

## **STUDY OF PITTING CORROSION ON MILD STEEL AND STAINLESS STEEL BY ELECTROCHEMICAL NOISE TECHNIQUE**

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### **ABSTRACT**

Pitting corrosion can be analyzed using electrochemical noise technique. Both mild steel and stainless steel samples were immersed in NaCl solution. Two different concentrations of NaCl solution were used; 1.0 M and 0.1 M. CaOH solutions was added to the electrochemical cell which contains mild steel sample to create a passivating layer on the sample. The chloride ions attacked the layers and form pitting corrosion. The cell was connected to a digital multimeter and was placed in a Faraday Cage. The data was processed and transferred to a computer for storage. Different electrolyte concentration and steel sample influenced the corrosion current.

**Keywords:** Mild Steel, Stainless Steel, Sodium Chloride, Electrochemical Cell, Faraday Cage.

### **INTRODUCTION**

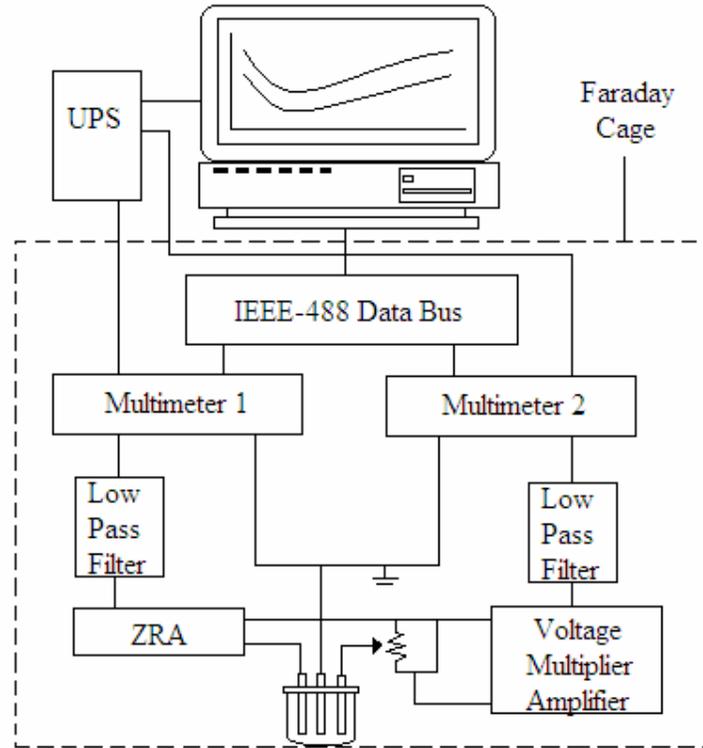
Corrosion is the deterioration of essential properties in a material due to reactions with its surroundings<sup>1</sup>. The alteration by a chemical or electrochemical oxidizing process will gradually return the metal to its original condition. Most metals have tendencies to return to their natural state as metallic ores<sup>2</sup>. When the metal reacted with the corrosion agent such as air and oxygen, the ore started to appear at the metal surface. Generally, there are two types of corrosion namely uniform corrosion and localized corrosion<sup>3</sup>.

Uniform corrosion is the well distributed with a low level attack on the entire metal surface with little or no localized penetration and it is also known as general corrosion<sup>3</sup>. It is the least damaging of all forms of corrosion. Uniform corrosion usually occurs in environments where the corrosion rate is inherently low or well controlled such as for chemically treated in closed circulating systems, and in some opens water systems.

Localized corrosion is defined as the selective removal of metal by corrosion on small areas or zones or on a metal surface which comes into contact with a corrosive environment. It takes place when small local sites are attacked at a much higher rate than the rest of original surface. There are several types of localized corrosion; they are pitting corrosion, crevice corrosion, erosion corrosion, galvanic corrosion, cavitations, fretting corrosion and intergranular attack corrosion<sup>4</sup>. In this study, pitting corrosion will be highlighted.

### **METHODOLOGY**

The instruments used in this study were divided into three parts namely faraday cage, data acquisition or signal conditioning unit and electrochemical cell.



