Erosive wear behavior of bio waste reinforced polymer composites

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Abstract

. Experiments were done to study the effects of impact velocity and erodent particle size on the solid particle erosive behavior of coir dust reinforced polymer composites. The erodent used here is silica sand having the size range 200-600 μm. However it was found that the erosion wear rate was decreased with increasing the coir dust amount because at higher amount of coir dust the mechanism dominated by the fiber material which is soft compare with the matrix material. Further, the erodent surface morphology was examined by using scanning electron microscopy (SEM), and possible erosion wear mechanisms were discussed. Decrement of erosion wear had observed with increasing erodent particle size

Key Words: coir dust, epoxy resin, erosion wear, impingement angle, SEM

Introduction

Most of the natural fibers such as jute, henequen, sisal, oil palm, bamboo, wood paper, and sugarcanes are discarded as wastage. However, much attention has been drawn to take advantage of their attractive characteristics. Natural fibers in their natural condition have been used as reinforcement agents of different thermosetting and thermo plastic resins [1-8]. During leaf defibration of henequen fibers and also during the transformation of the raw fibers into cordage, approximately 10 % of waste fibers are produced [9]. These waste fibers could be profitably used in the manufacture of fiber polymer reinforced composites because they posses attractive physical and mechanical properties [10]. Natural fibers having the unique properties such as bio degradability, environmental friendliness, low cost, less density, high specific strength and so forth have shifted the focus of researches from synthetic to natural fiber – reinforced polymer matrix composites.

The interest in natural fiber reinforced polymer composite materials is rapidly growing in terms of their tribological, industrial applications and fundamental research [11]. There are some possibilities where the composite may encounter impacts of lot of abrasions from splinters of materials, sand and slurry of solid particles so consequently the material may failure due to erosion wear. Hence, the study of erosion behavior of natural fiber reinforced polymer composite is vital importance. The erosion wear of reinforced polymer composite is usually higher than unreinforced polymer matrix [12]. The erosion resistance of polymer composite is low in comparison to monolithic materials [13]. The different possible application areas are wheels, impellers, seals, brakes gears, cams, artificial prosthetic joints and bearings etc.

In this paper, we have investigated the erosion wear behavior of bio-waste coir dust reinforced polymer composite. Experiments were done to study the effects of coir dust content, impingement angle and impact velocity of the erodent particle on the erosive wear behavior of the composite material.

2. Experimental Details

The matrix material was Epoxy LY556; chemically belonging to the 'epoxide' family is used as the Matrix Material. The hardener with IUPAC name NN0 (2-amineethylethane-1, 2- diamin) used with the epoxy has the designation HY-951. The epoxy resin and the hardener were supplied by Ciba Geigy India Ltd. Resin and hardener are mixed in a ratio of 8:1 by weight as recommended. Density of the epoxy resin system is 1.1 g/cc.

Coir dust is mixed with the epoxy resin by stirring at room temperature and square shaped samples (100×100) are prepared by uniaxial pressing at 2.00 ton load. Five samples i.e. sample A(pure epoxy), sample B(epoxy+10 wt% of coir dust), sample C(epoxy+20 wt% of coir dust), sample D(epoxy+40wt% of coir dust) and sample E(epoxy+60 wt% of coir dust) are prepared under the same conditions of pressure and temperature. Suitable pieces were cut from the composite sheets for erosion test.

The bulk density and void fraction of the composite materials can easily obtained as for the following equations by using archemidus principle.

$$\text{Density} = \frac{\text{Dry weight}}{(\text{soaked weight} - \text{suspended weight})}$$

$$\text{Apparent porosity} = \frac{(\text{Soaked Weight} - \text{Dry Weight})}{(\text{Soaked Weight} - \text{Suspended Weight})} \times 100$$

The solid particle erosion tests were carried out as per ASTM G76 standard on the erosion test rig. It consists of an air compressor, an air particle mixing chamber and accelerating chamber. Dry compressed air is mixed with the erodent particles, which are fed at constant rate from a sand flow control knob through the nozzle tube and then accelerated by passing the mixture through a convergent brass nozzle of 3mm internal diameter. These particles impact the specimen, which can be held at different angles with respect to the direction of erodent flow using a swivel and an adjustable sample clip.

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.

Experimental Details showed in the following Table 1.

The eroded surfaces of the pure epoxy and the composites are examined with scanning electron microscope JEOL JSM-64800LV.

3. Results and Discussion

Figure 1 shows the changes in the density and void fraction of the composite with variation of the amount of coir dust. From the figure it is clear that, with increasing coir dust amount the density of the material decreases. This is due to presents of high air content (from 24% to 89% by volume [14]. And with addition of coir dust in epoxy resin the volume fraction of voids is increased thus resulting in low density of the composite.

