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# Tribological behavior of squeeze cast aluminum matrix composites

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**Abstract**

Tribological behavior of squeeze cast aluminum alloy (2618, 6082, 7012 and 7075) matrix SiC particle-reinforced (50 vol.%) composites was examined using a reciprocating wear tester by rubbing a 10 mm diameter $Al_2O_3$ ball on the composite surfaces in air and in water. Wear tests conducted in air revealed that, at low test loads (≤3 N), the tribological performance of the composites were not remarkably influenced by the properties of the matrix alloy. At high test loads (≥4.5 N), where 7012 and 7075 aluminum alloy matrix composites exhibited superior tribological performance relative to 2618 and 6082 aluminum alloy matrix composites, the wear rate and coefficient of friction decreased with increasing matrix hardness. When compared to the sliding conditions during testing in air, the coefficient of friction and the wear rate of the composites were dramatically lower in water. Even at test loads as high as 24 N, tribological performance of composites tested in water was comparable to that of in air low load (≤4.5 N) testing conditions.

*Keywords:* Aluminum matrix composite; Coefficient of friction; Tribological behavior; Water; Wear

## 1. Introduction

Aluminum matrix composites, which are produced through the incorporation of hard ceramic particles in aluminum or its alloys, offer attractive properties for many engineering applications [1–6]. Among the group of hard ceramic particles available for use, SiC particles have been found to have excellent compatibility with aluminum matrices [7–9] and can be obtained at a low cost [10,11]. Depending on the volume fraction and the size of the SiC particles, as well as the type and state of the aluminum alloy acting as the matrix, composites offer attractive properties for weight-critical applications in the aerospace industry, and more recently in the automotive industry, due to their excellent combination of high specific strength and enhanced wear resistance [9,12,13].

Most of the available literature on the wear of aluminum matrix composites pertains to dry (in air) sliding conditions. It has been reported that reinforcement particles increase the wear rate of the mating counterface due to their abrasive action, and thus, reduce the overall wear resistance of the tribo-system while improving the wear resistance of the composites [14–16]. On the other hand, some authors have noted that [15,17,18], above a critical contact pressure, aluminum matrix composites may offer little improvement in wear resistance compared to monolitic matrix alloys under dry sliding conditions.

For sliding contacts where high friction and wear are undesirable in the tribo-system, the use of a lubricant becomes necessary [19,20]. The idea of lubrication involves the separation of moving surfaces by a lubricant film. In this case, the load is carried by pressure generated within the lubricant film, and resistance to friction is reduced by easy shearing of the lubricant film. However, leakage of oil from lubrication systems (i.e. journal bearings or mechanical seals) leads to pollution of the natural environment. Detrimental effects of oil on the environment can be eliminated by using water rather than oil in lubrication systems. Promising results have been obtained from $Si_3N_4$ and SiC-based ceramics, which tend to form a thin viscous film at the contact surfaces during sliding wear conditions in water [21–23].

In the present study, the tribological performance of SiC particle-reinforced aluminum matrix composites has been examined in air and in water. Many studies have demonstrated the improved sliding wear properties of SiC-reinforced aluminum matrix composites in air for SiC volume fractions of less than 30 vol.%; however, this study has focused on the tribological performance of high volume fraction (≥50 vol.%) SiC particle-reinforced aluminum matrix composites. For the wear tests

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Table 1
The chemical composition of the aluminum alloys used in this study

| Matrix alloy | Zn (wt.%) | Mg (wt.%) | Cu (wt.%) | Si (wt.%) | Fe (wt.%) | Mn (wt.%) | Ni (wt.%) |
|---|---|---|---|---|---|---|---|
| 2618 | 0.04 | 1.91 | 2.34 | 0.44 | 0.94 | – | 1.05 |
| 6082 | 0.10 | 1.70 | 0.02 | 1.11 | 0.34 | 0.45 | – |
| 7012 | 5.40 | 2.33 | 0.99 | 0.33 | 0.21 | 0.10 | – |
| 7075 | 4.88 | 2.84 | 1.54 | 0.37 | 0.30 | 0.04 | |

conducted in water, attention is devoted to the contribution of the SiC particles on tribological performance of the composites, even though water may have some corrosive effect on the aluminum matrix. In fact, wear [14–18] and corrosion [24–30] behavior of SiC reinforced aluminum matrix composites are separately available in the literature, published works dealing with corrosion and/or wear in water are rather limited in number [31]. Although the interaction between corrosion and wear is of utmost importance for engineering applications, corrosion of the aluminum matrix in water has not been examined in this work.

