Jurnal Reaksi (Journal of Science and Technology)
Jurusan Teknik Kimia Politeknik Negeri Lhokseumawe
Vol. 22 No.01, Juni 2024 ISSN 1693-248X

TESTING CHEMICAL ZINC PHOSPHATE BASE AS A CORROSION INHIBITOR ON CARBON STEEL IN THE CORROSION MEDIA OF COOLING WATER, SEA WATER AND PDAM WATER

Sariadi[1]*, Rengga Rahmat Kenady[1], I Irwan[1], Halim Zaini[1],
[1]Chemical Engineering, Lhokseumawe State Polytechnic, Jl. Banda Aceh-Medan Km. 280.3, Buketrata, Punteut Mosque, Blang Mangat, Lhokseumawe City, Aceh 24301, Indonesia
*E-mail:sariadi.kimia@gmail.com

ABSTRACT

Zinc phosphate base corrosion inhibitor which aims to determine the effectiveness of the inhibitor to provide protection to carbon steel against the rate of corrosion, with variations in inhibitor concentration at 0, 20, 40 and 60 ppm.This research uses the weight loss method and studies the performance of zinc phosphate base chemical inhibitors in the mediacooling water, sea water and PDAM waterThis is done by carrying out SEM (Scanning Electron Microscopy) testing. The type of steel specimen used in the research is Carbon Steel and deepCorrosion media are cooling water, sea water and PDAM water.The addition of zinc phosphate base carbon steel inhibitor is effective in reducing the corrosion rate of carbon steel in PDAM water and sea water. in sea water media without inhibitors, a drastic reduction in the corrosion rate was seen from 119.0457 mpy to 1.7754 mpy and in PDAM water media without inhibitors, a drastic decrease in the corrosion rate was seen from 18.5873 mpy to 3.4163 mpy, after adding inhibitors with a concentration of 60 ppm. The efficiency of the zinc phosphate base inhibitor in cooling water corrosion media was 30.262% at a concentration of 40 ppm and a soaking time of 20 days.

Keywords :*Inhibition efficiency, Corrosion Inhibitors, Corrosion in sea water, Corrosion in cooling water, Corrosion Rate, Zinc Phosphate base.*

1. INTRODUCTION

Corrosion is the process of degradation of a metal as a result of the metal's electrochemical reaction with the environment. In general, almost all environments are at some level. Some environments that are corrosive include humid air, sea water, gas fuel, hydrogen sulfide, acids, bases, and soil. This process often occurs in the oil and gas industry. In the industrial world, carbon steel is a type of material that can be used in various applications. The corrosion process that occurs on metal must be controlled because it can cause consequences including plant shutdown, decreased efficiency, product leakage, contamination and other disasters that can be detrimental both in terms of material and loss of life.

Carbon steel in general is often used as a construction material in industry and is considered a more economical choice compared to corrosion-resistant alloys which are relatively expensive. Carbon steel often contains less than 1.5% carbon accompanied by other elements such as Mn, Si, P, and S. Carbon steel is divided into three types based on its carbon content, including low carbon steel (<0.25% C), medium carbon steel (0.25 - 0.70 % C), and high carbon steel (0.70 - 1.05 % C). Carbon steel is generally susceptible to corrosion under industrial operating conditions so corrosion prevention is necessary for safe operation (Kestens and Petrov, 2009).

Various protection methods for carbon steel have been developed to prevent corrosion of carbon steel. Corrosion protection on carbon steel is generally carried out using coating methods, the use of inhibitors, and cathodic system protection (Setiawan et al., 2017).

