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NATRIUM CARBONATE (NA_2CO_3) AS INHIBITOR IN THE CORROSION PROTECTION ON STEEL PIPE ST 41 IN WATER PLUMBING ENVIRONMENTAL

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Abstract
This study aimed to analyze the effect of adding to the rate of steel corrosion inhibitor and comparing the rate of corrosion on steel pipes with and without inhibitors. The testing conducted in Puspitek shown that the most optimum of the inhibitor contained with the addition of 1% due to changes of the pH from 7.30 to 11.80. This shows the increasing of pH occurred sizable value and followed by the declines of potential value (E_{corr}) -700.53 mV to -512.39 mV. Thus, the decreasing occurred to the current corrosion value (I_{corr}) from 2.71 μA/cm^2 to 0.31 μA/cm^2, while the corrosion rate of carbon steel St 41 decreased most effective after adding 1% Na_2CO_3 as an inhibitor, the corrosion rate is changed from 1.2437 mpy to 0.1427 mpy.

Keyword: carbon steel St41, inhibitor, corrosion, corrosion rate, polarization resistance, potentiodynamic

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1. Introduction

The use of metal in everyday life is very diverse. One of the common uses is in the field of industry. Carbon steel material, for example, is widely applied in industrial pipes for oil and natural gas, which is as pipelines for exploration and production process. In the application of metal is constantly in touch with the environment such as air, water vapor, water and other chemicals. At the time of the metal in contact with the environment, there will be a chemical interaction between the metal and the surroundings, the results will be more easily corroded steel.

Corrosion is a process of material degradation and loss of quality of a material due to the influence of chemical reactions in an electrochemical process with a corrosive environment [1-3]. Carbon steel is one type of steel alloy consisting of elemental iron (Fe) and carbon (C). Where iron is the main ingredients for the manufacture of steel and carbon as an element of alloys. The addition of inhibitors is being applied in a concentration either continuously or sporadically. Inhibitors can adsorb ions or particles into the surface of the metal [4, 5]. An environment which can contribute to corrosion of a metal is an aqueous environment, an environment containing Cl- ions, and acidic environments [6].

Corrosion can also result in losses. The losses caused by corrosion are a form of maintenance costs, replacement costs of materials, plant shutdown, loss of production, and others [6]. The addition of inhibitor is useful in material that does not allow the use of protection methods such as coating and cathodic protection [7, 8]. The addition of inhibitors used in a concentration either continuously or sporadically. Inhibitors work by way of absorption of ions or particles into the surface of the metal [9-11]. It likewise proposes to bring down the corrosion rate by affecting the anodic reaction [8, 12], cutting the pace of dissemination of the reactants into the metal surface, as well as enhancing the electrical impedance of the metal surface [13].

Generally, inhibitors are substances that inhibit or decrease the rate of a chemical reaction [14]. Contrary to the nature of the catalyst, the inhibitor accelerates the rate of reaction. The mechanism of inhibitor is sometimes more than one type. A number of inhibitors to prevent the corrosion are through adsorption method to form an invisible thin layer that protects the metal from attacks that corrode metal and produce products that form a passive layer as well as eliminate the aggressive constituents [15]. One of the most commonly used cathodic inhibitors is sodium carbonate. It can reduce the oxygen transport in the surface and increase the acidity close to the steel [16]. Factually, sodium carbonate is famous to use as inhibitor in some research, such as in carbon steel, X70 steel, many others steel [17-19].

2. Experimental Details

In this study, the polarization resistance or polarization resistance calculation on corrosion rate

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method is used to get good results [17]. Polarization resistance is the resistance of a sample to oxidation during a given external potential and is used to calculate the speed of corrosion. This study also using Sotcorr 342 Corrosion Measurement software. However, in the advanced calculation, the corrosion rate must be determined beforehand I_{corr} (corrosion current) from the polarization values obtained. The following formula describes the relationship between polarization and I corr.

$$\frac{\Delta E}{\Delta I} = R_p = \frac{\beta A \bullet \beta C}{(\beta A + \beta C)(2{,}3 \bullet I_{corr})} \quad (1)$$

I_{corr} = corrosion currents (mA)
R_p = prisoners polarization or polarization resistance
βA = anodic Tafel constant
βC = cathodic Tafel constant

The value of R_p is analytically calculated by the relationship between current and voltage as in Fig. 1.