Figure 2 shows the variation of the erosion wear rate by varying the coir dust reinforcement, with increasing the coir dust amount the erosion rate was decreasing. This is because, with increasing coir dust content fiber-matrix interfacial bonding increases.

Generally erosion wear behaviour of the composite depends on the impingement angle of the erodent. Brittle behavoiur is characterized by maximum erosion rate at normal incidence (90°), and the ductile behaviour is characterized by the maximum erosion wear rate at lower angles i.e. ~15-30° impingement angle. Figure 3 shows the impingement angle dependence of erosion wear rate at different time intervals for samples A,B, and E. From the figure it is observed that, with increasing the impingement angle erosion rate of the composite has increased, attains a maximum value at impinge angle 90°. It means that the material shows the brittle type failure.

Figure 4 shows the impact velocity dependence of erosion wear rate at different time intervals for (a)sample A,(b)sample B, and (c) sample E. From the graphs we can observe that with increasing impact velocity erosion rate of the composite is increasing. This is because; with increasing erodent particle velocity the tangential component of the impact force dominates and is the cause for the increase in erosion rate.

Figure 5 shows the SEM micrographs of of surfaces eroded (a) at 30° (b) at 60° ,and (c) at 90° impingement angle for sample C with impact velocity 48 m/sec. From figure 5(a) we can observe that the intensive debonding of the composite due to the breakage of the fibers. Figure 5(b) shows the increament in the pulverization process with increasing the impingement angle, leading to the high erosive wear of the composite material. Figure (c) shows the brittle fracture of the composite. At 90^{o} impingement angle, the extent of fiber damage and material removal from the surface (initiated at fiber-matrix debonding followed by the microcracking, microcutting, pulverization and removal from the surface leaving behind weakened surface/ cavity) have increased.

4. Conclusions

Erosion wear behaviour of (bio-waste) coir dust reinforced polymer composites have been studied by varying amount of coir dust, impingement angle and impact velocities. From the experiments it was found that the erosion wear resistance has increased with increasing volume fraction of the coir dust because of the softness of coir dust compare to the matrix material. The composite exibit brittle failure mode since composite has exhibited maximum erosion rate at normal incidence and the possible wear processes (the microcracking, microcutting, damage and pulverization) have taken place.

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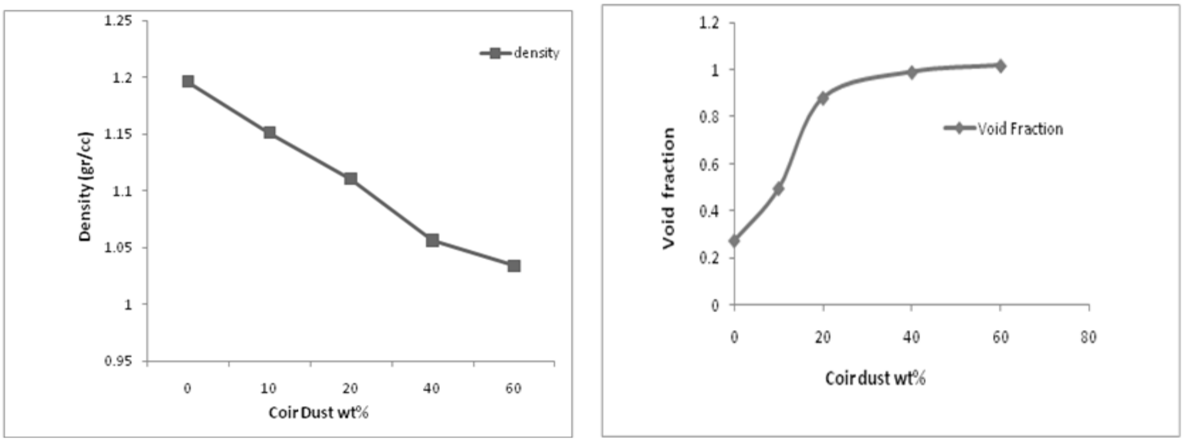
Table 1

Impingement angle	30° , 45° ,60° ,75° ,90°
Impact velocity	34 ,48 ,60 ,78 ,92 m/sec
Erodent particle size	200 , 300 , 400, 500 , 600 µm
Duration of erosion	25 min
Flux rate	0.650 g/min

Figure 1:



1.25
1.2
1.15
1.1
1.05
1
0.95
Density (gr/cc)
density
0
10
20
40
60
Coir Dust wt%
1.2
1
0.8
0.6
0.4
0.2
0
Void fraction
Void Fraction
0
20
40
60
80
Coir dust wt%

Figure 2:

