Electrochemical behavior of Al-SiC metal matrix composites

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Abstract

Silicon carbide particulate - reinforced aluminum (SiC-Al2014) composites possess an exceptional combination of high specific strength, high elastic modulus, good wear resistance and good thermal stability than the corresponding non-reinforced matrix alloy systems. These composites are prospective structural materials for aerospace and automotive applications. Morphological analysis was conceded by using SEM. The foremost snag of aluminium matrix composite is low resistant to corrosion compared to the Al base alloys. The surface is treated with a protective oxide surface film which imparts greater corrosion resistance. The existence of reinforcing phase in the composite material can lead to heterogeneities thereby causing discontinuities in the surface film and increasing the number of active sites available for corrosion to take place. The attack is more aggressive in acidic medium. Hydrochloric acid solutions are largely used for pickling, chemical and electrochemical etching and in various chemical process industries. It became more important to use corrosion inhibitors to protect aluminium alloy composite material against excessive corrosion. In the present work, inhibitive action of the corrosion behavior of Al2014-SiC composite in 3.5% NaCl solution (for Various Exposure Time) has been investigated using weight loss method.

Keywords: Al2014, SiC, SEM, Wear, Weight Loss Method

1. INTRODUCTION

Aluminium matrix composites (AMCs) have significant potential for military, automobile and aerospace applications because of their low density, high strength and high stiffness [1-6]. Further, the addition of ceramic reinforcements (SiC) has elevated the performance limits of the Al (6061) alloys [7]. It is recognized that aluminum matrix composites unveiled enhanced resistance to mechanical wear than their base alloy and hence they have excessive specific strength for numerous weight sensitive applications [8, 9]. One of the key drawbacks in the use of metal matrix composite is the impact of reinforcement on corrosion percentage. This is mostly significant in aluminum alloy based composites, where a protective oxide film imparts corrosion resistance. The addition of a reinforcing phase could lead to discontinuities in the film, thereby growing the number of sites where deterioration can be initiated and creating the composites more susceptible for corrosion [10]. Due to the extensive applications of such composites, they often come in contact with acid during cleaning, pickling, descaling, etc. Hence studying their corrosion performance in acid medium is of prime importance. Nevertheless, a significant amount of efforts has been expended to recognize the corrosion behavior of these composites, the results are not matching since the corrosion resistance of these composites differ with processing methods, type of reinforcements and particulate size of the reinforcements. Studies on the deterioration performance of 6061Al-SiC composites in hydrochloric acid medium and controlling the corrosion by using inhibitors have been reported [11, 12]. Hydrochloric and sulphuric acid solutions are used for pickling, chemical and electrochemical etching and in several chemical process industries wherein aluminum composites are used.

Maximum corrosion studies steered with Al matrix composites have been focused on the corrosion susceptibility in NaCl solution, as well as pitting potential and pit morphology [13], [14], [15], [16], [17]. In this current investigation the static immersion corrosion behavior of Al2014-SiC MMCs in 3.5 wt.% NaCl solution at both ambient and elevated temperatures were considered.

2. EXPERIMENTAL ANALYSIS

The aluminum alloy AA2014 and SiC composite was received as extruded rod in extruded rod form (extrusion ratio 30:1). The various parameters derived from weight loss measurements, regarding the corrosion of composite in 3.5% NaCl solution at 24 hrs, 48 hrs and 72 hrs are summarized in Table 1, 2 and 3.

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Table 1. Corrosion parameters obtained from weight loss studied for Al2014-SiC in 3.5% NaCl at 24 hrs

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Table 2. Corrosion parameters obtained from weight loss studied for Al2014-SiC in 3.5% NaCl at 48 hrs

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Table 3. Corrosion parameters obtained from weight loss studied for Al2014-SiC in 3.5% NaCl at 72 hrs

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Reinforced SiC (average particle size is about 25 micron) has 99.8 percent transparency. Assessment slips of 1.1 cm and 1.0 cm diameter of the composite and base alloy, respectively, are arranged from the extruded rod and metallographically mounted up to 20 mm height by using cold setting resin. The exposed flat surface of the mounted part was polished with SiC papers to 4/0 grit level and later disc polished using alumina, degreased with acetone and washed with double distilled water and dried. A water thermostat was used to uphold the essential constant temperature. For microstructural interpretations, the sample surfaces were primed cautiously by polishing. The samples were polished using emery papers of grits 200, 400, 600, 800 and 1000. The fine polishing was consummate by expending a suspension of 1μm alumina powders in distilled water on a cloth secured to a rotating wheel. The alumina power is exceptional to eradicate the twin layers of metal. The samples were sensibly lapped to remove all abrasive after fine polishing. Exceptionally polished Al-SiC composite sample and its base alloy with 0.95 cm$^2$ and 0.79 cm$^2$ surface areas, respectively, were exposed to corrosion medium at different temperatures of 303 °K to 323 °K.

