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Article

Control of Corrosion Rate of Metal Alloys: SS 304 And SS 201 Using Phosphate Inhibitor in Nacl 3.5%

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Abstract

Corrosion is metal damage caused by electrochemical reactions with its environment. This environment can be water, air, gas, acid solution, salt solution, and others. Metals are highly active in producing an oxide layer on the metal surface under the influence of an aerobic environment. Metal corrosion is a process where the action of the surrounding media damages metal materials by the introduction of corrosion ions. This study aims to determine the best conditions for phosphate in controlling the rate of corrosion and Knowing the inhibition of phosphate on controlling the rate of corrosion. The materials used were stainless steel 201, stainless steel 304, and phosphate as an inhibitor. Meanwhile the solution NaCl 3.5% as a corrosive media environment and distilled water. Based on this research, the best phosphate concentration in reducing the corrosion rate of stainless steel 201 and 304 is 100 ppm with a reduction in the corrosion rate of stainless steel 201 of 0.022312 mpy with an inhibition percentage of 89.68%, and a reduction in the corrosion rate of stainless steel 304 by 0.045694 mpy with the percentage of inhibition is 94.027%. The corrosion rate of 304 stainless steel is lower than that of 201 stainless steel caused by differences in the Cr element composition of each metal. Stainless steel 304 contains 18.24% Cr while stainless steel 201 contains 13.00% Cr. The lower the Cr content in stainless steel, the stainless steel will be more susceptible to corrosion.

Keywords: Corrosion, Metals Alloys, SS 304, SS 201, Phospate inhibitor

1. Introduction

Corrosion is metal damage caused by electrochemical reactions with its environment. This environment can be water, air, gas, acid solution, salt solution, and others. Corrosion causes a decrease in the quality of metal, for example, boiler leaks which affect the life of the equipment and will cause material loss[1].

Metals are highly active in producing an oxide layer on the metal surface under the influence of an aerobic environment. Metal corrosion is a process where the action of the surrounding media damages metal materials by the introduction of corrosion ions. Metal corrosion is a spontaneous chemical reaction that can be divided into chemical corrosion and electrochemical corrosion, according to the reaction mechanism [2]. Compared to damage caused by other natural catastrophes, metal corrosion damage to metal materials is regulated and preventive [3].

Statistics show that modern industrial technology may effectively reduce corrosion-related risks and financial losses by 20 to 30% if appropriate corrosion-prevention strategies are applied. Therefore, controlling and preventing metal corrosion is very important. There are many ways to prevent and manage metal corrosion at the moment, including using high-performance corrosion-resistant metals, covering the metal surface with protective coatings, using electrochemical technology to prevent corrosion, oxidizing and phosphorylating metal surfaces, and adding corrosion inhibitors [4]. In his initial 1860 patent application for corrosion inhibitors, Baldwin described how corrosion inhibitors prevent corrosion. Nitrite, chromate, silicate, molybdate, polyphosphate, tungstate, zinc salt, and other inorganic chemicals are the most common inorganic corrosion inhibitors [5].

Corrosion inhibitors are defined as additives that are added in small concentrations to an environment effectively reducing the rate of metal corrosion. Special advantages of corrosion inhibitors is that it can be executed or changed without interrupting the process [6].

Corrosion remains a significant challenge in preserving the integrity and reliability of metallic materials, particularly in various industrial applications. Among the commonly employed metal alloys, SS 304 and SS 201 are extensively utilized due to their favorable mechanical properties and corrosion resistance. However, their susceptibility to corrosion, even under mild environmental conditions, necessitates the development of effective corrosion control strategies.

In recent years, the use of corrosion inhibitors has emerged as a promising approach for mitigating the detrimental effects of corrosion on metals. Corrosion inhibitors are chemical compounds added to corrosive environments to reduce the rate of corrosion by hindering electrochemical reactions at the metal surface. The application of corrosion inhibitors has garnered considerable attention due to their demonstrated efficacy in inhibiting corrosion reactions, thereby extending the service life of metallic materials.

By employing synthetic materials as corrosion inhibitors to create organic corrosion inhibitors with superior corrosion inhibition capabilities, researchers have achieved substantial advancements in the study of corrosion inhibitors in recent years. After years of study, it has been said that corrosion on metal surfaces may now be detected as being inhibited utilizing weight-loss techniques, electrochemical techniques, molecular dynamics simulations, quantum chemistry computations, etc. [7]. [8] showed that the use of Artemisia annua extract in a hydrochloric acid solution effectively inhibits corrosion of carbon steel. An experimental scenario for the creation of green corrosion inhibitors is presented in this paper. To compile the most useful data on corrosion inhibition effectiveness, several researchers have undertaken substantial study on environmental corrosion inhibitors and a number of reviews.

