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Full Length Research Paper

Solid particle erosion of Bagasse fiber reinforced epoxy composite

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Experiments were carried out to study the effects of impingement angle and particle velocity on the solid particle erosion behavior of Bagasse Fiber Reinforced Polymer Composites (BFRPCs). The erosive wear is evaluated at different impingement angles from 30° to 90° at four different velocities of 48, 70, 82 and 109 m/s. The erodent used is silica sand with the size range 150 – 250 µm of irregular shape. The result shows brittle behavior with maximum erosion rate at 90° impingement angle. The morphology of the eroded surfaces was examined by using Scanning Electron Microscopy (SEM).

Key words: Bagasse fiber, erosive wear, erodent, brittle fracture.

INTRODUCTION

Environmental awareness today motivating the researcher's world wide on the potential use of natural fiber as reinforcement as an alternative to synthetic fibers in polymer composite. This is because natural fiber reinforced thermoplastics have a good potential for the future as a substitute for conventional inorganic fibers. In addition natural fibers are naturally occurring composites containing cellulose fibrils embedded in lignin matrix. The unique properties of natural fiber-reinforced polymer composites (NFRP) such as low density, low cost, high specific strength, environmental friendliness and so forth, have shifted the focus of researchers from synthetic to natural fiber- reinforced polymer composites. These composites after being widely accepted in aerospace applications heading their way towards tribological applications. Little information concerning the tribological performance of natural fiber reinforced polymer composite material (Tong et al., 2005; Hornsby, 1997; Yousif et al., 2006; Tayeb, 2008) has been reported. There are situations where these composites may encounter impacts of lot of abrasions from dust, sand, splinters of materials, and slurry of solid particles and consequently the material fail due to erosive wear. Therefore the study of erosion characteristics of NFRP composites is of vital importance. As pointed out by (Roy et al., 1994) the erosive resistance of polymer composite is low in comparison to monolithic materials. It is also established (Hager et al., 1995) that erosive wear of reinforced polymer composite is usually higher than unreinforced polymer matrix.

Visualizing the importance of polymer composites lot of work has been done by various researchers (Harsh et al., 2007; Tewari et al., 2003; Bijwe et al., 2001, 2002) to evaluate the erosion resistance of various types of polymers and their composites to solid particle erosion. Most of these workers have carried out wide range of thermosets and thermoplastics PMCs with synthetic fibers like glass, carbon, graphite and Kevlar. However there is no information available on erosive wear behaviour of NFRP composites.

The purpose of this research is the therefore to investigate the erosive wear behavior of bagasse fiber reinforced polymer composite. Experiments were carried out to study the effect of filler content, impingement angle and particle velocity on the erosive wear behavior of the composite.

MATERIALS AND METHOD

The type of epoxy resin used in the present investigation is LY 556, which chemically belongs to the 'epoxide' family. Its common name is Bisphenol-A-Diglycidyl-Ether. It possesses a density of 1.1 gm/cm^3. The low temperature epoxy resin and corresponding hardener (HY951) are supplied by Ciba- Geigy of India Limited. Fresh bagasse fibers were collected from Sakti Sugar Limited,

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located in Dhenkanal, Orissa, India. Fibers were spread on a water proof sheet to reduce the moisture content. From the available long fiber, small size (1 x 10 mm) fibers were cut with a pair of scissors from the rind portion only rejecting the pith portion. Small size fibers were selected in order to design a composite with consistent properties. These fibers were then cleaned with pressurized water. This procedure removes fine bagasse particles, sugar residues and organic material from the fibers. The fibers were then dried with compressed air.

Epoxy is mixed with hardener in the ratio 10:1 by weight. A wooden mold of dimension (120 x 100 x 6) mm was used for casting the composite sheet. A coat of gel was applied on the inner side of the mold and mold release spray was used for quick and easy removal of the composite sheet. Usual hand lay-up technique was used to manufacture the composite sheet of 6 mm thickness at room temperature. The neat resin composite plate was also made with the above dimension without any reinforcement. Suitable pieces of the above were cut from the composite plates for erosion testing.

