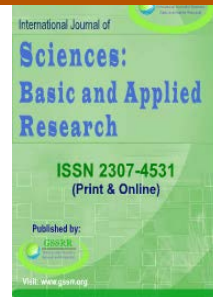




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## Electrochemical Measurement of Annealed and Normalized Mild Steel in the Presence of Lime of Milk Solution

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### Abstract

Mild steel have been widely used in production industries, particularly in engineering structure. This is because of its economical cost and easy formation. Various microstructures have a different performance with environmental effect. In this paper the electrochemical properties of various microstructure of mild steel in lime of milk solution  $\text{Ca}(\text{OH})_2$  has reported. Different grain sizes were obtained by heat treatment, and the Jeffries Planimetric method was applied to measure the average grain diameter. Scanning Electron Microscopy (SEM) was applied to study the surface characteristics, with addition of chemical composition by energy dispersive spectroscopy (EDS). The electrochemical behavior of mild steel was investigated at ambient temperature using potentiodynamic polarization. The result shows that lower grain size has a higher corrosion resistance as compared with higher grain size.

**Keywords:** Mild Steel; Electrochemical; grain size; surface analysis.

### 1. Introduction

A wide range of mild steel is uses in industries and engineering structure by considering its economic reasons and good weld ability. It has been widely used in different engineering structure and pipes that handling aqueous solution. However, the hazard of corrosion particularly increases during variation in temperature and acidic media[1] and greatly affects the lifetime of industrial equipments.

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It is a well known fact that the electrochemical behavior of carbon steel influence by a number of factors. It has been investigated[2]that alloying element particularly nickel contents increases the corrosion resistivity of carbon steel in salt solution contains 4% NaCl. It is concluded that electrochemical behavior of carbon steel are greatly depend on various manufacturers and, sometime a variation in the mechanical properties are induced in the material of the same grade[3]. The average grain size is greatly changes the corrosion behavior of carbon steel. Small grain size has a higher volume fraction of grain boundaries and therefore, higher corrosion resistance[4]than lower volume fraction of grain boundaries. It was also investigated that electrochemical behavior of carbon steel were seriously affected in sulfuric acid solution[2] and it is founded that oxidation of the iron take place in ferric state rather than ferrous state. Many researchers have studied the electrochemical behavior of mild steel in various aqueous media. It has been founded that corrosion behavior of mild steel is lower in nitric acids as compared with sulfuric acids[5, 6]. Abdel Salam Hamdy et. al [7] reported that protective passive film form on the surface of material in the form of oxide, is damaged due to the chemical reaction of sulfur with iron form iron sulfide, as a result localized corrosion produced on the material surface. The iron sulfide replaces the protective oxide layer which is responsible for corrosion protection. Moreover the electrochemical behavior of mild steel was studied [8, 9]and the corrosion behavior of the under investigated material retarded by silver nanocomposit layer in the presence of acidic medium. It has been reported [10, 11]that mild steel pipeline used in carbonated soft drink industries has corrosion much lower than acidic medium. It is due to the formation of active passive film more easily on the surface of material. It is also investigated [1, 12]that grain variation has a drastic effect on corrosion rate of carbon steel. The aim of this research is to investigate the electrochemical behavior of mild steel of the same grade with different microstructure obtained by heat treatment process. The corrosion properties were also studied through the result of potentiodynamic polarization techniques.

## **2. Experimental Details**

### **2.1 Material**

The material which is commonly called is mild steel with the chemical composition Fe 98.34%, C 0.10%, Mn 1.24%, P 0.05%, Si 0.23%, S 0.04%, with the balance is iron.

### **2.2 Heat Treatment**

The heat treatment process is carried out in an electric furnace with a proportional temperature controller with accuracy of  $\pm 10\text{ C}^0$  and furnace atmosphere at room temperature.

### **2.3 Sample Preparation**

One of the surface of each metallographic specimens annealed (designated AN) and normalized (NR) of each heat treated material are grounded mechanically on silicon carbide papers sequentially on 60, 120, 240, 320, 400, 600, 800 grit silicon carbide papers and polished on nylon cloth and fine slurry of Al<sub>2</sub>O<sub>3</sub>. All the polished specimens were etched using 2% nital solution (2 HNO<sub>3</sub> and Methanol). SEM, EDS and grain size measurement test were carried out of these polished and etched samples.

