

Review: General Study on Aluminum Corrosion Behavior in Artificial Seawater

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Abstract

Al and its alloys have a low atomic weight and high strength to density ratio. These properties make them very useful for the construction of parts in automotive industry, such as engine blocks or pistons. Al is prone to corrosion, due to its negative standard E of 1.66 V vs. NHE. In addition, Al corrosion resistance strongly depends on pH. Therefore, it is important to undertake a general study of Al corrosion behavior.

Keywords: Al; CI; corrosion; electrochemical behavior; oxides.

Introduction*

Al alloys have been the material of choice for structural components of airplanes since about 1930. Increasing aircraft payload and fuel efficiency has become a significant problem in the aerospace industry, which has sped up the development of highly modern materials with extremely specific properties. Al corrosion and passivation are a subject of tremendous technological importance, due to the increased industrial applications of this metal [1, 2]. Al widespread use arises from its different physical and chemical properties, such as its low specific gravity, good thermal and electrical conductivity, and relatively low toxicity [3]. Al also has significant resistance to corrosion, because it quickly develops a passive oxide film [4]. However, due to the general aggressiveness of acidic solutions, CI are commonly used to reduce their action on metallic surfaces [5]. Passivation and pickling inhibitors are the two types of CI. E_{corr} can be changed by passivation to more anodic levels. Pickling CI significantly lowers CR, while not affecting E_{corr} [6]. Anions adsorption and CI effect on Al in strong acidic media have been the subject of numerous studies [7-13].

Results and discussion

This essay addresses several elements of Al and its alloys passivity and pitting. Some hypotheses propose that anodic oxide coatings control the base metal

* The abbreviations list is in page 332.

corrosion resistance. It is widely accepted that different factors affect the pitting of Al and other metals and their alloys, and its presupposed mechanisms in halogen environments.

Due to the aging of Al and its alloys, which are extensively used in aerospace and automotive industries, there has been a recent increased interest in their localized CI. Four distinct pitting corrosion processes can be distinguished: on the passive film; inside the passive film; formation of so-called metastable pits, which begin and grow for a short time below the critical E_{corr} before re-passivating (pitting intermediate step); and on the passive film, at their interface with the solution. Stable pit growth takes place above a certain E known as critical E_{corr} .

Numerous articles on the creation of stable pits have been written over the years. Although quantitative research was not recorded until the 1980s, the earliest qualitative accounts of metastable pits date back 30 years [14]. The corrosion processes, which degrade the metal and interact with an oxide layer, on and inside the passive film, are still unclear, although it is known that they are influenced by the oxide sheet composition and structure, T , E , electrolyte composition, existence, distribution of micro and macro defects (inclusions, second phase particles, etc.), crystal structure and degree of non-crystallinity affect oxides structural properties.

CI

The primary method for evaluating CI effect on pitting was E_{corr} measurement. The most extensively studied and important CI for Al alloys is CrO_4^{2-} . So, research of CrO_4^{2-} CI will herein be the main topic of discussion. A protective oxide layer is typically formed by anodic CI on the metal surface, causing a significant anodic shift in E_{corr} . Typically, this change pushes the passivation zone towards the metal surface. In other words, CI reduce anodic CR and produce reaction products that thinly cover the anode. CrO_4^{2-} , nitrates, tungstate and molybdates are a few examples of these CI. In order to prevent reducing components diffusion into the surface, cathodic CI typically either slow down the cathodic reaction or precipitate (selectively) on the cathode. Namely, they produce reaction products that precipitate only at cathodic sites and stop electrons flow from the anode to the cathode [15]. Used XPS technique to examine NO_3^- and CrO_4^- ions impact as CI for Al. Hydrated Cr III, Al III oxide and a large amount of adsorbed (incorporated) VI species were thought to arise in films formed on Al when CrO_4^{2-} anions were present. The results showed that interactions between Al and various inhibiting or aggressive CI ions from the solution took place at E values that were considerably more negative than critical E_{corr} . The author discovered that, inside the shielding oxide film, the CI under study went through a reduction process.

Somewhat comparable results were reported by [16] using the SIMS method, it was determined that Cr uptake by Al occurred rapidly, being, in theory, connected to $\text{Cr}_2\text{O}_7^{2-}/\text{CrO}_4^{2-}$ reduction in the surface film. It was also discovered that it occurred more gradually, and was thought to be connected to $\text{Cr}_2\text{O}_7^{2-}/\text{CrO}_4^{2-}$ penetration in the outer layer. It was proposed that CrO_4^{2-} operates as CI, preventing Cl⁻, which was thought to be displaced from metal/oxide interface by O atoms provided by inhibitive oxyanions reduction, from being incorporated into the oxide film.