Erosive wear studies

The solid particle erosion experiments were carried out as per ASTM G76 standard on the erosion test rig shown in Figure 1. The test rig consists of an air compressor, an air drying unit, a conveyer belt type particle feeder and an air particle mixing and accelerating chamber. The dried and compressed air is then mixed with silica sand (200 ± 50 microns size) which was fed constantly by a conveyer belt feeder into the mixing chamber. Samples of composite (20 x 20 x 4 mm) were held at selected angles (30°, 45°, 60° and 90°) with respect to the flow of the impinging sand particles and eroded. The silica sand particles were accelerated by passing through a converging tungsten carbide nozzle of 4 mm diameter to bombard the target. The distance between the target material and nozzle was approximately 10 mm. The impact velocity of the erodent particle was determined using standard double disc method (Ives, 1975). Wear was measured by the weight loss method. Samples were cleaned with acetone before and after each test. Eroded samples were cleaned with a brush to remove fine sand particles attached to the surface and then wiped with a cotton plug dipped in acetone to avoid any entrapment of wear debris in the samples. The wear rate was expressed in terms of ΔWc (g)/ ΔWs (g); where ΔWc was the loss in weight of the composite and ΔWs was the total weight of erodent used. ΔWc was determined by weighing the sample before and after each experiment on a weighing balance having an accuracy of 0.001 mg. The experimental detail is presented in Table 1.

RESULTS AND DISCUSSION

Figure 2 shows the micro hardness values for different composites. Micro hardness measurement is done using a Leco's Vickers hardness tester. It is seen that with the increase in fiber content in the composite, its hardness value improves although the increment is marginal. Figures 3 - 6 shows the erosion rate of the composite with different fiber loading tested as a function of angle of impingement at different impact velocities (v = 48, 70, 82, 109 m/sec respectively). It is evident from the plot that the erosion rate increases with the impact angles and attains a peak value (α_{max}) at 90°. It is also observed that the (α_{min}) for 10 and 15% reinforcement is 30° while for 20 % reinforcement it is 45° at impact velocity of 70 m/s.

Table 1. Experimental details.

Dose of erodent	5.721 g
Flux rate	0.572 g/min
Impinging velocity of particles	48, 70, 82, 109 m/s
Duration of erosion	10 min
SOD	10 mm
Impact angles	30°, 45°, 60°, 90°

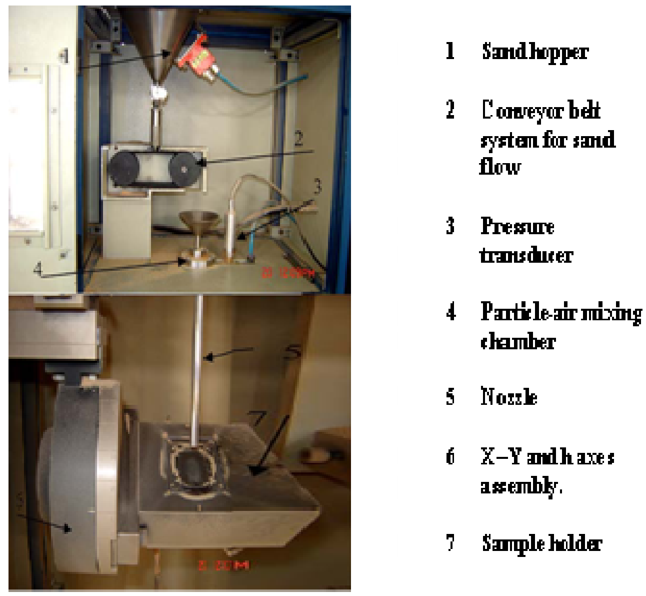


Figure 1. Schematic of air jet erosion test rig.

