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The relationship between corrosion rate of aluminum (AA 5083) and supply electric voltage in seawater

A.M.Muzathik[1,2]*, H.Sabri[1], C.W.M.Noor[1]
[1]Department of Maritime Technology, Faculty of Maritime Studies & Marine Science, Universiti Malaysia Terengganu, Kuala Terengganu, (MALAYSIA)
[2]Institute of Technology, University of Moratuwa, Katubedda, (SRI LANKA)
E-mail : muzathik64@yahoo.com

ABSTRACT

In this paper effect of electric voltage level on corrosion rate of Aluminum (AA 5083) was studied. Eighty samples plate surfaces were prepared according to the standard procedure. The corrosion studies have been carried out at room temperature using seawater. Various level of electric DC voltage (0, 1.5, 3 and 4.5 V) applied and samples were left for 10, 20, 30 and 40 days in order to determine its corrosion rate for each and every level of voltages supplied. These samples were analyzed to determine the weight loss, electrochemical test using Electrochemical Impedance Spectroscopy and morphology test to determine the corrosion rate of the Aluminium plate and effect of voltage levels. After 40 days, the final weights of all samples were differed compare to the initial weights. For 0 V sample initial and final weights were4.7375 g and 4.7164 g respectively, which is 99.7% of its initial weight. For 1.5 V sample, initial weight was 4.7262 g and final weight was 3.8833 g, which is 82.4% of its initial weight. Meanwhile, for samples of 3 V and 4.5 V, initial weights were 4.7225 g and 4.7511 g respectively, after 40 days; samples were loosed 1.3025 g and 1.5169 g respectively. The results reviled that electric voltage is one of the factor that can accelerate corrosion of Aluminium AA 5083 in seawater. Further, results indicated that introduction of electric voltage obviously maximize weight losses and enhance Aluminium dissolution in seawater. As a conclusion from this study, corrosion rate of Aluminium AA 5083 plate is increasing by increasing of DC electric voltage in seawater.
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INTRODUCTION

Corrosion is a chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties[1]. There are many factors that led to the corrosion, but also a catalyst that can accelerate the corrosion process itself. There are a lot of factors that researchers manage to identify, such as pH, temperature, electric current density, density of dissolved oxy-

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gen, the concentration of ions in a solution, and so forth.

According to available data, between 4 to 6% of gross domestic production (GDP) is lost to corrosion, approximately USD $1.6 trillion lost every year from the world's economy. In the Malaysian context, 4% of GDP would mean a loss of around RM 30 billion every year, that is more than RM 1200 annually for every citizen of the country and works out to just about the entire Malaysian healthcare budget for 2008[2].

Jones[3] have attributed the acceleration of corrosion rate in present of current to the ability of voltage reduce both anodic and cathodic polarization. Generally, in the present of electric voltage, corrosion potential is shifted toward the negative direction. Chin and Sachdev[4] have mentioned that the exchange current density increases and Tafel slope decreases, correspondingly Jones[3]. Electric voltage generally leads to the formation of porous and non-protective layer, in such case localized attack are very likely to occur[5]. This situation is supported by Goidanich et al.[6] as they stated that the effect of electric current interference on kinetic parameter; the effect on corrosion rate and corrosion mechanism in different solution on different metallic material were determined. Further, the influence of electric voltage on corrosion of kinetics characteristics of carbon steel, galvanized steel, copper and zinc was studied under different experimental conditions[6-8].

Nowadays ships are constructed using Aluminium. In general small electrical current leakage may available in ships due to of electric cable insulation problem, etc. Then, the ship could be exposed to the danger of corrosion because not all materials are completely Aluminium in Aluminium vessels, particularly in engine room. The detail study of corrosion of Aluminiom is more vital for the survival of Aluminium shipping industry. Aluminium alloy is very special metal since its have high resistant of corrosion even though it is exposed to corrosive environment. This advantage is due to passive film or layer, which are thin oxides layer that form naturally on its surface. As a result, this layer will greatly increase the resistant of the metal and thus, it reduces the rate of corrosion of the Aluminium alloy. Such passive film, however, are often susceptible to localized breakdown, resulting in accelerated dissolution of the underlying metal. Corrosion studies for Aluminium were highlighted in the literature for different electrolytes not in seawa-

ter[9-10].

