Fabrication and Tribological Properties of Al-Si/B₄C Metal Matrix Composites

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ABSTRACT

Aluminium composite materials are exponentially growing up and rapidly gaining importance because of their properties like low density, high strength, high stiffness, environmental resistance, low co-efficient of thermal expansion etc. In this context aluminium-boron carbide composites, with 2.5, 5 and 7.5 wt% of boron carbide (B₄C) particulate reinforced, were prepared by stir casting process and the effect of the percentage of reinforcement of B₄C on dry sliding wear and friction coefficient were investigated. The wear tests were carried out on a pin-on-disc type apparatus at a linear speed of 1 m/s, sliding distance of 500 m and a constant load of 30 N. The coefficient of friction was recorded on line. Wear rates were calculated from mass loss measurements. Scanning electron microscope was used to examine the tribo-surface of worn Al- B₄C composites. The results showed that the wear rate of 7.5 wt% B₄C composites is 0.375 mg/min which is significantly lower than pure Al alloy (3.125 mg/min). The friction coefficient decreases from 0.477 (for pure Al alloy) to 0.261 (for 7.5 wt% B₄C composites).

Keywords: Al-Si Alloy, Boron Carbide, Friction Coefficient, Scanning Electron Microscope, Wear

INTRODUCTION

Metal matrix composites (MMCs) have considerable applications in aerospace, automotive and military industries due to their high mechanical properties and good physical behavior including light weight, electrical and thermal conductivity (Boey, 1998; Pravin, 2008). The commonly used metallic matrices are Al, Mg, Ti, Cu and their alloys. These metals/alloys are preferred matrix materials for the production of MMC. The reinforcements being used are particulates and fibers. (Miyajima, 2003). Aluminium is favored as matrix material in MMCs because of its low density, easy fabricability and good engineering properties (Khan, 2006). Aluminium

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matrix composites (AMCs) can be reinforced with various ceramic particulates such as SiC, Al₂O₃, B₄C, TiC, AlN, BN, MgO etc. (Ipek, 2005; Kerti, 2005; Lee, 2001). The ceramic particulate reinforced composites find applications as cylinder blocks, pistons and piston insert rings, brake disks and calipers (Ceschini, 2001). While SiC and Al₂O₃ are common reinforcing materials in AMCs, limited research has been conducted on B₄C reinforced AMCs due to the higher cost of B₄C powders (Khan, 2006). B₄C is an attractive reinforcement material because of its high strength, low density (2.52 g/cm³), extremely high hardness (Hv=30GPa), good chemical stability and neutron absorption capability (Mohanty, 2008; Toptan, 2010). There was a strength reduction and improvement in hardness in aluminium based boron carbide composites with increasing B₄C reinforcement (Mohanty, 2008).

Un-reinforced aluminium shows the lowest wear resistance when compared with composites, since they have highest hardness and second-phase volume content (Bermudez, 2001). The effect of cadmium addition on microstructure and wear behavior of the Al-12%Si alloy under dry sliding conditions was studied by Abbass et al. (2010). They observed that the addition of cadmium to Al-Si matrix decreases the wear rate and improves the wear properties for alloys containing Cd under loads above 10N. The wear behavior of AA6061 aluminium alloy reinforced with Al₂O₃, B₄C, Ti₃Al, and B₄Ti was studied by Rosenberger et al. (2005) and observed that different type of reinforcement can generate mechanically mixed layers with similar wear resistance. Dry sliding wear characteristics of A356.2 aluminium alloy and A356.2/RHA (rice husk ash) composites was studied by Sivaprasad et al. (2012) and observed that A356.2/RHA composites exhibit higher hardness and resistance to wear as compared to un-reinforced Al alloy. Kumar et al. (2008) investigated the dry sliding wear behavior of AA7075 Al/SiCp composites and the effects of volume percentage of reinforcement, particle size of reinforcement, sliding speed, applied load and hardness of counter-part materials on wear rate was studied.

The tribological behavior of the B₄Cp/Al–12% Si chilled composites (with 3 to 12 vol% B₄C in steps of 3 vol%) was studied under dry sliding conditions and observed that the wear resistance, hardness and strength of the chilled composites increases with the increase in reinforcement content (Hemanth, 2005). The wear behavior of Al- B₄C and Al-SiC composites fabricated by stir casting method was investigated by Shorowordi et al. (2006) and reported that the wear rate of Al- B₄C is lower than the Al-SiC composites. The effect of B₄C volume fraction, applied load, sliding velocity and sliding distance on wear behavior of AlSi9Cu3Mg - B₄C composites was studied by Toptan et al. (2012).

The present work is aimed to manufacture the Al-Si/ B₄C composites with different weight fraction of B₄C through stir casting process and investigate the effect of B₄C content on wear rate and friction coefficient.

**EXPERIMENTAL WORK**

**Materials**

In the present study the aluminium-silicon alloy is selected as base material which is designated as LM6. The Al-Si alloy is actually a eutectic alloy having the lowest melting point that can be seen from the Al-Si phase diagram. Boron carbide particles of 30 microns average size with 2.52 g/cm³ density were mixed with Al-Si alloy with 2.5, 5 and 7.5 wt.% of reinforcement content. The chemical analysis of Al-Si alloy was done by Optical Emission Spectrometer and is given in Table 1.

**Fabrication of Composites**

The fabrication of Al-Si/B₄C composites was carried out by stir casting process. Boron carbide particles were preheated at around 800 °C for 2
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