Cooling water is a cooling medium used in many industries. Cooling water is used directly or indirectly to cool process fluids (e.g. chemical products, etc.) or solid materials (e.g. steel, etc.). The presence of deposits in the form of mud, slime, or corrosion products forming deposits on the surface of the pipe causes the film layer to be damaged. The reaction between the metal surface and oxygen occurs beneath the deposit layer and erodes the iron deeper. Sea water is one of the cooling media used in several oil and gas industries. Sea water is a good cooling medium because it can be obtained easily and at a small cost without any complicated processing. Sea water contains a lot of salt, which is a factor that can accelerate corrosion. The salt content of electrolytes makes it easier for electrons to be bound by oxygen in the air. This process is caused by an increase in the conductivity of the salt solution, where the salt solution is more conductive, causing the corrosion rate to be faster. Meanwhile PDAM water (Regional Drinking Water Company) is a regionally owned business unit which is engaged in distributing clean water to the general public. Clean water from PDAM goes through a water treatment process, the water processed is surface water which generally contains more germs or microorganisms, contains several types of minerals such as Ca, Mg, Sr, Mn, Fe in high concentrations, and contains chloride ions which are capable of reacting. with metal ions to form dissolved salts, causing an increase in metal levels in water.

Factors that influence the rate of corrosion include inhibitor concentration, temperature and exposure time (Fajar Sidiq, 2013, Yonna Ludiana and Sri Handani, 2012). The greater the inhibitor concentration value given, the corrosion rate value will decrease and the inhibition efficiency value will be higher (Anike Malfinora, Sri Handani, and Yuli Yetri, 2014). The inhibitor's ability to inhibit is measured by its efficiency. The efficiency value depends on the inhibitor concentration used. This happens because the inhibitor plays a role

corrosion inhibitor (Desi Mitra Sari, Sri Handani, and Yuli Yetri, 2013).

The use of chemical zinc phosphate base as a carbon steel corrosion inhibitor is a factor in testing the effectiveness of chemicals as inhibitors in cooling water, sea water and PDAM water conditions. This chemical product is usually applied to prevent corrosion in the cooling water system. This chemical contains phosphate and zinc. The mechanism of action of the chemical is to form a protective layer on the inside of the pipe, where the zinc phosphate content of the chemical binds with calcium ions in the cooling water. By forming this layer, it can inhibit the corrosion process. Zinc Phosphate is a coating pigment that is often used in metal coatings because of its environmentally friendly properties (Hao et al., 2013). The use of zinc phosphate as an anti-corrosion pigment is a promising method for increasing the corrosion resistance of iron and steel (Tamilselvi et al, 2015).

In this research, a study was carried out to see the effect of the effectiveness of chemical concentrations as steel inhibitors on cooling water, sea water and PDAM water conditions.

2. RESEARCH METHODS

2.1 Research Place

Corrosion rate measurements in this research used the immersion method with metal weight loss measurement data carried out at the Oil and Gas Operations Unit Laboratory, Chemical Engineering Department, Lhokseumawe State Polytechnic.

2.2 Materials and Tools

2.2.1 Materials

The materials used in this research include carbon steel plates, sea water from Ujong Blang Beach, North West Hagu, Lhokseumawe City, cooling water from PT. PIM and PDAM Lhokseumawe water as corrosion media, chemical zinc phosphate base as corrosion inhibitor and distilled water.

2.2.2 Tools

The equipment used is a beaker for dipping carbon steel, digital scales, calipers, sandpaper, measuring flasks.

2.3 Experimental and Testing Procedures

2.3.1 Inhibitor Preparation

a. The inhibitor used in this research is chemical zinc phosphate base.
b. Chemical dissolution was carried out in a 1 L beaker to make the specified concentration (0, 20, 40 and 60 ppm).

2.3.2 Test Metal Preparation

a. Carbon steel specimens were analyzed for their chemical composition using a metal spectrophotometer.
b. Carbon steel plate metal was cut to a length of 50 mm, width 30 mm, thickness 1.4 mm and a hole diameter of 3 mm as a place for placing the wire.
c. The surface of the test object was smoothed with sandpaper ranging from 400, 600, 800, 1000 and 1200 grids.
d. After that, the initial weight of each test object was weighed before immersing it in sea water.
e. Then morphological analysis was carried out using SEM equipment.

