Erosion Wear Behaviour of Bamboo Fibre Reinforced Epoxy Composites Filled with Alumina Particulate

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Abstract: The increase concern of environments resulted from the use of synthetic fiber reinforced polymer composite has triggered research effort to develop new forms of composites such as natural fiber composites. Besides possessing good specific physical properties, natural fiber composite is also cost-effective and environmentally friendly. For those reasons, natural fiber composites are frequently used in transportation, military applications, building and construction industries, packaging, consumer products etc. Due to the operational requirements in dusty environments, the study of the erosion characteristics of these composites is of high relevance. To this end, the wear behavior of bamboo fiber reinforced epoxy composites filled with alumina particles is investigated in this research work. Also a methodology based on Taguchi's experimental design approach to make a parametric analysis of erosion characteristics has been used.

Key Words: Alumina, Bamboo fiber, Epoxy resin, Taguchi method

1. INTRODUCTION

Solid particle erosion has been considered as a serious problem for being responsible for many failures in engineering applications. Now-a-days specific fillers/ additives are added to enhance and modify the quality of composites as these are found to play a major role in determining the physical properties and erosive behaviour of the composites. It also has the potential to be used as filler material in various polymer matrices. Al_2O_3 is hard, wear-resistant, has excellent dielectric properties, resistance to strong acid and alkali attack at elevated temperatures, high strength and stiffness. In past few studied has been made on wear behaviour of fiber reinforced polymer composites filled with different filler types and found significant improvements in wear properties [1-2]. Against this background, the present investigation is undertaken to study of the wear characteristics of Al_2O_3 filled bamboo fiber reinforced epoxy composites.

2. EXPERIMENTAL DETAILS

2.1 Composite fabrication and experimental set-up

Roving bidirectional bamboo fibers are reinforced in Al_2O_3 filled Epoxy LY 556. The epoxy resin and the hardener are supplied by Ciba Geigy India Ltd. The filler material Al_2O_3 (density 3.89 gm/cc) is provided by NICE Ltd India sieved to obtain particle size in the range 70-90 μm. The average thickness of bamboo fibers is about 1.5 mm. The extracted fibers are dried in an oven at 105^0C for 72 h to remove moisture. Each ply of bamboo-fiber is of dimension 200 × 200 mm^2. A stainless steel mould having dimensions of 210 × 210 × 40 mm^3 is used. The solid particle erosion experiments are carried out as per ASTM G76 using a standard erosion test rig.

3. RESULTS AND DISCUSSION

In the present study, the variation of erosion wear rate of the composites with impingement angle is studied by conducting experiments under specified operating conditions. The erosion wear rates of alumina filled bamboo-epoxy composites as a function of impingement angle are shown in Figure 1. The figure shows the peak erosion taking place at an impingement angle of 60^o for the unfilled as well as the alumina filled bamboo-epoxy composites. This behaviour can be termed as semi-ductile in nature which may be attributed to the incorporation of bamboo fibres and alumina particles within the epoxy body. Microstructures of the un-eroded surface of Al_2O_3 filled bamboo-epoxy composite are presented in Figures 2a. Scattered Al_2O_3 particles are observed on the upper surface. The distribution of filler as seen in the micrograph is reasonably uniform although at places the particles are seen to have formed small and big clusters. In the case of worn surface studies of the composite, however, the most visible dominant features are fracture and cutting of fibers. Figure 2b for the composite eroded at 90^o shows mainly matrix fracture. Comparatively more matrix appeared damaged but not extensively removed due to normal impact of erodent. At this impingement angle there is no parallel component of particle speed and parallel force. Hence, no abrasive wear is expected. The worn surfaces exhibit sign of plastic deformation in the matrix regime at an impact velocity of 54 m/sec and erodent temperature of 60^oC which indicates the initiation of surface damage (Figure 2c). Subsequently under similar condition as mentioned above there is removal of matrix material from the surface resulting in exposure of breaking fibres to erosive environment which can be clearly seen (Figure 2d). In this micrograph, the fibres are still held firmly in place as yet by the matrix surrounding them. Some of these features are reflected in the micrograph (Figure 2e, f).