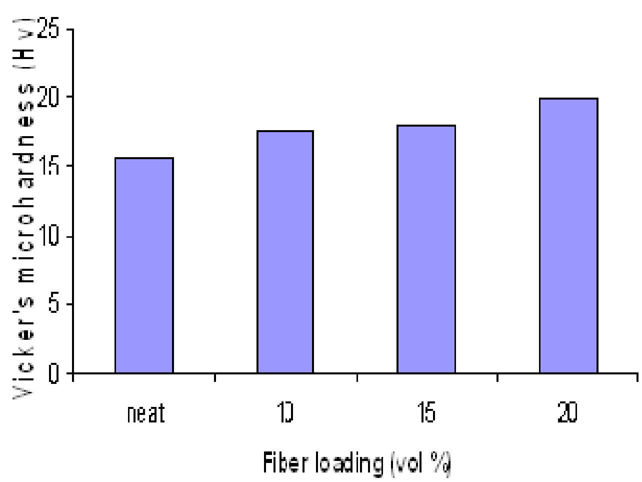


Figure 2. Micro hardness values for different composites.

It is also found that at impact velocities of 82 and 109 m/s, α_{min} and α_{max} for 10, 15 and 20% reinforcement are

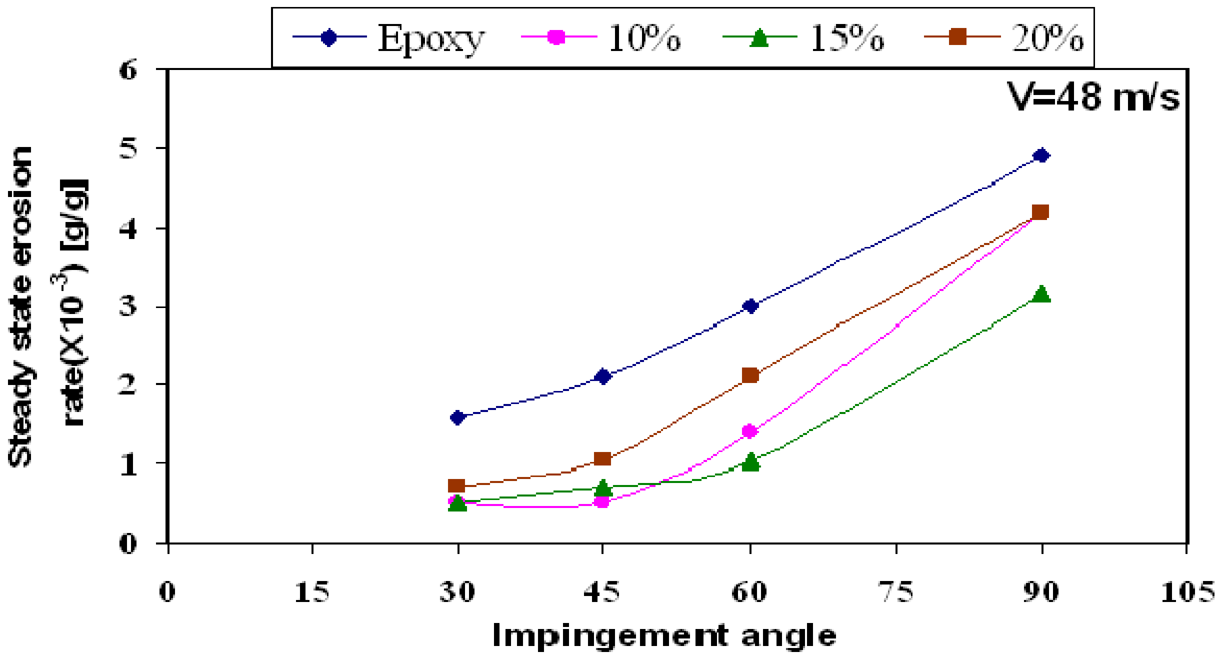


Figure 3. Variation of erosion rate as a function of angle of impingement at V = 48 m/s