2.3.3 Corrosion Rate Testing with the Effect of Concentration and Soaking Time

a. The steel specimens that have been prepared are each soaked in sea water and inhibitors are added according to the independent variables.
b. Variations in the concentration of the inhibitor solution are 0, 20, 40 and 60 ppm
c. Meanwhile, the soaking time is 20 days
d. After the soaking time was reached, the steel samples were removed and then washed with distilled water.
e. The carbon steel specimen was rinsed with distilled water and rinsed again with alcohol and then dried.
f. Reweigh the sample to get the final weight (W1)
g. Perform SEM and FTIR analysis

2.3.3 Corrosion Rate Calculation

The corrosion rate testing standard used in this research is ASTM G31-72 Standard Practice for Laboratory Immersion Corrosion Testing of Metals. The corrosion rate testing method used is the weight loss method. This method is often used because the equipment used is simple, and the test results are accurate. The corrosion rate calculation is carried out using the following equation (Callister, 2007: 631).

$$CR = \frac{534\,W}{D\,A\,T} \qquad (3.1)$$

Where :

CR= corrosion rate, mpy
W = weight of iron lost (mg)
D = density (grams/cm^3)
A = surface area (in^2)
Q = Time (hours)

2.3.4 Morphology Testing Procedure Using SEM (Scanning Electron Microscopy)

The morphology testing procedure using Scanning Electron Microscopy (SEM) can be carried out in the following steps:

a. Sample morphology testing was carried out on carbon steel before immersion, immersion without using inhibitors, and using inhibitors.
b. Carbon steel samples before immersion were prepared and abrasive to a fineness of 1200 grids and morphologically tested using SEM.
c. Carbon steel samples that had been soaked without using inhibitors and

using inhibitors were tested for morphology using SEM without using an abrasive process.

2.3.5 FTIR (Fourier Transform Infra Red) Test Procedure

When testing with an FTIR tool, the following steps can be carried out:

a. The samples tested were corrosion products resulting from immersion without using inhibitors and using inhibitors.
b. The corrosion product is prepared according to the sample specified for FTIR testing.
c. Next, the sample was tested using an FTIR tool.

3. RESULTS AND DISCUSSION

The aim of this research is to determine the effectiveness of zinc phosphate base inhibitors on the corrosion rate of carbon steel in the corrosion media of cooling water, PDAM water and sea water.

Carbon steel in general is often used as a construction material in industry and is considered a more economical choice compared to corrosion-resistant alloys which are relatively expensive. Carbon steel is generally susceptible to corrosion in industrial operating conditions so corrosion prevention is necessary for operating and construction equipment. Various protection methods for carbon steel have been developed to prevent corrosion of carbon steel. In general, inhibitor pigments are often used as the main ingredient in inhibiting the corrosion process. Inhibitory pigments can be classified into active pigments and barrier pigments based on their inhibitory mechanism. Barrier pigments work to inhibit corrosion of metal by extending the diffusion path for water and ions to the metal surface so that the metal's corrosion resistance increases. Active pigments (such as red lead and chromate) are toxic so their applications are limited by environmental requirements even though their corrosion inhibition properties are very good. Therefore, in this study, inhibitors from zinc phosphate base were used as coating pigments which are often used in metal coatings because of their environmentally friendly properties. The use of zinc phosphate as an anti-corrosion pigment is a promising method for increasing the corrosion resistance of carbon steel.

In this research, we studied the effect of inhibitor concentration treatment on the corrosion rate characteristics of carbon steel in cooling water, sea water and PDAM water environments. The inhibitor used in this research uses a commercial coating based on zinc phosphate. Carbon steel corrosion rate analysis was carried out using a weight loss test based on the ASTM G31 standard. The results of this research can be seen in Table L.2.