Therefore, in this research, the effect of electric voltage on correction rate of Aluminium (AA 5083) plate in seawater was studied to overcome the present practical problems. In this experiment, the samples of Aluminium AA 5083 were tested with different levels of voltage via electrochemical test. The corrosion of Aluminium AA 5083 then tested by using electrochemical impedance spectroscopy (EIS) to obtain the Tafel slope, Nyquist plot and Bode plot where FRA software is applied.

METHODOLOGY

Test specimens were cut into 25mm×25mm×3mm coupons for electrochemical tests. Before exposure, the samples were mechanically grinded and polished using Grinding & Polishing Machine. The 600, 800 and 1200 emery papers were used for grinding purpose and lubricated it by applying distilled water for polishing purposes. The polished samples were cleaned with acetone then washed using distilled water, dried in air and stored over desiccators.

After undergoing the surface preparation procedure according to ASTM G1-03 procedure[11,12], the electrochemical test was conducted by taking the Aluminium AA 5083 plates which was served as anode while mild steel was served as cathode. The circuit of electrochemical system was then connected with DC power supply. Ensured all electrical connections were well connected and the anode and cathode completely immersed in the seawater solution. The DC power supply then was switched on. Then the level of electric voltage supply was adjusted at 1.5 V. The test circuit kept for 10 days, after 10 days the samples were taken out for further test. This procedure was repeated for 20 days, 30 days and 40 days. Then the level of alternating voltage changed to 3V and 4.5 V and tested for 10 days, 20 days, 30 days and 40 days.

Morphology test

After undergoing the surface preparation procedure, the sample was mounted firmly in "dinolite" microscope in order to obtain the picture of initial condition of the sample. The sample was then set up in electrochemical test for test period at specified voltage of electric sup-

plied. Then, the sample was removed from the electro-chemical circuit. The sample was then cleaned with distilled water and dried, then immersed in a nitric acid for 2 to 3 min to remove the corrosion products. Finally, the coupons were washed with distilled water and were dried. After the samples are completely dried the sample was mounted firmly under the "dinolite" microscope for final observation and a picture was taken. Then the final condition was compare with the initial condition of the test sample. The steps were repeated for every level of electric voltage supplied for the tested samples for 10 days, 20 days, 30 days and 40 days.

Weight lost test

Every sample was weighed for the original weight. Then, the samples were set up in electrochemical circuit for 10 days. The corroded samples were then removed from the solutions. The samples were then cleaned with distilled water and dried, then immersed in a nitric acid for 2 to 3 min to remove the corrosion products. Finally, the coupons were washed with distilled water, dried and weighed again in order to obtain the final weight. The steps for samples in electrochemical circuit which were left for 10 days, 20 days, 30 days, and 40 days for every level of voltage supplied were repeated.

Electrochemical test

All electrochemical measurements were accomplished with "Autolab" frequency response analyzer (FRA) coupled to an "Autolab" potentiostat connected to a computer[13]. The cell used is a conventional three electrodes with a platinum wire counter electrode (CE) and a saturated calomel electrode (SCE) as reference to which all potentials are referred. The working electrode (WE) was in the form of a square cut so that the flat surface was the only surface in the electrode. The exposed area to the test solution was 3.75 cm^2. Corrosion current densities (I_{corr}) and corrosion potential (E_{corr}) were evaluated from the intersection of the linear anodic and cathodic branches of the potential curves (PC) as Tafel plots. Electrochemical impedance spectroscopy (EIS) measurements were carried out using AC signal of impedance measurements and were conducted at the corrosion potential. Data were presented as Nyquist plots. The results were analyzed using the fit program of FRA.

