family. Its common name is Bisphenol-A-Diglycidyl-Ether. The hardener with IUPAC name NNO-bis (2aminoethylethane-1,2diamin) has been used with the epoxy designated as HY 951. Both the epoxy and hardener were supplied by Ciba-Geigy of India Ltd.

B. PREPARATION FOR THE TEST SPECIMENS

Hybrid laminates (4 plies) of bamboo and glass composite were prepared by the hand layup technique with different stacking sequence. A wooden mold of (150x60x5) mm³ was used for composite fabrication. For quick and easy removal of the composite a mold release sheet is placed on the top and bottom of the wooden mold. The mold release spray is also applied to the inner surface of the mold wall to facilitate easy removal of the composite specimen. A calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was thoroughly mixed with a mechanical stirrer. After that ceramic zirconia (ZrO₂) and titania (TiO₂) are mixed indivisibly in the epoxy resin before the bamboo/glass fiber is reinforced in the matrix, the composites are prepared with micro, zirconia (ZrO₂) (3, 6, and 9 wt%) and titania (TiO₂) (3, 6, and 9 wt%) is used as filler materials and mixed in the epoxy resin before the bamboo/glass fiber is reinforced in the matrix.

The weight percentage of matrix in all the composites is nearly 78%. In micro filler addition the matrix weight percentage varies as the filler percentage increases. After 5 min stirring, the mixture was poured into the mould uniformly and bamboo fiber mat and glass fiber mats was placed in the mold. The process was continued for 4 layers of bamboo/glass mat and for each time, a roller was used to roll over the fiber in order to remove the air bubbles from it. Care is taken to ensure that the excess polymer will not squeeze out of the mould. Each composite is cured under a load of about 30 kg for 24 h at room temperature before it is removed from the mold. Then, the laminate was cut into required size of mechanical and tribological tests by the diamond cutter. The density of epoxy resin, bamboo and glass fiber is 1.2, 0.9 and 2.24g/cm³ respectively.

C. EROSION TEST

The solid particle erosion wear tests of bamboo-glass hybrid composite were carried out as per ASTM G76 standard on the erosion test rig is shown in Figure 3. The erosion test rig consists of compressor, drying unit, a conveyor belt-type particle feeder which helps to control the flow of sand particle and an air particle mixing and accelerating chamber. The compressed air is then mixed with the selected range of the silica sand which is fed constantly by a conveyor belt feeder into the mixing chamber and then passing the mixture through a convergent brass nozzle of 3 mm diameter. The erodent particles impact the specimen which can be held at different angles (i.e. 30, 45, 60 and 90°C) with respect to the direction of erodent flow using a swivel and an adjustable sample holder. The conditions under which the erosion tests are carried out are listed in Table 1. After each experimental run the eroded samples are cleaned with acetone and dried for 5mins and then weighed to an accuracy of ± 0.01 mg before and after the erosion trials using electronic balance. The weight loss is recorded for subsequent calculation of erosion rate. The process is repeated till the erosion rate attains a constant value called steady state erosion rate.

The wear rate was expressed in terms of $\Delta w_1 / \Delta w_2$

Where Δw_1 - is the loss in weight of the composite

Δw_2 - is the total weight of the erodent used

Table 1 Experiment conditions

Erodent	Silica sand
Erodent size (µm)	200 ± 50
Impingement angle (α ⁰)	30, 45, 60, 90
Impact velocity (m/s)	48, 70, 82
Erodent feed rate (g/min)	4
Test temperature	RT
Nozzle to sample distance (mm)	10
Nozzle diameter	4
Time	15 min.

