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STUDY OF WEAR BEHAVIOR OF AS CAST TIC/7075 COMPOSITE

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ABSTRACT

Aluminum alloy 7075 reinforced with *in situ* 3 wt. % TiC particles was synthesized successfully by using reaction technique. The produced composite has shown a significant enhancement in mechanical properties in comparison to the base alloy. The wear behavior of both composite and base alloy at 5, 10 and 20 N was studied. At normal load of 5 N, the wear resistance of composite was higher than that of the base alloy. The wear rate increased with the increase on applied load.

KEYWORDS: Study of Wear Behavior of As Cast Tic/7075 Composite

INTRODUCTION

Aluminum alloys are the most widely used non ferrous materials in engineering applications owing to their attractive properties such as high strength to weight ratio, good ductility, excellent corrosion resistance, availability and low cost (1). However, their applications have often been restricted because conventional aluminum alloys possess poor wear resistance. On the other hand, Aluminum alloy matrix composites are known to offer better wear resistance and bulk mechanical properties. In addition, these composites exhibit high stiffness coupled with superior strength. This suite of properties makes the reinforced aluminum metal matrix composites (MMCs) attractive to a wide range of applications in aerospace, automotive, military and transport industries (2,3). Carbides, nitrides, borides, oxides and different intermetallics compounds have been used extensively as reinforcing materials for aluminum matrix composites (4,5). SiC and$Al_2O_3$are the most commonly used ceramic reinforcements in aluminum alloys(6). Recently Ni Al, Ni_3 Al and intermetallics compounds have been shown to improve the wear resistance of aluminum and magnesium alloys to a level similar to that of SiC reinforced composite, whilst reducing counter face wear rates (7-9). Conventional practice of developing aluminum based composites reinforced with hard ceramic particles involves ex situ technique. It involves addition reinforcement particles into the molten matrix alloy using liquid metallurgical route, which could lead to segregation of reinforcement particles and poor adhesion at interface, unless good wetability between the matrix and particles exists or suitably modified (10,11).

Recently, in situ technique has been developed to fabricate metal matrix composites (MMCs), which exhibits a clean matrix/reinforcement interface, and consequently leads to better improvement in mechanical properties of the composites (12). In in situ process ultrafine ceramic particles are formed by exothermic reaction between elements or their compounds with molten matrix alloy (13,14). The in situ technique provides advantages such as uniform distribution of reinforcement, finer particle size, clean interface, thermodynamically stable reinforcement phase and process economy in comparison with the conventional ex situ processes. These advantages will lead to better and improved mechanical and tribological properties [15].

TiC was not investigated enough as a ceramic reinforcement to aluminum alloys, however it is particularly attractive because its high melting temperature (3160º C), low thermal coefficient of expansion, extraordinary hardness, high elastic modulus excellent wear and abrasion resistance [14,16,17]. TiC is also relatively inexpensive and exhibits good wetting characteristics in molten aluminum. Tone [18] found that TiC phase in TiC/Al composites has a coherent or near coherent interface with α-Al and that the TiC particles may act effectively as active nucleation sites of α-Al during solidification.

7075 aluminum alloy has some advantages compared to pure aluminum since the presence of elements such as Zn and Mg can significantly reduces surface tension of molten aluminum alloys [19,20] , which is beneficial for reducing the contact angle between the second phase (reinforcement phase) particles and the matrix. Moreover, the 7075 aluminum alloy is considered a high strength alloy and can be heat treated and therefore the properties of composite material can be further improved. The present work is aimed to investigate the influence of in situ TiC particulates on the microstructure and wear resistance of 7075 aluminum alloy.

EXPERIMENTAL PROCEDURES

Elemental Ti (200 mesh, 97 % purity), graphite (200 mesh, 99 % purity), and Al (200 mesh, 97 % purity) were dry mixed in a gate mortar to produce a powder mixture of 95 wt % TiC and 5 wt % Al. After mixing, the powder mixture was mechanically pressed into cylindrical compacts with 24 mm in diameter and 20 mm in height at pressure 40 MPa. using a universal tensile compression machine.

Adequate weights from high purity Al, Mg, Zn and Al-Cu master alloy were melted in a crucible furnace to produce 7075 Al alloy with the composition given in **Table 1**.

