

Corrosion Behavior of Mild Steel in Seawater from Two Different Sites of Kuala Terengganu Coastal Area

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Abstract - Corrosion behavior of mild steel in seawater from different sites was investigated by using weight loss method and potentiodynamic polarization test. Samples were immersed at two different sites near Kuala Terengganu coast and analyzed for its parameters. There is slight difference of corrosion behavior from both sites. Samples immersed in site 1 gave higher corrosion rate and corrosion current densities (i_{corr}) while the value of corrosion potential, E_{corr} for site 1 shifted to negative region which indicates the increasing of corrosion activity. Small differences of seawater parameters causes the corrosion behavior of mild steel from both sites to be same where all the plots recorded shows the same pattern.

Keyword : Mild steel, Polarization, Seawater, Weight loss

I. INTRODUCTION

There is increasing attention being given to deterioration of infrastructure exposed to actual hostile marine environments. As a result structural engineers and naval architects are increasingly interested in the rate of loss of strength of steel and hence in the loss of material in infrastructure systems. The loss of material even for short-term exposures is important in part because protective measures are not always wholly effective.

Mild steel is the most versatile, least expensive and widely used engineering material which has found extensive application in various industries [1]. It is used in large tonnages in marine applications, nuclear power and fossil fuel power plant, transportation, chemical processing, petroleum production and refining, pipelines,

mining, construction as well as metal-processing equipment. However, the corrosion resistance of mild steel is relatively limited. This causes many corrosion problems to be arising in the related industries.

This paper investigates the corrosion behavior of mild steel in seawater [2-4]. Seawater as corrosive media was taken from two different sites to compare the corrosion behavior of mild steel. Temperature data from both sites were recorded and two different studies conducted including weight loss analysis and polarization study.

II. EXPERIMENTAL

A. Sample preparation

The metal employed was mild steel (25 × 25 × 3 mm). The samples were mechanically polished using 400, 800, 1200 emery paper respectively. After that the metals were lubricated using distilled water. The polished samples were cleaned with acetone, washed using distilled water, dried in air and stored in desiccators. They were weighed for the original weight. Seawater as corrosive media was taken from Kuala Terengganu coastal area shown in Fig.1. The compositions of mild steel are shown in Table 1 [5].

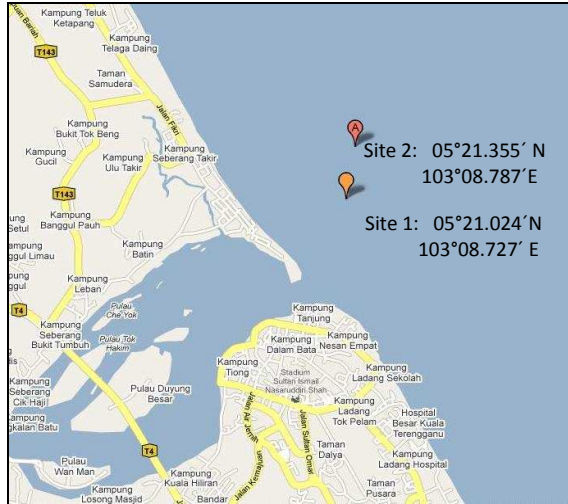


Fig. 1: Location of immersion site

Table 1 Composition of mild steel

Element	Percentage
Copper	0.14%
Manganese	0.35%
Silicon	0.17%
Sulphur	0.025%
Phosphorus	0.03%
Iron	remainder

B. Weight loss analysis

Before the samples were cleaned with acetone, the samples were weighed for the original weight (w_o) by using Sartorius Cole-Polmer analytical balance (readability: 0.0001g) and placed at site 1 and site 2 (Fig. 1) for 60 days. Then one sample was taken out in 10 days interval for 6 weeks. Before weighing, the sample was cleaned with distilled water and dried. Then the sample was immersed in sulphuric acid (H_2SO_4) to remove the corrosion products. Finally, the sample was washed with distilled water, dried and weighed in order to obtain the final weight (w_f).