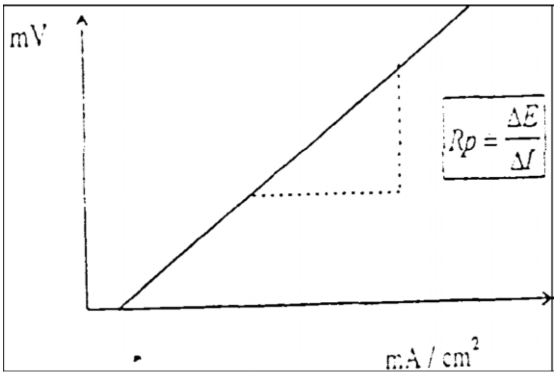

Fig. 1. Polarization resistance curve

Furthermore, the value of I_{corr} which can be inserted into the following formula:

$$(Corr\ Rate)(mpy) = 0{,}13 I_{corr} \frac{(EW)}{A.D} \quad (2)$$

I_{corr} = corrosion currents (mA)
EW = equivalent weight (g)
A = surface area of the sample (cm^2)
D = mass density (g/cm^3)
mpy = milliinch per year (mils per year)

The resistance technique is applied to observe the pattern of the linear polarization curve of the cathode or anode between - 20 mV to 20 mV in the E_{corr} area (meeting anodic and cathodic curve).

3. Result and Discussion

The selection of inhibitor's concentration normally 0.5-3% [1]. Thus, the concentrations of inhibitor used in the experiment were 1%, 2%, and 3%. The result of the study of metal-carbon steel St 41 in running water environment without and with the Na_2CO_3 inhibitor is obtained as follows.

Table 1. The polarization resistance data of carbon steel St 41

Media / Indicator	running water	1% Inhibitor Na_2CO_3	2% Inhibitor Na_2CO_3	3% Inhibitor Na_2CO_3
pH	7.30	11.80	11.85	12.00
E corr (mV)	-700.53	-512.39	-541.58	-532.96
Cathodic Tafel (mV)	18.32	13.74	14.87	26.79
Anodic Tafel (mV)	22.01	23.64	31.17	91.89
I corr ($\mu A/cm^2$)	2.71	0.31	1.05	1.11
Corr Rate (mpy)	1.2437	0.1427	0.4809	0.5115

Based on Table 1, carbon steel St 41 in running water environment without the inhibitor with polarization resistance technique shows the pH values are around 7.30, neutral environment. At the same time, the corrosion potential (E_{corr}) is -700.53 mV, the corrosion current (I_{corr}) is 2.71 $\mu A/cm^2$, and the corrosion rate is 1.2437 mpy.

The addition of 1% Na2CO3 inhibitors on carbon steel St 41 running water environment changes the pH value, from 7.30 to 11.80. The fact shows the increased of pH that followed by the decline of potential value (E_{corr}) from -700.53 mV to -512.39 mV, Fig.s 2 and 3. In the other hand, the corrosion current (I_{corr}) decrease from 2.71 $\mu A/cm^2$ to 0.31 $\mu A/cm^2$ as well as the corrosion rate which is apparent decrease 1.2437 mpy to 0.1427 mpy.

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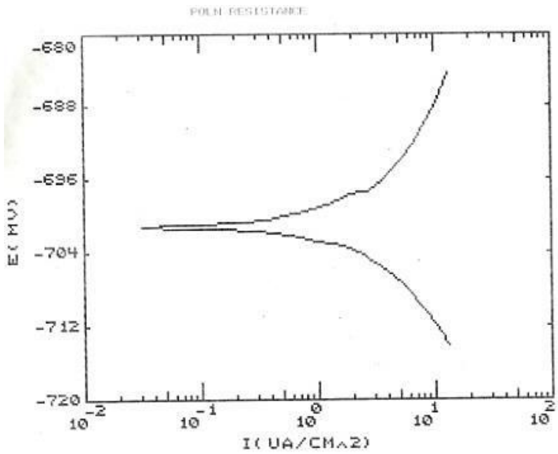

Fig. 2. Polarization curves of carbon steel St 41 in running water without inhibitor.

