Solid Particle Erosion behavior of Rubber wood particulate Reinforced Epoxy Composite

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Abstract

This work focuses on the mechanical properties and solid particle impact behaviour of Rubber wood particulate reinforced epoxy composite. Composites were prepared using the general hand lay-up technique with different weight fraction of particulates from 10-40wt% with a step of 10 wt% . The erosive wear test was carried out using an air jet erosion tester according to the ASTM G76 standard. The experimental parameters studied for the erosion rate of the RW epoxy composites were impingement angle (30° to 90°) and particle velocity (48 m/s to 109 m/s). Analysis of the results revealed that the composite behaves in a semi ductile nature. Possible erosion mechanisms were discussed using scanning electron microscopy (SEM).

Introduction

Nowadays Fibre-reinforced composites are widely used as components in engineering structures because of their enhanced stiffness and strength properties in comparison to traditional materials (Rout et al. 2001; Li and Matuana 2003). However, increasing concern for greenhouse gas effects and environmental awareness is limiting their use in the industry. Alternatively, over the last few years, natural fibres have been chosen by researchers as a reinforcement material to replace synthetic fibres in polymer composites. Most of the industrial and manufacturing components are exposed to tribological loading, such as adhesives, abrasives, etc., during various types of service. Therefore, it is important to study the tribological performance of a material while designing a mechanical component. Many studies have emphasised the erosion behaviour of natural composites, generating the opinion that erosion is not only an intrinsic behaviour of natural fibre, but is also strongly dependent on many operating parameters (Deo and Acharya 2009; Mishra and Acharya 2010; Gupta et al. 2011; Patel et al. 2011). Solid particle erosion manifests itself in thinning of components, surface roughening, surface degradation, macroscopic scooping appearance and reduction in functional life of the structure. Hence, solid particle erosion has been considered as a serious problem as it is responsible for many failures in engineering applications. Many researchers have evaluated the resistance of various types of polymers like nylon, epoxy, polypropylene, bismileimide, etc and their composites to solid particle erosion. The most important factors influencing the erosion rate of the composite materials can be summarized under four categories; (i) The properties of the target materials (matrix material properties and morphology, reinforcement type, amount and orientation, interface properties between the matrices and reinforcements, etc.), (ii) Environment and testing conditions (temperature, chemical interaction of erodent with the target), (iii) Operating parameters (angle of impingement, impinging velocity, particle flux–mass per unit time, etc.) and (iv) The properties of the erodent (size, shape, type, hardness, etc.).

Materials

The rubber wood powders were collected from IWST Bangalore. The epoxy resin LY556 (diglycidyl ether of bisphenol A) was used as the matrix material. The epoxy resin and the hardener HY 951 were mixed at a ratio of 10:1 (wt. %).

Fabrication of composite

The conventional hand lay-up technique was used to fabricate composites having 10-40 wt present of fiber with a step of 10 wt percent. For different wt. % of fibres, a calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was thoroughly mixed with gentle stirring to minimize air entrapment. Different wt percent of fibres were kept in a mould with the dimensions 140 mm x 100 mm x 6 mm under uniform load after pouring the epoxy and hardener mix into the mould. The composites were cured for 48 h at room temperature and post-cured for another 24 h after the removal from the mould. Specimens of the required dimensions were cut using a diamond cutter for use in the erosion testing experiments.

Erosion wear test

A sand blast-type machine (Magnum Engineers, Bangalore, India) was used for this test. The test apparatus was designed to be representative of an erosive situation over a wide range of particle sizes, particle fluxes, impact velocities, and impact angles. The room-temperature solid particle erosion test on prepared RW reinforced epoxy composites were carried out at impingement angles ranging from 30 to 90°. Dry silica particles of 250 ± 50 μm were used as the erodent. The erosion test was conducted according to the ASTM G76-13 (2013) standard.

Results and Discussion

Figure-1 illustrate the erosion wear rates of Rubber wood reinforced epoxy composite as a function of impingement angle under impact velocities of 48m/s . It is observed that Rubber wood fiber reinforced epoxy composite of different percentages of weight fraction(10-40wt%) shows peak erosion rate (Er max) at 45° and 60° impact angle and minimum erosion rate (Er min) at normal incidence (90°) under all velocity of impact. This behaviour can be termed as semi-brittle in nature. It is further observed that irrespective of impact velocity and impact angle, the erosion rate decreases to minimum as the % wt. fraction of fiber increases and the optimum value was found in 30% wt. fraction of Rubber wood fiber reinforced epoxy composite.