Corrosion rate is calculated assuming uniform corrosion over the entire surface of the coupons. Corrosion rates, CR are calculated from weight loss methods. The formula used to calculate corrosion rate is as in Equation 1 [6]:

$$CR \text{ (mm /y)} = 87.6 \times (W / DAT) \quad (1)$$

Where:

W = weight loss in milligrams

D = metal density in g/cm^3

A = area of sample in cm^2

T = time of exposure of the metal sample in hours

C. Polarization

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) is in the form of a square cut so that the flat surface will be the only surface in the electrode [7]. The potentiodynamic current-potential curves record the data after the electrode potential was automatically changed from -100mV to +100mV with the scanning rate of $10mVs^{-1}$. The results were analyzed using the fit program GPES. Corrosion current (I_{corr}) was calculated by using the Stern-Geary where b_a is anodic Tafel slope, b_c is cathodic Tafel slope and R_p is polarization resistance [8]:

$$I_{corr} = \frac{b_c \times b_a}{2.303R_p(b_c + b_a)} \quad (2)$$

D. Seawater parameter

In measuring seawater parameter in this study, the instrument in used was YSI 556 multi-parameter system. This instrument is ready-to-use, handheld system for field measurements of dissolved oxygen, salinity, conductivity, pH and temperature. The display shows temperature in $^{\circ}C$ along with temperature compensated conductivity (milliSiemens/cm), salinity in part per million (ppm) and dissolved oxygen in mg/l. The YSI 556 multi-parameter system is placed in the sampling area to measure the seawater parameter. Seawater parameter was measured during interval of metal immersion

period and compared between site 1 and site 2.

III. RESULTS AND DISCUSSION

A. Weight loss analysis

The corrosion performance of mild steel was studied by using weight loss method. As seen from Fig. 2, the percentage of weight loss of mild steel in seawater increases with respect to time.

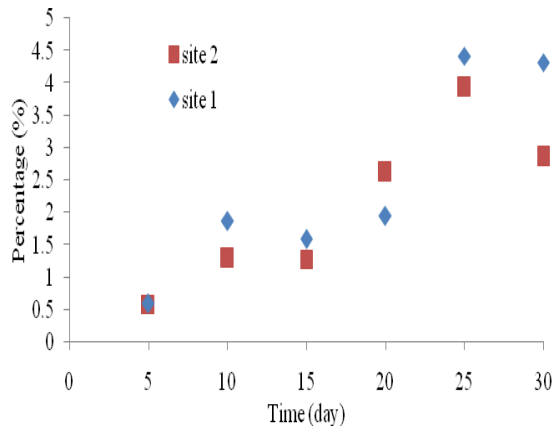


Fig. 2 Percentage of weight loss

As the immersion period increase, the percentage of weight loss also increase. The percentage of weight loss for site 1 is higher than site 2. The temperature and salinity data gained from both sides show that temperature for site 1 is higher than site 2 (Fig. 3a and 3b). Corrosion because of hydrogen evolution will increase the corrosion rate for every 30°C rise of temperature. Even though the temperature rise of the two sites did not exceed 30°C, a little rises in temperature affects the increasing in corrosion rate. Therefore, weight loss percentage was also increased as immersion period increase.

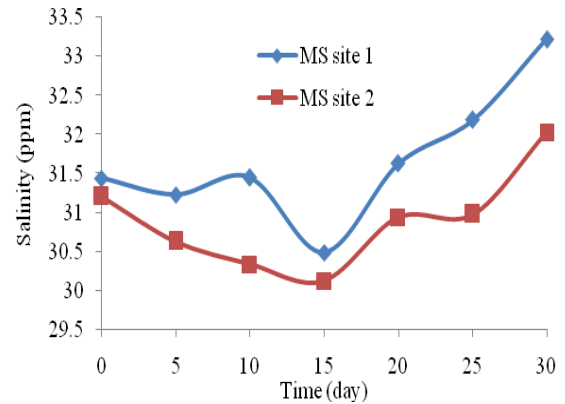


Fig. 3a Salinity data for seawater

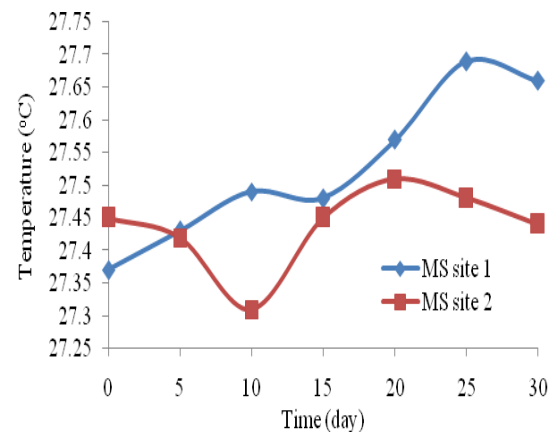


Fig. 3b Temperature data for seawater

B. Potentiodynamic polarization test

The value of i_{corr} was tabulated in Table 2. As seen, in Fig. 4, the logarithm trend line for site 1 increases while for site 2 the value is decreasing. It is clear that the value of i_{corr} can be used to calculate the corrosion rate where site 1 shows higher corrosion rate compare to site 2.

