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Full Length Article

Dry sliding wear behavior of epoxy fly ash composite with Taguchi optimization

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ABSTRACT

Epoxy resin matrix composite reinforced with fly ash particles was prepared by ultrasonic stirring method. Pin-on-disc wear test of the composite was carried out and compared according to Taguchi design-of-experiment. An orthogonal array exhibited and examined the influencing parameters like % of fly ash debris, typical load, sliding speed and track distance on the composite. Signal to noise ratio analysis optimizes the parametric condition that yields minimum wear rate, minimum frictional force and minimum coefficient of friction. A multi-criteria decision analysis method, TOPSIS is used to optimize the output, and confirmation test has been done to verify the projected model. ANOVA shows that applied normal load plays a vital role in increasing dry sliding wear of epoxy composites.

1. Introduction

Polymer matrix composites are advanced materials that have high strength at low weight, which make them usable at various applications like automobile, aerospace and household appliances. The decision of material for a specific application relies on the variables like material expense, thickness, quality and working conditions. Polymer composites which are used in sliding conditions are normally employed in low energy transfer. The possible reason in sudden increase in wear rate is due to the frictional temperature reaching the material melting temperature under the loading condition [1]. Hence, wear is one of the real issues that should be handled to enhance the life of the part [2]. This will bring higher working temperature with increment in wear and leads to speedier substitution of parts [3]. Lightweight polymer matrix composites are the most suitable materials for weight sensitive application in aerospace and automobile industries. Current work concentrates on waste utilization, product development as a composite material which result better wear properties. Deuis et al. (1996) [3] explained the impact of volume percentage, sliding conditions (time, distance, speed, etc.) and applied load that impacts the dry sliding wear of the composites.

Biswas and Satapathy (2010) [4] concluded that the particulate filled polymer composites are mostly encouraging building materials because of their reasonable determination of lattice and fortifying strong molecule stage. It prompts a composite with a blend of quality modulus better than those of traditional metallic materials. Polymer composites have replaced the traditional metal and ceramic materials in making high strength and low conductivity applications like pump wear ring, bushings, line shaft bearings, interstage bushings and pressure reducing bushings. Laguna-Camacho et al., (2015) [5] suggested that unreinforced epoxy were not satisfactory because of its high fragility. The consideration of ceramic fillers into polymers for commercial application rises, and it enables good aesthetic sense with good mechanical properties. Silica assumes an imperative part in enhancing electrical, mechanical and thermal properties of the material. Fly ash is an industrial waste, largely available in thermal power plants, which mostly contains silica and alumina. Fly ash has been used earlier as a reinforcing material in polymeric materials, but a few investigations have been carried out on tribological properties of the material by varying different parameters of pin on disc sliding wear. Xu et al. (2015) [6] described that the sliding is mainly influenced by contacting parts and tribological behavior of the materials. To make a suitable wear resistant composite, one has to evaluate the relation between varying parameters and wear rate. This technique has effectively sought parametric evaluation in different wear procedures of an extensive variety of polymer composites [7–10].

In our investigation, tribological behavior of the fly ash reinforced epoxy polymer composite is measured, and wear, frictional

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force and coefficient of frictional are tabulated. Optimization technique is applied to get the suitable combination to get the minimum value of wear. The percentage contribution of each parameter is evaluated.

2. Experimental details

2.1. Matrix and filler materials

Epoxy resin (LY 556), a high viscous semi-solid material having density 1120 gm/cm^3 is utilized as the matrix material whose chemical name is Bisphenol-A-Diglycidyl-ether. An amino group hardener (HY 951) is used for hardening the material. Both the epoxy resin and the hardener are supplied by ATUL Industries Pvt. Ltd, Kolkata. Epoxy acts as a good matrix material due to its high corrosion resistance, high thermal stability and good mechanical properties. Fly ash being a ceramic filler is used as a reinforcement. Fly ash (Class C) used in this experimental work is collected from CPP 2 of Rourkela Steel Plant, Odisha. The fly ash particles are spherical in shape as revealed by the SEM micrographs as shown in Fig. 1. A graph has been plotted between particle size and volume percentage of fly ash from the data provided by the particle size analyzer (MALVERN MASTERIZER). The average particle size is 27.26 μm as determined from the Fig. 2. Normally, if the particle size is in the order of nanometer then it reduces the friction and wear [11]. But here, the particle size is in the order of micrometer which increases the rate of wear. The detail chemical compositional analysis shown in Table 1revealed that the major elements present in fly ash are 46% SiO_2 and 35% Al_2O_3 which makes it a good ceramic material. Si and Al make the fly ash harder, rigid and give more flexibility as a filler material.