## 2. Experimental procedure

Disc-shaped composites having a 50 mm diameter and 15 mm thickness were produced using a squeeze casting technique [32]. As the matrix, 2618, 6082, 7012, and 7075 aluminum alloys having compositions as listed in Table 1 were utilized. Magnesium was added to these alloys at a fraction of 1 wt.% before casting to improve the wettability between the melt and the SiC particles [33–35]. Abrasive grade green SiC particles having a mean particle size of 30 μm were used as the reinforcement. Forty-five grams of aluminum alloy and 45 g of SiC particles were utilized to manufacture disc-shaped composites.

Before processing, the mold and the SiC particles were heated to 300 and 1000 °C, respectively. The aluminum alloy, melted at 800 °C, was poured into the pre-heated mold immediately after transferring the pre-heated SiC particles. Subsequently, 600 MPa pressure was applied on the mixture by a hydraulic press.

Macroscopic and microscopic examinations (Fig. 1) revealed that the distribution of SiC particles was homogenous throughout the thickness of the discs [32]. On the cross-section macro-structures (Fig. 1a) SiC free regions, which would appear in characteristic light color of aluminum, were not detected. Microstructure examinations conducted at the various regions of the cross-section revealed that SiC particles were not compacted, where as the aluminum matrix was continuous. This arrangement can be characterized by a network structure of the aluminum matrix along with discontinuous SiC particles. Even at higher magnifications there were no evidence of either porosity or local discontinuity between the matrix and the SiC particles. The volume fraction of the SiC particles was measured to be approximately 50 ± 3 vol.% by linear intercept method, regardless of the type of matrix [32].

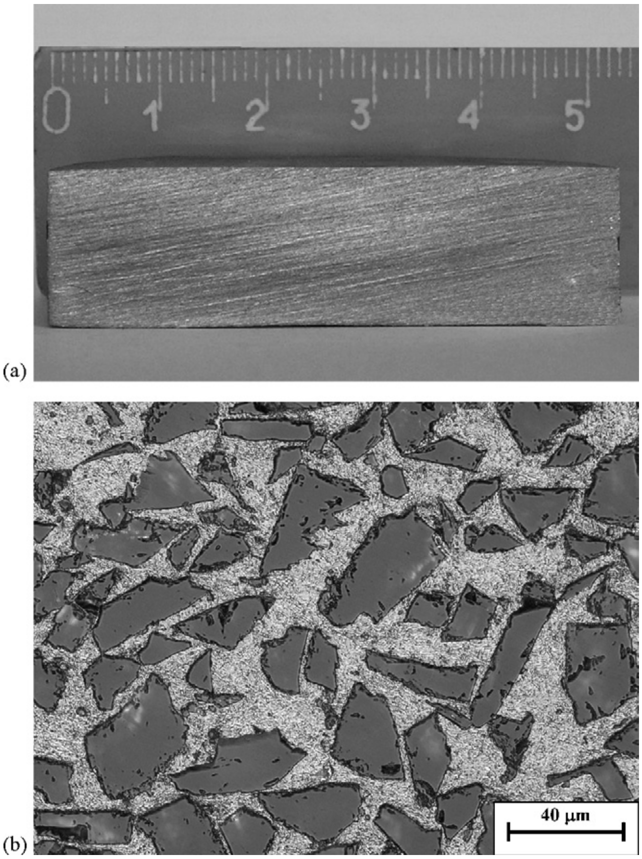

Fig. 1. Representative (a) macro- and (b) micro-structures of as-cast composites utilized in this study.

In the scope of the present study, composites were tested in as-cast and T6-treated states. The procedures of the applied T6-treatment are given in Table 2. Although the volume fraction of the SiC particles of the examined composites are at the same level (50 vol.%), their hardness values (Table 3) varied over a

Table 2
T6-treatment procedure applied to the examined composites

| Matrix alloy | T6-treatment route |
|---|---|
| 2618 | Solutionizing at 530 °C for 2 h + quenching in water + ageing at room temperature for 48 h + ageing at 175 °C for 13 h |
| 6082 | Solutionizing at 540 °C for 2 h + quenching in water + ageing at 170 °C for 12 h |
| 7012 and 7075 | Solutionizing at 480 °C for 2 h + quenching in water + ageing at room temperature for 48 h + ageing at 125 °C for 12 h |