Marine Extracts as Corrosion Inhibitor for Aluminum in Seawater Applications

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ABSTRACT

Aluminium alloy type 5083 or AA 5083 is known for exceptional performance in extreme environments. AA 5083 shows excellent corrosion resistance mostly in seawater and industrial chemical environment. Nowadays, corrosion is entrenched in maritime industry where the ship plate undergoes corrosion and the corrosion rate varies with different environment. As a remedy, natural inhibitor was used to overcome this problem. This study investigates the use of marine microalgae extracts to retard corrosion. Anti corrosive activities of ethanolic and dichloromethane marine extracts from South China Sea were investigated. Low concentration of marine extract which is 5ppm was used. The characterization of the corrosion was performed by using Potentiodynamic Polarization, weight loss and Electrochemical Impedance Spectroscopy. The corrosion rate (CR) was calculated and this study showed that the corrosion rate can be decreased with the introduction of 5ppm marine microalgae extracts. This extract is believed to form a surface layer as it protects AA 5083 from reacting with the environment.

Keywords – **Aluminum alloy, Corrosion, Marine, Natural inhibitor, Seawater**

I. INTRODUCTION

According to some definitions [1], corrosion is the reaction of an engineering construction metal (material) with its environment with a consequent deterioration in properties of the metal (material). In other words, corrosion can be defined as the chemical reaction between a metal surface and its environment. Corrosion can cause the effect of the hardness of metals and increase the cost for maintenance.

One factor that can influence the corrosion rate is the concentration of the extract adhered to the metal. According to El-Etre *et al.* [2], based on their studies, the inhibition efficiency increases with the increasing of the extract concentration. Based on their studies, the other angle that can be studied is to investigate the effect of the low concentration of the marine extract as a corrosion inhibitor towards the corrosion rate of aluminium alloy. The low concentration of extract gives the low fraction of the aluminium surface that covered by the absorbed molecules decreasing to lower inhibition efficiency [3].

Corrosion inhibitor is the substance which is added in small concentrations to corrosive media to decrease or prevent the reaction of the metal with the media [1]. One of the existing controllers is by using inhibitor. The existing of inhibitor can interrupt the chemical reaction between metals that can reduce the corrosion rate.

Many synthetic compounds offer good anticorrosive action, but most of them being highly toxic to both human being and environment [4-6]. Thus the application of synthetic corrosion inhibitor should be replaced with natural inhibitor. Many researchers have studied the use of plant based inhibitor and the results shows that this new type of inhibitors is proven effectively to reduce the corrosion rate on the metal [7-9].

II. MATERIALS AND METHODS

A. Materials

In this experiment, aluminum alloy type AA 5083 was used. Marine microalgae was extracted by using Rotary Evaporator (Rotavap). The extracts are of ethanolic and dichloromethane types. The details of the extraction method were similar with our work on tapioca starch [9]. In this study, 108 pieces of aluminum coupons were used. The aluminum coupons were of marine grade.

B. Methods

Weight Loss

AA 5083 was cut into 25mm x 25mm x 3mm coupons for immersion test. Before exposure, the samples were polished manually using 600, 800 and 1200 grit of emery paper and lubricated using distilled water. The samples were then cleaned by acetone and distilled water. The initial weight (W_1) of the samples was determined and the coupons were hung in test solution for 60 days in 20*L* of filtered sea water. Three aquarium tanks were used to keep the seawater with diluted marine extracts and one is for control. Table 1 gives the explanation of solution for each tank.

Table 1: Explanation of solution for each tank

Tank label	Explanation
A	Control – filtered seawater
B	Filtered seawater + 5ppm marine extract (ethanolic)
C	Filtered seawater + 5ppm marine extract (dichloromethane)

Each tank was hung with six coupons and the data was analyzed for each 10 days of immersion. The corroded specimens were then removed from the solution and cleaned with distilled water, dried and weighted again in order to obtain the final weight (W_F). The experiment was conducted in a room temperature. Weight loss percentage was calculated using the following equation:

$$WL(\%) = 100\left(1 - \frac{W_I}{W_F}\right) \quad (1)$$

where W_I and W_F are initial weight and final weight, respectively. The inhibition efficiency for weight loss was calculated using the following equation:

$$IE(\%) = 100\left(1 - \frac{W_o}{W_i}\right) \quad (2)$$

where W_o and W_i are weight loss of the AA 5083 in the presence and absence of inhibitor, respectively.

