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Effect of La surface treatments on corrosion resistance of A3*xx.x*/SiC_p composites in salt fog

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Abstract

The influence of the SiC_p proportion and the matrix concentration of four aluminium metal matrix composites (A360/SiC/10p, A360/SiC/20p, A380/SiC/10p, A380/SiC/20p) modified by lanthanum-based conversion or electrolysis coating was evaluated in neutral salt fog according to ASTM B 117. Lanthanum-based conversion coatings were obtained by immersion in 50 °C solution of La(III) salt and lanthanum electrolysis treatments were performed in ethylene glycol mono-butyl ether solution. These treatments preferentially covered cathodic areas such as intermetallic compounds, Si eutectic and SiC_p. The kinetic of the corrosion process was studied on the basis of gravimetric tests. Both coating microstructure and nature of corrosion products were analyzed by scanning electron microscopy (SEM), atomic force microscopy (AFM), energy dispersive X-ray analysis (EDS) and low angle X-ray diffraction (XRD) before and after accelerated testing to determine the influence of microstructural changes on corrosion behaviour during exposure to the corrosive environment. The corrosion process was more influenced by the concentration of alloy elements in the matrix than by the proportion of SiC_p reinforcement. Both conversion and electrolysis surface treatments improved the behaviour to salt fog corrosion in comparison with original composites without treatment. Additionally, electrolysis provided a higher degree of protection than the conversion treatment because the coating was more extensive.

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Keywords: Aluminium; Silicon carbide; Composites; Lanthanum; Chemical conversion; Salt spray

1. Introduction

Al–Si casting alloys reinforced with SiC_p have emerged as a class of materials capable of advanced structural, aerospace, automotive, electronic and thermal management applications, due to recent advances in casting technology [1]. However, it was reported that they could undergo severe degradation, especially in aerated chloride containing environment [2].

While there is a wealth of information concerning the corrosion behaviour of Al alloys and methods of

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corrosion protection, relatively little is known about the corrosion behaviour and effectiveness of corrosion protection methods of Al MMCs [3]. The trend is to use the same type of coating or protection system as the one designed for aluminium alloys, however the efficiency of the system is always lower for composites [4].

Cr^{6+} compounds, mainly chromates, have been widely used as inhibitors or incorporated in anticorrosive pre-treatments of aluminium alloys due to their high efficiency/cost ratio. Unfortunately, hexavalent chromium is toxic and is environmentally unacceptable [5,6], and thus environmentally friendly replacements of hexavalent chromium have to be found [7].

According to Cohen [8], the development of viable alternatives to chromates is still at its infancy. One of the most promising systems is based on rare earth elements. Lanthanides ions, as Ce^{3+}, Y^{3+}, La^{3+}, Pr^{3+}, Nd^{3+} and Sm^{3+} forming insoluble hydroxides, have a low toxicity and their ingestion or inhalation is not considered harmful to health [9]. Furthermore, lanthanides can be considered economically competitive products since some of them are relatively abundant in nature [10].

The pioneering studies concerning the application of lanthanides for the corrosion protection of aluminium alloys are those by Hinton [11–15]. This author studied the effect of increasing the concentration of $CeCl_3$ on both uniform and pitting corrosion of AA7075 alloy. In spite of the efforts focused on the use of cerium other lanthanides also show promising possibilities, several researchers [7,16–19] demonstrated that treatments with aqueous solutions of rare earth salts (lanthanum, samarium, neodymium and yttrium) effectively inhibit the corrosion of aluminium alloys. Even, Montemor et al. report that pre-treatments based on $La(NO_3)_3$ seem to be slightly more effective than those based on $Ce(NO_3)_3$ or $Y(NO_3)_3$ [20,21].

Corrosion protection can be attributed to the formation of an oxide/hydroxide lanthanide on the metallic surface. In earlier studies the rare earth treatments were obtained by prolonged immersion in aqueous solutions. Unfortunately, such long time period make these immersion treatments commercially unattractive. Therefore, these treatments have mainly been improved by thermal [22–24] and electrochemical activation [25–26].

The treatments of surface modification with lanthanide elements allow protecting in a very effective way most of the aluminium alloys [27–30]. Nevertheless, there are few studies on MMCs protection, probably due to a major interest on the improvement of its mechanical properties.

The salt spray fog test is highly useful as an accelerated laboratory corrosion test that simulates the effects of marine environments on different metallic materials with or without protective coatings [31]. The conventional materials present an important grade of damage.

The object of this paper was to study the effect of La protection on corrosion behaviour of aluminium matrix composites (A360/SiC/10p, A360/SiC/20p, A380/SiC/10p, A380/SiC/20p) reinforced with SiC_p in high chloride concentration environments (salt fog). The effect of lanthanum protection, particle volume and concentration matrix on corrosion resistance was observed using gravimetric tests, scanning electron microscopy (SEM), atomic force microscopy (AFM), energy dispersive X-ray analysis (EDX), and low angle X-ray diffraction (XRD).

2. Experimental procedure

The materials used were A360 and A380 aluminium alloys reinforced with SiC particles. Unreinforced A361 cast alloy was used as reference. The samples were homogenized at 500 °C for 2 h and quenched in cold water. Matrix chemical compositions are shown in Table 1. Metallographic characterization was performed by conventional polishing and chemical attack in 0.5 wt.% HF.

The optimal variables for lanthanum-based conversion coatings were performed in the following sequence: (a) degreasing with isopropyl alcohol in an ultrasonic bath for 5 min at 25 °C; (b) immersion in 2000 ppm La ($LaCl_3{\cdot}7H_2O$) −3.5 wt.% NaCl solution for 1 h at 50 °C; (c) cleaning with water and drying for 30 min in a furnace at 105 °C. The optimal variables for electrolysis treatment followed the sequence: (a) degreasing with isopropyl alcohol in an ultrasonic bath for 5 min at 25 °C; (b) immersion in 75 vol.% ethylene glycol mono-butyl ether solution with 2000 ppm La ($LaCl_3{\cdot}7H_2O$) and 1.5 wt.% NaCl and application of a potential of