**Figure 1:** Faraday cage, electrochemical cell and data acquisition system.

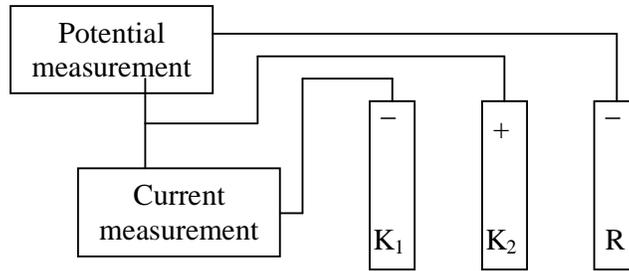
Faraday cage is an important instrument in electrochemical noise study. This is because the measurement of electrochemical noise will be influenced by the surrounding factors such as the electromagnetic waves, electric charge and the electric field. It is used as a special covering to protect materials and instruments from being exposed violently to the noise. The cage is made from aluminum sheet with the dimension of (2' x 2' x 2').

Stainless steel and mild steel were chosen as electrode samples. They were in a rod form and cut into pieces of height 0.5 cm and diameter 0.8 cm. They were then moulded and exposing only one surface.

Sodium Chloride Solution of 0.1M and 1.0M were used as electrolyte for stainless steel sample. The mild steel sample, the mixtures of Sodium Chloride Solution (0.1M and 1.0M) and Saturated Calcium Hydroxide were used. Electrolyte works as ion transferring and oxidizing agent. The experiments were repeated four times using Mild Steel and Stainless Steel in 0.1M and 1.0M Sodium Chloride Solutions. All data was transferred to a PC for storage and subsequent processing.

## RESULTS AND DISCUSSIONS

Twelve sets of data were taken; each set consists of 8192 pairs of potential and current values. These sets of data were analyzed and the best results were further analyzed. The analyzed data are presented in two sections, one represents the initial part and the other represents the final part of the experiment.