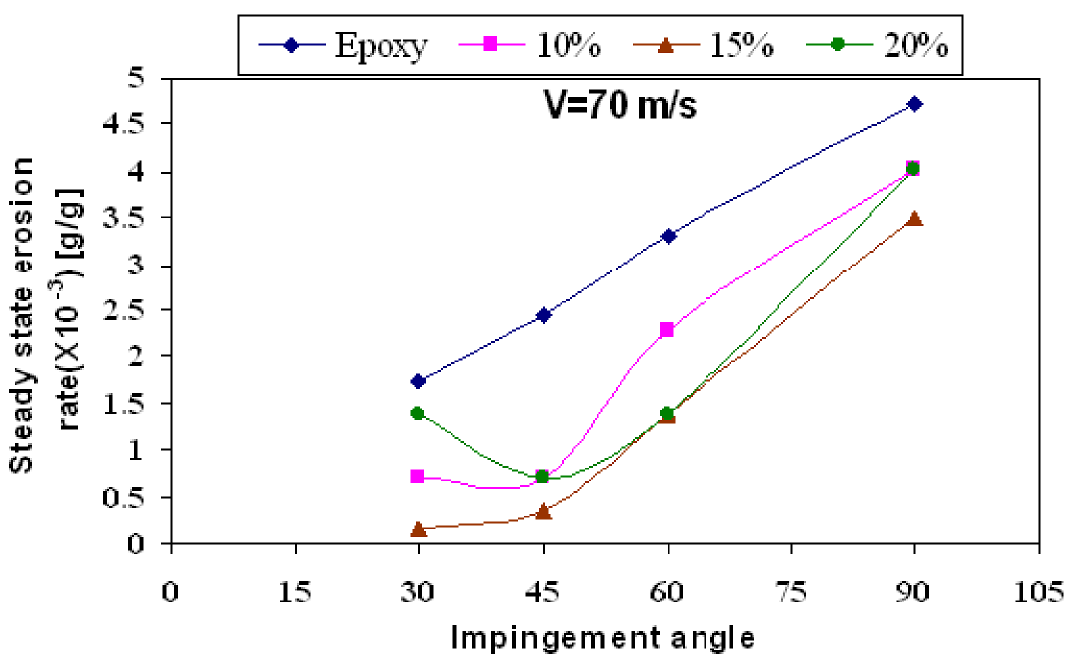


Figure 4. Variation of erosion rate as a function of angle of impingement at V = 70 m/s.

30° and 90° respectively. The composite could not be studied at 15° because a sample of required size was not available. In general α_{max} for ductile material remains in the range 15° – 30° and α_{min} 90° while for brittle material the behavior is opposite. It is available in the literature ture that, there are no fixed trends available which correlates ductility or brittleness of materials with α_{max} or α_{min}. It is found that some polymers erode in a ductile manner; some show evidence of both ductile and brittle characteristics (Hager et al., 1995; Karasek et al., 1992;

