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Microstructure and tribological performance of an aluminium alloy based hybrid composite produced by friction stir processing

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ABSTRACT

In this study, friction stir processing (FSP) was utilized to incorporate SiC and MoS_2 particles into the matrix of an A356 Al alloy to form surface hybrid composite. A constant tool rotation rate of 1600 rpm and travel speed of 50 mm/min with a tool tilt angle of 3° was used. The wear resistance of the processed samples improved significantly as compared to that of the as-cast alloy. Microstructural analyses showed a uniform distribution of reinforcement particles inside the nugget zone, and a MoS_2 rich mechanically mixed layer (MML) on the top of worn surface. This MoS_2 layer is considered to stifle plastic deformation and thus, to improve tribological properties of the alloy.

1. Introduction

Materials with improved tribological properties have become the pre-requisite of advanced engineering design. Surface metal matrix composites are a unique class of such materials. They offer superior properties such as high hardness and excellent wear resistance [1,2]. Wear performance of surface metal matrix composites reinforced with hard ceramic particles is reported by various researchers. Lim et al. [1] found that the addition of SiCp (SiC particles) into the matrix of A356 Al alloy leads to increase in wear resistance. Garcia et al. [2] have noticed that the wear resistance of AA6061/SiCp composites increases with increase in volume fraction and size of reinforcement. Hard ceramic particles have been proved to increase the hardness and wear resistance of the composite. However, these hard reinforcements increase the wear rates of the counterfaces [3]. Other problem associated with these particles is their tendency to be detached from the matrix and act as third-body abrasives that leads to increase in wear [4]. Recent investigations [4–6] have shown that the addition of solid lubricant particles, such as graphite or MoS_2, along with hard particles further improves the tribological properties of these composites under sliding wear conditions. This is due to the combination of increase in bulk mechanical properties as a result of addition of hard particles and decrease in friction coefficient as a result of formation of lubrication film. The investigations of Basavarajappa and Riahi [4,5] have indicated that Al/SiCp/graphite hybrid composites displayed a transition from mild wear to severe wear at loads and sliding speed combinations which were higher than those of the unreinforced A356 and Al 2219 substrates and graphite free Al/SiCp composites. Moreover, Basavarajappa et al. [6] have focused upon the influence of lubricant particles on the degree of subsurface deformation under sliding wear conditions in Al 2219/SiCp/graphite hybrid composite. It was found that graphite smears on the sliding pin surface and forms a layer which leads to decrease the friction coefficient and reduce the plastic deformation in the subsurface region avoiding severe wear.

It should be pointed out that fabrication of surface metal matrix composites by conventional techniques based on liquid phase processing at high temperatures, such as laser melt treatment and plasma spraying, may lead to the deterioration of composite properties [7,8]. During these techniques, it is very difficult to avoid the interfacial reaction between reinforcement and metal matrix and formation of some detrimental phases. Furthermore, critical control of processing parameters is necessary to obtain the desired solidification microstructure in surface layer.

Recently, much attention has been paid to friction stir processing (FSP) as a solid-state surface modification technique [9–11]. A rotating tool with a specially designed pin and shoulder is inserted into a substrate and produces a highly plastically deformed zone (stir zone). It is well known that the stir zone consists of fine and equiaxed grains produced due to the dynamic recrystallization [11]. FSP has also been used to fabricate surface composites. Mishra et al. [12] fabricated the Al/SiCp surface composites by FSP, and showed that SiCp were well distributed in the Al matrix, and good bonding with the Al matrix was obtained. Since processing of surface composite during FSP is carried out at temperatures below melting point of substrate, the problems in conventional techniques based on liquid phase processing at high temperatures can be avoided. In the present study, an attempt has been made to enhance the wear resistance of A356 Al alloy by dispersion of

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