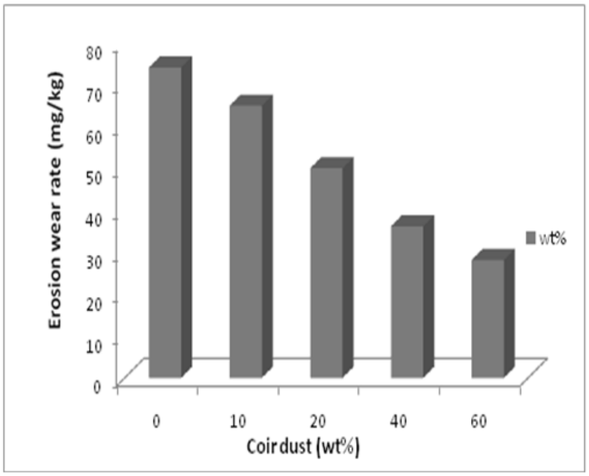
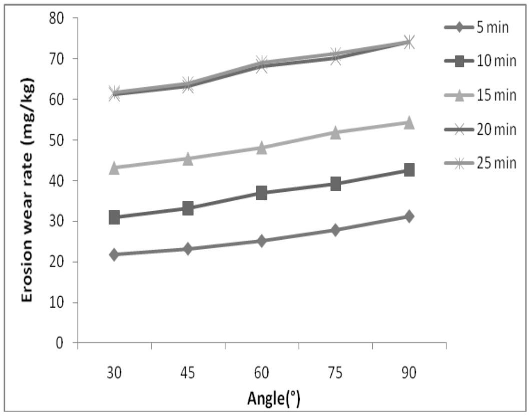

Erosion wear rate (mg/kg)
80
70
60
50
40
30
20
10
0
0
10
20
40
60
Coir dust (wt%)
wt%

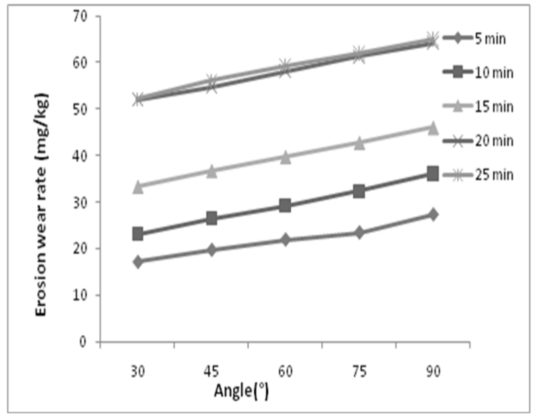
Figure 3:

(a)



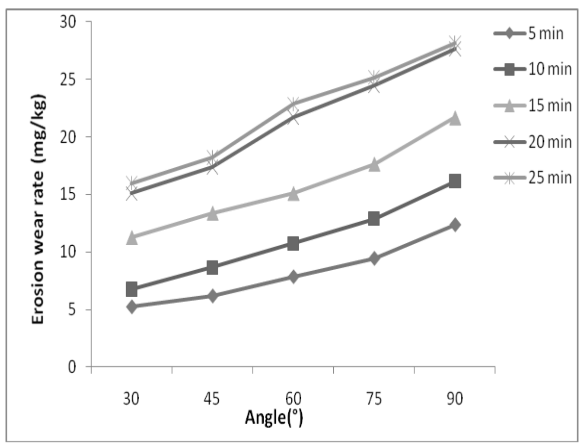
Erosion wear rate (mg/kg)
Angle(°)
0
10
20
30
40
50
60
70
80
30
45
60
75
90
5 min
10 min
15 min
20 min
25 min

(b)



Erosion wear rate (mg/kg)
Angle(°)
0
10
20
30
40
50
60
70
30
45
60
75
90
5 min
10 min
15 min
20 min
25 min

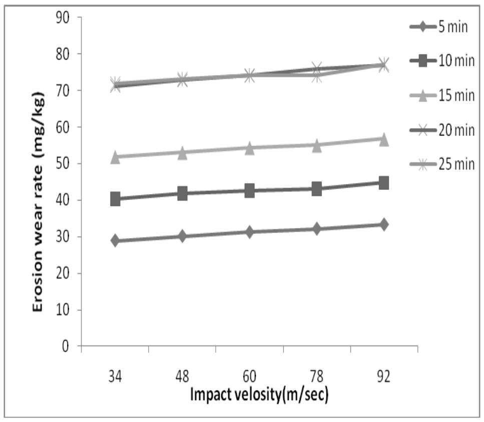
(c)



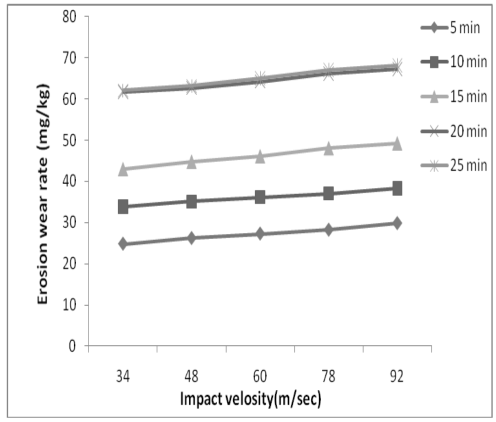
Erosion wear rate (mg/kg)
Angle(°)
0
5
10
15
20
25
30
30
45
60
75
90
5 min
10 min
15 min
20 min
25 min

