식염수에서 내식성 성능에 대한 Al 와이어의 5%Mg 합금 효과

Effect of 5%Mg alloying in Al wire on corrosion resistance performance in saline solution

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Abstract

The presence of chloride (Cl-) ions in environments causes localized corrosion resulting decrease the durability of the structures. In this study, 5% Mg containing Al alloys (Al-5Mg) wire used vis-à-vis compared its corrosion resistance with pure Al in 3.5wt.% NaCl solution with exposure periods. Initially both wires exhibited identical open circuit potential (OCP) attributed to the presence of native oxide film on the surface but with the exposure periods it shifted towards active direction owing to the dissolution of oxide film. The pure Al continuously shifted the OCP towards active direction while Al-5Mg shows stabilization of OCP after 8 days of exposure. The OCP of Al-5Mg is slightly higher compared to pure Al wire owing to the activeness of Mg. The total impedance of the Al-5Mg alloy is almost three times greater than pure Al with exposure periods in 3.5 wt.% NaCl solution. It might be formation of Al-Mg LDH (layered double hydroxide) thin film onto the surface.

Keywords : wire, corrosion, solution, open circuit potential, electrochemical impedance spectroscopy

1. Introduction

Al is susceptible to pitting corrosion in saline environment. Moreover, Al form protective oxide layer from 4.0-8.5 pH ranges depending upon temperature, nature of oxides and presence of soluble or insoluble complexes on to the surfaces[1]. The solubility of the Mg in Al matrix is temperature dependent and the maximum 15% Mg can be soluble but it causes stress corrosion in high amount due to precipitation in grain boundary of Al[2]. The precipitated grain boundary i.e. Al_3Mg_2 or Al_8Mg_5 exhibited open circuit potential (OCP) around -1.150 V vs SCE (saturated calomel electrode) that is quite high in corrosive environment and act as anodic sites for corrosion reaction which leads to cause intergranular and stress corrosion[3]. Therefore, Mg was limited to 5% for excellent mechanical and corrosion performance. In the present work, we have studied the corrosion resistance properties of 1.6 mm diameter Al and Al-5Mg alloy wires in 3.5 wt.% NaCl solution. This composition wire is frequently used in thermal spray coating as feed stock material for corrosion protection of marine infrastructure.

2. Materials and methods

A 1.6 mm diameter of Al and Al-5Mg wires was procured in local market of South Korea. A 10 cm length of wires cut from 1.6 mm diameter and 100 cm length to assess the corrosion characteristics in 3.5wt.% NaCl solution with exposure periods. A three electrode system was used for the electrochemical studies where these wires act as working electrode, saturated calomel electrode (SCE) as reference and 316L stainless steel wire as counter electrode. The electrochemical impedance spectroscopy (EIS) was performed at open circuit potential (OCP) by VersaSTAT potentiostat (Princeton Applied Research, Oak Ridge, TN, USA) from 100 kHz to 0.01 Hz with a 10 mV sinusoidal voltage.

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3. Results and Discussion

It can be seen from Figure 1a that the open circuit potential (OCP) of both wires are identical i.e. -0.753 V vs SCE while exposed for 1 h owing to the formation of Al_2O_3 native oxides on the surfaces. Once the exposure periods are extended, the OCP shifted towards active direction for both wires. Alternatively, the OCP of Al-5Mg wires become stabilized after 15 days of exposure at -0.852 V vs SCE while in the case of Al, the OCP is gradually shifted towards active direction and still not stabilized until 41 days of exposure. It is attributed to the dissolution and de-stabilization of Al_2O_3 film in chloride containing aqueous solution which tends to form $Al(OH)_3$ and $AlCl_3$. The Cl- ions trigger to break the film and leads to cause localized and pitting corrosion. On the other hand, the Al-5Mg alloy make the wire galvanically more active and form greater amount of $Al(OH)_3$ which accumulated over the surface and make it immune for corrosion and stabilized the OCP. However, due to the presence Mg in Al, it shows the active OCP compared to pure Al wire.

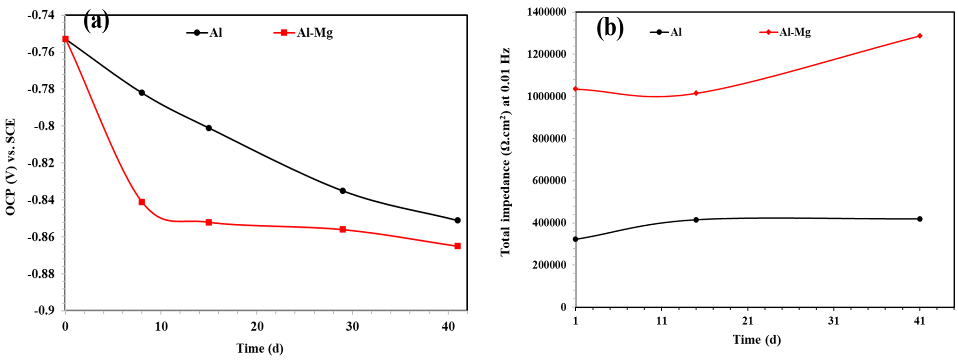

Figure 1. Corrosion assessment (a) OCP and (b) total impedance at 0.01 Hz of Al and Al-5Mg wires in 3.5 wt.% NaCl solution.

The total impedance of both the wires exposed to 3.5 wt.% NaCl solution are shown in Figure 1b. There is significant improvement in impedance of Al-5Mg alloy with exposure periods while marginal increment or consistent value is observed in pure Al wire. The increment and higher impedance of Al-5Mg wire attributed to the formation of Al-Mg LDH ($Mg_6Al_2(OH)_{16}CO_3.4H_2O$). It is due to the high dissolution of Mg in alloy where the local pH of solution increases at cathodic sites whereas in the case of pure Al, it forms $Al(OH)_3$ which subsequently transformed into $AlCl_3$ in chloride containing solution.

4. Conclusions

From the above results and discussion, it is concluded that the addition of 5%Mg in Al significantly improved the corrosion resistance properties of wires compared to pure Al exposed to 3.5 wt.% NaCl solution. The OCP of Al-5Mg alloy wire is active and become stabilized after 8 days of exposure attributed to the presence of Mg and formation of Al-Mg LDH at cathodic site which block the active surface of the wire, respectively; while in the case of Al, it continuously shifts to active direction. The total impedance of Al-5Mg alloy wire is significantly increased and higher compared to pure Al attributed to the formation of Al-Mg LDH.

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