### 3. Result and Discussion

#### 3.1 Metallographic Studies of Mild Steel

Figure 1(a) and Figure 2(a) shows the microstructure of Annealed and, Normalized samples respectively (the magnification were 2000X). The variation of the average grain diameter with the change of heat treatment is also listed in Table 1. The average grain diameter was determined via Jeffries Planimetric method as shown in Figure 1(b) and 2(b). It is identified that the average grain diameter is bigger for annealed samples and get smaller for normalized samples. The numerical values are listed in Table 1 in addition to image shown in Figure 1(a) and 2(a); confirm that annealed grain diameter decreases with normalizing. Here, the average grain diameter for annealed samples was reported to be  $23\mu\text{m}$ , and decreases to  $12\mu\text{m}$  with ASTM grain size number 7.5 and 9.9 respectively. The change in the average diameter of the material is because of heat treatment and cooling in open air in which the grain are not further growing. This concludes that increasing cooling rate will decreases average grain size and therefore, the average grain diameter.

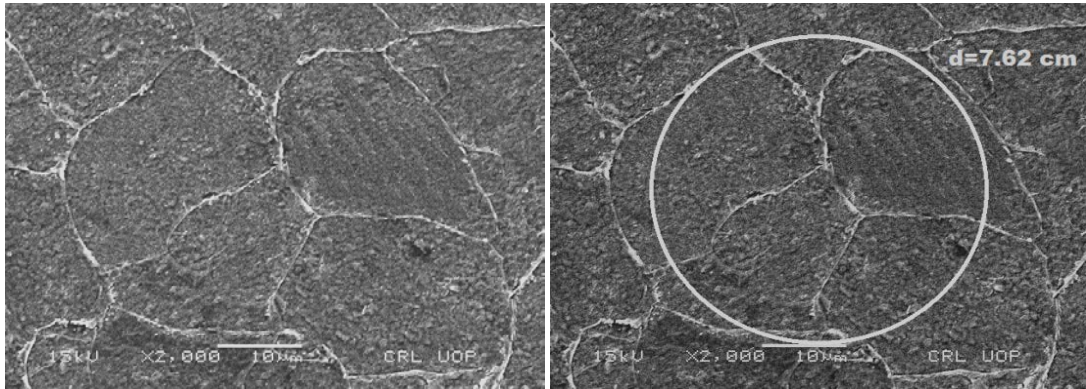


Figure 1: (a) Microstructure of Annealed Sample.

Figure 1: (b) Jefferies Planimetric Method.

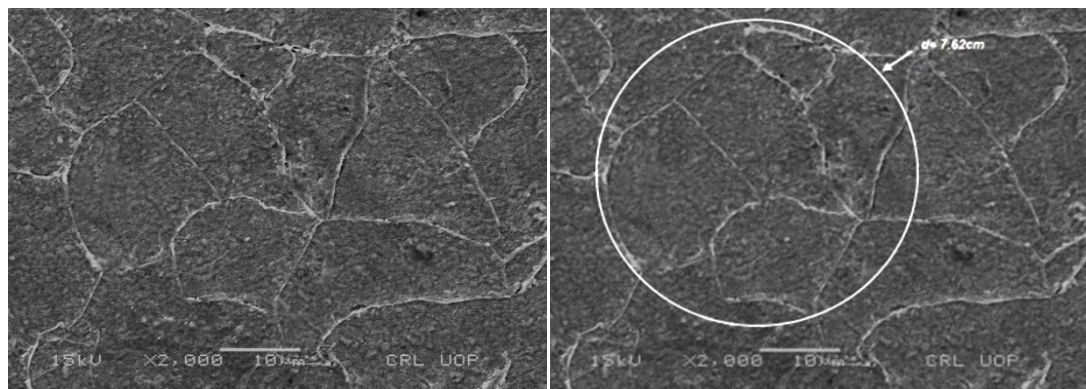


Figure 2: (a) Microstructure of Normalized Sample.

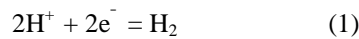
Figure 2: (b) Jefferies Planimetric Method.

**Table 1:** Numerical Values for Annealed tested Samples

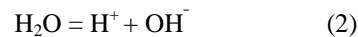
Material	Average Grain Diameter	ASTM Grain Size Number(G)
Annealed	26 $\mu\text{m}$	7.5
Normalized	11 $\mu\text{m}$	9.9

### 3.2 Effect of Grain Size on Electrochemical Behavior

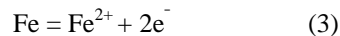
The potentiodynamic polarization behavior of annealed and normalized steel was recorded at room temperature in 3.5% NaCl solution. In a potential range vs. SCE the behavior of both the steel are studied. The galvanostatic anodic and cathodic polarization curves are shown in Figure 4 and Figure 5 for annealed and normalized sample respectively. the value of  $E_{\text{corr}}$ , and  $I_{\text{corr}}$ , were calculated and listed in Table 2. the cathodic reaction for steel in acidic solution has been reported to be the evolution of hydrogen ion as follows;