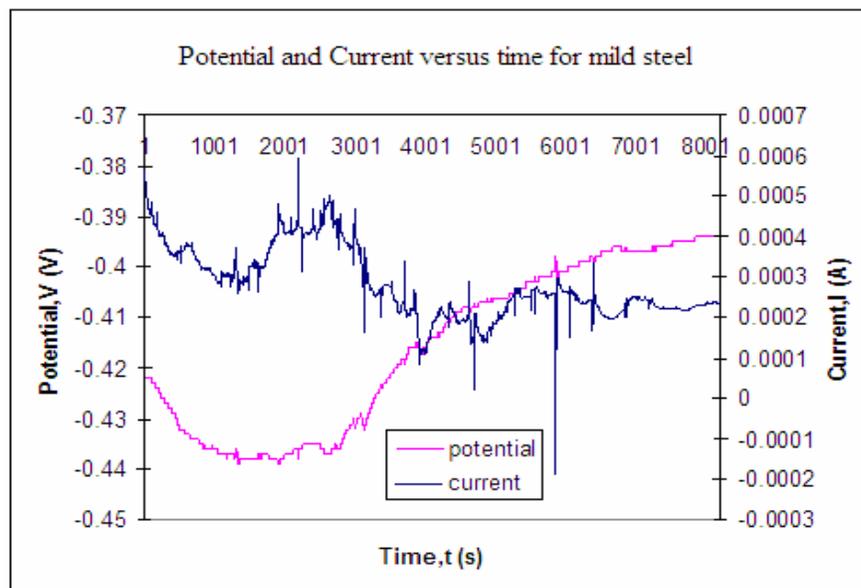


**Figure 2:** Block diagram for the measurement of current and potential of working and reference electrode

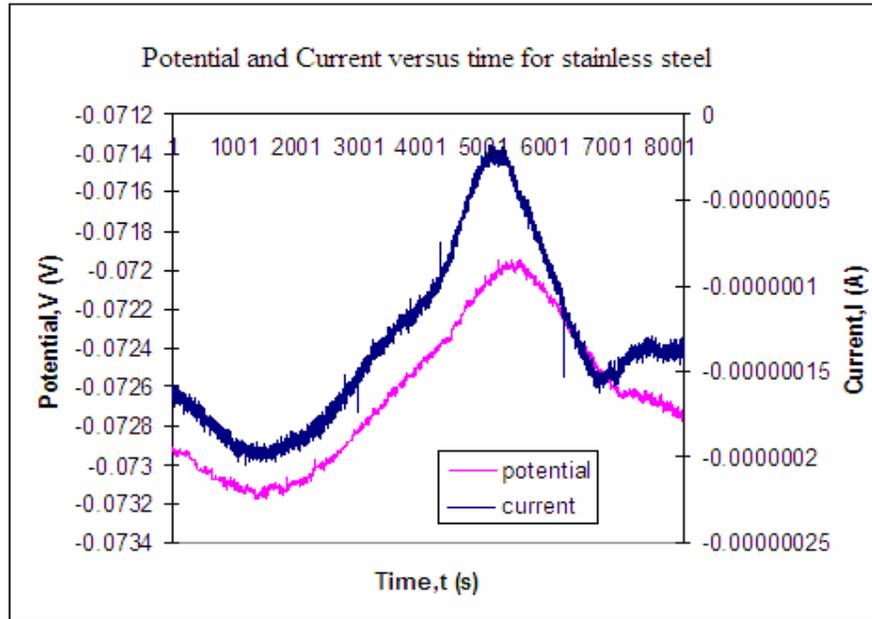
The data was analysed in two domains, which are time domain and frequency domain. For the time domain, the current and potential curves were plotted versus time. The results of mild steel and stainless steel sample immersed in a 1.0M NaCl solution was chosen to be compared. Figure 3 shows the reaction in mild steel sample while figure 4 illustrates the chemical reaction occurs on stainless steel sample.

In Figure 3, the pattern of the curve shows transients caused by the molar concentration of the NaCl solution. The molar concentration of NaCl plays important function in corrosion studies, the production of charges occurs more frequently. Even though the peak is not very clear, but later the graph peak become more apparent. The presence of pits could not be confirmed visually due to the small size of the pits.

Figure 4 shows small changes in both potential and current curve. The transients on this sample are too small and nearly zero, the concentration of 1.0M NaCl solution cannot afford to break the oxide (passivating) layer. It caused by the structure of stainless steel which was firm and persistent. Hence, low concentration acid hardly penetrates the sample. The observation failed to prove that the pits presents on sample due to the sample structure and concentration of electrolyte.

