Statistical Modeling and Analysis of Dry Sliding Wear of SiC Reinforced Aluminum MMCs

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ABSTRACT

The dry sliding wear behavior of SiC reinforced aluminum alloy composites produced by liquid metallurgy was studied by means of a pin-on-disc type wear set up. Dry sliding wear tests were carried out on SiC reinforced Metal Matrix Composites (MMCs) and its matrix alloy sliding against a steel counterface. Different contact stresses, reinforcement percentages, sliding distances and sliding velocities were selected as control factors and the response selected was Wear Volume Loss (Y1) and Coefficient of Friction (Y2) to evaluate the dry sliding performance. An L25 orthogonal array was employed for the experimental design. Initially empirical relations were deduced for Y1 and Y2 in terms of control factors. Further, the optimal combination of the testing parameters was determined for Y1 and Y2 responses by implementing Taguchi method for the experimental observations. Finally, Analysis of Variance (ANOVA) was performed to know the impact of individual factors on Y1 and Y2. The results indicated that the sliding distance for Y1 and Y2 responses is found to be the most effective factor among the other control parameters on dry sliding wear. The study also shows that the Taguchi method is applicable to solve this type of problem with minimum number of trials compared with a full factorial design.

Keywords: *Aluminum, Analysis of Variance (ANOVA), Dry Sliding Wear, Metal Matrix Composites (MMCs), Silicon Carbide (SiC) Particulates, Taguchi*

1. INTRODUCTION

Metal Matrix Composites (MMCs) are being increasingly used in aerospace and automobile industries owing to their enhanced properties such as elastic modulus, hardness, tensile strength at room and elevated temperatures, wear resistance combined with significant weigh saving over unreinforced alloys. New fibers, new matrices, novel composite architectures and innovative manufacturing processes continue to provide exciting opportunities for improvements in

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performance and reductions in cost, which are essential to maintain competitiveness in increasingly globalized world markets. Predicting composite behavior continues to improve with enhanced scientific understanding and modeling capability, allowing much more effective and reliable use of these complex materials (Cantor et al., 2003). Composite materials offer superior combination of properties in such a manner that today no existing monolithic material can rival. Over the years, several types of composite materials have been used in numerous structural, non-structural and functional applications in different engineering sectors. Aluminum matrix composites (AMCs) refer to a class of light weight high performance aluminum centric material systems. The reinforcement in AMCs could be in the form of continuous/discontinuous fibers, whisker or particulates, in volume fractions ranging from different percentages. Properties of AMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route (Surappa, 2003).

Wear is one of the most commonly encountered industrial problems, leading to frequent replacement of components, particularly abrasion. The particulate reinforcement such as Al_2O_3 and aluminide (Husking et al., 1982; Hutching, 1987) are generally preferred to impart higher hardness. Although there is no clear relation between mechanical properties of the composites, volume fraction, type of reinforcement and surface nature of reinforcements, the reduced size of the reinforcement particles is believed to be effective in improving the strength of the composites (Ma & Tjong, 1997). The structure and properties of the reinforcements control the mechanical properties of the composites. Further, the improved interface strength and better dispersion of the particles in the matrix can also be achieved by preheating the reinforcements (Chen et al., 1997; Thakur & Dhindaw, 2001). Kumar and Balasubramanian (2008) developed a mathematical model to evaluate wear rate of AA7075/SiCp powder metallurgy composites. The results showed that the volume fraction of reinforcement, sliding speed and applied load were varying directly proportional with wear rate, while particle size of reinforcement and hardness of counterpart materials were having inversely proportional with wear rate. Modi et al. (2001) showed that the effect of applied load on the wear rate of both zinc alloy and the 10 wt. % Al_2O_3 particle-reinforcement composite using statistical analyses of the measured wear rate at different operating conditions. The effect of applied load on the wear rate of the composite was found to be more severe.

How and Baker (1997) investigated the wear behavior of Al6061 alloy filled with short saffil and concluded that saffil reinforcement are significant in improving wear resistance of the composites. Straffelini et al. (1997) found that the matrix hardness has a strong influence on the dry sliding wear behavior of Al_2O_3 particulate Al6061 MMC. Martin et al. (1999) investigated on the tribological behavior on Al6061 reinforced with Al_2O_3 particles and concluded that a characteristic physical mechanism exists during the wear process. When a sufficiently high load is applied on the contact, the matrix phase is plastically deformed, and the strain is partially transferred to the particulates, which are brittle with small failure strains. Yu et al. (1997) demonstrated that the effects of applied load and temperature on the dry sliding wear behavior of Al6061 alloy matrix composites reinforced with SiC whiskers or SiC particulates and concluded that, the wear rate decreased as the applied load is increased. MMCs having SiC of 3.5, 10, and 20 micron size with 15 vol. %, produced by powder metallurgy route displayed good wear resistance with increasing particle size in sliding wear (Liang et al., 1995). The wear resistance of the composites improved by incorporating TiB_2 particle reinforcement and the refinement of the matrix grains greatly improved the mechanical properties of the composites. Further the TiB_2 particles markedly improve the wear performance of the Al-Cu alloy (Chaudhary et al., 2005). Wear behavior of various particle-reinforced aluminum alloy matrix composites has been investigated

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