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Effect of friction stir processing on corrosion of Al-TiB2 based composite in 4.5wt% sodium chloride solution

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Abstract:

The impact of solution heat-treatment and alumina volume percentage on the corrosion behavior of Al (6063) composites and its monolithic alloy in settings with acidic, basic, and salt water is looked into. Using two-step stir casting, Al (6063) - TiB2 particulate composites with volumes of 6, 9, 15, and 18 percent alumina were created. The corrosion behavior of the composites was assessed using measures of mass loss and corrosion rate. Al (6063) – TiB2 composites were found to have superior corrosion resistance in NaCl medium. In NaCl media, the unreinforced alloy showed marginally greater corrosion resistance than the composites, however, the composites showed improved corrosion resistance. Furthermore, while the effect of volume percent alumina on corrosion resistance did not follow a consistent pattern, solution heat-treatment enhanced corrosion resistance for both the composites and the unreinforced alloy.

Keywords: Stir casting; Al (6063) – TiB2 composite; solution heat-treatment; Corrosion rate; mass loss

INTRODUCTION

Materials engineers in poor nations are showing a great deal of interest in the development of Al-based metal matrix composites [1]. The low cost of aluminum-based alloys relative to other possible metal matrices and the variety of properties they offer—such as enhanced wear and abrasion resistance, controlled thermal expansion coefficient, high specific strength and stiffness, and improved high temperature properties—are the main reasons for this interest [2-4]. The majority of studies on Al-based matrix composites that have been published in the literature have focused on the 2XXX and 6XXX series. Al-Mg-Si alloys in the 6XXX series are frequently employed as medium strength structural alloys because of their excellent weldability, resistance to corrosion, and resistance to stress corrosion cracking [5–6]. Nevertheless, the application of Al (6063) alloy as a metal matrix has received very little attention [6]. The majority of developing nations can process large amounts of Al (6063) alloy at a reasonable cost, which contributes to the present interest in the alloy's potential for the production of metal matrix particle composites based on Al. The goal of the experiment is to evaluate the alumina reinforced Al (6063) matrix composites' corrosion resistance in conditions that are acidic, salty, and basic and that are typical of service / industrial processing atmospheres [10].

MATERIALS AND METHOD

Materials

Alumina (Al2O3) particles with a particle size of 28 m and aluminum 6063 alloy, which served as the matrix, were used as the materials in the current investigation. Table 1 provides the breakdown of the aluminum 6063 alloy's chemical makeup.

Table 1. Chemical Composition of Aluminium 6063 Alloy

Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
0.45	0.22	0.02	0.03	0.50	0.02	0.03	0.02	Bal.

Stir Casting

Charge calculations were used to determine the amount of aluminum alloy (6063) and al2o3 particles needed to create composites with 6, 9, 15, and 18 volume percent alumina. In order to enhance wettability with the Al (6063) alloy, the alumina particles were first warmed at a temperature of 2500C for 5 minutes. A gas-fired crucible furnace containing ingots of the alloy Al (6063) was charged with the alloy, which was heated to a temperature of 750°C ±30°C (above the alloy's liquidus temperature), and then allowed to cool in the furnace to a semi-solid state at a temperature of roughly 600°C. At this temperature, the preheated alumina was added, and the slurry was manually stirred for five minutes. After that, the composite slurry was heated to 7200C and given another stirring with a mechanical stirrer. To help increase the distribution of the alumina particles in the molten Al (6063) alloy, the stirring operation was carried out for 10 minutes at a speed of 300 rpm. The molten mixture was then poured into sand molds that had been created. For control experiments, Al (6063) alloy without reinforcement was also made.

Solution Heat-treatment

The as-cast condition and the solution heat-treated condition were the two temper conditions used in this study. The samples were solutionized at 550°C for 4 hours to complete the solution heat treatment, and they were then quenched in water.

Solution Preparation

In line with Yussof et al. [11], a 3.5 wt% NaCl solution was prepared to replicate an aggressive marine environment. 210 grams of solid sodium chloride were dissolved in 6000 cm3 of deionized water to create the solution. The pH 0.9 solution of 0.3MH2SO4 was used as a benchmark for an acidic environment. The 0.3MH2SO4 solution was made by mixing 6000cm3 of deionized water with 97.8cm3 of concentrated H2SO4 with a specific density of 1.84 and 98% purity. Using 24 grams of solid NaOH and 6000 cm3 of deionized water, a basic environment of 0.1M NaOH solution was also created.