Figure 4:

(a)


90
80
70
60
50
40
30
20
10
0
Erosion wear rate (mg/kg)
34
48
60
78
92
Impact velosity(m/sec)
5 min
10 min
15 min
20 min
25 min

(b)


80
70
60
50
40
30
20
10
0
Erosion wear rate (mg/kg)
34
48
60
78
92
Impact velosity(m/sec)
5 min
10 min
15 min
20 min
25 min

(c)

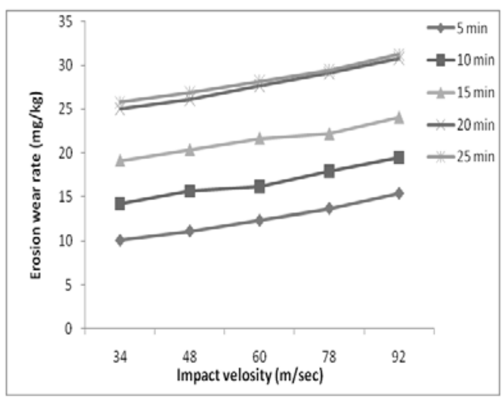
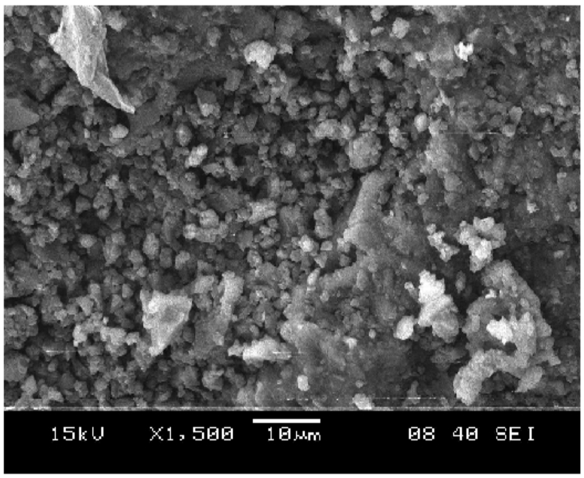
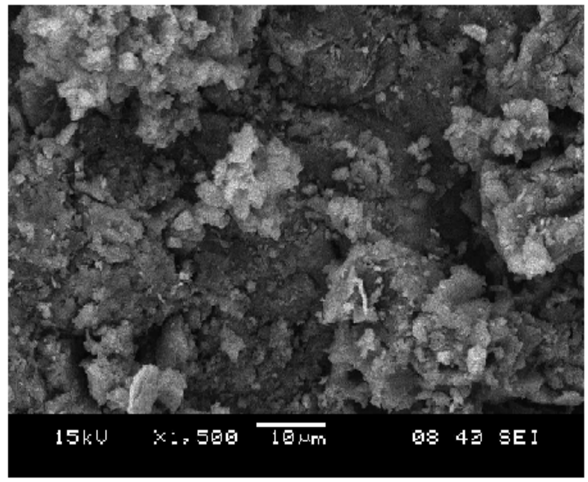

35
30
25
20
15
10
5
0
Erosion wear rate (mg/kg)
34
48
60
78
92
Impact velosity (m/sec)
5 min
10 min
15 min
20 min
25 min

Figure 5:

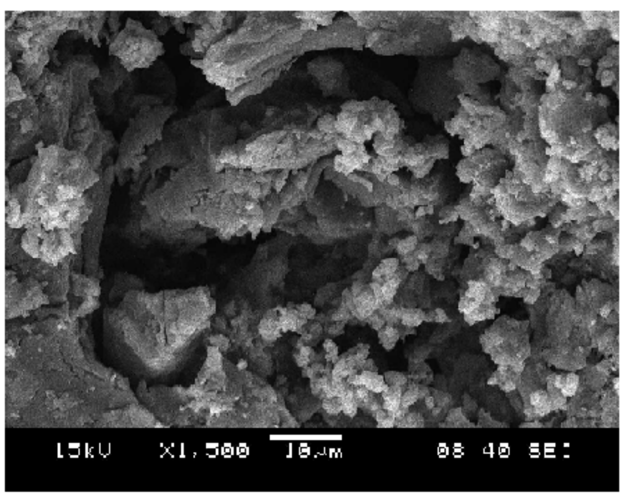
(a)


15kV
X1,500
10μm
08 40 SEI

(b)


15kV
10μm
SEI

(c)


15kV
X1,500
10μm
08 40 SEI