This research endeavors to explore the efficacy of employing corrosion inhibitors as a means to control corrosion rates in two prevalent metal alloys, SS 304 and SS 201. The study will investigate various types of inhibitors that have the potential to be applied in diverse industrial settings. It aims to compare the efficiency of these inhibitors concerning the specific corrosion types encountered by these two alloy types and evaluate their implications for sustainability and system reliability.

The study will build upon the existing body of knowledge documented in previous research related to the use of inhibitors for corrosion control. Several relevant studies have identified effective inhibitors for various applications, and we will assess whether these findings can be extrapolated to SS 304 and SS 201 alloy systems.

Through this research, it is anticipated that sustainable and efficient solutions for controlling corrosion rates in SS 304 and SS 201 alloys will be elucidated. Such findings will contribute to the enhancement of the reliability and service life of equipment and structures associated with these alloys.

This study aims to determine the best conditions for phosphate in controlling the rate of corrosion and Knowing the inhibition of phosphate on controlling the rate of corrosion.

2. Material and Method

The materials used were stainless steel 201, stainless steel 304, and phosphate as an inhibitor. SS 201 alloy steel is a type of austenitic stainless steel stainless steel which has a composition of 0.15%C, 13.5%Mn, 0.03%P, 0.03%S, 0.15%Si, 13.00%Cr, 1.02%Ni, and the rest Fe. Some mechanical properties are Type 304 carbon steel has, among other things: tensile strength of 580 Mpa, yield strength 198 Mpa, elongation 50%, hardness 87HRB [7]. Meanwhile the solution NaCl 3.5% as a corrosive media environment and distilled water.

The equipment used are a set of potentiostat test equipment, beaker glass, pipette, measuring flask, measuring cup, and spatula.

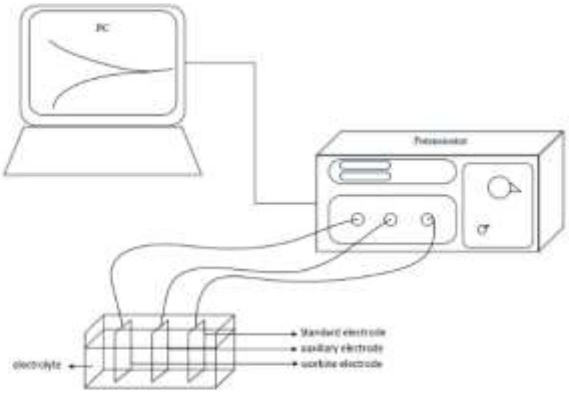


Fig. 1. potentiostat analysis equipment

The variables used were concentration of NaCl (3,5%), Volume of Sodium Chloride Solution (250 ml), Volume of Aquadest (100 ml), Coupon size (1 cmx1cmx0,15cm), standart electrode (kalomel), auxiliary electrode (platina), scanning time (2 mins), concentration of phosphate (50, 100, 200, 300, 400, 500 ppm) and working electrode (SS 201 and SS 304).

Preparation of workpieces/test objects

Metal alloys using stainless steel as the working electrode are cut with dimensions of 1cm (L), 1cm (P), and 0.15cm (T). Stainless steel on the surface is smoothed using scouring paper grade 300 to 1000, then washed with water and alcohol then dried. Stainless steel is one of them the tip is wrapped with epoxy resin so that it is in contact with the test solution only on the front surface with an exposure area of 1 cm^2.

Preparation of Sodium Tripolyphosphate in Aquadest

Sodium tripolyphosphate 50 ppm,100 ppm, 200 ppm, 300 ppm, 400 ppm, and 500 ppm dissolved in distilled water.

Analysis potensiostat

In polarization analysis, the working electrode is installed in the electrochemical cell facing the auxiliary electrode and the calomel electrode. Potentiodynamics is turned on and connected to Autolab software until the monitor screen appears: the relationship between cell potential and current at all times. After the analysis is complete, the tafel curve will appear and the parameters. Sample analysis was attempted for 2 minutes accordingly with the settings in the software used.

3. Results and Discussion

The quantitative analysis method using the potentiodynamic method aims to obtain a graph of the corrosion rate.