3.1 Effect of Inhibitor Concentration on Corrosion Rate

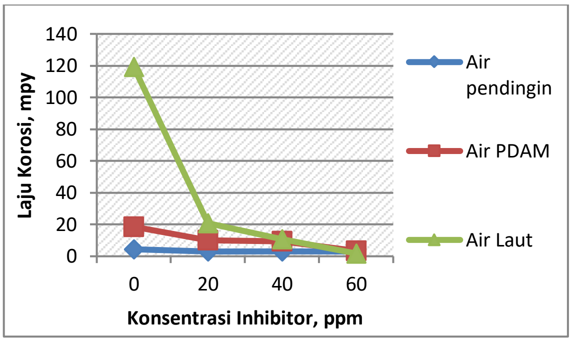

Figure 3.1 Effect of zinc phosphate base inhibitor concentration on corrosion rate

Effect of inhibitor concentration*chemical zinc phosphate base*The corrosion rate of carbon steel can be seen in Figure 3.1, that the higher the inhibitor concentration, the corrosion rate of carbon steel decreases. In seawater corrosion media without inhibitors, a drastic reduction in the corrosion rate was seen from 119.0457 mpy to 1.7754 mpy after adding inhibitors with a concentration of 60 ppm. The media for carbon steel corrosion using sea water before the use of inhibitors has a great influence on the rate of steel corrosion, because sea water contains a lot of salt which can accelerate corrosion. The corrosion process can also be caused by an increase in the conductivity of the salt solution, where a more conductive salt solution can cause the corrosion rate to be higher. The chloride content which is acidic and aggressive towards steel in corrosive water will cause corrosion of carbon steel. Shows that the corrosion product of carbon steel in seawater has a relatively high chloride and oxygen composition which leads to the formation of a corrosion product in the form of FeCl2 which is formed due to the reaction of Fe with chloride. After using inhibitors in mpy units, it can be categorized as the level of corrosion resistance of carbon steel in sea water as very good. From Figure 3.1, the corrosion rate in PDAM water and cooling water media before the addition of inhibitors still looks high because there is no corrosion rate inhibitor for carbon steel due to the presence of dissolved gas, the presence of dissolved solids, the influence of the pH level of the water, the influence of temperature and the influence of microbes. It can also be seen that the reduction in the corrosion rate of carbon steel in cooling water and PDAM media with the addition of inhibitor concentration can be categorized as very good after a soaking time of 20 days, based on the ASTM G31 standard in Table 2.2.The decrease in the corrosion rate is due to the effect of inhibitors which inhibit the corrosion rate on carbon steel.

4.2 Inhibition Efficiency

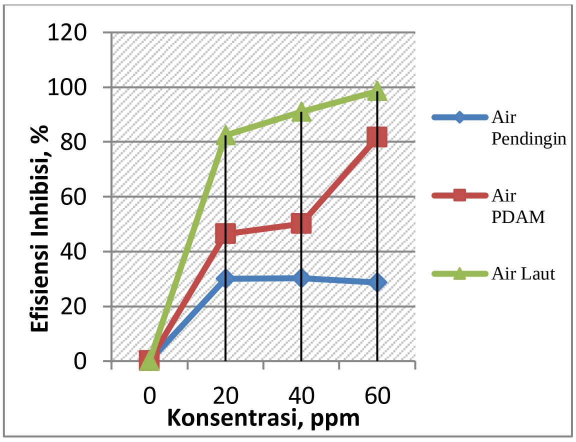

Figure 3.2 Inhibitor efficiency towards increasing concentration

Inhibitor efficiency*zinc phosphate base*on the corrosion rate of carbon steel can be seen in Figure 3.2, in the cooling water corrosion medium the inhibitor efficiency at a concentration of 40 ppm obtained a result of 30.262%. The inhibitor efficiency in PDAM water corroding media was obtained at a value of 81.6202% and sea water was 98.5086% at an inhibitor concentration of 60 ppm. In PDAM water and sea water conditions it cannot be said to be efficient with the addition of inhibitor concentration, the greater the corrosion rate value, the smaller the inhibition efficiency value. However, the use of inhibitors is quite effective in reducing the corrosion rate of carbon steel in PDAM water and sea water.