Electrochemical Measurements

AA5083 coupon for each parameter was immersed in 80ml of respective test solutions. The electrochemical measurements were obtained using Autolab General Purpose Electrochemical System (GPES) and Frequency Response Analyzer (FRA). For potentidynamic polarization (PP), the coupons were embedded in solution with an exposed area of $1.0cm^2$. The potentiodynamic current and potential curves were recorded by changing the electrode potential automatically from -0.7mV to +0.7mV with the scanning rate $0.5mVs^{-1}$. Corrosion current densities (I_{corr}) and corrosion potential (E_{corr}) were evaluated from the intersection of the linear anodic and cathodic branches of the PC as Tafel plots. The data obtained was used to calculate inhibition efficiencies (IE) for polarization resistance (R_p), corrosion current density (I_{corr}) and corrosion rate. IE were obtained using the following equations:

$$IE_{Icorr}(\%) = 100\left(1 - \frac{Icorr'}{Icorr}\right) \quad (3)$$

$$IE_{R_P}(\%) = 100\left(1 - \frac{R_P}{R'_P}\right) \quad (4)$$

$$IE_{C_R}(\%) = 100\left(1 - \frac{C_R'}{C_R}\right) \quad (5)$$

where I_{corr}' and I_{corr} are the corrosion current density with and without inhibitor respectively followed by R_p' and R_p are the polarization resistance with and without the presence of inhibitor. C_R' and C_R are the corrosion rate with inhibitor and without inhibitor.

III. RESULTS AND DISCUSSION

A. Potentiodynamic Polarization (PP)

Fig. 1 represents the anodic and cathodic polarization curves of aluminum coupons in three seawater environments. The straight lines which lines which extended along more than one decade of log I, from -5 to about -4, were taken as Tafel lines which were used for determination of the corrosion parameters. Inspection of the figure reveals that the presence of marine extract shifts the anodic curves toward the noble direction and the cathodic curves toward active direction. This behavior suggests the inhibitive effect of the marine extracts.

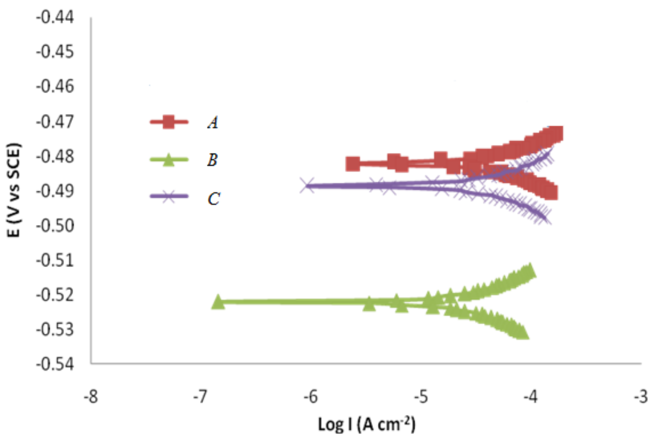

Fig. 1: Tafel plots of mild steel afer immersion in different solutions

Inspection of Table 2 reveals that when marine extract was introduced, the corrosion potential (E_{corr}) shift more negative direction. Moreover, the corrosion current (I_{corr}) decreases markedly in the presence of the additive (The corrosion current density was calculated from the intersection of cathodic and anodic Tafel lines). Moreover, it can seen that the corrosion rate decrease markely with the presence of marine extracts.

We also found that the value of anodic and cathodic Tafel constants are markedly changed in the presence of marine extract. This result reflects the effect of the extract on both anodic and cathodic reactions. Therefore, it could be concluded that marine microalgae extract acts as a mixed inhibitor.

Table 2: Potentiodynamic polarization parameters of aluminum after immersion

Parameter	i_{corr} (µA/cm²)	E_{corr} (obs/mV)	*Corrosion rate* (mm/year)
(A) Control	7.4335	-877.32	11.118
(B) Ethanolic	4.0447	-876.08	6.0596
(C) Dichloromethane	4.1611	-819.07	6.2552

B. **Electrochemical Impedance Spectroscopy (EIS)**

Fig. 2 is plotted by using electrochemical techniques. The corrosion behavior of aluminum metal in filtered seawater in the presence of marine extract was investigated by EIS at 25°C after 10 min of immersion. Fig. 2 shows the results of EIS experiments in the Nyquist representation.

