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Taguchi approach to influence of processing parameters on erosive wear behaviour of Al7034-T6 composites

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Abstract: Taguchi technique was used to predict the influence of processing parameters on the erosive wear behavior Al7034-T6 composite reinforced with SiC and Al_2O_3 particles in different mass fractions. These hybrid metal matrix composites (HMMCs) were fabricated by using a simple technique called stir casting technique. Scanning electron microscope (SEM) was used to study the surface morphology of the composite and its evolution according to processing time. The design of experiment (DOE) based on Taguchi's L_{16} orthogonal array was used to identify various erosion trials. The most influencing parameter affecting the wear rate was identified. The results indicate that erosion wear rate of this hybrid composite is greatly influenced more by filler content and impact velocity respectively compared to other factors. This also shows the significant wear resistance with the increase in the filler contents of SiC and Al_2O_3 particles, respectively.

Key words: hybrid metal matrix composite; erosive wear; stir casting; SiC; Al_2O_3; Taguchi design

1 Introduction

Aluminium is widely used in engineering applications such as in automobile, aerospace, and defense owing to its excellent physical and mechanical properties. The use of such materials has increased substantially in the present scenario. This has led to the development of many new composite materials. However, for many applications, pure aluminium cannot be used because of its lower strength and ductility. In the category of lightweight, high-performance material, the aluminium matrix composites (AMCs) are widely used by several industries. Due to their exceptional properties, a composite made of aluminium, reinforced with hard particles is of wide interest. Primary fabrication methods used for aluminium metal matrix composites are stir casting, squeeze casting, compo castings, infiltration, spray deposition, direct melt oxidation process and powder metallurgy. However, MMCs suffer from various problems viz, insufficient process stability, reliability, and ability to operate in the high-temperature environment. To overcome these problems, the hybrid metal matrix composites (HMMCs) were developed [1]. The increase in demand for high-performance materials has led to the development of HMMCs reinforced with hard particles. These HMMCs possess excellent mechanical and wear resistant properties and are considered as potential engineering materials for many wear-related applications. Some researchers have studied different wear mechanisms of MMCs reinforced with ceramic particulates like SiC, Al_2O_3 and facing sand particles, and have observed improvement in wear resistance, abrasion resistance and creep resistance [2]. It is hard to choose the desired hard metal type and grade because of the lack of a standard measure of assessment that enables estimates to be made of serviceability in erosive wear conditions. The as-cast aluminium alloys are versatile engineering materials. It is very hard to get properties such as strength, toughness, rigidity, bearing performance and economical cast ability, from other alloy system. Aluminium alloys are feasible matrix materials owing to their good bearing and wear properties, lower casting temperatures, and lower cost. Aluminium alloys reinforced with SiC show better wear and abrasion resistance with increasing SiC contents [3]. Al/SiC alloys are critical bearing materials, especially suitable for high-performance applications, particularly in the aerospace sector. It is not conducive for applications where low cost and high volume are as

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important as performance [4]. The critical parameters such as reductions in cost, lightweight, and high strength, when reinforced with suitable alloy, make these alloys dominate over other alloys. However, the major limitations associated with these alloys are their ability to operate at elevated temperature [5]. The mechanical and wear resistance properties of metals and alloys such as aluminum, magnesium, titanium, and nickel−chromium alloys which undergo extensive plastic deformation under impact are of interest in many erosive wear applications. These materials can be substantially strengthened by various surface treatment techniques [6]. In general, MMCs in commercial use rely on discontinuous reinforcements, although applications exist for MMCs with continuous graphite, SiC and Al_2O_3 fibers. For example, discontinuously reinforced aluminum alloy MMCs provide high damping and low density and allow undesirable mechanical vibration and wave propagation to be concealed [7]. Among various manufacturing processes available for discontinuous MMCs, stir casting is typically accepted as a particularly promising route. Its simplicity lies in controlling the parameters like melting temperature, stirring speed, stirring time, and cost effective process [8]. Fabrication technique plays a significant role in defining the material properties of the composites. The fabrication process was chosen depending on the type of matrix material and reinforcement. Good wetting action between matrix and reinforcement requires the pretreatment of reinforcement particles. The pretreatment of the particles improves the surface condition of the reinforcement and the properties of the composites [9]. CANAKCI et al [10] predicted the effect of reinforcement size and volume fraction using ANN on Al2014/B_4C composites produced by stir casting method. They revealed that ANN is also an alternative method for determining the wear behavior of the composites. CANAKCI et al [11] also investigated the physical and mechanical properties of AA2024/B_4C_p composites produced by stir casting method. They concluded that the heat-treated composites show better properties which are in agreement with Ref. [9]. The mechanical alloying process is a powder metallurgy technique used to obtain the homogeneous distribution of blended particles in a metal alloy matrix material. VAROL and CANAKCI [12] studied the effect of milling parameters on Al2024/B_4C composite powders produced by the mechanical alloying method. They found that milling time and particle sizes have a greater influence on the uniform distribution of particles in the matrix materials. The reinforcement size is the most important parameter that strongly affects the particle size in a composite. Similar results have been reported in the previous study by VAROL et al [13] for Al2024/B_4C composites produced by powder metallurgy technique. In recent days, extensive work has been carried out to improve the mechanical properties of functionally graded aluminium metal matrix composites. It is found that the density, hardness and bending strength of the composites, fabricated through powder metallurgy technique have been remarkably improved [14]. The powder metallurgy technique has many advantages over stir casting process, and is less expensive than stir casting process. The intention of developing HMMCs is to meet several requirements, viz, static and dynamic loading conditions and the critical demands about the phenomena of wear, erosion, and corrosion. It is hard to have such materials which satisfy these requirements. The only possible way is to manufacture by material combination or a composite design. To improve the surface property of untreated substrate, mechanical surface treatment, surface diffusion treatment, and surface overlay coatings are used [15].

Erosive wear is due to the impact of solid particles or liquid stream against the surface of an object. The liquid stream may entrain the solid particles aiding the wear process [16]. Given this, a study on the influence of processing parameters on the erosion resistance potential of Al7034-T6 composites was taken into consideration in this work. In the experimental part of this study, the impact of more than one parameter on erosion wear of the SiC/Al_2O_3-filled Al7034-T6 composites was experimentally analyzed. The problems associated with the fractional design can be easily overcome by implementing. Taguchi method is a statistical technique used to optimize the process parameters. The design of experiment gives more consistent outputs, irrespective of the environment in which it is used. Taguchi design uses an orthogonal array which makes the design process very easy and coherent. The inexpensive and easy experimental strategies based on Taguchi's parameter design were adopted by many researchers [17] to study the effect of various parameters and their interactions in the wear process were studied.

2 Experimental

2.1 Materials

The material selected was a composite, based on an Al7034-T6 matrix, reinforced with silicon carbide (SiC) and aluminium oxide (Al_2O_3) particles (size 10−20 μm) in mass fraction range of 0−9% at a step of 3% each. Fenfe metallurgical provided these materials in extruded and T6 heat treatment conditions. Material composition is shown in Table 1.

2.2 Composite fabrication

This process involved melting of the Al7034-T6 alloy (matrix) carried out separately about 750 °C, and

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