3. RESULTS AND DISCUSSION

The Taguchi’s response analysis was employed to determine the optimum level for the desired performance characteristics.

3.1 Weight loss Measurement

The corrosion behaviours of SiC-Al2014 composites are evaluated by immersing the samples in 3.5% NaCl solution. The weight loss rates of the two different materials were calculated from the weight loss per unit time and per unit area. Figures 3.1 to 3.3 illustrates the plots of corrosion rate versus temperature for composite in 3.5% NaCl at 308 0K. From the plots, Fig. 3.1, 3.2 and 3.3, it is very clear that the corrosion rate of composite in the different test solutions increases with temperature. It can be seen that the mass loss and corrosion rates of the two materials increase with an increase of temperature.

![Fig. 3.1](image1.png) Effect of concentration of Silicon Carbide on Corrosion rate of Aluminium2014 at 24 hrs.

![Fig. 3.2](image2.png) Effect of concentration of Silicon Carbide on Corrosion rate of Aluminium2014 at 48 hrs.

![Fig. 3.3](image3.png) Effect of concentration of Silicon Carbide on Corrosion rate of Aluminium2014 at 72 hrs.
3.2 Effect of concentration of the inhibitor on inhibition efficiency

Results presented in the tables 3.1-3.3 show that corrosion rates decrease in the presence of inhibitors corresponding to increase in inhibition efficiency. It can be realized from all tables and Figure 3.4 that the inhibition efficiency increases with increase in inhibitor concentration. This can be attributed to the adsorption of the inhibitors onto the Composite surface leading to corrosion inhibition phenomenon. Corrosion inhibition is initiated by the displacement of adsorbed water molecules by the inhibitor species leading to specific adsorption of the inhibitor on the metal surface.

3.3 Surface characterization

The corroded surfaces of the test samples are analyzed using a Scanning electron microscope (SEM). The specimens were exposed to corroding solutions for 240 minutes before they are examined. Figure 4 shows SEM micrographs of the fabricated SiC-Al2014 composites.

Figure 5 displays pictures of the surface of some corroded specimens investigated in this work. Visual inspection illustrates that the HCl solution has stronger effect on the surface of Al - based materials than the NaCl solution. Though, such kind of subjective judgment is rather essential, but at least it provides us a feeling of what is happening in the corrosion test. Throughout the test period and specifically in the initial periods, pitting corrosion is the foremost type of corrosion followed by formation of white and light-gray powder layers on the specimen surfaces. The amount of that powder was perceived significantly in the 3.5% NaCl solution. However, polished surfaces were obtained after the termination of the corrosion test in 3.5% NaCl as shown in Figure 5. In the HCl solution it was witnessed from various studies that continuous pitting corrosion of surface with decreasing corrosion rate owing to the etching effect of acidic solutions. The etched layer forms some anti-corrosion film which enhances corrosion resistance of interior matrix.
4. CONCLUSION

The major type of corrosion of aluminum-based materials in both solutions is pitting corrosion. In the current work, it was found that the addition of aluminum and silicon carbide into Al-4 wt.% Mg alloy tend to diminish the excellent corrosion resistance of pure aluminum in both acidic and alkaline media.

The accumulation of SiC particles will also lessen the corrosion resistance of Al-4 wt.% Mg alloy since it is hard to realize very good bond-ability between ceramic and metal. On the other hand, during corrosion tests in particularly both solutions, Al surface enrichment likely occurs by particle dissolution and de-alloying and possible de-alloying of the matrix phase. It was found that both Al-based alloys and their associated composites have fewer tendencies to corrode in HCl compared to NaCl environment. SEM examination indicates that the corrosion effect on the silicon carbide containing composites is more severe compared to corresponding Al-4 wt.% Mg-Cu alloys.

The reaction between the SiO2 layer on the surface of SiC and Al in the alloy melt improves the Cu/Mg ratio around the SiC particles. This allows the inhibition of the precipitation phase.

REFERENCES