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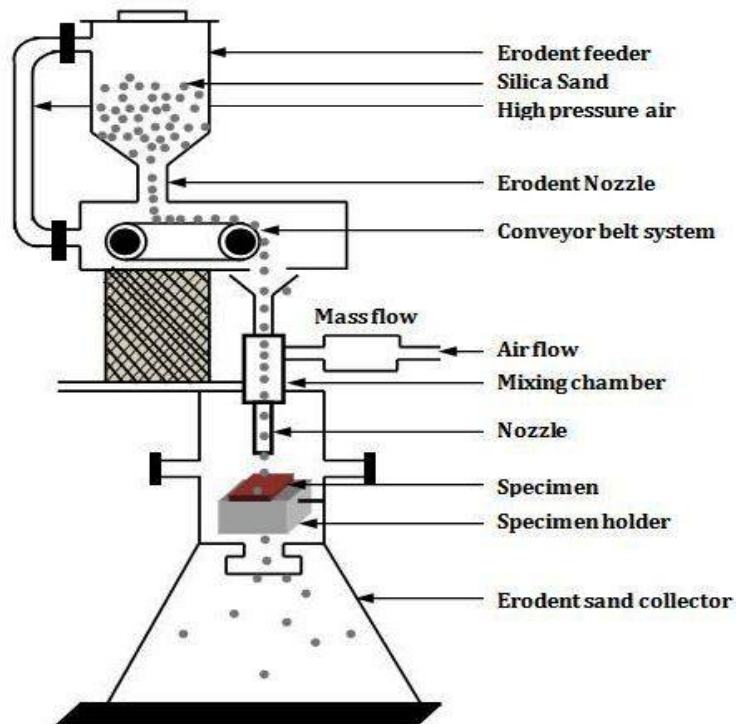


Fig. 3 Schematic of air jet erosion test Rig[20]

III. RESULTS AND DISCUSSION

It is known that impingement angle is one of the most important parameters for the erosion behaviour of materials. In the literature materials are classified as ductile or brittle based on the dependence of their erosion rate with impingement angle.

The ductile behaviour is characterized by maximum erosion rate at low impingement angle typically $15^\circ < \alpha < 30^\circ$. On the other hand, if the maximum erosion rate occurs at normal impact ($\alpha = 90^\circ$) the behaviour of the material is brittle. However the maximum erosion occurring in the angular range $45^\circ - 60^\circ$ indicates the semi ductile behaviour of the material. Based on the tabulated results various graphs were plotted and presented for different sequential layered composites under different test conditions.

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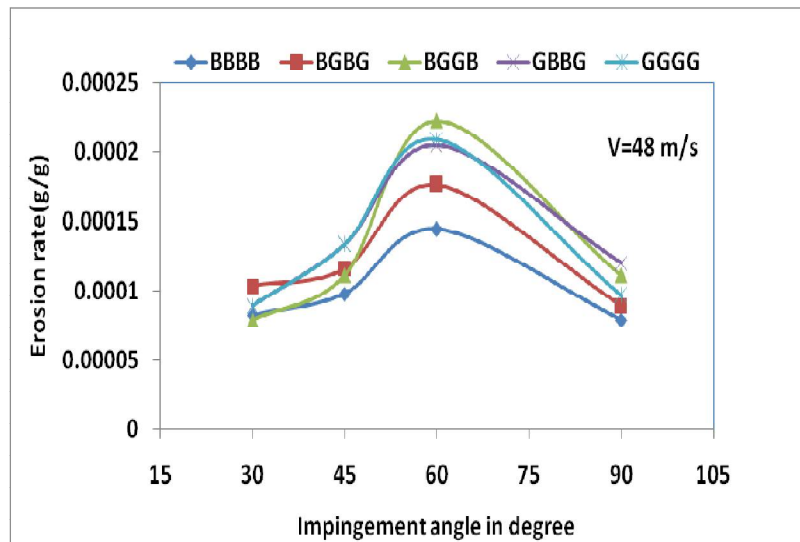


Fig. 4 Variation of erosion rate with different Impingement angle at velocity 48m/s

Figure 4 shows the influence of impingement angle (α) on the erosion rate of bamboo-E-glass epoxy composites under 48 m/s impact velocity. It is observed that the peak of erosion rate is around 60° impingement angle for different layered composites and BBBB epoxy composite shows minimum wear as compared to other composite. According to literature if the maximum erosion occurring in the angular range 45°-60° then the composite material possesses semi ductile behaviour.