Table 1: Chemical Composition (wt%) of Prepared 7075 Al Alloy

Zn	Mg	Cu	Al
5.9	2.2	1.4	Balance

The melt was superheated at1173 K, then the 95 % TiC + 5 %Al compacts were inserted into the molten alloy in the amount adequate to produce 4 % TiC composite alloy and kept at this temperature for 20 minutes. the melt was poured in a 11 × 60 × 140 mm^3steel mold.

The microstructure was examined by Meiji optical microscope fitted with a digital camera. The specimens for microstructure examination were prepared by standard metallographic procedures according to Standard ASTM E3-11,then etched in a solution of mixed acids (2 ml HF+3ml HCl+5ml HNO_3 + 250 ml H_2O).

Additionally, hardness measurements were carried out according to standard ASTME348-11 using LECO Vickers Micro-Hardness Tester LV800AT.

Dry sliding wear tests were carried out using a pin-on-disc machine. Test pins of 12 ×12 × 30 mm^3were held against a rotating heat-treated tool steel disc. The applied load was varied from 5 to 20 N. The weight loss during wear testing was measured using a micro-balance with a resolution of ±0.1 mg.

RESULS AND DISCUSSIONS

Microstructure

Figures 1 and 2 show typical microstructure of the as-cast 7075 aluminum alloy and3 wt.% TiC/7075 composite respectively. It is obvious that the grain size of the composite (60 µm) is smaller than that of the alone 7075 alloy (91 µm). This is because the fine solid TiC particles serve as sites for heterogeneuous nucleationand consequently decrease effectively the growth rate of the grains during the solidification process. It is also obvious that the as cast 7075 alloy has dendritic structure which is nearly transformed to equiaxed grain structure for3 wt.% TiC/7075 composite confirming the transformation from homogeneous nucleation for 7075 alloy to heterogeneuous nucleation for 3 wt.% TiC/7075 composite. This besides the presence of unwanted rectangular strips of Al_3Ti phase with a mean width of 15 µm in the formed 3 wt.% TiC/7075 composite. X-ray analysis confirmed the presence of TiC and Al_3Ti phases in the composite.

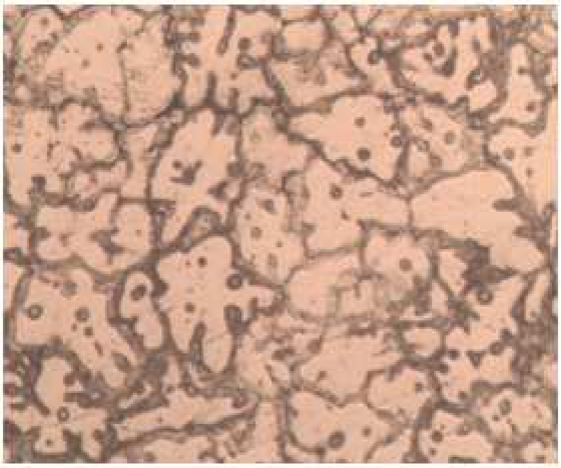

Figure 1: Microstructure of as Cast 7075 Aluminum Alloy (X 200)

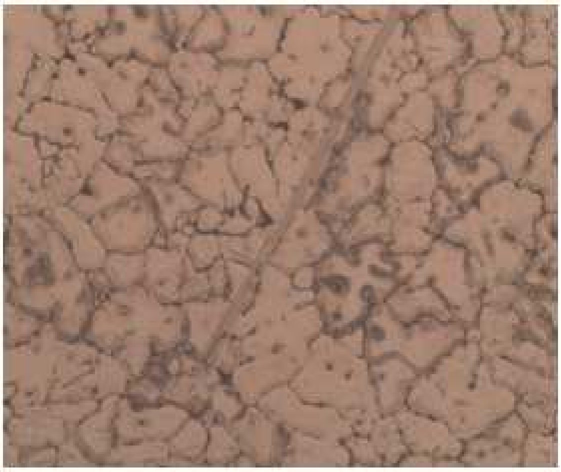

Figure 2: Microstructure of as Cast 3 wt. % TiC/7075 Composite(X 200)

Microhardness

Table 2 gives the microhardness values for both the as-cast 7075 aluminum alloy and 3 wt.%TiC/7075 composite. The increase in hardness of TiC/7075 composite is attributed to the effect of both TiC reinforcement and grain refinement.