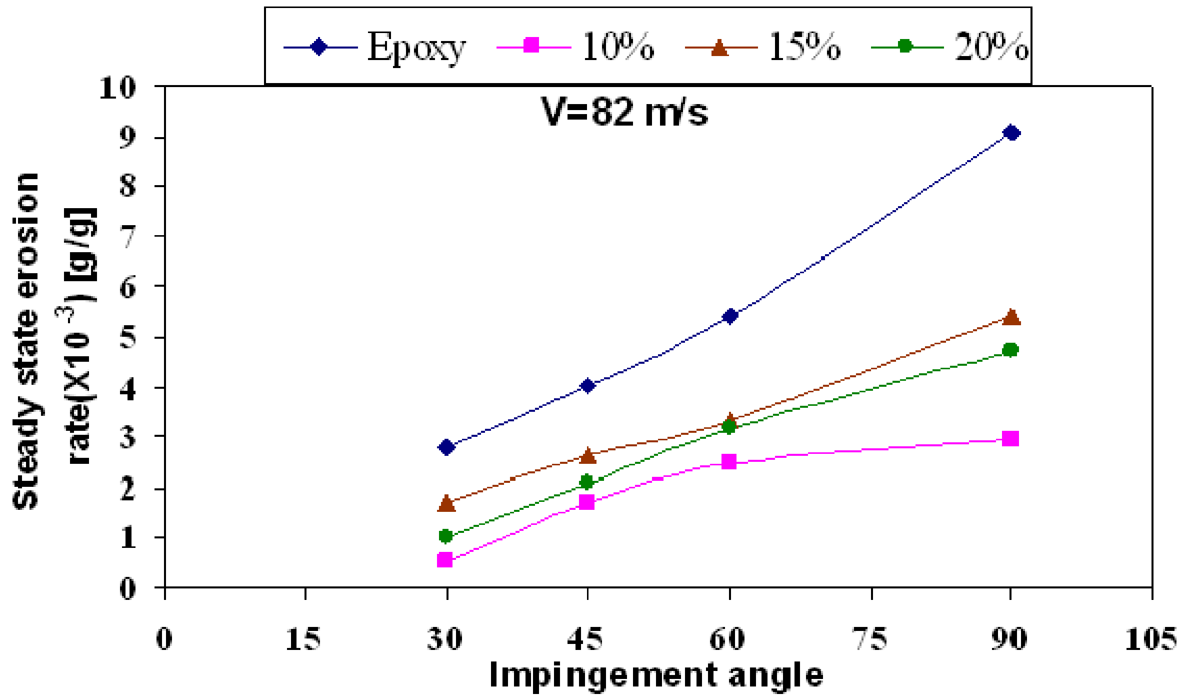


Figure 5. Variation of erosion rate as a function of angle of impingement at V = 82 m/s.

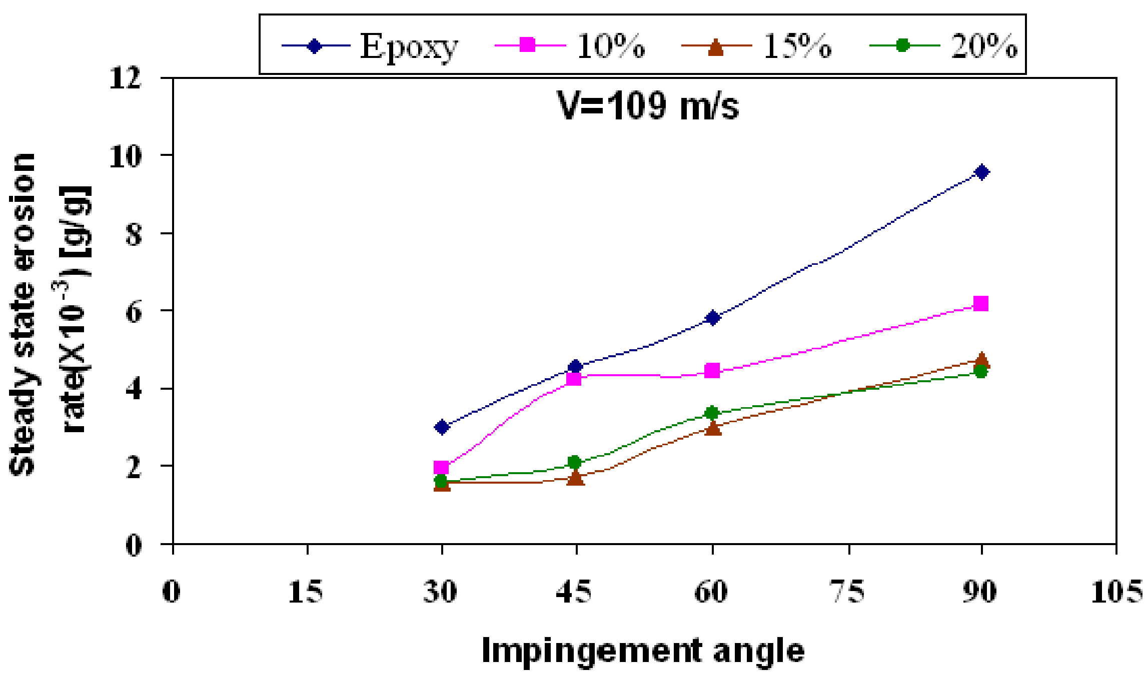


Figure 6. Variation of erosion rate as a function of angle of impingement at V = 109 m/s.

Barkoula et al., 2002). Pool et al 1986 reported that the maximum erosion rate occurred at normal incidence for the UD and woven graphite reinforced epoxy composite implying a brittle type of erosion behavior. In this present study the BFRPCs also shows maximum erosion at normal incidence indicating brittle type failure.