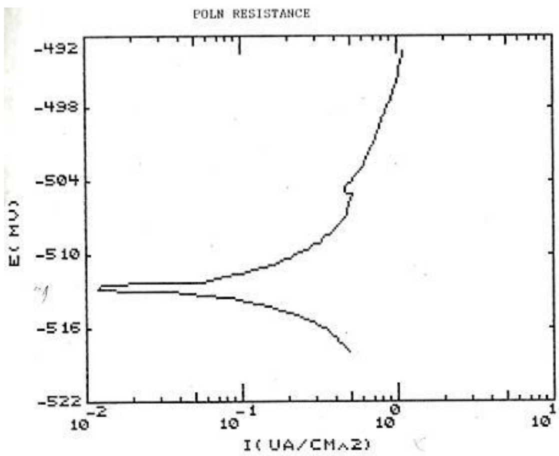

Fig. 3. Polarization curves of carbon steel St 41 in running water with 1% inhibitor.

Fig. 4 shows the data in addition of 2% Na_2CO_3 inhibitor to carbon steel St 41. The water pH decreased from 7.30 to 11.85, while the corrosion potential (E_{corr}) increased from -700.53 mV to -541.58 mV. This fact indicates a potential decrease in the stricken area, cathodic. Whereas the corrosion current (I_{corr}) decrease from originally 2.71 µA/cm^2 to 1.05 µA/cm^2. It means that the corrosion current (I_{corr}) decline. The corrosion rate decreased from 1.2437 to 0.4809 mpy, a decrease in the rate of corrosion.

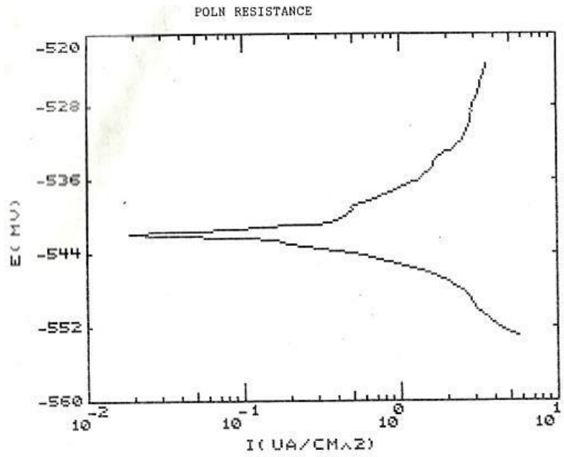

Fig. 4. Polarization curves of carbon steel St 41 in running water with 2% inhibitor.

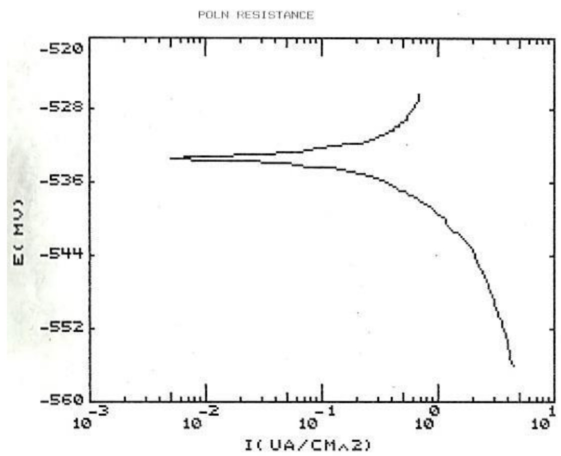

Fig. 5. Polarization curves of carbon steel St 41 in running water with 3% inhibitor.

The comparison between Fig. 2 and Fig. 5 shown the decreasing of pH from 7.30 into 12.00 while its corrosion potential (E_{corr}) also decrease from -700.53 mV to -532.96 mV. Additionally, the corrosion current and the corrosion rate decreased as 1.6 µA/cm^2 and 0.7322 mpy respectively.

From the analysis above, it can be seen that the smallest rate of corrosion for the carbon steel St 41 in running water environment is with 1% inhibitor, 0.1427 mpy, which is more effective to protect the carbon steel pipe in the water rather than the others.

The potentiodynamic tests are performed by the Tafel analysis and the specimen analysis of carbon steel St 41 in running water environment with a variety percentage of Na_2CO_3 Inhibitor, 1%, 2%, and 3%, to affect the rate of corrosion.

The corrosion potential (E_{corr}) used in the potentiodynamic tests is -100 mV to 600 mV. The aims of this test are to obtain the Tafel curves, as shown in Figs. 6, 7, 8, and 9.

