INHIBITION CHARACTER ANALYSIS OF CORROSION INHIBITOR ON CARBON STEEL MATERIALS IN 1M HCL SOLUTION USING THE EIS METHOD

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ABSTRACT

INHIBITION CHARACTER ANALYSIS OF CORROSION INHIBITOR ON CARBON STEEL MATERIALS IN 1 M HCL SOLUTION USING THE EIS METHOD. Research on the effect of the concentration of the inhibitor on the corrosion behavior of carbon-steel material has been done. The research was started by immersing the prepared carbon-steel plate in a 1 M HCl environment. After that, corrosion inhibitor was added with several concentrations, which are 0, 100, 200, 300, and 400 ppm in to that environment, to be stirred using a magnetic stirrer at 300 rpm for 30 minutes under room temperatur condition. The effect of the added inhibitor was then analyzed using the Electrochemical Impedance Spectroscopies (EIS) method. The experiment results showed that the greater the concentration of the inhibitor, the greater the resistance, so that the metal is more protected from corrosion attack. The calculation results showed that the inhibitor efficiency is directly proportional to the concentration of inhibitor that is achieved at a concentration of 400 ppm with an efficiency of 71.24%.

Keywords: corrosion, inhibitor, EIS method, carbon-steel

ABSTRAK

ANALISIS SIFAT INHIBISI PADA INHIBITOR KOROSI TERHADAP MATERIAL BAJA KARBON DI LINGKUNGAN HCL 1M MENGGUNAKAN METODE EIS. *Telah dilakukan Penelitian tentang pengaruh konsentrasi inhibitor terhadap sifat korosi pada material baja karbon. Penelitian ini diawali dengan perendaman baja karbon yang sudah dipreparasi ke dalam lingkungan HCl 1 M. Kemudian dilakukan penambahan inhibitor korosi dengan konsentrasi 0, 100, 200, 300, dan 400 ppm ke dalam lingkungan tersebut sambil dilakukan pengadukan menggunakan magnetic stirrer dengan kecepatan 300 rpm selama 30 menit dalam kondisi temperatur kamar. Untuk mengetahui pengaruh konsentrasi inhibitor pada material baja karbon, maka dilakukan analisis menggunakan metode Spectroskopi Impedansi Elektrokimia (EIS). Hasil eksperimen menunjukkan bahwa semakin besar konsentrasi inhibitor, maka semakin besar pula hambatannya sehingga logam semakin terlindungi dari serangan korosi. Hasil perhitungan menunjukkan bahwa nilai efisiensi inhibitor berbanding lurus dengan konsentrasi inhibitor yang dicapai pada konsentrasi 400 ppm dengan nilai efisiensi sebesar 71,24 %.*

Kata kunci *: korosi, inhibitor, metode EIS, baja karbon*

INTRODUCTION

RSG-GAS is a 30 MWt research reactor having two cooling systems, which are the primary and secondary cooling system. The primary cooling system has a function to cool the reactor core and also acts as a moderator [1]. The light water used in the primary cooling system is a demineralized water as required by the reactor requirements. The secondary cooling system has a function to transfer heat from the primary cooling system to the environment. The secondary cooling system is an open system, which is directly connected with the outside environment. The water on the secondary cooling system is derived from the water source facility of the research center area (PAM Puspiptek), so that air or oxygen will be easily in touch with the secondary cooling system and trigger the oxidation process in the material system. Carbon-steel is a material type that is used on the pipe in the secondary cooling system.

The carbon-steel is one of the strong metals but is relatively easily corroded. Corrosion is an electrochemical reaction that is a natural process, therefore corrosion can not be prevented or stopped all together [2]. The corrosion process is not only caused by the presence of oxygen, but also because of the presence of some trace elements such as, chloride ions [3,4]. Corrosion inhibitor is added to the secondary cooling system with the purpose to inhibit the corrosion rate. The corrosion inhibitor will make a passive layer in the form of a thin layer or film on the metal surface that serves as a barrier between the metal to corrosive media [5].

