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Corrosion Studies of AA2024 in Sea Water using Sodium Benzoate as an Inhibitor

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Abstract

Many different types of destructive attack can occur to marine structures, ships and other equipments used in sea water service. Year upon year the cost of marine corrosion has increased until it is estimated today at 4% of the Gross National Product. Aluminium alloys are important materials and commonly used in marine applications. In this aluminum 2024 were subjected to seawater. Sodium Benzoate was used as corrosion inhibitors for aluminium alloy in aggressive marine environment. In order to study the corrosion behavior of aluminum alloy AA2024 in seawater, the electrochemical behavior of aluminum alloy was investigated with different inhibitor concentrations, potentiodynamic polarization and electrochemical spectroscopy (EIS). The morphology study was carried out to observe the development of thin film on the specimen and this study was performed using Scanning Electron Microscopy (SEM). EIS data showed that the mechanism of corrosion depends on inhibitor concentration.

Keywords: Corrosion; Marine environment; Aluminum alloy

Introduction

Many ship superstructures and liquid cargo containers are made of aluminum due to its low weight and acceptable strength. The most popular aluminium alloys for use in corrosive environments such as seawater are the 2xxx and 6xxx series alloys, which demonstrate adequate strength and excellent corrosion resistance. These series are highly suitable in various marine structures, machinery and port buildings. Alloy 2024 is a heat treatable aluminium-magnesium-silicon alloy. It provides good combination of extrudability and mechanical properties. It also responds well to polishing chemical brightening, anodizing and dyeing. Ship cargo containers are exposed to sea environment. Not only the outside of the cargo containers are exposed to corrosive environment, the internal compartments are also exposed to corrosive aqueous media. Marine corrosion is a perennial problem not only to moving vessel but also ports and anything kept in the sea or exposed to sea environment for a period of time. Corrosion is fundamental process which plays an important role in economics and safety. Apparently, corrosion cannot be avoided, but its severity can be reduced to a lower magnitude. The term 'aqueous corrosion' describes the majority of the most troublesome problems encountered when metal material is in contact with sea water. Various methods have been employed to reduce corrosion [1-3]. Several techniques and methods have been developed to combat corrosion efficiency are continually being sought after, as a result of exorbitant amount spent on corrosion annually The use of inhibitor for the control of corrosion of shore and offshore metal and alloys which are in contact with aggressive marine environment is an accepted Benzoate compounds offer interesting possibilities for corrosion inhibition and are of particular interest because of their safe use and high solubility in water. Corrosion inhibitors seem to be attractive because of their low cost and easy handling, compared to other preventive methods. Normally inhibitors are chemicals that interact with a metallic surface, [4] or the environment this surface is exposed, giving the surface a certain level of protection. Inhibitors often work by adsorbing themselves on the metallic surface by forming a film and reducing corrosion.

Corrosion inhibitors

Inhibitors have always been considered to be the first line of defense against corrosion. Several corrosion inhibitors are available today. The objective of this study was to evaluate the effectiveness of sodium benzoate as an inhibitor to slow down or prevent corrosion. This research work involves the use of potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) to evaluate inhibitive action of sodium benzoate on corrosion behavior of AA2024 aluminium alloy in seawater. The electrochemical measurements showed that the presence of sodium benzoate as an inhibitor significantly decrease the weight loss, corrosion current densities (i_{corr}), corrosion rates and double layer capacitance (C_{dl}), [5-7] whilst increasing the polarization resistance (R_p). Sodium benzoate converts to benzoic acid when used in acidic mixtures. Benzoic acid has good anti-microbial features, but does not dissolve well in water, whereas sodium benzoate dissolves very well in water. It is also used as a corrosion inhibitor in automotive anti-freeze products.

Methodology

Materials

In this laboratory scale study, the material employed was AA2024 (25 × 25 × 1.5 mm coupons). The actual seawater was used as the test solution. The inhibitor used was sodium benzoate, NaBz (1 g/dm^3 concentration). Several studies have been carried out on corrosion inhibitor; many of them concluded that corrosion was uniform with sodium benzoate [8]. Benzoic acid and its sodium salt (sodium benzoate) are the most common, safe, food preservatives and antimicrobial agents (Figure 1).

Electrochemical Impedance Spectroscopy (EIS)

Circuit model or circuit description code and initial circuit

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parameters were assumed and input by the operator based on the shape of the EIS spectrum. The program then fits the best frequency response of the given EIS spectrum, to obtain fitting parameters. The quality of the fitting was judged by how well the fitting curve overlaps the original spectrum. Impedance measurements were conducted over a frequency range of 10^4 Hz to 10^{-1} Hz. The data were presented as Nyquist plots [9,10].

Potentiodynamic studies (Tafel Slope)

Electrochemical potentiodynamic commonly used polarization testing method for measuring corrosion resistance and is used for a wide variety of functions. Potentiodynamic polarization is a technique where the potential of the electrode is varied at a selected rate by application of a current through the electrolyte. This technique uses a potentiodynamic scan over a range of potentials from passive to active (called reactivation) [11].