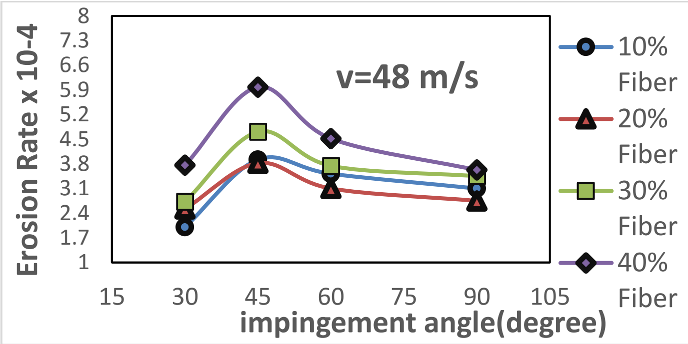


Fig. 1- Variation of erosion rate with impingement angle of rubber wood epoxy composite at impact velocity of 48 m/s.

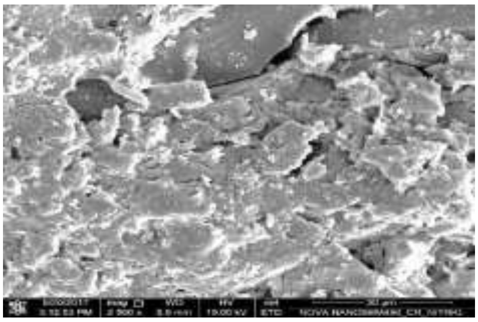
In the solid particle impact experiments the impact velocity of the erosive particles has a very strong effect on erosion rate. For any material, once steady state conditions have reached, the erosion rate 'E_r' can be expressed as a simple power function of impact velocity

$$E_r = kv^n \text{ ………………… } (1)$$

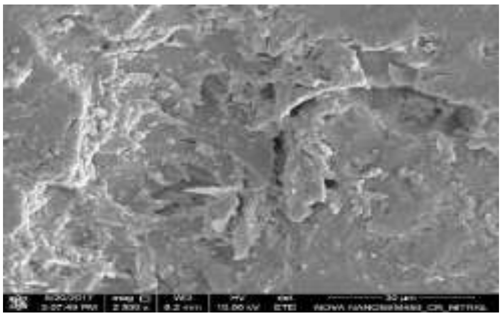
where k is the constant of proportionality includes the effect of all the other variables and 'n' is the velocity exponent. The value of 'n' and 'k' are found by least square fitting of the data points in plots which represent the erosion rate dependence on impact velocity by using the power law. The value of 'n' is typically between 2 and 3, although much higher exponent is seen under some circumstances. For polymer composites behaving in ductile manner, the velocity exponent 'n' varies in the range 2-3 while for polymer composites behaving in brittle fashion the value of 'n' should be in the range of 3-5.The velocity exponents found for the present case for 30°, 45°, 60° and 90° impingement angles are in the range of 1.482-1.695, 1.361-1.778, 1.159-1.809 and 0.705-1.778 respectively. The value of velocity exponent 'n' shows that Rubber wood filled epoxy composite behaves in a semi-ductile manner

Surface morphology

To characterize the morphology of eroded surfaces the eroded samples were observed under a scanning electron microscope. Figure 2(a) shows the surface of 30 vol% of rubber wood epoxy composite eroded at 600 impingement angle. It can be seen from the surface of the samples that material removal is mainly due to micro-cutting and micro-ploughing. Figure 2(b) shows the micrograph of surfaces of 30 wt% of rubber wood epoxy composite eroded at an impingement angle of 450 with higher particle speed. It is seen that the fiber in composite subjected to particle erosion, encountered intensive debonding and breakage of the fibers, which were not supported enough by the matrix. The continuous impingement of silica sand on the fiber breaks the fiber because of the formation of cracks perpendicular to their length. Also the bending of fibers becomes possible because of softening of the surrounding matrix, which in turn lowers the strength of the surrounding fibers.



(a)



(b)

Fig.2- SEM micrographs of eroded surface of 30 vol% of Rubber wood epoxy composite at a impact angle of; (a) 60^0 angle(b) 45^0 angle

Conclusions

1.Study of influence of impingement angle on erosion rate of the composites reveals semi ductile nature of the composites. The peak erosion rate is found to be occurring at 45° impingement angle at lower to medium impact velocities and at 60° at higher velocities for the rubber wood reinforced composite

2.The influence of impingement angle on erosive wear of composites under consideration exhibits semi-brittle erosive wear behavior with maximum wear rate between 45°-60° impingement angle The wear rate steadily falls and attains a stable state with increasing the sliding distance.

3.With increasing of the velocity of impingement, erosion rate gradually increases.

4.The morphologies of eroded surface of the samples observed by SEM indicate that, materia removal is mainly due to micro-cutting and micro-ploughing.

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