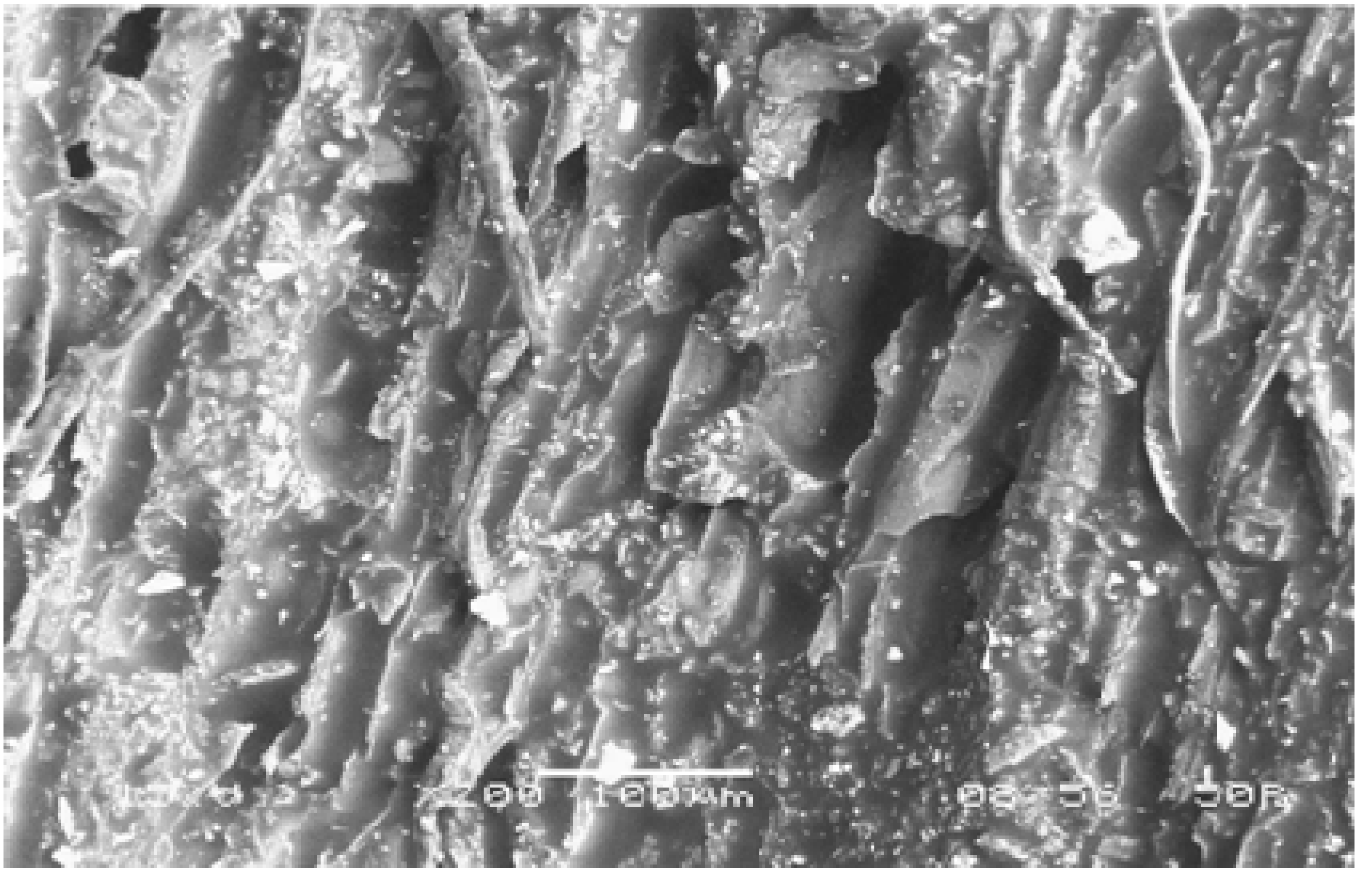


Figure 7. SEM micro graph of surface eroded at 30°.