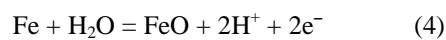
Here, the source for hydrogen ion is the dissociated water, according to the following reaction;



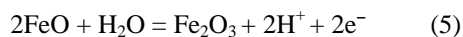
The anodic reaction of the steel at the same condition is the dissociation of iron as follows;



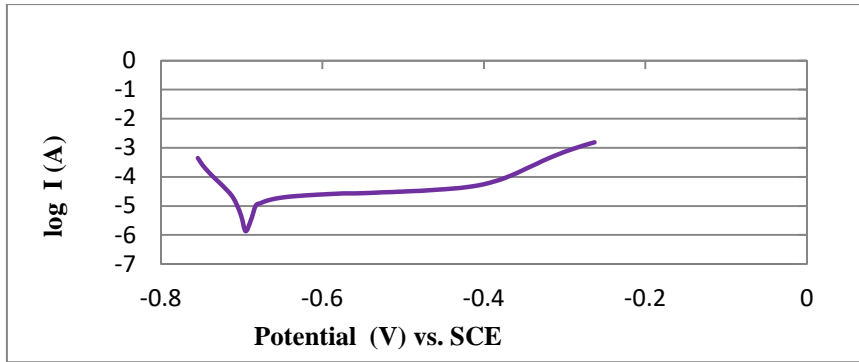
The free electrons which are produces during chemical reaction at anode surface are consumed at cathode. It has been reported [2]that at anodic branch there is a less negative potential than  $E_{\text{corr}}$  therefore, the iron oxide, FeO, is formed on the surface of material, as by the following reaction;



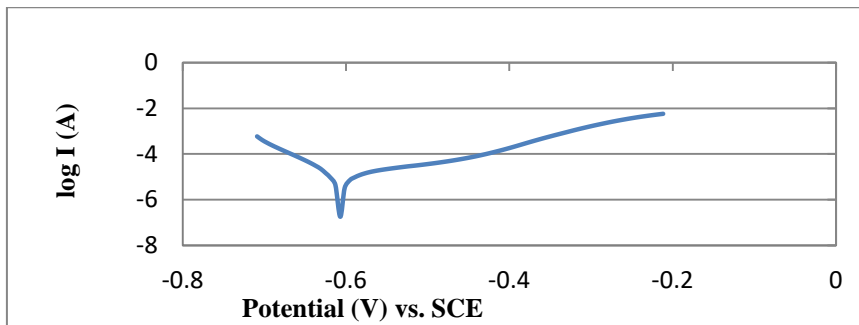
Additionally with FeO, the iron oxide film  $\text{Fe}_2\text{O}_3$ , also developed on the surface of test specimen[2]at much less negative potential of steel;



It is seen from Fig. 3 that iron had been annealed heat treated dissolved rapidly in the test solution with the same potential as compared with normalized. Fig. 4 shows the electrochemical behavior in 3.5% NaCl solution of normalized material. It has a small grain sizes as shown in Table. 1 and has a high volume fraction of grain boundaries. The potential is shifted towards more positive indicates that the migration of electron are decreases as the material microstructure varies.

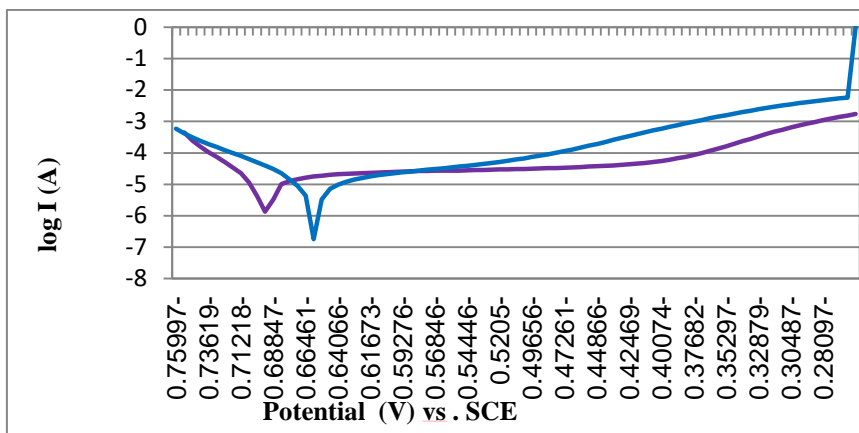


**Figure 3:** Electrochemical behavior of Annealed Sample



**Figure 4:** Electrochemical Behavior of Normalized Sample

It is clearly shown in Fig. 5 that annealed sample corrode rapidly as compared with the normalized sample. This is because weak protective passive film is developed on the surface of material, which directly related to surface hardness and material microstructure. Material of large average grain diameter has a coarse grain structure, and hence a weak ability to form protective film against corrosion. The corrosion rate increases with the increase of corrosion current density as shown in Table 2 indicates that the protective film is breakdown as the current density increases further. The positive shift of the potential curve Fig. 5 of normalized material reveal that small average grain diameter has a less corrosion rate comparatively.