RESULT AND DISCUSSION

Morphology test

Based on observations on the experiment samples, the pitting corrosion can be observed clear and obviously. Every sample show different pattern and trend of pitting condition. The conditions of the samples, for 10 days experiment can be observed as shown in row one of TABLE 1. The sample pictures for 20 days, 30 days and 40 days also given in the table. From the surface image of every sample was taken, for 0 volt, the oxide layer is obviously diminished, but no pitting corrosion occurred. For 1.5 volt, the oxide layer is completely diminished and pitting corrosion can be observed even with naked eyes. For 3.0 volt, the pitting corrosion became bigger than 1.5 volt experiment set. The pitting seems to affect the adjacent pit, make its pit area became larger. For 4.5 volt experiment set, the no pit is visible due to the sample is completely corroded. Based on morphology test, as the electric voltage increase, the corrosion rate is tended to increase.

Weight loss test

Weight loss test is one of traditional and effective way to determine, calculate and predict the corrosion rate of the metal. When the metal is exposed to the damped environment and corrosive solution (in this case, seawater solution), the corrosion is occurred, and the metal is tended to decrease it weight. As a result, the final weight of the sample is less than its initial weight.

The results of the weight lost test are given in Figures 1 and 2. Based on the weight loss test results the rate of corrosion can be observed and compared. It showed all samples weight is around 4.6 - 4.8 g. After 40 days, the final weight of all samples are differ compare to the other. For 0 volt sample it initial weight was 4.7375 g, it loss it weight approximately 0.0121 g as it final weight was 4.7164 g which is 99.7% of its initial weight. For 1.5 volt sample, the weight loss became higher where it initial weight was 4.7262 g. It experienced decrement as much as 0.8281 g, which make its final weight is at 3.8833 g, 82.4% of its initial weight. Meanwhile, for sample of 3 volt and 4.5 volt, the initial weight of the samples were 4.7225 g and 4.7511 g, respectively, after 40 days, they loss 1.3025 g and 1.5169 g, respectively, which make their final weight as

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3.4976 g and 3.2603 g, respectively. Based on this result one can conclude that the electric voltage sup-plied increase, the weight loss of sample is also in-creased.

TABLE 1 : Morphology test.

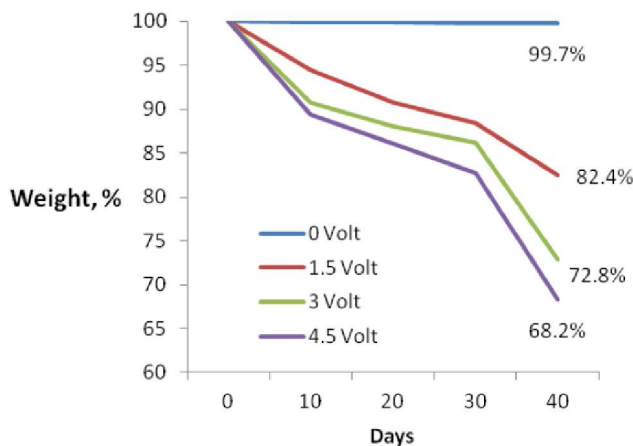| Voltage (V) → / Time (Days)↴	0	1.5	3	4.5
10				
20				
30				
40				

Figure 1 : Weight percentage Vs days.

Figure 2 : Weight loss Vs days.

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Electrochemical test

General purpose electrochemical system (GPES) is one of the basic modules, being used in orders to determine the corrosion characteristic and then analyzed them. The data obtain in form of Tafel slope from the general purpose electrochemical system was converted in potentiodynamic curve as shown in the Figures 3, 4, 5 and 6 for 10 days, 20 days, 30 days and 40 days test, respectively.
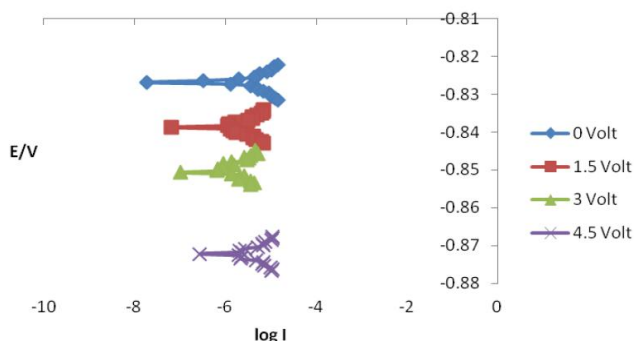