Table 2: Microhardness Values of 7075 Al Alloy and 3 wt.% TiC/7075 Composite

Material	7075 Aluminum Alloy	3 wt.% TiC/7075 Composite
Microhardness value, Hv	57	81

Wear Behavior of the As-Cast 7075 Aluminum Alloy and 3 wt.% TiC/7075 Composite

Figure 3 shows the weight loss at different times due to wear at 1140 rpm and load 5 N for the as-cast 7075 aluminum alloy (cast 1) and 3 wt.% TiC/7075 composite (cast 4). Under these conditions the wear resistance of the as cast composite (cast 4) was significantly higher than that of the as cast 7075 Al alloy.

Figures 4 and 5 show the micrographs of the worn surfaces of both 7075 aluminum alloy (cast 1) and 3 wt.% TiC/7075 composite (cast 4) at 1140 rpm and load 5 N respectively. It is clear that the grooves on the worn surface of the 7075 aluminum alloy were wider compared to those of 3 wt.% TiC/7075 composite. This besides great plastic deformation

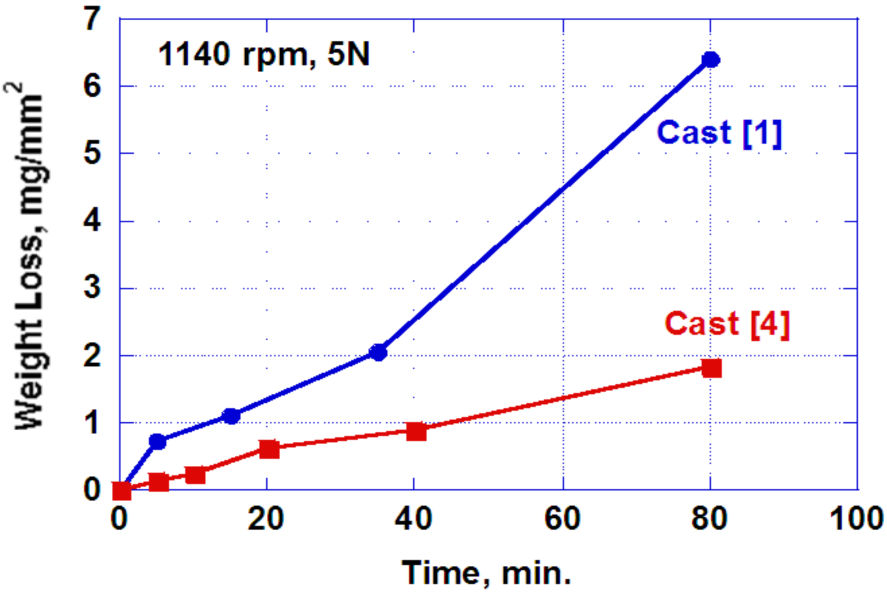

Figure 3: Weight Loss at Different Times Due to Wear at 1140 rpm and Load 5 N for the as-Cast 7075 Aluminum Alloy and 3 wt.% TiC/7075 Composite

Figure 4: Photomicrograph of Worn Surface of 7075 Aluminum Alloy at 1140 rpm and Load 5 N after 80 min

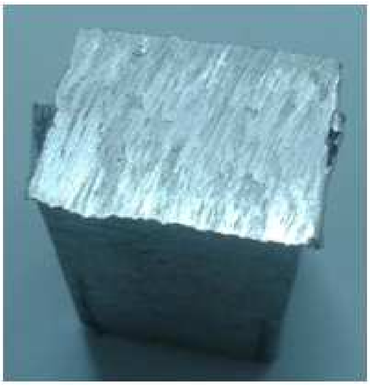

Figure 5: Photomicrograph of Worn Surface of 3 wt.% TiC/7075 Composite at 1140 rpm and Load 5 N after 80 min

occurred on TiC/7075 composite. Consequently the higher wear resistance of composite (cast 4) is attributed to both its higher hardness as shown in **Table 2** and the significantly greater plastic deformation occurred on it during wear as shown on **Figure 5**.