Based on potentiostat measurements, corrosion rate data was obtained. Curve Polarization is a curve that connects the potential and current density of the coupon metal. Corrosion current ($Icorr$) can be calculated by extrapolating the tafel to the current log curve with potential. This extrapolation is to select a curve that is related to the corrosion potential ($Ecorr$). Corrosion potential is defined as the potential obtained when the total speed of all anodic reactions is balanced by the total speed of all cathodic reactions. The intersection of the curves from the extrapolation results will produce point with coordinates ($Icorr$, $Ecorr$). From this point the coordinates can be known price of corrosion current. Corrosion current measured from the extrapolation line intersection ($Icorr$) can be used to calculate the corrosion rate with the formula as follows corrosion rate:

$$CR = K \frac{\alpha \; x \; Icorr}{n \; x \; D}$$

CR = Corrosion rate (mpy), K = Factor Constant (0.129 for mpy), α = Metal atomic mass, Icorr = Corrosion current density (μA/cm2), n = Number of valence electrons, D = Density (gr/cm2).

Inhibitor Efficiency (%IE):

$$\% IE = \frac{CR_o - CR_i}{CR_o} x \; 100\%$$

Table 1. Corrosion rate of Stainless Steel 201 with inhibitors phosphate using potesionstat

PO_4 Conc (ppm)	Corrosion rate (mpy)	efficiency (%)
0	0,21628	without inhibitor
50	0,11006	49,112
100	0,022312	89,684
200	0,036466	83,139

300	0,10366	52,071
400	0,13041	39,703
500	0,20237	6,431

Table 2. corrosion rate on Stainless Steel 304 with inhibitors phosphate using potesionstat

PO$_4$ Conc (ppm)	Corrosion rate (mpy)	efficiency (%)
0	0,21628	without inhibitor
50	0,11006	49,112
100	0,022312	89,684
200	0,036466	83,139
300	0,10366	52,071
400	0,13041	39,703
500	0,20237	6,431

Influence of inhibitor concentration on corrosion rate show that Figure 2.

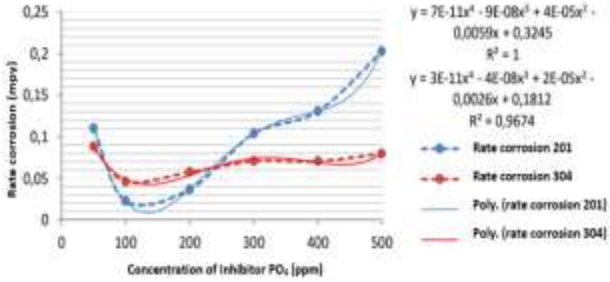


Fig. 2. Effect of PO4 inhibitors with concentrations between 50 ppm to 500 ppm on the corrosion rate of SS 201 and SS 304

Based on Figure 2, it shows that the corrosion rate on stainless steel 201 and 304 at a concentration of 50 ppm amounted to 0.11006 mm/year and 0.087974 mm/year, at a concentration of 100 ppm the corrosion rate on metal decreased by 0.022312 mm/year and 0.045694 mm/year, this is due to Phosphate inhibitors can form a thin film layer that coats stainless steel 201 and stainless steel 304 so that it can slow down the rate of corrosion. At concentrations of 200 ppm to 500 ppm there was an increase of 0.20237 mm/year and 0.079371 mm/year, this is because excess phosphate inhibitors can damage the thin film layer, causing the corrosion rate of the metal to increase. The reaction between oxygen and sodium triphosphate is as follows:

$$4Na_3PO_4 \quad + \quad 3O_2 \quad \rightarrow \quad 6Na_2O \quad + \quad 4PO_4$$

Natrium Triphosphate Oxygen Sodium Oxyde Phosphate Ions

It show that the corrosion rate of stainless steel 304 is lower than stainless steel 201 due to differences in material composition. Stainless steel 304 contains 18.24% Cr and 201 stainless steel contains 13.00% Cr. The lower the Cr in stainless steel, the more stainless steel it will be more susceptible to corrosion. The best point of deep phosphate inhibitors reduces the corrosion rate of Stainless Steel 201 and Stainless Steel 304 at concentration of 100 ppm with a reduction in the corrosion rate of 0.022312 mm/year for stainless steel 201, and 0.045694 mm/year for stainless steel 304.