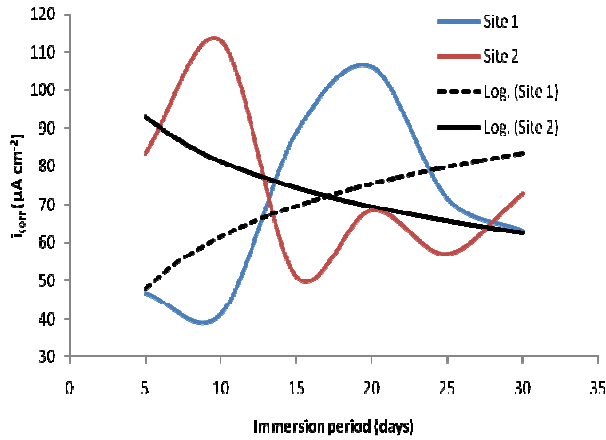


Fig. 4 corrosion current, i_{corr} versus immersion period

Table 2 Corrosion potential, E_{corr} and corrosion current, i_{corr} of mild steel from polarization study

Solutions	Days	Potentiodynamic Polarization	
		E_{corr} (mV)	i_{corr} ($\mu A\ cm^{-2}$)
MS S1	5	-717	46.74
	10	-661	41.33
	15	-706	88.65
	20	-705	106.2
	25	-723	71.79
	30	-723	62.99
MS S2	5	-709	83.63
	10	-706	113.0
	15	-737	51.24
	20	-726	68.58
	25	-702	57.06
	30	-719	72.82

The increasing values of i_{corr} lead to the increasing of corrosion rate where at this point, the cracks and pores might be presented. The increasing of corrosion rate can be seen in Fig. 5.

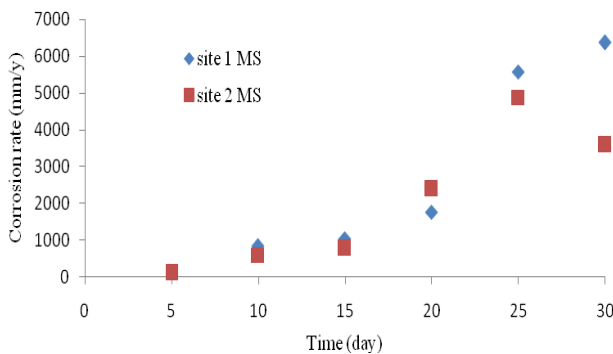
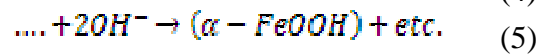
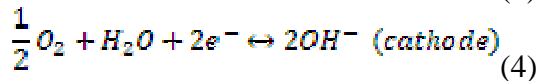


Fig. 5 Corrosion rate versus immersion period

The existence of this cracks and pores allows the electrolyte to flow through it and directly react with metals where corrosion process begins to arise [9]. The early stage of corrosion mechanism usually involves the reactions which follow conventional electrochemical rules where iron molecules are changed to various forms of ferrous hydroxides [10,11].



At this stage, the reaction is controlled by activation energy of the reaction and consecutively the reaction later is controlled by oxygen kinetics transport. As this reaction occur, the metals tend to lose its weight as this reaction is a function of surface roughness and dissolve oxygen. Hence, the value of i_{corr} increase at early immersion period. As the immersion period increases, the value of i_{corr} decreases. The rate of oxygen supply at this point has sufficiently inhibited by the gradual build up of corrosion product [12]. Therefore, the corrosion rate was also decrease. The data of E_{corr} was plotted in Fig. 6.

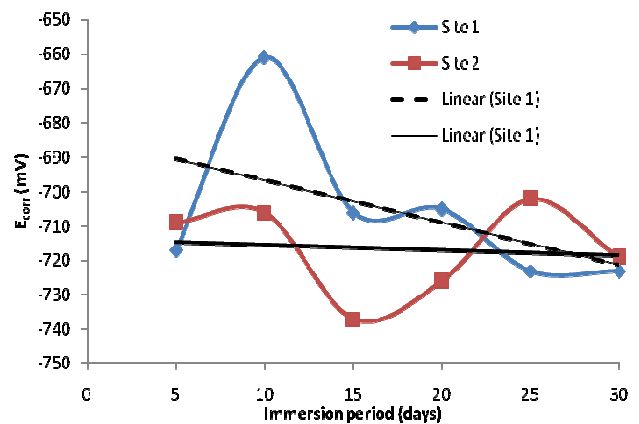


Fig. 6 Corrosion potential, E_{corr} versus immersion period

The value of E_{corr} gained from linear trend line decreasing with respect to immersion period and samples immersed in site 1 show highest E_{corr} value compare to samples in site 2. As the value of E_{corr} shifted to more negative value, the system tends to increase its metal dissolution and hydrogen evolution process [13].