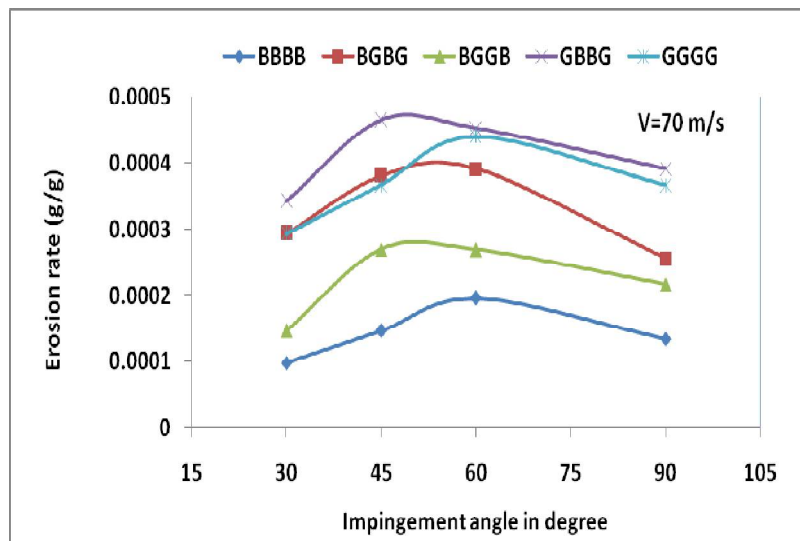


Fig. 5 Variation of erosion rate with different Impingement angle at velocity 70 m/s

As the impact velocity increases from 48 to 70 m/s the rate of material removal is slightly more, is clearly observed from the Figure 5. There is no change in material behaviour and also similar observation is found i.e. BBBB layered composite shows minimum wear.

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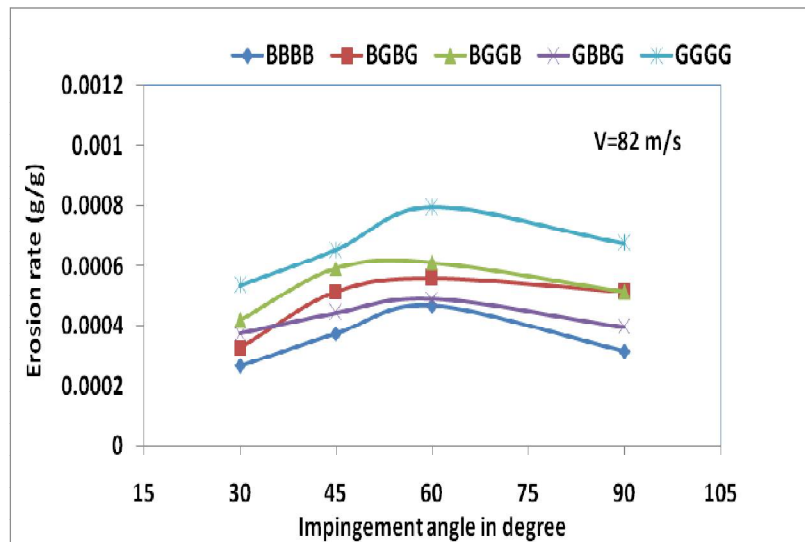


Fig. 6 Variation of erosion rate with different Impingement angle at velocity 82m/s

The analogous observation is found in figure 6. If the impact velocity increases from 70 to 82 m/s the rate of material removal is more as compared to Figure 5. This clearly indicates that these composites respond to solid particle impact, neither in a purely ductile nor in a purely brittle manner. This behaviour can be termed as semi-ductile in nature.

