Available online at www.sciencedirect.com
ScienceDirect
Trans. Nonferrous Met. Soc. China 23(2013) 1199−1208
Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Effects of magnesium chloride-based multicomponent salts on atmospheric corrosion of aluminum alloy 2024

Bin-bin WANG, Zhen-yao WANG, Wei HAN, Chuan WANG, Wei KE

State Key Laboratory for Corrosion and Protection, Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, China

Received 28 March 2012; accepted 25 May 2012

Abstract: Atmospheric corrosion of aluminum alloy 2024 (AA2024) with salt lake water was simulated through a laboratory-accelerated test of cyclic wet-dry and electrochemical techniques. Effects of the soluble magnesium salt contained in the salt water were investigated by scanning electron microscope (SEM), transmission electron microscope (TEM), energy dispersive spectrometer (EDS), electron probe micro analyzer (EPMA), X-ray diffraction (XRD), infrared transmission spectroscope (IR), and atmospheric corrosion monitor (ACM). The results showed that, with the deposition, atmospheric corrosion of AA2024 could occur when the relative humidity (RH) was lower than 30%. A main crystalline component of corrosion products, layered double hydroxides (LDH), $[Mg_{1-x}Al_x(OH)_2]^{x+}Cl_x^-\cdot mH_2O$ (LDH-Cl), was determined, which meant that magnesium ion played an important role in the corrosion process. It not only facilitated the corrosion as a result of deliquescence, but also was involved in the corrosion process as a reactant.

Key words: aluminum alloy 2024; atmospheric corrosion; magnesium chloride; relative humidity; corrosion products

1 Introduction

Aluminum and its alloys have been extensively used in the fields of transport, building, aircraft and aerospace. In these fields, atmospheric corrosion will occur in various forms, which depends on the environmental conditions. In unpolluted atmosphere, aluminum and its alloys have good corrosion resistance. While, in polluted atmosphere, they will suffer severe corrosion, especially in marine environment with the deposition of chloride-aerosols which can cause severe damage to passive film formed on metal surface [1−5]. Various corrosion behaviors of aluminum and its alloys in marine atmosphere are always attributed to the high relative humidity and deposition of sea-salt particles [2].

Salt lakes are widely distributed in Western China. As well as the high chlorides deposition is concerned, these regions belong to an arid-climate region with small precipitation and large evaporation, and the annual relative humidity varies from 30% to 50%, or lower [6], which are different from desert atmosphere and marine atmosphere. With the deepening of the western development of China, the corrosiveness of arid and salt-rich atmosphere for common metals in basic construction has drawn enormous attention. It was reported that in arid and salt-rich atmosphere, aluminum and its alloys (like AA2024) suffered more severe corrosion than in marine environment and acid rain environment [7−10]. It is well known that due to the moisture absorption of polluted deposition like chlorides, it will facilitate the atmospheric corrosion in lower relative humidity [11,12]. Therefore, the serious corrosion behaviors of aluminum in arid and salt-rich atmosphere were attributed to the high salts deposited simply. However, in marine atmosphere with the similar deposition amount, the corrosion of aluminum was less serious. On the contrary, the corrosion rate of carbon steels in the arid and salt-rich atmosphere was much lower than that in marine atmosphere [7,13,14].

It was found that these regions were abundant in magnesium salt which was different from seawater [6,12]. However, investigations of the effects of cations like Mg^{2+} on the corrosion of metals were scarce. Furthermore, the laboratory studies performed in controlled environments presented discrepancy results

Foundation item: Project (51131007) supported by the National Natural Science Foundation of China
Corresponding author: Zhen-yao WANG; Tel: +86-24-23893544; Fax: +86-24-23893544; E-mail: zhywang@imr.ac.cn
DOI: 10.1016/S1003-6326(13)62584-4

about the effects of different cations, and the role of magnesium ions in the forming of corrosion products was not reported [12,15,16].

