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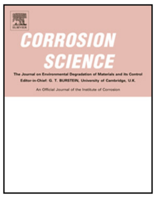

Corrosion behavior of Zn-Al alloys in saturated $Ca(OH)_2$ solution

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ABSTRACT

The influence of aluminium content on the corrosion behavior of Zn-x%Al alloys (x = 0, 0.2, 1, 3 and 6) exposed in aerated saturated $Ca(OH)_2$ solution was investigated using open circuit potential, potentiodynamic polarization, SEM, EDS and XRD techniques. The passivation of the five samples was observed with the prolonging of immersion time. The corrosion rates of the five samples increased in the order of Zinc > Zn-0.2%Al > Zn-1%Al > Zn-3%Al > Zn-6%Al. The formation of calcium aluminum hydroxide hydrate($Ca_2Al(OH)_7{\cdot}3H_2O$) loosened the corrosion product layer, which was responsible for the poor corrosion resistance of Zn-Al alloys compared with pure zinc.

1. Introduction

Hot-dip galvanizing is considered as an effective preventive measure for corrosion control of steel materials, e.g. the building, automotive materials exposed to carbonation or mild contamination with chlorides [1–8]. The corrosion behavior of hot dip galvanized coatings in alkaline environment was extensively studied in the last several decades. It is established that hot dip galvanized coating exposed in simulated concrete pore solution develops very stable corrosion products at the coating surface [1,8–16]. During the last decades, a vast amount of research efforts was conducted to add some alloying elements, e.g. aluminium, magnesium, cobalt, nickel, manganese, tin to the molten zinc bath to limit the zinc–iron reactivity and to improve the bath fluidity and the corrosion resistance of the zinc-based coatings [17–20]. Among these alloying elements, the addition of Al in molten zinc bath was widely used in the industry to get the Zn-Al alloys. And the corrosion behavior of Zn-Al alloys under atmosphere environments containing chloride ion was widely studied, all the researchers agree that the addition of Al enhanced the corrosion resistance of Al-containing coatings [2–4,6,21–23].

However, research on corrosion behavior of Zn-Al alloys in alkaline concrete environments is limited. Some research reported that the addition of Al in Zn-5Al and Zn-55Al alloys resulted in poor corrosion resistance in high alkaline solutions [24,25], while these studies were focused on the electrochemical behavior of Zn-Al alloys with short-time immersion under alkaline concrete environments. The corrosion mechanism of Zn-Al alloys with long exposed time under alkaline concrete environments is not clear.

The present study is aimed to investigate the influence of Al on the corrosion behavior of Zn-Al alloys in alkaline concrete environments, and focused on the corrosion behavior of the as-cast Zn-Al alloys in saturated $Ca(OH)_2$ solution. The experiment results will be helpful to get better understanding about the corrosion behavior of the Zn-Al alloys deposited on steel reinforcement, which will be carried on in further study. In this paper, the corrosion behavior of Zn-x%Al (x = 0.2, 1, 3 and 6) alloys exposed in aerated saturated $Ca(OH)_2$ solution was studied in comparison with pure zinc. The electrochemical behavior of Zn-Al alloys and pure zinc was investigated by open circuit potential, potentiodynamic polarization. The corrosion products were characterized by scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS) and X-ray diffraction (XRD).

2. Experimental

2.1. Materials and solution

The Zn-Al alloys were prepared in a crucible resistance furnace with Al ingot (purity of 99.996%) and Zn ingot (purity of 99.995%). The argon shield was used when adding Al by means of graphite rod to place Al ingots into the zinc bath at 670 °C, the alloy bath was incubated for 4 h at 540 °C after Al ingots was melt in the zinc bath, then cast in a ferrous mold (φ 20 mm × 50 mm) under atmospheric conditions. The Zn-Al alloys and pure zinc ingots were cut into sheets as samples which were mounted with epoxy resin leaving

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an exposed area of 1.42 cm^2. Before the experiment, the surface of the samples used as working electrodes was mechanically abraded with emery paper up to 2000, followed by a final polishing with 1 μm diamond paste. Samples were finally degreased with ethanol in ultrasonic, cleaned carefully with distilled water and dried. The chemical composition of the Zn-Al alloys is listed in Table 1.

The aerated saturated $Ca(OH)_2$ solution, which was prepared using distilled water and chemically pure calcium hydroxide, was used as the simulated concrete pore solution. The exposed experiment was carried out at temperature 25 ± 2 °C. The electrolyte was static which was simulated as the concrete environments. The saturated $Ca(OH)_2$ solution (1000 ml for each sample) was put into a plastic beaker. In order to minimize the influence of carbon dioxide on the alkaline solution, the plastic beakers were placed in a carbon dioxide-removal chamber which had one air inlet and one air output for air circulation, carbon dioxide could be removed by calcium oxide which was placed in the two channels. During the long-time testing, fresh saturated $Ca(OH)_2$ was carefully added in the beaker to maintain the exposed solution with constant volume (1000 ml), Noted that a layer of calcium hydroxide was designed in bottom of the plastic beaker to keep the $Ca(OH)_2$ solution was in

Table 1
The chemical composition of the samples tested in this paper.