Scanning electron microscopy studies

To characterize the morphology of as received and eroded surfaces and the mode of material removal, the eroded samples are observed under scanning electron microscope (SEM) Joel JSM-6084LV. The eroded samples are mounted on stubs with silver past. To enhance the conductivity of the eroded samples, a thin film of platinum is vacuum evaporated on to them before the photographs are taken. Figure 7 shows the SEM photograph for the composite eroded at 30°. It clearly indicates the fracture of fibers. More number of fibers is seen to be damaged but not extensively removed, though tangential component of the impact force is more effective due to oblique impact.

Figure 8 shows micrograph of the surfaces eroded at an impingement angle of 45°. It appears that the composite encountered intensive debonding and breakage of the fibers, which were not, supported enough by the matrix. The bending of fibers becomes possible because of softening of the surrounding matrix which in turn lowers the strength of the surrounding fibers.

Figure 9 shows the surface eroded at 60°. The process of fiber damage and pulverization has increased with increase in angle of impingement leading to higher wear of composite. Hence the process of fiber damage and pulverization appears to be the most dominant mechanism. The tangential component of the impact force is more effective in micro cracking followed by micro cutting of fibers in many places leading to severe pulverization of fibers.

Figure 10 for the composite eroded at 90° show mainly fiber fracture. Cracks that are generated can not propagate easily because of fibers present. During energy dissipation it causes fracture of a fiber, crack propagation in both the direction, forward and backward, towards the eroding surface is very difficult since cracks have to cross the ductile matrix between the fibers. Thus, wear of such composite was mainly due to easy fracture of brittle fiber and subsequent removal of fiber debris.

Conclusion

Based on the study of the erosive wear behavior of BFRP composites at various impingement angles for different fiber volume fraction with silica sand as erodent the following conclusions are drawn.