The velocity of the erosive particle has a very strong effect on the wear process. If the velocity is very low, then stresses at impact are insufficient for plastic deformation to occur and wear proceeds by surface fatigue. When the velocity increases, the eroded material may deform plastically upon particle impact. In this regime, wear is caused by repetitive plastic deformation.

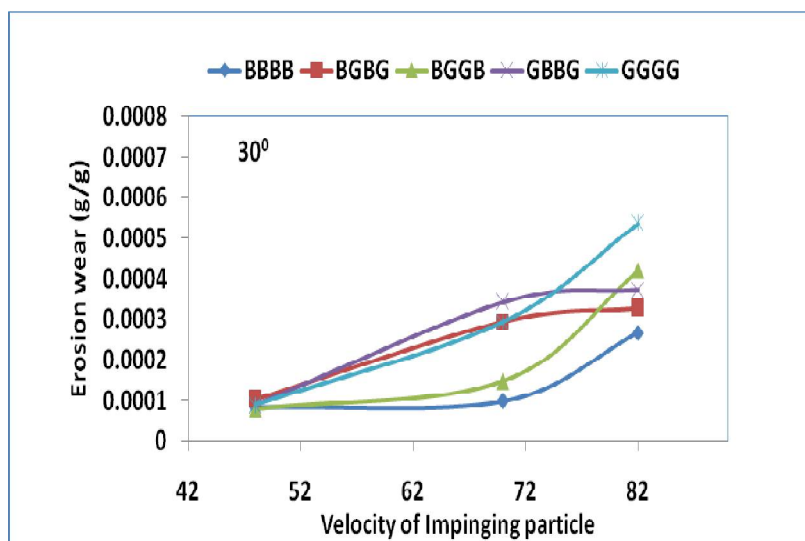


Fig. 7 Variation of erosion rate with velocity of impinging particles at Impingement angle 30°

The variation of erosion rate of all the sequential layered composites with different impinging angles (30°, 45°, 60° & 90°) is shown in Figure 7-10. Erosion trials are conducted at four different impact velocities (48, 70 & 82 m/s) under constant operating condition.

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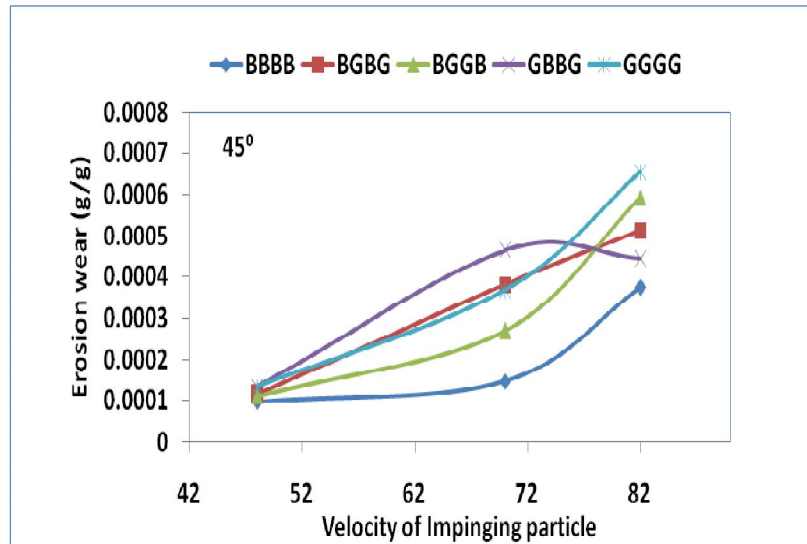


Fig. 8 Variation of erosion rate with velocity of impinging particles at Impingement angle 45°

The plots were obtained by determining the steady state of the weight loss. The cumulative weight of impinging particle to achieve steady state value was varying with material. The nature of the curve is also different for different materials tested.