The effect of PO4 inhibitor concentration (ppm) on efficiency (%) is shown in Figure 3

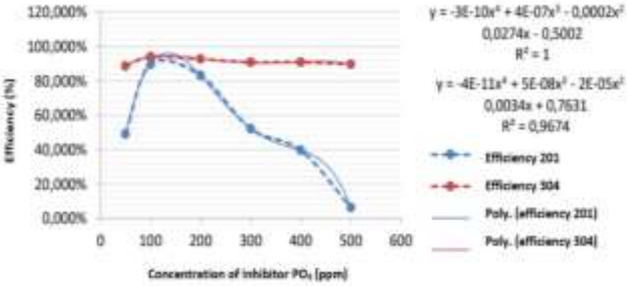
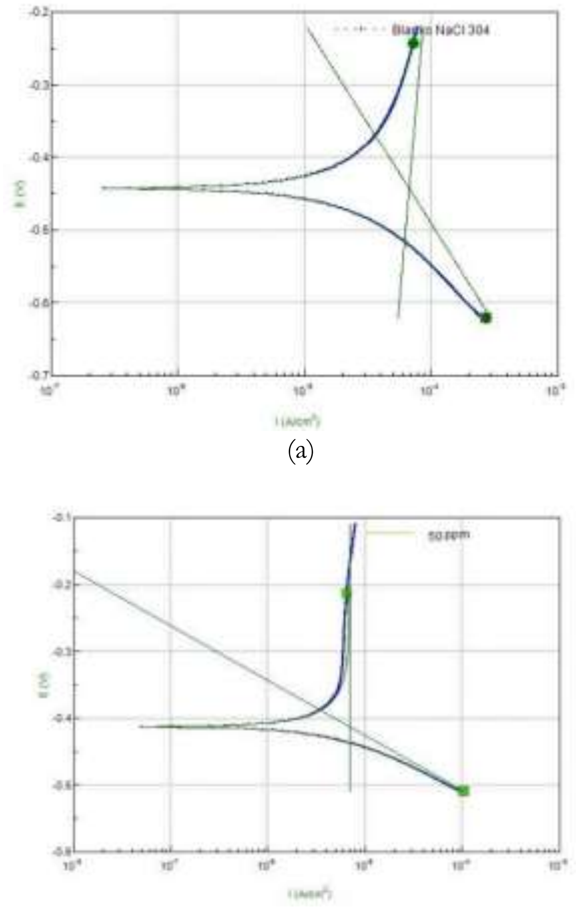


Fig. 3. Effect of PO4 inhibitor concentration (ppm) on efficiency (%).

Based on Figure 3, the inhibitor efficiency of stainless steel 201 and stainless steel 304 obtained the highest inhibitor efficiency at a concentration of 100 ppm 89.684%, and 94.027%, this is caused by a concentration of 100 ppm inhibitor Phosphate can form a thin film coating that coats stainless steel 201 and 304 thereby slowing down the rate of corrosion. At concentrations of 200 ppm up to 500 ppm decreased, this was caused by inhibitors Excessive phosphate can damage the thin film layer so that it can accelerate the rate of corrosion on stainless steel 201 and stainless steel 304. Efficiency The lowest inhibitor for stainless steel 201 at a concentration of 500 ppm was 6.43% and for stainless steel 304 at a concentration of 50 ppm, it is 88.5%.

The relationship between potential, E and current log can be seen in Figure 4.



(a)

(b)

Fig. 4. (a) Relationship between potential, E (V) and log current, I (A/cm^2) without inhibitors (blank solution) in SS 304; (b) Relationship between potential, E (V) and log current, I (A/cm2) with 50 ppm phosphate inhibitor on SS 304

Based on Figure 4. Shows that relationship between potential, E (V) and log current, I (A/cm^2) in SS 304 without inhibitors and using inhibitors. Based on data fitting shows the E without inhibitors is 0,4438 volts, and using inhibitors is 0,41347 volts.

4. Conclusions

The best phosphate concentration in reducing the corrosion rate of stainless steel 201 and 304 is 100 ppm with a reduction in the corrosion rate of stainless steel 201 of 0.022312 mpy with an inhibition percentage of 89.68%, and a reduction in the corrosion rate of stainless steel 304 by 0.045694 mpy with the percentage of inhibition is 94.027%. The corrosion rate of 304 stainless steel is lower than that of 201 stainless steel caused by differences in the Cr element composition of each metal. Stainless steel 304 contains 18.24% Cr while stainless steel 201 contains 13.00% Cr. The lower the Cr content in stainless steel, the stainless steel will be more susceptible to corrosion.

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