This paper will discuss the inhibition properties of the corrosion inhibitor on carbon steel material in the 1 M HCl environment using Electrochemical Impedance Spectroscopy (EIS). Using the EIS method, the correlation between concentration and inhibition properties (coating) of inhibitors on carbon-steel material can be obtained. In order to analyze the effect, several preparation have to be done on the carbon-steel material, such as immersion, adding the inhibition concentration, testing the specimen using the EIS, and analyzed the results by calculation.

The method of Electrochemical Impedance Spectroscopy (EIS)

Electrochemical Impedance Spectroscopy (EIS) is a method to analyze the response of a corroded electrode against a potential signal. In principle, the EIS method can be used to specify a number of parameters related to the amount of electrochemical value, such as polarization resistance (Rp), solution resistance (Rs), and an electric double layer capacitance (Cdl). The value of Rs depends on the concentration of ions, type of ion, temperature and the geometry area of the current conduction. While Rct is obtained from the difference impedance at low and high frequency. Rct value is a measure of the transfer of electrons on a metal surface, that is proportionally inverse of the corrosion current (I0) as calculated by the equation 1. Impedance spectra resulting from measurements using the EIS method is presented in the Nyquist diagram. Before the EIS measurements, Open Circuit Potential (OCP) measurements are conducted in order to get the steady state condition of the interaction between the electrode and the solution [6].

$R_{ct} = RT/nFI_0$.. (1)

The results of EIS measurements are shown in the Nyquist diagram. The electrical resistance of the EIS is stated as the impedance (Z). The Impedance is a measure of the ability of a circuit to withstand the electric current. The Nyquist diagram is a semicircular form diagram for assessing the real impedance (real) and the imaginary impedance (imaginar). In general, the resulting Nyquist diagram does not show a half circle, but a semi-circle. This behavior can be attributed to frequency dispersion resulting from the electrode surface roughness [7]

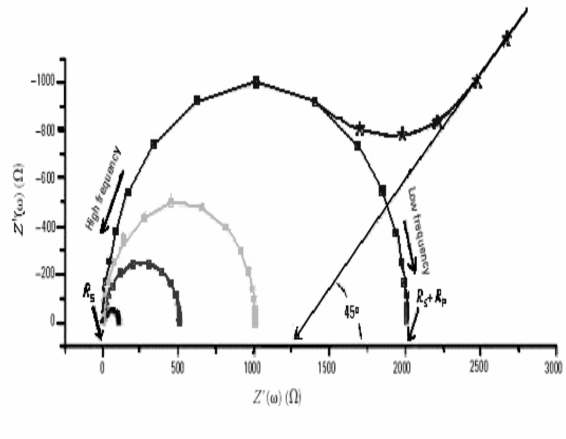

Fig. 1. Typical Nyquist diagram resulted from the EIS measurement

Figure 1 shows the typical Nyquist diagram defining the relation between the two impedances. The angle shows that the kinetics of electrochemical systems is limited by diffusion control process (concentration polarization). Extrapolation semicircle as the intersection of the real impedance Z ' is graphically expressed as a polarization resistance, Rp. Figure 2 shows the model of circuit used in the EIS testing describing the position of Rs, Rp, and Cdl.

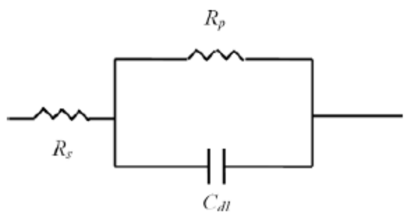

Fig. 2. Circuits model for EIS testing

As showing in Figure 2, the potential is used to the circuit and a conductivity response for frequency signal is used as impedance data. Impedance data is associated with the phase angle changes, variations potential, and conductivity.

METHODOLOGY

Equipment and material specimen preparation

The equipments used in this research are LCR HIOKI 3532-50 HiTESTER machine, polishing machine, Beaker glass, 100 mL measuring cup, pipette, ruler, sandpaper grade 600 and 800, plate cutting tools, lathe, magnetic stirrer, and magnetic stirrer machine. The material used for the experiment consists of a carbon-steel plate, 1 M HCl Solution, and inhibitor solution with a various concentration of 0, 100, 200, 300, 400 ppm and demineralized water with conductivity less than 0.6 μSv / cm.