Figure 3 : Potentiodynamic curve for 10 days.
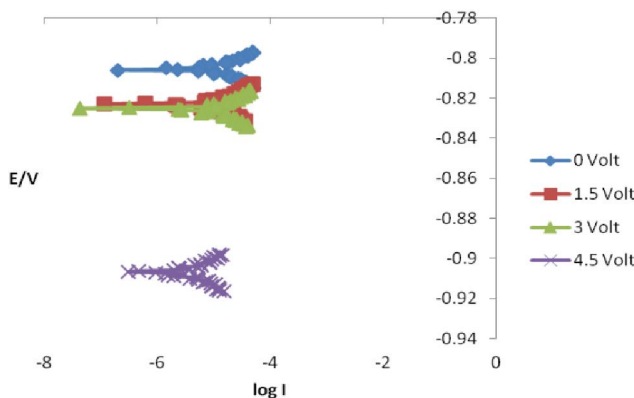

Figure 4 : Potentiodynamic curve for 20 days.

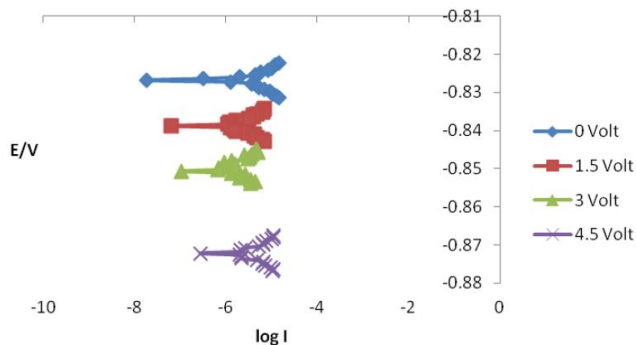**Figure 5 : Potentiodynamic curve for 30 days.**

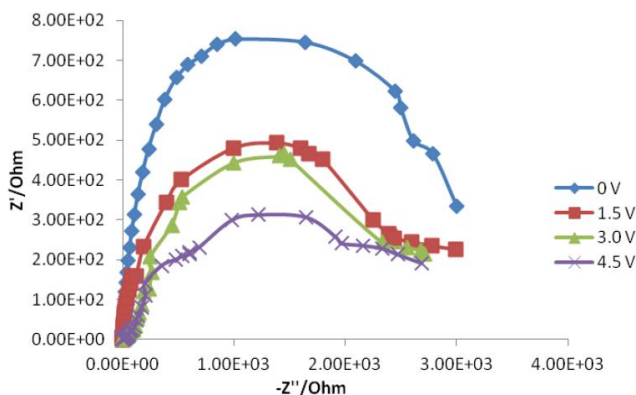**Figure 6 : Potentiodynamic curve for 40 days.**

Figure 7 : FRA module results for 10 days.

From the figures one can observed clear differences between the potentiodynamic curves of different electric voltage supply. The data of all set were analyzed using GPES software. The results show that both of the anodic and cathodic current densities obtained in the presence of electric voltage were higher as compared to that of in the absence of the electric voltage. The E_{corr} values in the presence of resistant are shifted to negative direction; this effect is obviously after the addition of electric voltage. As the voltage supplied increased, the potentiodynamic curve is tend to shifted away from noble direction, thus the I_{corr} values were also increased.