3.3 Morphological Analysis

Analysis*Scanning Electron Microscopy*(SEM) provides information regarding the surface morphology of steel. The results of morphological analysis using SEM taken at a magnification of 10,000× can be seen in Figures 4.3, 4.4 and 4.5. Figure 3.3 shows a carbon steel sample that has been prepared without going through the soaking process as a comparison for carbon steel plates that have been soaked without using inhibitors and using inhibitors. It can be seen in the picture that there are holes formed as a result of corrosion and there are scratch lines due to a poor sanding process because the sanding was done manually.

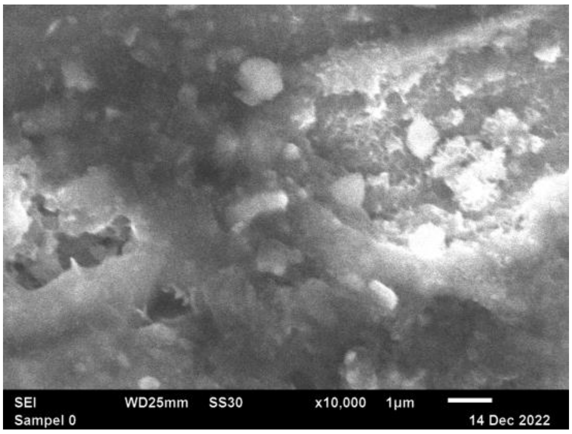

Figure 3.3SEM test results of untreated carbon steel samples

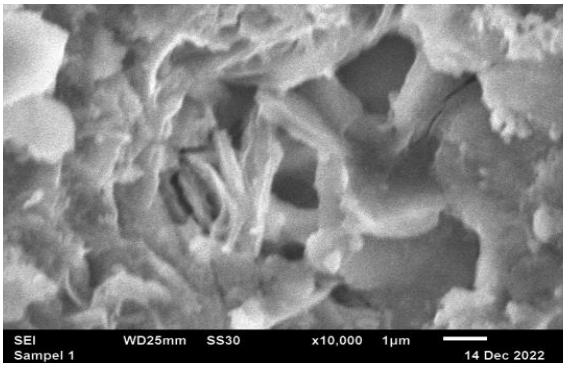

Figure 3.4SEM test results of carbon steel samples without inhibitors

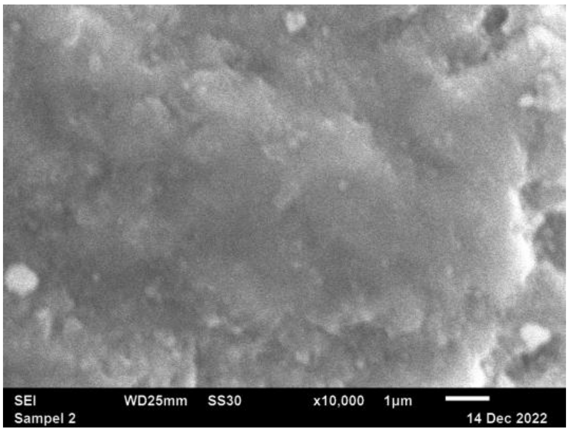

Figure 3.5SEM test results of carbon steel samples using 40 ppm inhibitor

In the SEM test results of carbon steel samples without inhibitors and using inhibitors which were soaked for 20 days in cooling water media can be seen in**Figure 3.4**and Figure 3.5. Where in Figure 3.4, the SEM test results of carbon steel samples without inhibitors show differences in the morphological structure which causes degradation on the carbon steel surface to form corrosion holes that continue to grow. Meanwhile, Figure 3.5 shows a carbon steel sample soaked in cooling water with the addition of 40 ppm zinc phosphate base inhibitor. It can be seen that a protective layer has formed on the metal surface. This shows that the corrosion that occurred has been covered by a layer formed by the use of inhibitors on the carbon steel surface.