Specimen Preparation and conduct of experiment

The carbon-steel plate is cut using a cutting tool to obtain 10 pieces of plates with the size of 1 cm x 1 cm x 0,3 cm each. Each specimen is then polished using the papersand. The environment for the experiment is prepared by providing a 1 M HCl solution and inhibitor solution with various concentration of 0, 100, 200, 300, 400 ppm. The carbon-steel is then immersed in the HCl solution and the corrosion inhibitors with variouse concentrations are added. The solution is stirred using the magnetic stirrer at 300 rpm speed for 30 minutes under room temperature condition. After that, the EIS testing is performed to determine the nature of inhibition of corrosion inhibitors on the carbon steel specimens. The EIS testing is conducted to evaluate the response of an electrode, which undergoes corrosion. Before using the EIS, several arrangements are needed such as setting the amplitude values from peak to peak of 10 mV, the frequency from 0.1 Hz to 10,000 Hz, and OCP (Open Circuit Potential) time for 4 minutes . After steady state condition is achieved, the EIS measurement can be started.

RESULTS AND DISCUSSION

Analyses on the corrosion behavior using the EIS is basically a Nyquist diagram analysis to assess the relation between real impedance (Z) and imaginary impedance (Z '). Electrochemical parameters obtained from this test are Rs, Rp, Rct, and Cdl, where Rs is the solution resistance, Rp is the polarization resistance, Rct is t he charge transfer resistance, and Cdl is the capacitance of the double layer formed on the interfacial layer. The value of curvature expresses the corrosion resistance of the carbon-steel, where the greater the curvature is generated, the more the resistance of the material from the corrosion process is built. In other word, the corrosion attack by the corrosive ions will occur in a long time span.

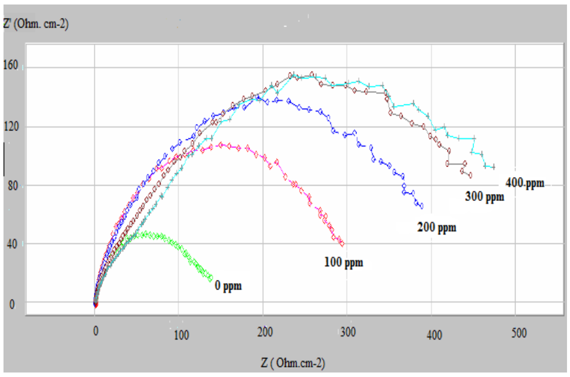

Fig 3. Nyquist Diagram with several concentrations of corrosion inhibitor on HCl 1 M Solution.

The results of EIS testing as the form of Nyquist Diagram are shown in Figure 3. Figure 3 shows that the Nyquist diagram plot will increase with the increasing concentration of inhibitor. This indicates that the adding of the corrosion inhibitor can inhibit the corrosion rate of the carbon material in the HCl 1M Solution. The efficiency of inhibition by inhibitors is obtained from the following equation:

$$EF(\%) = \frac{CR_{noninhibitor} - CR_{inhibitor}}{CR_{noninhibitor}} x100\% \quad .(2)$$

The calculation results as shown in Table 1 indicate the correlation between inhibitor concentration and inhibition efficiency in the carbon-steel as obtained by the EIS measurements.

Table 1. The correlation between inhibitor concentration and inhibition efficiency in the carbon-steel

Concen tration (ppm)	HCl 1 M Solution		
	R_p (ohm.cm^2)	C_{dl} (µF/cm^2)	Inhibition Eficiency (%)
0	140.2	49.75	-
100	295.3	27.00	52.52
200	389.7	18.83	64.02
300	452.1	16.11	68.98
400	487.5	14.21	71.24

From the above table, it can be concluded that the inhibition efficiency of corrosion inhibitors is increased with the increased inhibitor concentration. The increased concentration would be able to inhibit the corrosion rate of the carbon steel significantly.

CONCLUSIONS

Using the Electrochemical Impedance Spectroscopy (EIS) method, the effect of the corrosion inhibitor to inhibit the corrosion rate of the carbon-steel has been assessed. The experiment showed that the greater the concentration of corrosion inhibitor, the bigger the resistance was formed to inhibit the corrosion rate. In general, the inhibition efficiency of corrosion inhibitors will increase along with the inhibitor concentration, that is achieved at a concentration of 400 ppm with an efficiency of 71.24 %.

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