Using XRF, [17] investigated CrO_4^{2-} species interaction with Al-supporting air-formed and anodic films. Depending on the oxide layer thickness, they detected different Cr species valences. When a specimen with an air-generated film was immersed in a $\text{CrO}_4^{2-}/\text{Cl}^-$ solution, Cr (III) was discovered to be present. On the other hand, a significant amount of Cr (VI) was found in a thick anodic film. In an intermediate thickness film (6 nm), both Cr (III) and Cr (VI) were present. The authors claimed that CrO_4^{2-} species rapid reduction proceeded at bases. For air-formed films, when their outer portion has been disaggregated or dissolved, it is thought that CrO_4^{2-} species penetration may be decreased by an electron conduction process via the remnant film.

Due to their outstanding corrosion resistance, better conductivity and high strength-to-weight ratio, Al alloys are widely employed in the shipbuilding sector [18, 19]. Two common types of Al alloys for ship uses are AA5083 and AA6061 [20-23]. Intermetallic inclusions improve Al alloy mechanical characteristics, while increasing corrosion resistance. Mg and Fe/Mn-rich phases are the two main forms of intermetallic inclusions in AA5083. Fe/Si and Mg-rich phases are the two main types of intermetallic inclusions in AA6061 [24-27].

Numerous factors influence Al alloy corrosion behavior in seawater [28-30]. Cl ions have a potent eroding impact on metals, which can eventually lead to localized corrosion and ruin passive films [31]. Seawater contains SO_2 that dissolves to generate HSO_3^- , which can hasten Al alloys corrosion [32, 33]. Another important aspect that greatly affects how Al alloys behave in terms of corrosion is T. The influence of various conditions on the corrosion behavior of AA5083 and AA6061 must be studied.

Due to water scarcity and contamination, naturally occurring reserves cannot satisfy fresh water demands [34, 35]. Fortunately, desalination technology has been developed and shown to be an effective solution to this problem [36, 37]. Desalination is widely used in Asia, Africa, Arabian countries, Europe, the Middle East, America and Australia, to meet their fresh water needs [38, 39]. RO, MED and MSF are the three desalination technologies most frequently used [40-46].

Al brass is widely used to build water boxes, pipes, evaporator shells, tube plates, heat exchanger tubing and evaporators for MSF and MED technologies in modern desalination facilities. Since they require prolonged operation in a seawater desalination environment [47], investigating Al brass corrosion behavior and mechanism is crucial for the protection of these plants.

For Al alloys in Sw environment, pitting is the most common and destructive type of corrosion [48], since the oxide film that forms on the metal has a positive surface charge and may take in Cl^- . When the oxide layer is penetrated by absorbed Cl^- , which has a short radius, pitting corrosion develops at the metal substrate/oxide film interface [49]. Pitting corrosion is a complicated process that depends on several variables, including the type and C_t of aggressive ions in the solution, T , the wet period length, and the native oxide deposit structural properties [50-54].

Several studies have examined Al and its alloys pitting behavior in Cl^- presence, including laboratory simulation acceleration experiments and field exposure corrosion testing. High Cl^- deposition rates and anoxic conditions brought on by

corrosion products dissemination [54] on pure Al 1060, in a marine atmosphere in Xisha, were crucial factors in the pit depth continuous rise with exposure time. When examined Al pitting corrosion behavior, by sea, under various environmental circumstances, they discovered that it was worsened by higher Ct of Cl⁻. In previous studies, the authors investigated 2A02 Al alloy electrochemical corrosion behavior in a marine-like environment under accelerated conditions, having discovered that corrosion products could slow CR. In media containing Cl⁻, Al and its alloys are often susceptible to pitting corrosion [55].

Further information must be obtained in order to understand the many forms of pits, how Cl⁻ interacts with the oxide layer to degrade it, and how pitting corrosion manifests itself. Pitting corrosion can also happen by accident [56-59], which has to be assessed by using certain statistical methods. Although Al and its alloys corrosion behavior has been extensively studied, it varies significantly with the environment. Field exposure corrosion testing can offer more precise and reliable information about atmospheric corrosion, which is influenced by several different elements.

Conclusions

Al electrochemical and corrosive behavior was herein discussed extensively, with a focus on situations where it is present in natural and artificial water sources. Moreover, generic information has been considered, such as CI used for Al.

Author's contribution

This study was entirely carried out by Hoda Abd El-Shafy Shilkamy.

Conflict of interest

The author has no conflicts of interest to declare, and there is no financial interest to report. he certifies that the submission is an original work and is not under review at any other publication.

Abbreviations

CI: corrosion inhibitor/inhibition

Cl: chloride

CR: corrosion rate

CrO₄²⁻: chromate

Ct: concentration

E: potential

MED: multi-effect distillation

MSF: multi-stage flash

NHE: normal hydrogen electrode

RO: reverse osmosis

SIMS: secondary-ion mass spectrometry

T: temperature

XPS: X-ray photon spectroscopy

XRF: X-ray fluorescence spectroscopy

Sw: sea water

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