**Figure 4:** Comparison of Electrochemical Behavior of Annealed and Normalized Sample

**Table 2:** Electrochemical Data for Annealed and Normalized Samples

Material	E <sub>corr</sub> (mV)	I <sub>corr</sub> (μA)
Annealed	-702.0	12.20
Normalized	-607.0	6.170

#### 4. Conclusion

The electrochemical behavior of mild steel of two different grain sizes in corrosive environment was analyzed by potentiodynamic techniques. It is concluded that material of large average grain size has different electrochemical behavior as compared with small average grain diameter. Moreover, the corrosion behavior was largely influenced by variation in microstructure. Material of refine grains structure has an increased corrosion resistance that of coarse grain structure.

#### References

- [1]. Lingzheng Kong, K.W., Yupeng Zhan, Yu Zhang, Effect of Heat Treatment on Electrochemical Behavior of 304L Stainless Steel in Nitric Acid. *Internatinal Journal of Electrochemical Science*, 2017. **12**: p. 2973-2986.
- [2]. El-Syed, M.S., Hany S. Abdo, S. Zein El-Abedin,, Electrochemical Corrosion Behavior of Fe64/Ni36 and Fe55/Ni45 in 4 percent Sodium Chloride Solution. 2017. **12**: p. 1600-1611.
- [3]. Sami I. Al-Rubaiey, E.A.A., Mahdi M. Hanoon, The Influence of Microstructure on the Corrosion Rate of Carbon Steel. *Journal of Engineering and Technology*, 2013. **31**: p. 10.
- [4]. Vahid Afshari et al, The Influence of Grain Size of Pure Iron Metal on Corrosion Inhibition in Presence of Sodium Nitrate. *International Journal of Electrochemical Science*, 2012. **5** p. 793-800.
- [5]. Khadija M. Hijazi, A.M.A.-G., G.O. Younis, Electrochemical Behavior of Mild Steel in HCl and H<sub>2</sub>SO<sub>4</sub> Solution in Presence of Loquat Leaf Extract. *Internatinal Journal of Electrochemical Science*, 2015. **10**: p. 4366-4380.
- [6]. Rabab M. El-Sherif, G.G., Electrochemical Investigation of Simulated Surface Scales Formed on X65 and J55 Pipeline Steel. *International Journal of Corrosion Science*, 2017. **12**: p. 3483-3502.
- [7]. Abdel Salam Hamdy, M.A.S., A.G. Sa'eh Y. Barakat, The Electrochemical Behavior of Mild Steel in Sulfide Polluted NaCl at Different Velocities. *Internatinal Journal of Electrochemical Science*, 2008. **3**: p. 1142-1148.
- [8]. Ayeman M. Atta, G.A.E.-M., Hamad A. Al-Lohedan, Abdelrahman O. Ezzat, Electrochemical Behavior of Mild Steel in Acidic Medium Based on Eco-Friendly Stabilized Monodisperse Silver Nnoncomposit. *Internatinal Journal of Electrochemical Science*, 2017. **9**: p. 8226-8238.
- [9]. L.Y. Yu, M.L., H.Y. Jing, Y.D. Han, Electrochemical Behavior of Corrosion Resistance of X65/Inconel 625 Welded Jionts. *Internatinal Journal of Electrochemical Science*, 2013. **8**: p. 2069-2079.
- [10]. D. Mareci, L.C.T., V.V. Cotea, R.M. Souto, Electrochemical Study on the Stability and Corrosion

Resistance of Tow Austinitic Stainless Steel for Soft Drink Container. Internatinal Journal of Electrochemical Science, 2017. **12**: p. 5438-5449.

- [11]. Harish Kumar, V.Y., corrosion charactrization of mild steel under different atmospheric condition by vapour phase corrosion inhibitor. american journal of material science and enginnering, 2013. **Vol 1 (3)**: p. 34-35.
- [12]. Hangwei Wang, C.Y., Effect of Grain Size on Corrosion Properties of Low Alloy Steel Under H<sub>2</sub>S/CO<sub>2</sub> Environment. Internatinal Journal of Electrochemical Science, 2017. **12**: p. 4327-4340.