Immersion Test

The corrosion experiments were conducted in solutions of 0.3M H2SO4 (pH 0.9), 0.1M NaOH (pH 12.7), and 3.5wt% NaCl (pH 7.4) that were made in accordance with established practices. The test specimens were cut to a 20x20x5mm size, and then the sample surfaces were mechanically polished with emery papers ranging in size from 120grit to 640grit. The samples were cleaned with acetone, washed in distilled water, and then immersed in prepared still solutions of 3.5 weight percent NaCl, 0.3 mass percent H2SO4, and 0.1 mass percent NaOH, all of which were exposed to ambient air. The surface area ratio of the solution to the sample was roughly 150 ml cm-2. By measuring mass loss and the rate of corrosion at intervals of two days, the outcomes of the corrosion tests were assessed. The samples spent 40, 29 and 45 days, respectively, in the acidic, basic, and alkaline conditions. According to ASTM standard recommended practice ASTM G31 [12], mass loss (measured in mg/cm2) for each sample was calculated by dividing the weight loss (measured using a four decimal digit electronic weighing scale) by its entire surface area. Following accepted practices, the corrosion rate for each sample was assessed via weight loss measurements.

RESULTS AND DISCUSSION

Corrosion Behaviour in 4.5wt% NaCl Solution

The mass loss and corrosion rate charts for the as-cast and solution heattreated samples submerged in the 3.5wt% NaCl solution are shown in Figures 1 and 2. Figure 1 shows that in the as-cast condition, the corrosion rates of both the unreinforced alloy and the alumina reinforced composites were typically very low (less than 0.1mmpy). This shows that the passive films generated on the surfaces of both the unreinforced alloy and the composites when submerged in a 4.5wt% NaCl environment are reliable and resistant to damage. This is a definite sign that the composites will work well in marine settings. However, the mass loss profiles (Figure 1b) demonstrate that the composites have somewhat worse corrosion resistance than the unreinforced alloy (as indicated by the relatively lower weight gain values). Similar trends in alumina fiber reinforced aluminum composites have been confirmed by Zhu and Hihara [13]. They explained these trends as being caused by corrosion preferentially starting at the alumina/aluminum matrix contact. The composites showed nearly the same levels of corrosion resistance, making it difficult to discern the effect of alumina volume percent on the corrosion properties.

In compared to the composites as-cast (Figure 1), solution heat-treatment (Figure 2) is shown to result in a small improvement in the composites' corrosion resistance, especially for the 15 and 18 volume percent alumina reinforcement. The enhanced alumina particle dispersion in the Al (6063) matrix and the dissolution of second phase particles in the unreinforced alloy are responsible for the small improvement in corrosion resistance [14].