All electrochemical measurements were accomplished with CH-Instruments coupled to an computer. The potentiodynamic current-potential curves were recorded by changing the electrode potential automatically from - 250 mV to + 250 mV with the scanning rate of 5 mVs^{-1} (Figure 2) [12].

Immersion Test

The weight loss of AA2024 alloys in seawater with static condition with and without NaBz as inhibitors (Figure 3). Figure 4 presents the corrosion rate versus the immersion time of the aluminium alloy samples in seawater with and without inhibitor. Figure 2 represents the potentiodynamic polarization curves of AA2024 in seawater in the absence and the presence of NaBz [13,14].

Result and Discussion

Weight loss measurements

Results from Figure 3 show that the weight losses of AA2024 for all samples increase with the immersion time. The corrosion rate tends to be increased by decreasing temperature, pH, and flow velocity and by increasing dissolved oxygen. Values of salinity and pH measured during the immersion test are stable (in the range of nature seawater). Clear differences can be noted between the samples exposed to seawater containing NaBz as compared to that immersed in the absence of the inhibitor. The test without inhibitor addition had the higher weight loss. There was a reduction in weight loss; hence reduced the corrosion rate with the introduction of NaBz as an inhibitor into the seawater for both cases in static condition. The obtained results from Figure 4 demonstrate that the test without inhibitor addition in static condition had the higher corrosion rate. The results indicated that introduction of NaBz obviously minimize the rate of corrosion and abridged aluminium dissolution in seawater. Therefore this inhibitor can be considered as efficient inhibitor for AA2024 in seawater.

Potentiodynamic polarization studies

The changes observed in the polarization curves after addition of the inhibitor are usually used as criteria to classify inhibitors as cathodic, anodic or mixed. From Figure 4, it can be seen that the anodic and cathodic current densities obtained in the presence of inhibitor are lower than as compared to that of in the absence of inhibitor. The corrosion potential (E_{corr}) values in the presence of inhibitor are shifted to negative direction and leftward displacement in the cathodic branch of the curves. EIS research has proved that EIS is a powerful and accurate method for measuring corrosion rates. In order to access the charge transfer resistance and polarization resistance that is proportional to the corrosion rate at the monitored interface, EIS results is interpreted by model of the interface. Advantage of EIS techniques is the possibility of using very small amplitude signals without disturbing the properties being measured. In EIS measurement, a small amplitude signal, usually a voltage between 5 to 50 mV is applied to a specimen over frequency range of 0.001 Hz to 100,000 Hz.

Electrochemical impedance spectroscopy

The shape of the obtained Nyquist plots shows single capacitive semicircles, showing that the corrosion process was mainly charge-transfer controlled. The general shape of the curves is very similar for all the samples and this is maintained throughout the whole test period, indicating that almost no change in the corrosion mechanism occurred either due to the immersion time or to the inhibitor addition. Inspection of the data reveals that the impedance spectra consists of a large capacitive loop at high frequencies corresponding to the

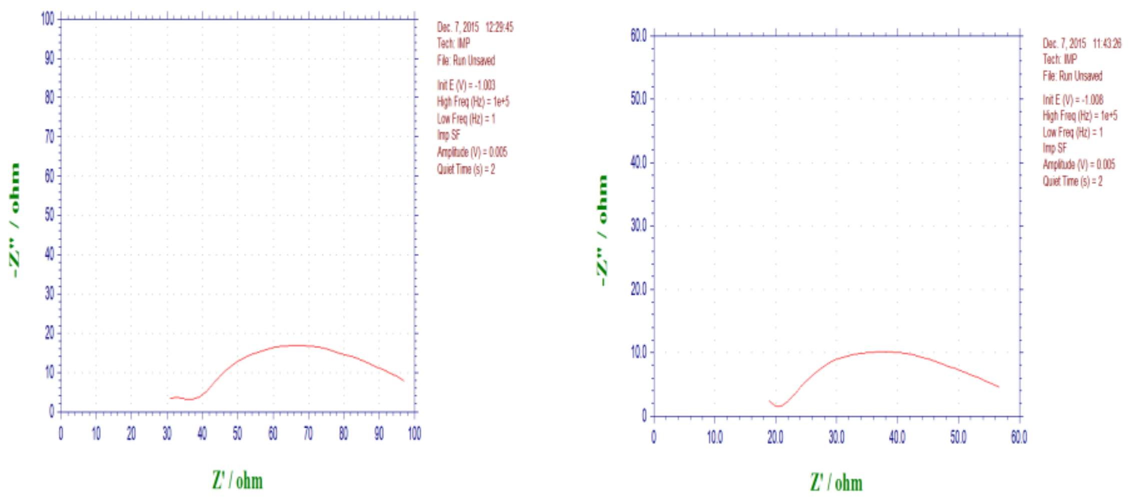

Figure 1: Shows data on Nyquist plots.