Frequency response analyzer (FRA)

The results of FRA module are given in Figures 7, 8, 9 and 10 for 10 days, 20 days, 30 days, and 40 days, respectively for comparison. The values of 0 volt sample are quite larger than the other 3 sets of voltages for all the study periods. This may occur due to high resistant of Aluminium oxide layer on the surface of the Aluminium plate samples. The 1.5 volt results show lower values then the 0 volt set for all test periods. This is due to formation of pit after the oxide layer is no

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more protect the Aluminium surface. The results from FRA show that, if the electric voltage supply increases the corrosion rate is also increase.
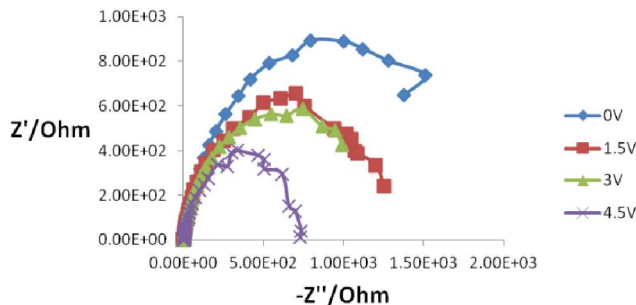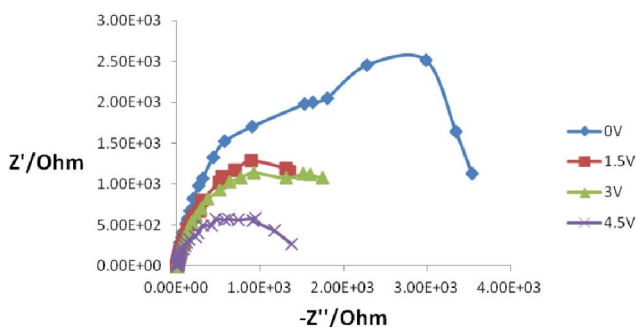

Figure 8 : FRA module results for 20 days.

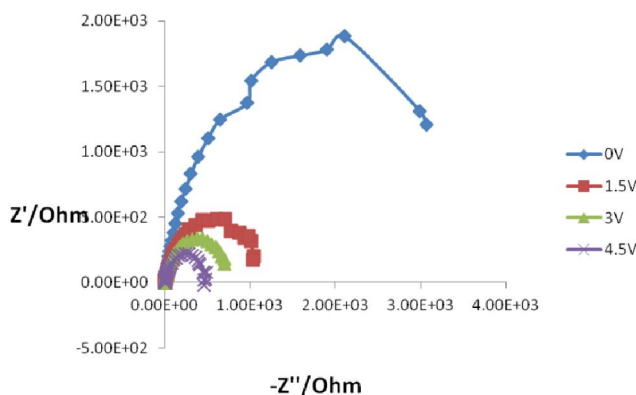**Figure 9 : FRA module results for 30 days.**

Figure 10 : FRA module results for 40 days.

CONCLUSION

This research was conducted in order to study the corrosion rate behavior and relationship between corrosion rate with different electric voltages level are supplied on Aluminium AA 5083 sample. This project comprising of 4 set of experiment, named as 10 days set, 20 days set, 30 days set and 40 days set. The corrosion studies of AA5083 were carried out at room temperature using seawater. EIS, consist of GPES and FRA modules, is a powerful method to provide information

on corrosion process to distinguish corrosion processes which take place on Aluminium AA 5083 with and without electric voltage. The results obtained lead to the conclusion that electric voltage is one of the factors that can accelerate the corrosion of Aluminium AA5083 in seawater. Further, the results indicated that the introduction of electric voltage obviously maximize the weight losses and enhance Aluminium dissolution in seawater. According to EIS measurements, increasing of electric voltage level the corrosion rate is also increase of Aluminium AA 5083 samples in seawater. Pitting corrosion is also induced with the presence of electric voltage and shown in morphology test result.

Since the experiment is focusing on voltage level only, it is good to add some other parameter that can be used in order to harmonize the experiment. May use different pH level of electrolytes in order to determine which level may accelerate the corrosion rate.

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