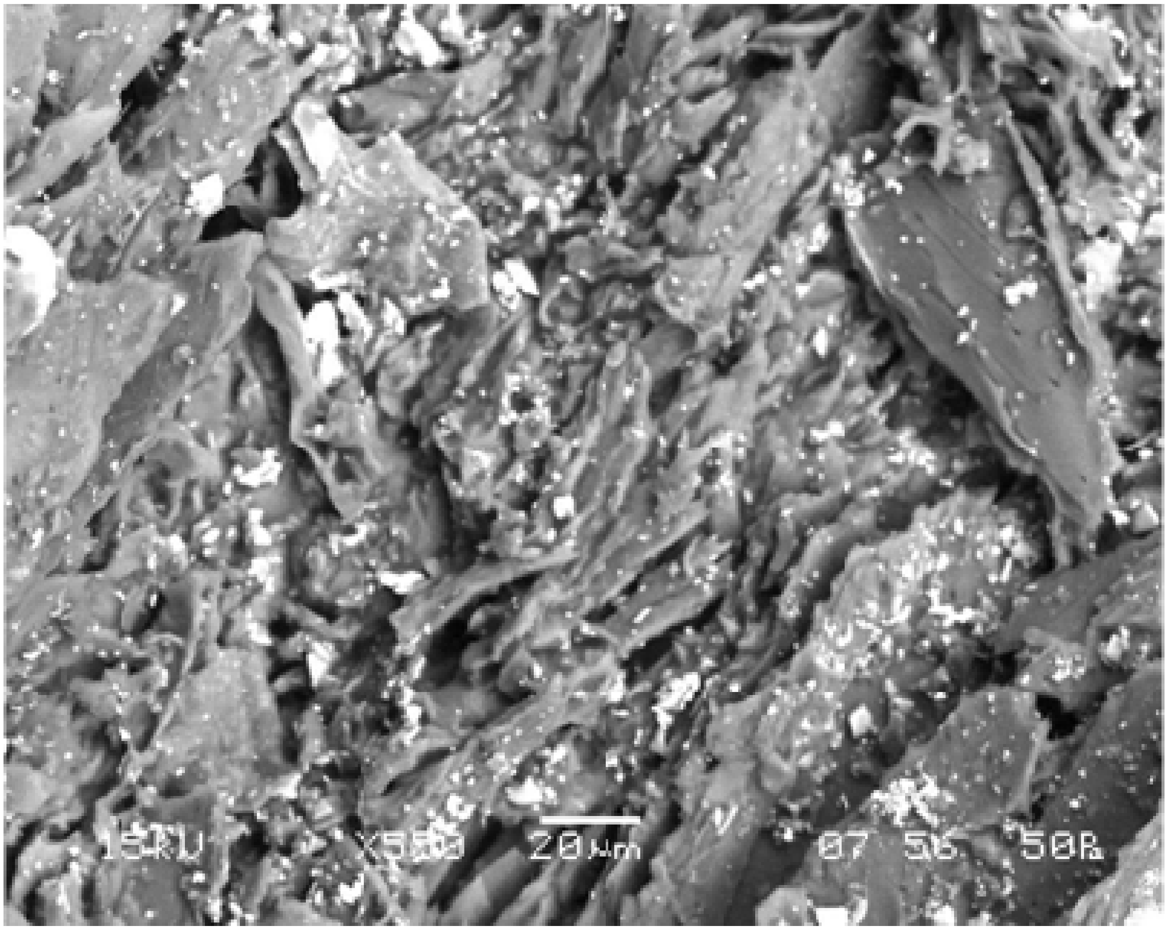
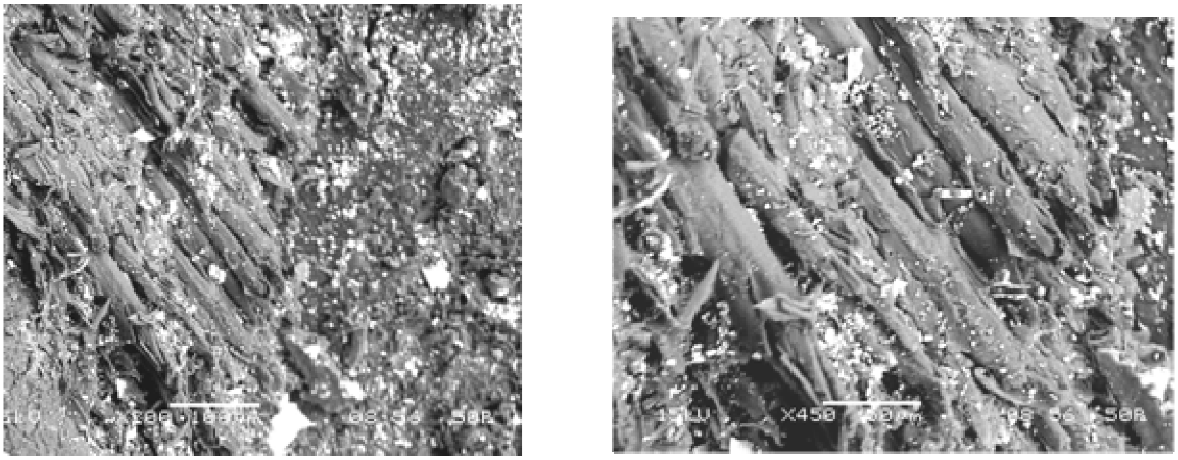


Figure 8. SEM micro graph of surface eroded at 45°.

Figure 9. SEM micro graph of surface eroded at 60°.



(a) (b)

Figure 10. SEM micrographs (a) eroded at 90° (b) Magnified view of surface eroded at 90°.

1. The composite exhibited a maximum erosion rate at an impingement angle of 90° under present experimental condition indicating brittle behavior.
2. Fiber volume fraction has a significant influence on the erosion rate of the composite.
3. The morphologies of the eroded surfaces observed by SEM suggests that overall erosion damage of the composite consists of matrix material removal in the resin area and breakage of fiber as well as that of the material from the fiber-resin interface zone.
4. Possible use of these composites in components such as pipes carrying coal dust, desert structure low cost housing ,boats/sporting equipments, Partition boards, doors and window panels is recommended.
5. To increase the fiber matrix adhesion the fibers surfaces can be modified by chemical treatments. In future this study can be extended to treatment of fiber surface by available methods and their effects on erosive wear can also be studied and resulting experimental findings can be analyzed.

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