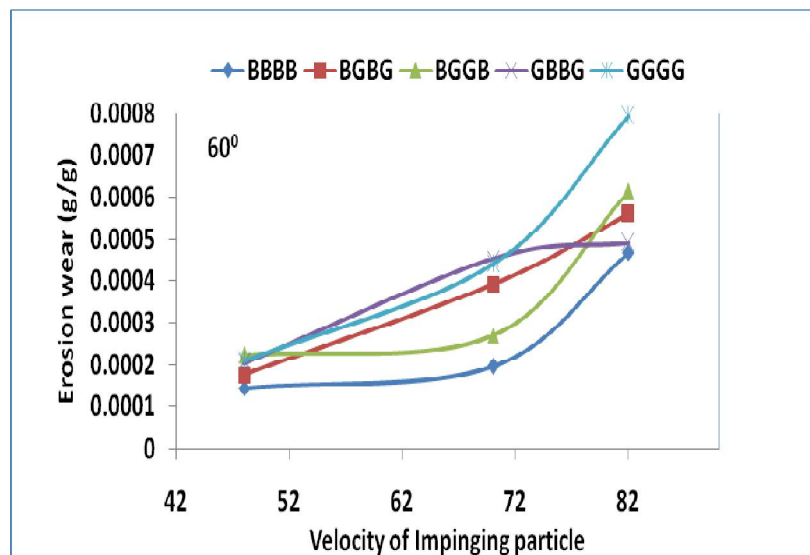


Fig. 9 Variation of erosion rate with velocity of impinging particles at Impingement angle 60°

In all these curves no incubation or induction period is observed for different material tested. Instead figures clearly show that the response of material to the weight of the erodent was acceleration, peaking, deceleration and stabilization. It also shows higher erosion rate with increase in impact velocity for different target materials.

From the figure it is clear that as the velocity increases gradually the rate of material removal is also increases at different Impingement angle. The erosion rate reaches its maximum at the impact velocity of 82 m/sec for all bamboo-glass layered composites.

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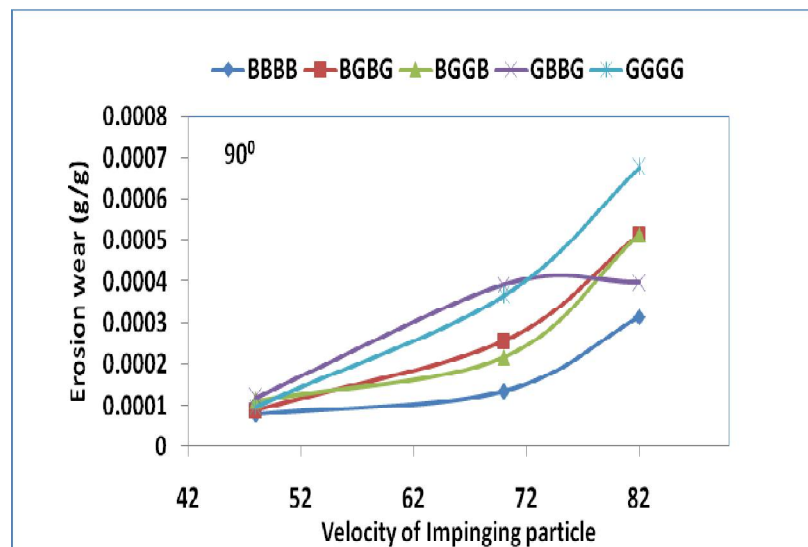


Fig. 10 Variation of erosion rate with velocity of impinging particles at Impingement angle 90°

IV. CONCLUSIONS

The hybrid composites of bamboo/glass fiber reinforced epoxy were made in order to evaluate the effect of stacking sequence on erosive wear properties of hybrid polymer composites, have been experimentally evaluated. From the results incorporation of bamboo in glass fiber composites enhances the properties resulting hybrid composites. Wear behaviour possessed by the GGGG composite are reduced by hybridizing with bamboo fiber. The least erosion is observed in BBBB composites.

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