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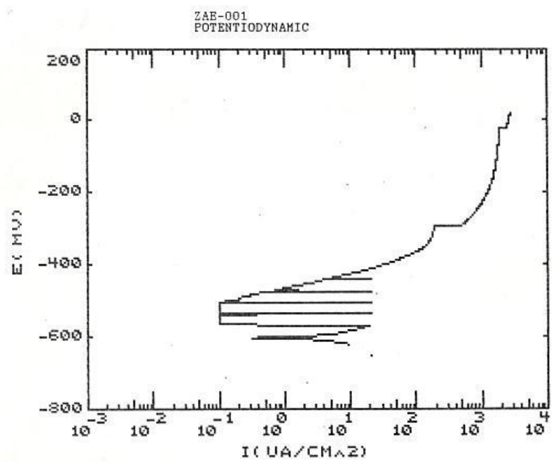

Fig. 6. The potentiodynamic curve on running water environment without inhibitors.

Fig. 6 shows that the material of carbon steel St 41, started very reactive to react with the ions forming the solution, coating the surface with layers of minerals. This condition occurs when a material run into corrosion at a potential (E_{corr}) with limited current density (I_{corr}). In potentiodynamic test without inhibitor, the potential of corrosion is about at a point -600 and passive at 101. The curve also showed the oxidation reaction that occurred fairly reactive. It is characterized by a gentle curve or growing shift.

Tafel curves of potentiodynamic testing with the addition of inhibitors shown in Figs. 7, 8, and 9.

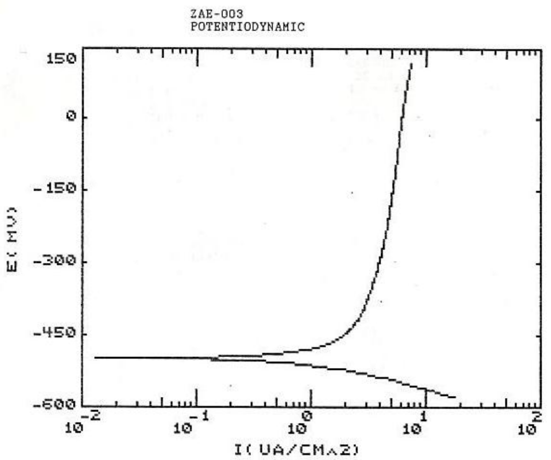

Fig. 7. The potentiodynamic curve on running water environment with 1% inhibitors.

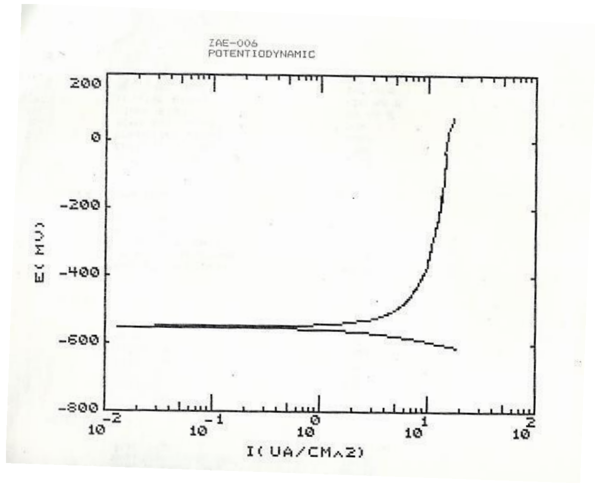

Fig. 8. The potentiodynamic curve on running water environment with 2% inhibitors.

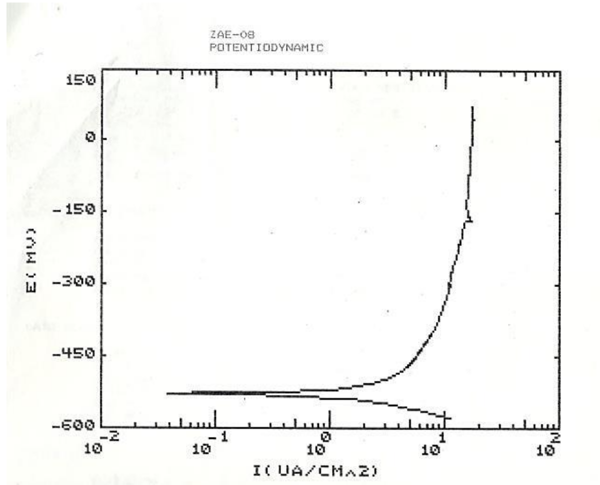

Fig. 9. The potentiodynamic curve on running water environment with 3% inhibitors.