IV. CONCLUSION

The corrosion behavior of mild steel was investigated in seawater at tow different sites near Kuala Terengganu coastal area. Weight loss analysis and polarization study was conducted and the result shows that the corrosion rate increases with respect to immersion period. A little differences on seawater parameters causes similarity of behavior for mild steel immersed in seawater from both sites. This research can be enhanced by studying the inhibitors where it can retard the corrosion of mild steel in seawater.

V. SCOPE AND LIMITATION

This research was conducted to indicate the corrosion behavior of mild steel near Kuala Terengganu coastal area. Two characterization were done which were weight loss analysis and potentiodynamic polarization test.

VI. REFERENCES

- [1] R.A. Prabhu, T.V. Venkatesha, A.V. Shanbhag, G.M. Kulkarni and R.G. Kalkhambkar, "Inhibition effects of some Schiff's bases on the corrosion of mild steel in hydrochloric acid solution," *Journal of Corrosion Science*, vol. 50, no.12, pp. 3356-3362, 2008.
- [2] Lei Han and Shizhe Song, "A measurement system based on electrochemical frequency modulation technique for monitoring the early corrosion of mild steel in seawater," *Corrosion Science*, vol. 50, pp. 1551–1557, 2008.
- [3] R.E. Melchers and R. Jeffrey, "Early corrosion of mild steel in seawater," *Corrosion Science*, Vol. 47, pp. 1678–1693, 2005.
- [4] K. Dae-Kyeong, S. Muralidharan, H. Tae-Hyun, B. Jeong-Hyo, H. Yoon-Cheol, L. Hyun-Goo and J.D. Scantlebury, "Electrochemical studies on the alternating current corrosion of mild steel under cathodic protection condition in marine environments," *Electrochimica Acta*, vol. 51, pp. 5259–5267, 2006.
- [5] M.A. Quraishi and Danish Jamal, "Corrosion inhibition of N-80 steel and mild steel in 15% boiling hydrochloric acid by a triazole compound — SAHMT," *Materials Chemistry and Physics*, vol. 68, pp. 283–287, 2001.
- [6] P. Venkatesan, B. Anand and P. Matheswaran, "Influence of formazan derivatives on corrosion inhibition of mild steel in hydrochloric acid medium," *Journal of Chemistry*, vol. 6, no.S1, pp. 438-444, 2009.
- [7] R. Rosliza, H.B. Senin and W.B. Wan Nik, "Electrochemical properties and corrosion inhibition of AA6061 in tropical seawater," *Journal of Colloids and Surfaces A: Physicochemical and engineering aspects*, vol. 312, no. 2-3, pp. 185-189, 2008.
- [8] H. Ashassi- Sorkhabi, D. Seifzadeh, and M.G. Hosseini, "EN, EIS and polarization studies to evaluate the inhibition effect of 3H-phenothiazin-3-one, 7-dimethylamin on mild steel corrosion in 1 M HCl solution," *Corrosion Science*, vol. 50, pp. 3363–3370, 2008.
- [9] N.F. Atta, A.M. Fekry and H.M. Hassan, "Corrosion inhibition, hydrogen evolution and antibacterial properties of newly synthesized organic inhibitor on 316L stainless steel alloy in acid

- medium,” *International Journal of Hydrogen Energy*, vol. 36, pp. 6462-6471, 2011.
- [10]U.R. Evans, “The corrosion and oxidation of metals: scientific principles and practical applications,” Edward Arnold (Publishers) Ltd., London, 1960.
- [11]D. Jones, “Principles and Prevention of Corrosion,” second ed., Prentice-Hall, Upper Saddle River, NJ, 1996.
- [12]R.E. Melchers, “Mathematical modelling of the diffusion controlled phase in marine immersion corrosion of mild steel,” *Corrosion Science*, vol.45, pp. 923–940, 2003.
- [13]A. Phanasgaonkar & V.S. Raja, “Influence of curing temperature, silica nanoparticles- and cerium on surface morphology and corrosion behavior of hybrid silane coatings on mild steel,” *Surface & Coatings Technology*, vol. 203, pp. 2260-2271, 2009.