Alloy	Al (wt.%)	Zn (wt.%)	Label
Zinc	–	100	Zinc
Zn-0.2%Al	0.19	99.81	Zn-0.2Al
Zn-1%Al	1.02	98.98	Zn-1Al
Zn-3%Al	3.02	96.98	Zn-3Al
Zn-6%Al	5.96	94.04	Zn-6Al

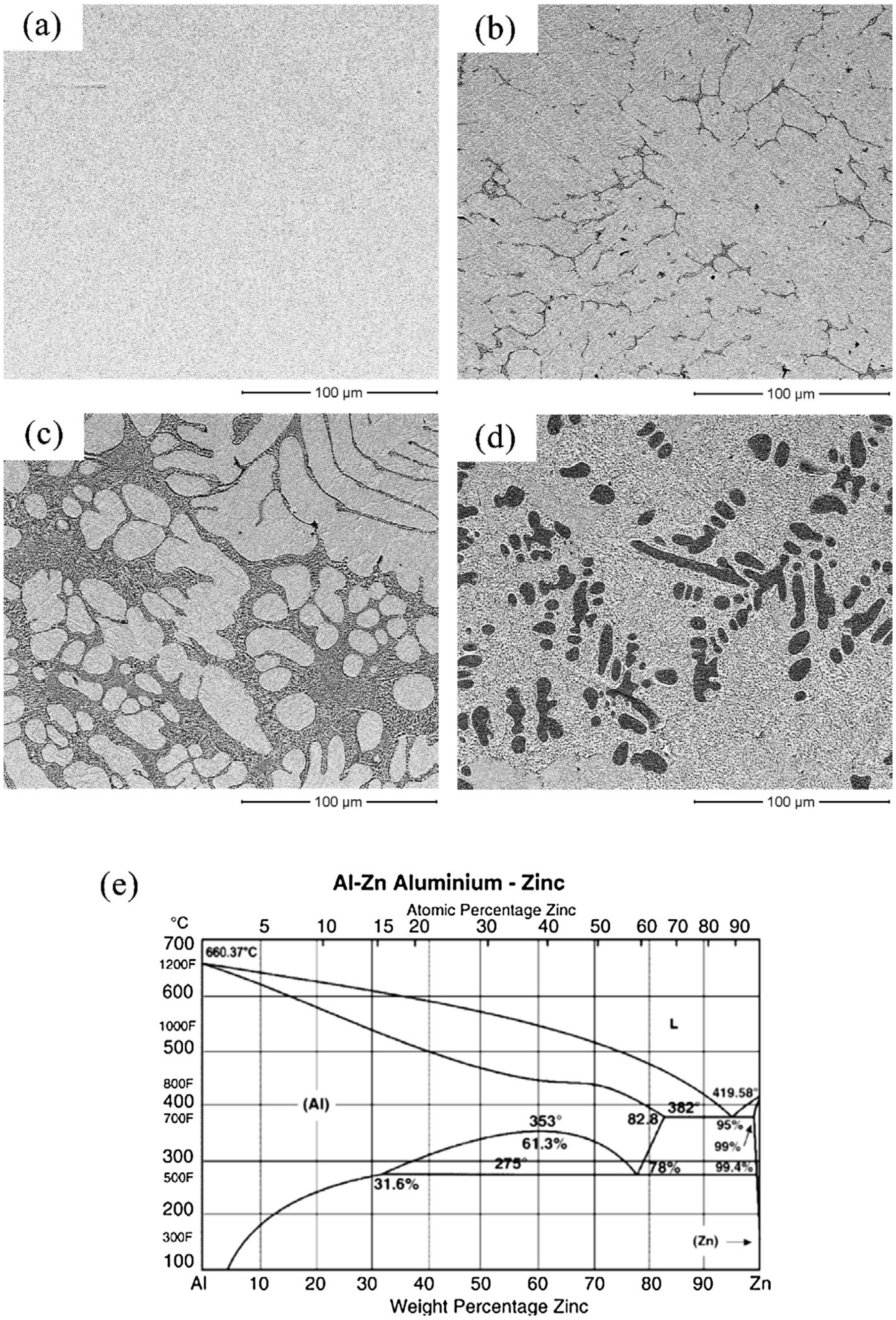

Fig. 1. Surface morphology of the tested samples: (a) Zinc, (b) Zn-1Al, (c) Zn-3Al, (d) Zn-6Al and (e) Zn-Al phase diagram [26].