Figure 6 shows the weight loss due to wear at different loads at 1140 rpm and after 10 minutes for the as-cast 7075 aluminum alloy (cast 1) and 3 wt.% TiC/7075 composite (cast 4).Generally the weight loss increased with the increase on applied load for both 7075 aluminum alloy and TiC/7075 composite. For TiC/7075 composite, it initially increased slowly with increasing load from 5 to 10 N followed by higher increase at higher loads. At 5 N, the wear resistance of TiC/7075 compositewas higher than that of 7075 aluminum alloy, while at 10 and 20 N the wear resistance of 7075 aluminum alloy was the higher.This is because at lower loads (below 5 N), the TiC particles act as load supporting elements which are useful for preventing the softer aluminum matrix from becoming directly involved in the wear process(14,-21-23). With increasing load, the TiC particles tend to fracturing when the load reached above critical value. Concurrent with the TiC particle fracture, large strains were generated within the Al matrix adjacent to the contact surfaces. This led to subsurface crack growth and delalmination(24).Such subsurface cracks were observed on the 3 wt.% TiC/7075 composite (cast 4) after wear for 10 min. at 1140 rpm and applied load of 20 N. as shown in **Figure 7**. On the other hand as shown in **Figure 8**, significant plastic deformation without any subsurface cracks was observed on 7075 aluminum alloy (cast 1) under the same conditions.

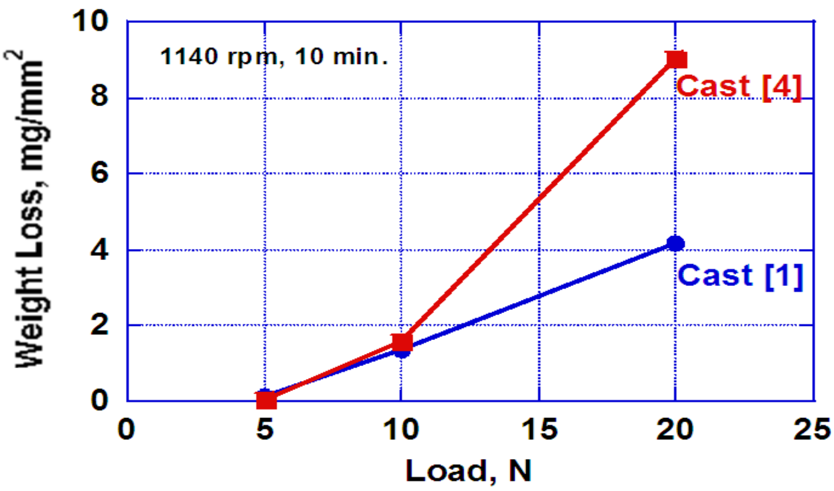

Figure 6: Weight Loss Due to Wear at Different Loads at 1140 rpm and after 10 Minutes for the as-Cast 7075 Aluminum Alloy (Cast 1) and 3 wt.% TiC/7075 Composite (Cast 4)

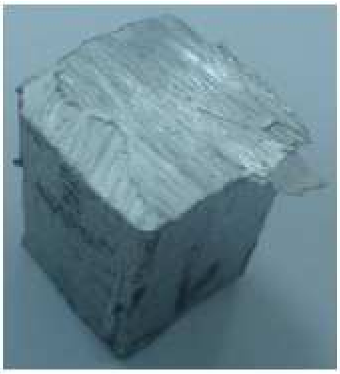

Figure 7: Photomicrograph of Worn Surface of 3 wt.% TiC/7075 Composite at 1140 rpm and Load 20 N after 10 Min

Figure 8: Photomicrograph of Worn Surface of 3 wt.% TiC/7075 Composite at 1140 rpm and Load 20 N after 10 Min

CONCLUSIONS

- A reaction technique, with which TiC particles are formed by *in situ* reactions in matrix melt, has been successfully applied to produce 3 wt. % TiC/7075 composite.
- The as cast 7075 alloy has dendritic structure which is nearly transformed to equiaxed grain structure for 3 wt.% TiC/7075 composite.
- The grain size of the 3 wt. % TiC/7075 composite (60 μm) was smaller than that of the alone 7075 alloy (91 μm).
- At normal load of 5 N and 1140 rpm, the wear resistance of the as cast 3 wt. % TiC/7075 composite was significantly higher than that of the as cast 7075 Al alloy.
- The wear rates of 7075 Al alloy and 3 wt. % TiC/7075 composite increased with applied load.

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