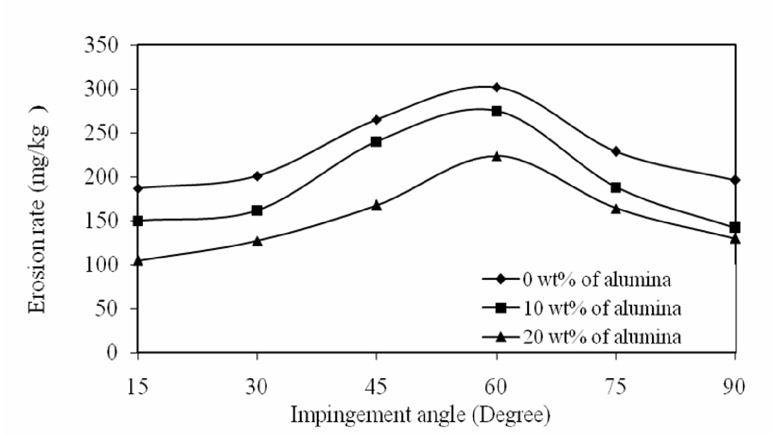

Figure 1. Effect of impingement angle on the erosion wear rate of the composites

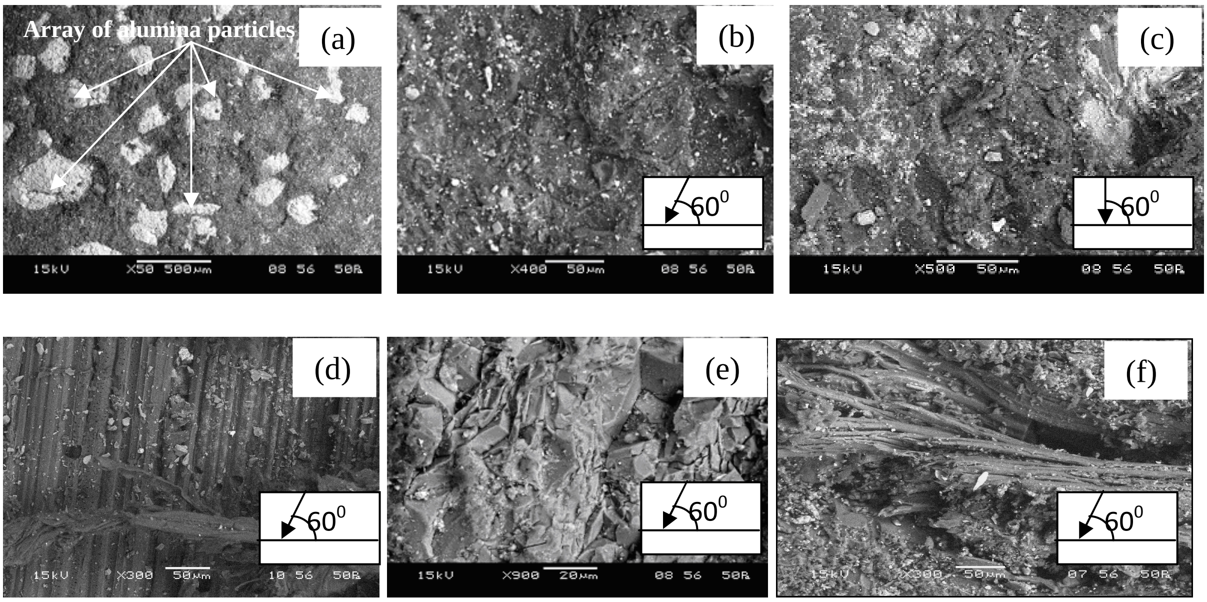

Figure 2. SEM images of eroded surfaces of Al_2O_3 filled bamboo-epoxy composites.

3.1 Design of Experiment

Taguchi experimental design has been used to make a parametric analysis of erosion characteristics of composites. Six factors such as impact velocity, filler content, erodent temperature, impingement angle, stand-off distance and erodent size with each three levels has been used [1]. The estimated S/N ratios for erosion rate are calculated with the help of **Taguchi L_{27} (3^6)** orthogonal array design [3]. The final step in any design of experiment approach is to predict and verify improvements in observed values through the use of the optimal combination level of control factors. The confirmation experiment is performed by taking an arbitrary set of factor combination $A_3B_2C_2E_3F_1$, for bamboo based epoxy composites and but factor D has been omitted due to its least effect on performance characteristics. The estimated predictive equation as follows:

$$\bar{\eta}_{\text{bamboo fiber}} = \bar{T} + (\bar{A}_3 - \bar{T}) + (\bar{B}_2 - \bar{T}) + [(\overline{A_3B_2} - \bar{T}) - (\bar{A}_3 - \bar{T}) - (\bar{B}_2 - \bar{T})] + (\bar{C}_2 - \bar{T})$$
$$+ [(\overline{B_2C_2} - T) - (\bar{B}_2 - \bar{T}) - (\bar{C}_2 - \bar{T})] + (\bar{E}_3 - \bar{T}) + (\bar{F}_1 - \bar{T}) \qquad (1)$$

$\bar{\eta}_{\text{bamboo-epoxy}}$: Predicted average for bamboo fiber reinforced epoxy composites.

$\bar{T}$: Overall experimental average, $\bar{A}_3, \bar{B}_2, \bar{C}_2, \bar{E}_3$ and $\bar{F}_1$: Mean response for factors and interactions at designated levels. By combining like terms, the Eq. (1) reduces to

$$\bar{\eta}_{\text{bamboo fiber}} = \overline{A_3B_2} + \overline{B_2C_2} - \bar{B}_2 + \bar{E}_3 + \bar{F}_1 - 2\bar{T} \qquad (2)$$

A new combination of factor levels $\bar{A}_3, \bar{B}_2, \bar{C}_2, \bar{E}_3$ and $\bar{F}_1$ is used to predict deposition rate through prediction equation and it is found to be $\bar{\eta}_{\text{bamboo-epoxy}} = -53.4930$ and from experimentally the erosion rate is -50.5776db. The resulting model seems to be capable of predicting erosion rate to a reasonable accuracy. An error of 5.45 % for the S/N ratio of erosion rate is observed. However, the error can be further reduced if the number of measurements is increased.

4. CONCLUSIONS

The erosion wear performance of these composites greatly influenced by addition of Al_2O_3 filler. Erosion characteristics of these composites can be successfully analyzed using Taguchi experimental design scheme. Study of influence of impingement angle on erosion rate of the composites filled with different weight percentage of Al_2O_3 reveals their semi-ductile nature with respect to erosion wear. The peak erosion rate is found to be occurring at 60^o impingement angle for all the composite samples under various experimental conditions.

5. REFERENCES

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