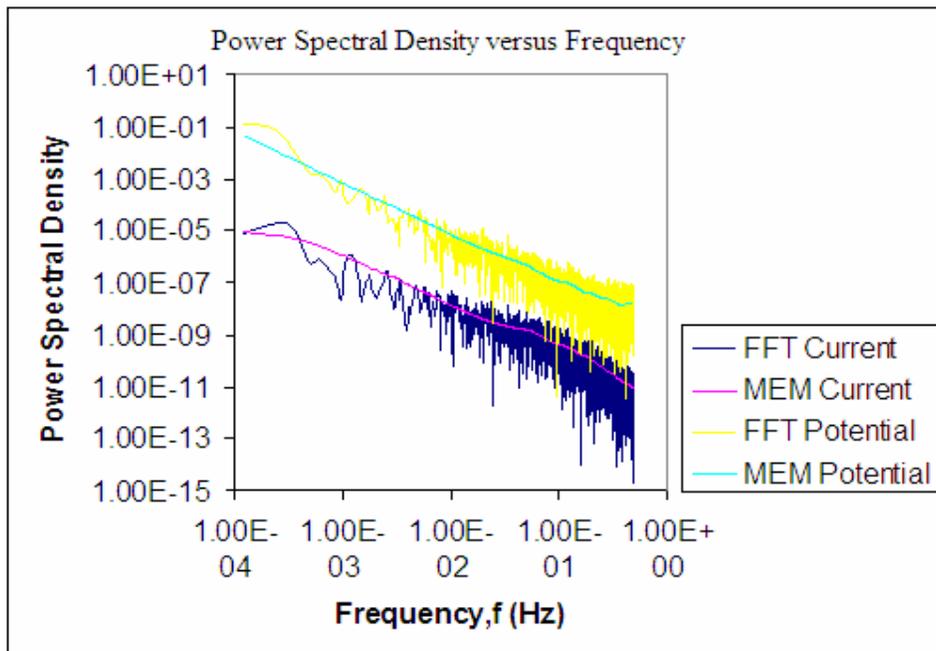


**Figure 3:** Graph of potential and current versus time for mild steel.

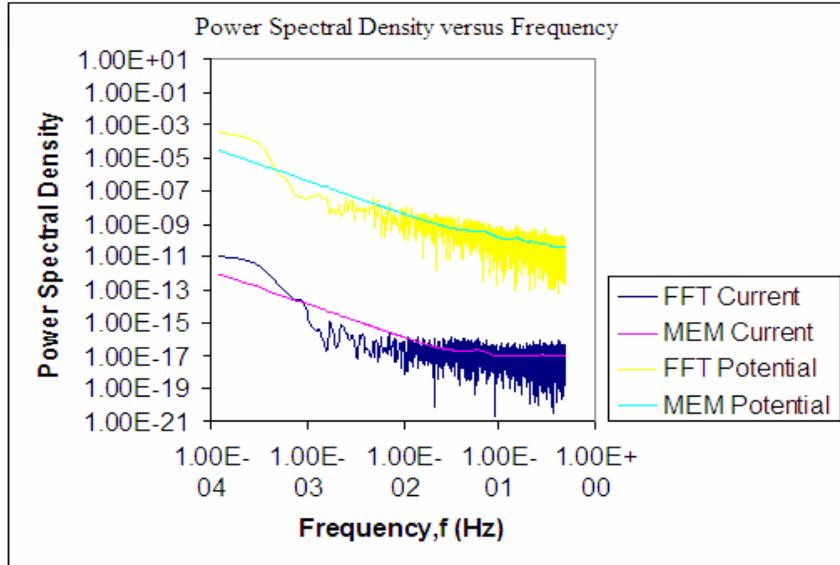


**Figure 4:** Graph of potential and current versus time for stainless steel

For frequency domain, the current and potential curves were plotted versus frequency. The results of mild steel and stainless steel sample immersed in a 1.0M NaCl solution was chosen for comparison. The main reason is to estimate the power present for all frequencies for an infinitely long time record.



**Figure 5:** Graph of Power Spectral Density for mild steel



**Figure 6:** Graph of Power Spectral Density for stainless steel

In frequency domain analysis, the three parameters that you are looking for are the low frequency pattern, knee frequency and the roll-off slopes. However, if these three parameters are similar, it means the technique is not reliable to distinguish.

From the data taken, several values can be determined such as mean current, mean potential and standard deviation of current and potential. It can be attained by using Batch EnAnalyse or EnAnalyse software.

**Table 1:** The value of  $\bar{I}$ ,  $\sigma_I$ ,  $\bar{V}$  and  $\sigma_V$  for experiment B (mild steel) and D (stainless steel).

EXPERIMENTS	Mean Current, $I$ $\times 10^{-04}$ (A)	Standard Deviation of Current, $\sigma_I \times 10^{-05}$	Mean Potential, $V$ $\times 10^{-01}$ (V)	Standard Deviation Of Voltage, $\sigma_V \times 10^{-04}$
B (initial)	9.920	1.5400	-4.370	7.79
B (final)	2.830	1.4100	-4.160	4.55
D (initial)	-0.052	0.0015	-0.719	0.31
D (final)	-0.013	0.0003	-0.726	0.15

Usually in pitting corrosion, the mean current and voltage are larger compared to uniform corrosion due to the transient of the curve. Thus, the standard deviation for both current and voltage were also large.

These parameters are important to calculate and determine the value of noise resistance ( $R_N$ ), coefficient of variation ( $C_0V$ ), charge in transient ( $q$ ), localization parameter ( $LI$ ) and corrosion current ( $I_{corr}$ ). However, only noise resistance ( $R_N$ ) and corrosion current ( $I_{corr}$ ) were used to distinguish the phenomena of pitting.

$$\text{Noise resistance, } R_N = \frac{\sigma_V}{\sigma_I} \quad (2.1)$$

$$\text{Corrosion current, } I_{\text{corr}} = \frac{B}{R_N} \quad (2.2)$$

The value of noise resistance usually approaching zero and it is inversely proportional to the corrosion current. Thus, the corrosion current value was large for pitting corrosion.

## CONCLUSION

From the experiment, we can conclude that the mild steel and stainless steel in higher concentration electrolyte reacts faster with sample compared to the lower concentration. The corrosion current for mild steel is greater than the corrosion current for stainless steel of the same electrolyte concentration. The saturated calcium hydroxide solution creates a protective layer (passivating layer) on mild steel. In pitting corrosion, the value of standard deviation of current and potential is large. The value of charge in transient,  $q$  was high for pitting corrosion. The spikes or transients appear on potential and current noise in time records show occurrence of pitting corrosion.

From the results and observation, we can conclude that this research was successful and the research objectives were met.

## ACKNOWLEDGEMENTS

The authors would like to acknowledge Jabatan Perkhidmatan Awam (JPA) for its financial assistance and OCRG laboratory, Faculty of Science, UTM for its facilities.

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