Fig. 7 shows that the sample of potentiodynamic curves in running water environment with the addition of 1% inhibitor. It showed samples were still in active regions with a potential around -500 mV which the steel oxide compounds formed passive. Passivation is a film forming on the surface of metal oxide that is one of oxidation products which is resistant to corrosion, so as prevention for further corrosion.

Fig. 8 shows the similar results with the previous figure. It shows the sample of potentiodynamic curves in running water environment but with the addition of 2% inhibitor. It showed samples were still in active regions with a potential around -550 mV which the steel oxide compounds formed passive.

Fig. 9 shows that the sample of potentiodynamic curves in running water environment with the addition of 3% inhibitor. The curve is showing the sample has a passive behavior and run into the

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smaller corrosion rate of passivation. The amount will easily damage the passive layer; this is due to the excessive amount of chemical substances.

Table 2. The comparison of I_{corr} and E_{corr}

Inhibitor	I_{corr} (mA/cm^2)	E_{corr} (mV)
Without	0.56	-700
1 %	0.47	-500
2 %	0.39	-550
3 %	0.42	-285

Based on the results above, the lowest potential is in using of 2% inhibitor. This result occurred by the productivity of complex material surrounding the surface. The corrosion rate analysis shows the optimum condition to prevent the corrosion.

Fig. 10. Optical photo of carbon steel St 41 surface in running water environment without using inhibitors.

The addition of inhibitors can reduce the rate of corrosion and may increase the value of inhibition. The ability to measure the effectivity of inhibition is by its efficiency. Efficiency may depend on the concentration of inhibitor used. The higher the concentration of inhibitor is used it will produce higher efficiency.

The presence of the inhibitor on the surface of carbon steel St 41 impacts their adsorption. Adsorbs arise due to the adhesion force between the inhibitor to the surface of carbon steel St 41. The inhibitor molecule adsorption on the surface of carbon steel St 41 will produce a kind of thin layer (film) on a carbon steel St 41 can inhibit the corrosion rate.

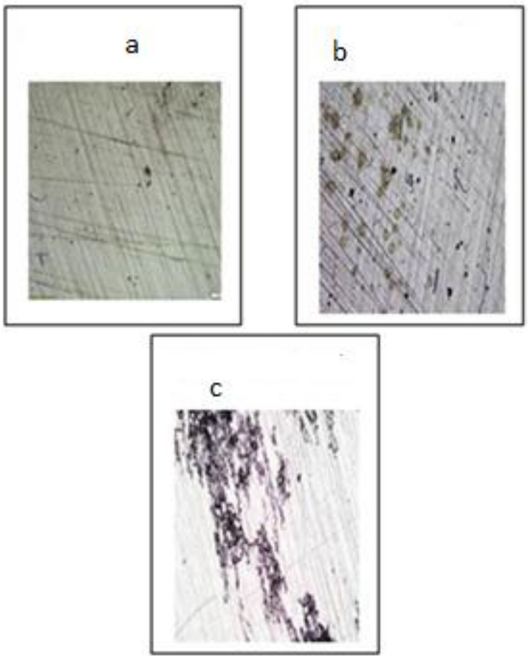

Fig. 11. Optical photo of carbon steel St 41 surface in running water environment with 1% (a), 2% (b), and 3% (c) inhibitors.

4. Conclusions

1. The analysis of carbon steel St 41 in running water environment shown the pH value, corrosion potential, corrosion current, and corrosion rate are 7.30, -700.53 mV, 2.71 mA/cm^2, and 1.2437 mpy respectively.
2. The pH and the potential corrosion analysis of carbon steel St 41 with 1%, 2%, and 3% Na_2CO_3 inhibitor in running water environment shown the pH value is always higher than without inhibitor.
3. The lowest value of the cathodic constant is the carbon steel St 41 with 1% inhibitor, 13.74 mV. It shows that the inhibitor has cathodic protection.
4. The corrosion rate analysis shows the best percentage of using inhibitor is only for 2% Na_2CO_3. It shows the optimum condition to prevent the corrosion.

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