2.2. Composite fabrication

Epoxy resin and fly ash are mixed in four different weight percentages and put under an ultrasonic sonicator with its horn dipped partially inside the mixer for 10 min with a pulse time of 5 sec. Once it is complete, 10 wt % of hardener is added and hand stirred gently to avoid trapping of bubbles, and poured into plastic pipes of 10 mm diameter and 1 inch in height, and allowed to cure at room temperature for 24 hrs. Once it is hardened, the plastic pipes were cut to remove the solidified cylindrical samples which are dimensionally accurate for the pin-on-disc (DUCOM) machine. Briscoe (1990) [12] explained that temperature, pressure, strain rate and even the environment may make an enormous difference to the mechanical response of polymers. So, controlled atmosphere is maintained while making of samples for uniformity.

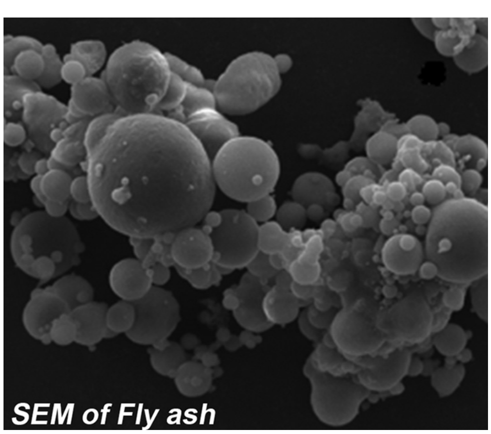

Fig. 1. SEM micrograph of fly ash particles.

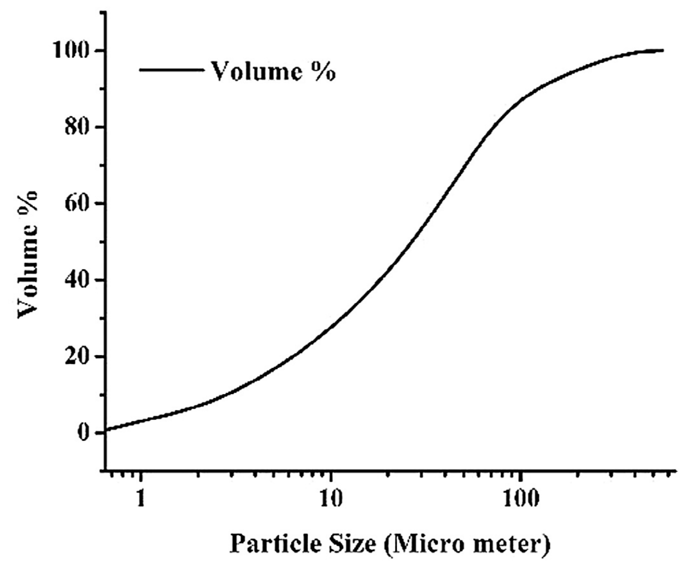

Fig. 2. Particle size analysis of fly ash particles.

2.3. Dry sliding wear test

Dry sliding wear test has been carried out in pin-on-disc machine as per ASTM G99 standard. This ASTM standard is fixed for polymeric samples. The disc of the machine is made up of stainless steel with negligible amount of surface roughness. The specimen is held tight with the help of a sample holder and screws and perpendicular to the rotating disc with four screw fasteners, and load is applied with a lever attachment. Other parameters, like time of rotation, speed in RPM and track diameter have to be fixed manually prior to each experiment. Fig. 3shows a schematic diagram of sliding wear machine with different attachments. Here, the load has to be provided manually by placing discs of desired weight prior to each experiment. An AC motor helps in rotating the disc, while the flat sample surface remains fixed and unmoved.

Virtually, all of the frictional work ultimately appears as heat which is conducted out of the boundaries of the system. However, there will be volumes of material adjacent to the contacts where the work is initially dissipated mainly in inelastic deformations. These regions will be called the primary energy dissipation zones [13]. It is noted that the wear increases with increase in normal applied load and sliding distance [14].

2.4. Experimental design

Kumar and Dhiman (2013) [15] described how wear is a critical parameter while considering the characterization of any material.

Table 1
Chemical compositional analysis of fly ash.

Constituents	Vol %
Fe_2O_3	8.1
MgO	1.14
Al_2O_3	24.98
SiO_2	55.85
P_2O_5	0.15
SO_3	1.16
K_2O	0.85
CaO	2.54
Na_2O	0.2
TiO_2	1.75
CO_2	1.56