Considering the effects of chloride deposits on different metals and the previous studies, it is believed that some other factors influence the corrosion behavior of aluminum induced by the deposition in arid and salt-rich atmosphere. Firstly, in outdoor environments, salt particles deposited on the metal surface exist as aerosols which are multicomponent and mixed. The deliquescence and efflorescence behaviors of multicomponent mixed-salts are more complicated than those of single-component salt, which will significantly influence the time of wetness (TOW) on metal surface in arid atmospheric environment [17]. Secondly, when compared with the chemical synthesis of magnesium−aluminum layered double hydroxides (LDHs) according to a coprecipitation reaction, it was found that with magnesium chloride deposition, reaction conditions in atmospheric corrosion process of aluminum and aluminum alloys were similar to those in the coprecipitation reaction [18]. Thus, it is reasonable to postulate that magnesium salt plays an important role in the process of corrosion product formed.

In this work, the effects of magnesium chloride ($MgCl_2$)-based multicomponent mixed-salts on the TOW of atmospheric corrosion of AA2024 in low relative humidity environment and the role of magnesium ions in the process of corrosion product forming were investigated through galvanic current measurement and analysis of corrosion products, respectively.

2 Experimental

2.1 Materials preparation

Commercial AA2024-T3 plates were used for the test and their chemical compositions are given in Table 1. The sizes of samples were 100 mm×50 mm×0.9 mm. The alloy material was clad with a layer of aluminum for increasing the corrosion resistance. Thus, the layer was removed using 5% NaOH solution at 75 °C. The thickness of the samples without cladding was 0.7 mm. Prior to test, all the samples were degreased with acetone, rinsed using ethanol, and weighed (exactness 0.1 mg) by analytic balance after drying.

Table 1 Chemical compositions of AA2024-T3 (mass fraction, %)

Fe	Si	Cu	Mn	Zn	Mg	Al
0.50	0.50	4.18	0.30	0.30	1.30−1.80	Bal.

A copper−AA2024 coupled electrode with comb-like arrangement was used in galvanic current measurement. The schematic diagram of the monitoring electrode is shown in Fig. 1. Each metal slices of the electrode was 20 mm×5 mm×1.5 mm, and the insulating spacing between each slice was 300 μm. The electrode was mechanically ground down to 1000 grit SiC paper.

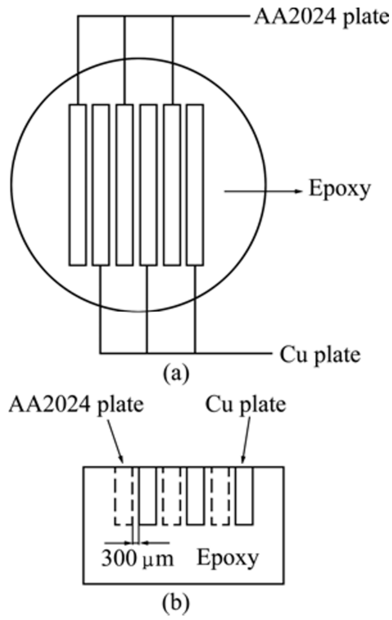

Fig. 1 Schematic of monitoring electrode: (a) Top view; (b) Transverse cross-sectional view

2.2 Simulated tests

2.2.1 Galvanic current measurement

In order to investigate the effect of salt-deposition on the time of wetness (TOW) of atmospheric corrosion of AA2024, the galvanic current of the electrode with $MgCl_2$-based multicomponent mixed-salts deposited was detected in different relative humidity (RH) environments varying from 10% to 80% using an atmospheric corrosion monitor. A WDB-5A aerosol sprayer filled with $MgCl_2$-based salt lake water was used to deposit micro-droplets on the electrode surface. The compositions of salt lake water are listed in Table 2. Then, the electrodes were put into a vacuum desiccator. After drying, salt particles were deposited on the electrodes with different amount (5 mg/cm^2 and 0.5 mg/cm^2). The relative humidity in the simulated environment was achieved by a series of different saturated salt solutions placed in a closed chamber. RH was monitored using a humidity meter with error of ±1%. And the temperature was maintained at (20±0.5) °C. Putting the electrode with deposition into environment chamber from lower RH to higher RH respectively, the galvanic current was recorded when the current was stable. After each record as well as the moisture absorption of salt particles did not change at a certain RH, the electrode was placed in an environment with the RH much lower than the deliquescence relative humidity