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Solid particle erosion of glass fibre reinforced flyash filled epoxy resin composites

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Abstract

Experiments were carried out to study the effects of flyash filler, impingement angle and particle velocity on the solid particle erosion behaviour of E-glass fibre reinforced epoxy (GFRP) composites. The erosive wear of flyash filled composites is evaluated at different impingement angles from 30° to 90° and at three different velocities of 24, 35 and 52 m s^{-1}. The erodent used is silica sand with the size range 150–250 μm of irregular shapes. The result shows semi-ductile erosion behaviour with maximum erosion rate at 60° impingement angle. The erosion rate (R) displays a strong dependence on impact velocity (V), which follows and the power law $R \propto V^n$ for all the materials. We find that erosive wears of GFRP composite with 4 g flyash as filler is the lowest. This filler restricts fibre–matrix debonding. Pure glass epoxy without any filler shows the highest erosion rate due to weak bonding strength. The morphologies of eroded surface were examined by the scanning electron microscope.

Keywords: E-glass fibre; Epoxy resin; Flyash; Erosion rate; Impingement angle; Particle velocity

1. Introduction

Fibre reinforced plastic (FRP) composites have various applications in automobile, aerospace and marine. FRP composites are applied to inlet cone, fan exit-guide vanes and other parts of structures in a turbofan engine for lightening an engine. Due to operational requirements in dusty environments, the erosion characteristics of the FRP composites are of vital importance. Erosion tests have been performed under various experimental conditions on different target composites. It has been observed that the composite materials present a rather poor erosion resistance [1–3]. In order to obtain the desired material characteristics for a particular application, it is important to know how the composite performance changes with the fibre content under given loading conditions. The erosive wear behaviour of FRP composite systems as a function of fibre content has been studied in the past [4,5]. Miyazaki and Hamao [6] have examined the effect of fibre inclusion on the erosion behaviour by comparing the erosion rate of an FRP with that of a neat resin, which is a matrix material of the FRP. It was observed that the inclusion of brittle fibres in both thermosetting and thermoplastic matrices leads to compositions with lower erosion resistance. They have also studied the erosion behaviour of treated and untreated glass fibre reinforced epoxy resin composites. The results show the clear correlation between interfacial strength and erosion rate.

Tilly and Sage [7] have also investigated the influence of velocity, impact angle, particle size and weight of impacted abrasive for nylon, carbon fibre reinforced nylon, and epoxy resin, polypropylene and glass fibre reinforced plastic. Their results shows that for the particular materials and conditions of their tests, composite materials generally behave in an ideal brittle fashion, i.e., maximum erosion rate occur at normal impact. However, E-glass fibre reinforced epoxy composite exhibits erosion rates less than those of the other composites by a factor of 5. This was

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attributed to better adhesion between the matrix and the fibres as well as the lower porosity of this composite [8]. The E-glass epoxy composite exhibits semi-ductile erosion behaviour with a maximum weight loss at an impingement of 45° and 60°, while others eroded in brittle manner with a maximum weight loss occurring at 75–90° [9].

The fracture surface energies of epoxy and polyester resin and their resistance to crack propagation are relatively low. If particulate filler is added to these brittle resins, the particles inhibit crack growth. As the volume fraction of filler is varied, the fracture energy increases up to a critical volume fraction and then decreases again. Fracture properties of epoxy resin can be improved by addition of other materials. Fillers affect the tensile properties according to their packing characteristics, size and interfacial bonding [10]. The maximum volumetric packing fraction of filler reflects the size distribution and shapes of the particles. Srivastava and Shembekar [11] showed that the fracture toughness of epoxy resin could be improved by addition of flyash particles as filler.

In the present work, experiments were carried out to study the effects of flyash filler, impingement angle and particle velocity on the solid particle erosion behaviour of E-glass fibre reinforced epoxy resin composites.

2. Experimental technique

2.1. Test materials

A curing agent is mixed into the liquid epoxy to polymerize the polymer and to form solid network cross-linked polymer. The type of epoxy resin used in the present investigation is CY-205 and hardener HY-951 supplied by Ciba-Geigy of India Limited. E-glass fibres utilized in the present work was taken from Fibre Pilkington Ltd. They were reinforced in the above matrix.