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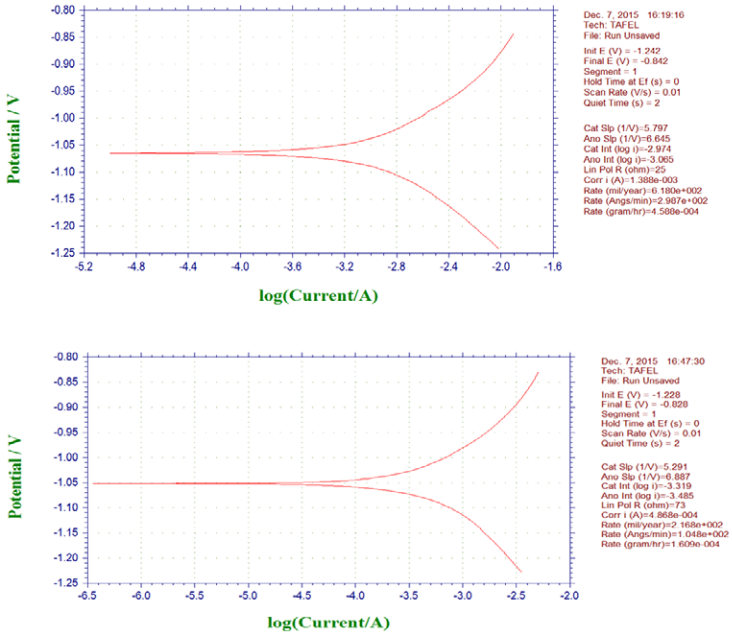

Figure 2: Potentiodynamic polarization curves for AA2024.

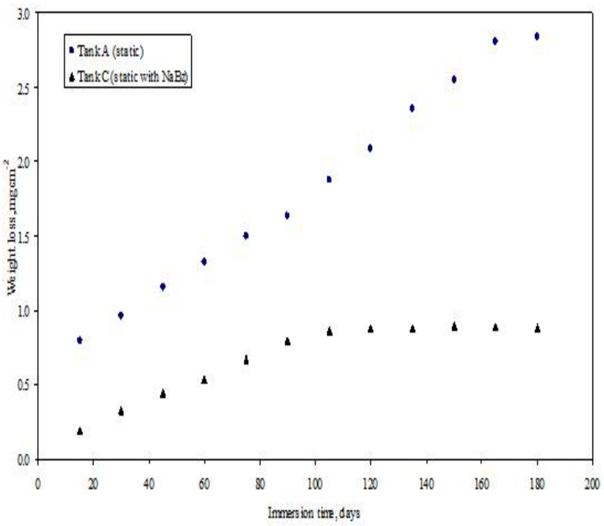

Figure 3: Weight losses versus immersion time of AA2024.

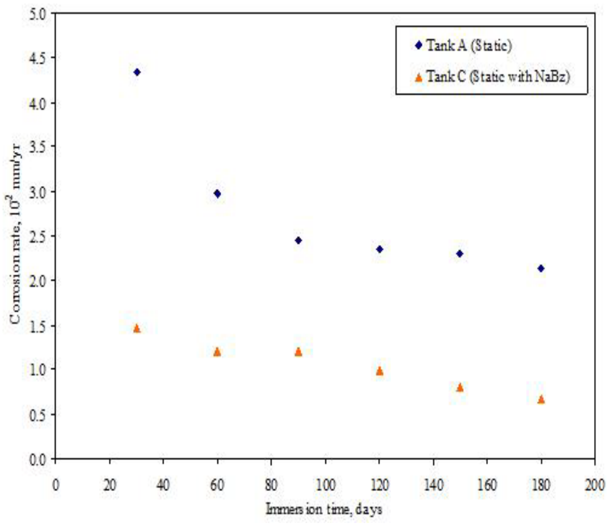

Figure 4: Corrosion rate versus immersion time of AA2024.

relaxation processes in the oxide film covering the electrode surface. In all cases, single capacitive loops are observed which sizes decrease with the exposure time. After 180 days immersion time, the charge transfer resistance, R_{ct} for the aluminium alloy decreased to the likely formation (or thickening) of a corrosion product layer on the electrode. The R_{ct} values were higher for AA2024 after addition of inhibitor at all the immersion time, indicating that NaBz is inhibiting the corrosion rate. It can be concluded that NaBz is an effective inhibitor for the aluminium alloy.

Conclusion

The corrosion studies of AA2024 aluminium alloy have been carried out at room temperature using seawater. The results obtained lead to the conclusion that NaBz is an effective corrosion inhibitor of AA2024 in seawater. The potentiodynamic polarization curves suggested a cathodic character for the inhibition process in seawater. EIS measurements clarified that the corrosion process was mainly charge-transfer controlled and no change in the corrosion mechanism occurred either due to the immersion time or the inhibitor addition to seawater.

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