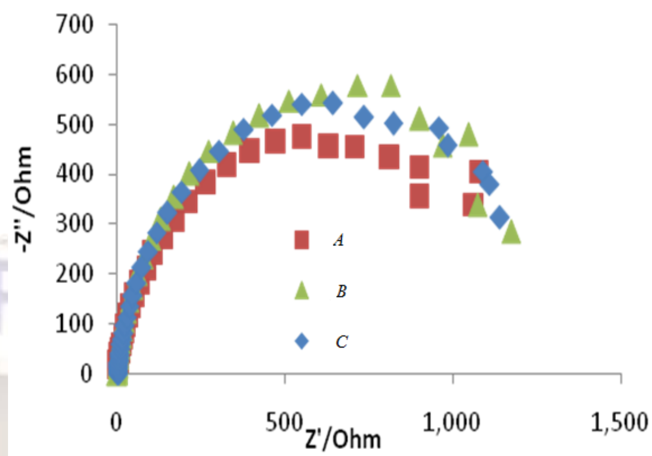

Fig. 2: Nyquist plots of mild steel afer immersion

After analyzing the shape of the Nyquist plots, it is concluded that the curves approximated by a single capacitive semi-circles, showing that the corrosion process was mainly charge transfer controlled. The general shape of the curves is very similar for all samples. The shape is maintained throughout the whole concentrations, indicating that almost no change in the corrosion mechanism occurred due to the inhibitor addition. The diameter of Nyquist plots (R_p) increase for the seawater containing marine algae extracts. These results suggest the favorable inhibition behavior of micro algae extract on corrosion of aluminium metal. Lysosomal activity is believed the reason for the corrosion inhibition performance. Similar result was achived by Hellio et al [5] during their study using marine extracts as potential antifouling additive.

C. **Weight Loss Measurement**

Fig. 3 shows the graph of corrosion rate versus immersion time of aluminium alloy type AA 5083 in two different solvent. This experiment has been conducted by using marine extract as a corrosion inhibitor and the effect of the different solvent had been studied.

Data obtained from weight loss calculation was analyzed using graphical method. The percentages of weight loss for both parameters have been determined as a function of the immersion time. From Fig. 3, control coupons (in seawater A) have greater rate of weight loss compared to the addition of marine extract as the inhibitors. There was a rapid of weight loss for control during 10 days to 20 days. Here can be assumed that the coupons were reacted with the filtered sea water to form a layer which is aluminum oxide (Al_2O_3). This phenomenon is what makes aluminum alloys type 5083 so special. It can instantly create a layer of aluminum oxide (Al_2O_3) for corrosion resistance.

Graph shows the increasing and decreasing of the corrosion rate versus immersion time. For ethanol extraction, the corrosion rate is increasing for the first 10 days and after next 10 days, the corrosion rate is decrease. This is because after some time marine extract was found to precipitate at the bottom of the aquarium tank which can be assumed that it cannot dissolve naturally in sea water.

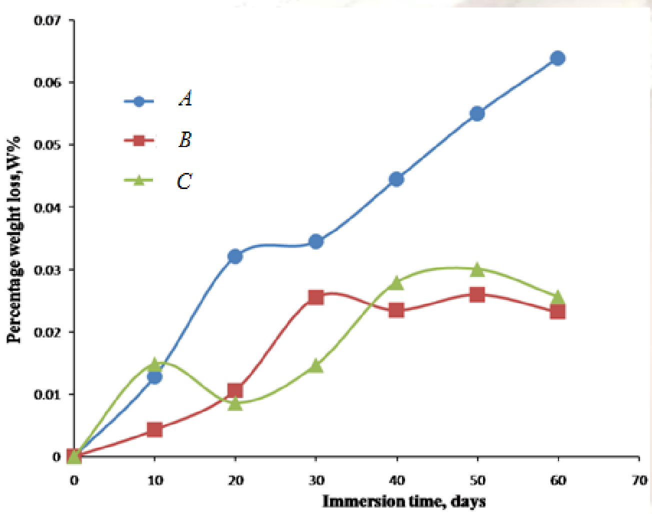

Fig. 3: Weight loss of aluminum after some immersion period

IV. CONCLUSION

From the all the results, it indicates that the test solutions with the presence of inhibitor show inhibitory effect of marine extract. Marine extract shows mixed type inhibitor but predominantly to cathodic branch. From the data also can be described that marine extract extract work as good inhibitor for aluminium alloy type 5083. Lysosomal activity is believed the reason for the corrosion inhibition characteristic.

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