The flyash collected by the mechanical precipitator in the Obra Thermal Power Station, Mirzapur, India was used. It was sieved to obtain flyash mesh size of 105 μm. Generally, flyash contains the different chemical constituents, i.e., silicon oxide, aluminium oxide, calcium oxide, iron oxide and magnesium oxide. The density of flyash is 3.385 g cm^{-3}.

Epoxy is mixed with hardener in the ratio of 10:1 by weight. To avoid formation of bubbles by liberated CO_2 in resin, it was degassed in vacuum at 110 °C before use. Epoxy resin and flyash particles were mixed thoroughly in the ratio of 4:1. The cross-plied E-glass fibre sheet was reinforced in the mixture of epoxy resin and flyash. E-glass fibre reinforced flyash filled epoxy resin composites plates (3 mm thick) were moulded at room temperature. The cross-plied glass fibre reinforced epoxy resin composite plate was also made with the above dimension without any particulate filler. The castings were cured at room temperature overnight. Suitable pieces of the above were prepared with suitable hardness, tensile, erosion characterization for our experiment.

2.2. Test apparatus

Fig. 1 shows the schematic figure of the erosion test apparatus, which is composed of an air compressor, air-drying unit, a magnetic particle feeder, an air particle mixing and accelerating chamber. Dry compressed air is mixed with the particles, which are fed at a constant rate from a conveyor belt type feeder in the mixing chamber and then accelerated by passing the mixture through a converging nozzle of 4 mm diameter. These accelerated particles impact the specimen, which can hold at various angles with respect to the impacting particles using an adjustable sample holder. Monitoring the distance between the particle feeding hopper and belt drive the particles to the mixing chamber that control the feed rate of the particles. Changing the pressure of the compressed air results in the variation of the impact velocity of the particles. The velocity of the eroding particles is determined using a rotating disc method. In the present study, silica sand was used as an erodent. Square samples of size 30 mm × 30 mm with 3.0 mm of thickness were utilized for erosion tests. The conditions under which erosion tests were carried out are given in Table 1.

A standard test procedure was employed for each erosion test. The samples were cleaned in acetone, dried and weighed to an accuracy of 10^{-5} using electronic balance. It was then eroded in the test rig for 5 min and weighed again to determine the weight loss. The ratio of this weight loss to the weight of the eroding particles causing the loss (testing time particle feed rate) is then computed as the dimensionless incremental erosion rate. This procedure is repeated till the erosion rate attains a constant steady state value.

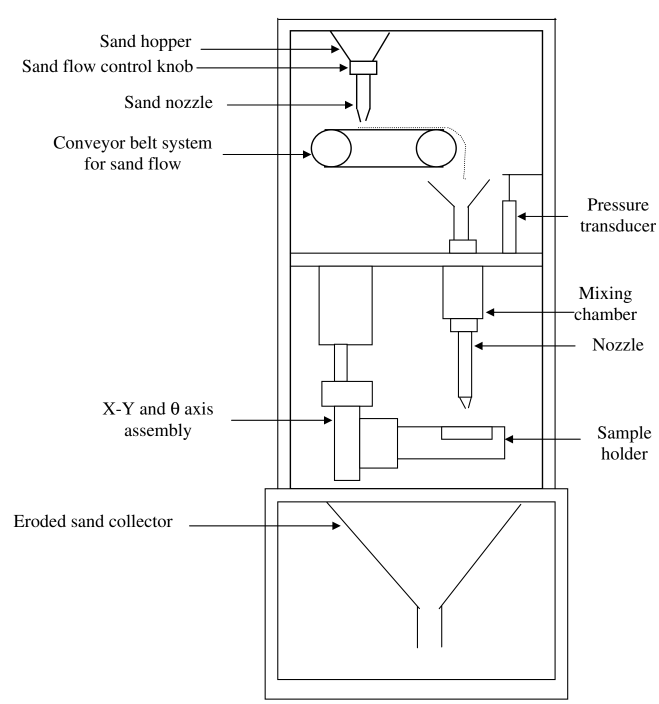

Fig. 1. Schematic diagram of erosion test rig.