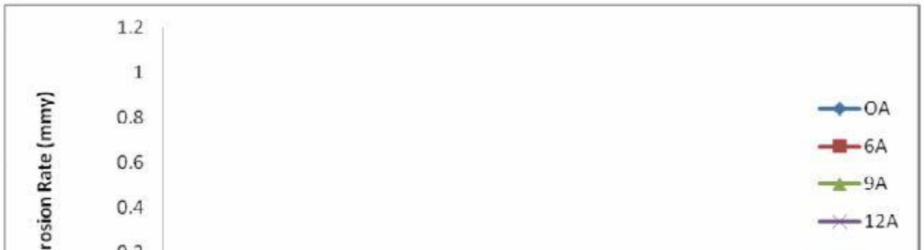

Figure 1a Variation of corrosion rate of as-cast samples in 4.5%NaCl

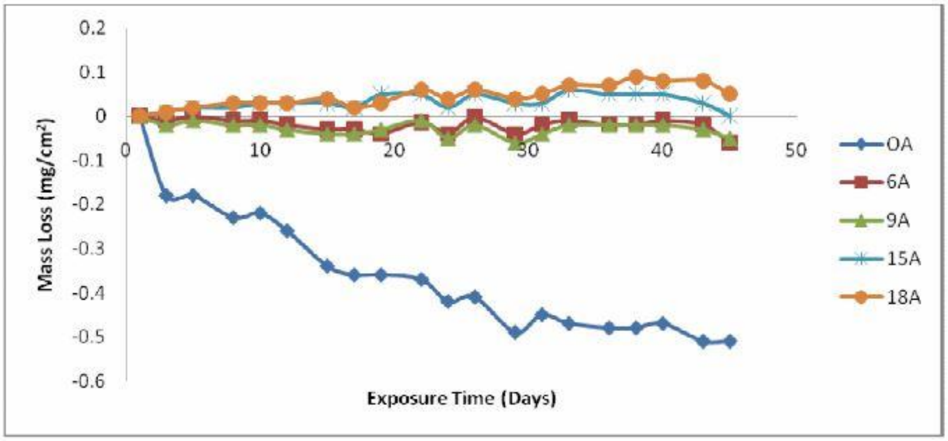

Figure 1b Variation of corrosion rate of as-cast samples in 4.5%NaCl

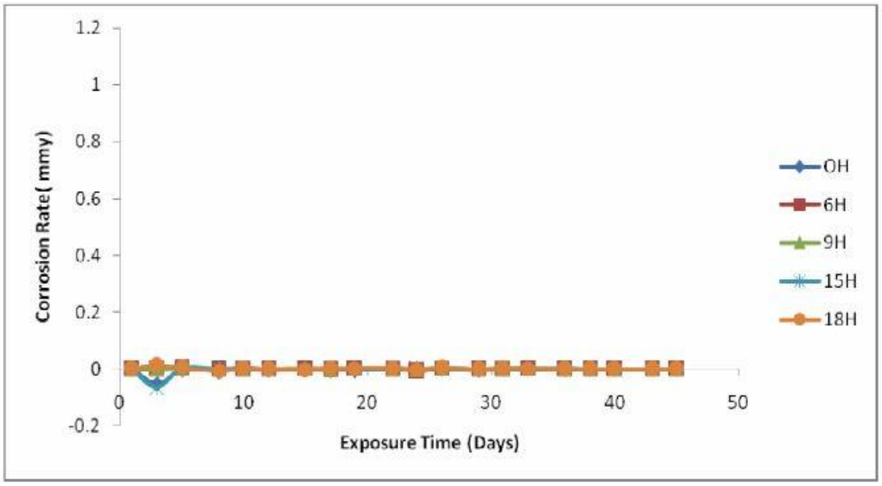

Figure 2a. Variation of corrosion rate of solution-heat treated samples in 4.5%NaCl

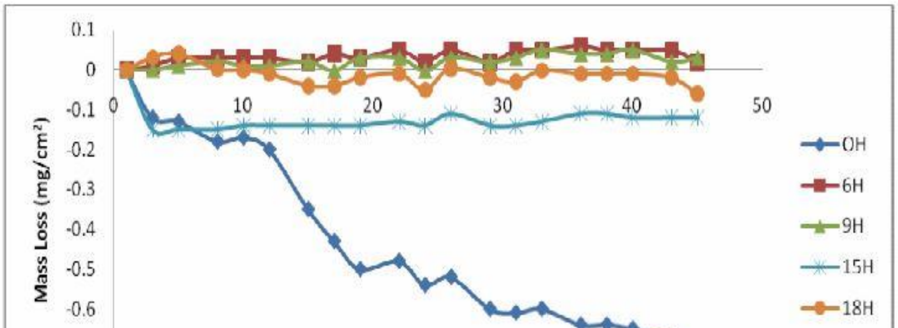

Figure 2b. Variation of mass loss of solution-heat treated samples in 3.5%NaCl

CONCLUSION

In the study, the corrosion behavior of the composite AA6063/Al2O3p in NaCl, NaOH, and H2SO4 was examined. According to the findings, Al (6063)-Al2O3 composites showed superior corrosion resistance in NaCl medium compared to NaOH and H2SO4 medium. In NaCl and NaOH media, the unreinforced alloy showed marginally greater corrosion resistance than the composites, but the composites had better corrosion resistance in H2SO4 media.While the effect of volume percent alumina on corrosion resistance did not follow a consistent pattern, solution heat-treatment enhanced corrosion resistance for both the composites and the unreinforced alloy.

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