The type of corrosion that occurs in the steel sample can be seen from its morphological structure. In samples without treatment from the morphological structure, it can be seen that the type of corrosion that occurs is a uniform type of corrosion, corrosion caused by chemical reactions on the carbon steel surface which erodes the layer to become thin due to the presence of moist air. Meanwhile, in carbon steel samples without inhibitors, it can be seen that the type of corrosion that occurs is pitting corrosion, because the morphological test results show the formation of holes on the surface of the carbon steel samples. Likewise, in samples that used inhibitors, holes were visible on the surface of the sample, which was identified as a type of pitting corrosion.

3.4 Fourier Transform Infra Red (FTIR) Spectrum Analysis

FTIR measurements aim to determine the functional group content in a compound by using the penetrating power of infrared light on functional group bonds. Where the reading results are in the form of a percentage graph (%) of the absorption power of a functional group at a certain wavelength. To determine the discovery of the presence of functional groups in the zinc phosphate inhibitor samples and the polymer contained, they were identified from specific peaks on the graph which were then represented according to the classification of group types according to the wavelength. It can be seen from the FTIR spectra results in Figure L.6.1 of the zinc phosphate base inhibitor sample and Figure L.6.2 of the residual zinc phosphate base inhibitor sample on carbon steel that the functional group waves are not much different, where from the analysis results it is proven that the inhibitor works in coating carbon steel. to inhibit the rate of corrosion due to the presence of residuals that can be read on carbon steel samples after immersion using inhibitors.

The presence of a zinc phosphate base inhibitor consisting of Zn in the form of $Zn_3(PO_4)_2.4H_2O$, in the case of the formation of a zinc phosphate layer on zinc has a relatively simple reaction and composition. However, when zinc phosphate comes into contact with the surface of carbon steel the situation becomes more complex because zinc iron phosphate or $Zn_2Fe(PO_4)_2.4H_2O$ (phosphophyllite) is formed. The presence of a high concentration of ferrous ions causes ions at the interface of the solution and metal, thus providing a place for the deposition of zinc iron phosphate so that the use of inhibitors is effective in inhibiting the rate of corrosion reaction on carbon steel.

Identification of zinc phosphate compounds and polymer content using an FTIR spectrophotometer was analyzed at wave numbers in the 4000 - 400 cm-1 area. At the wave number 3078.39 cm-1 there is a wide absorption with a strong intensity indicating the presence of the O – H group. At a wavelength of 2459.24 cm-1 with a sharp absorption and weak intensity indicating the presence of the phosphoric acid and P – H ester groups, and at a wavelength of 2337.72 cm-1 with a weak intensity, it shows the phosphine stretching group. The sharp band and strong intensity at the wave number 1670.35 cm-1 shows the presence of a primary amide group C = O. And at the wave number 1517.98 cm-1 shows the group of asymmetric nitro aromatic NO_2 compounds. The wide absorption and weak intensity at the wave number 1139.93 cm-1 indicates the presence of the C – O – C ether group.

The low absorption and weak intensity at the wave number 923.9 cm-1 indicates the presence of the P - H phosphine group and is strengthened by the presence of a wave of 813.95 cm-1 indicating the stretching of the P = S group. The suspicion of a phosphate compound is strengthened by the absorption at The wave number 1444.68 cm-1 shows the P – C aromatic group and the wave number 1340.53 cm-1 shows the P = O aromatic group with weak intensity and a sharp band shape. These peaks strengthen the suspicion that the analysis results are specific peaks from phosphate compounds.

The results of this study are not the same as other similar studies, this is due to several factors, including the use of different types of inhibitor materials or differences in the corrosive media solutions used. Another influencing factor is determining the inhibitor concentration and soaking time.

4. CONCLUSION

From the research results, several conclusions can be drawn as follows:

1. The concentration of chemical zinc phosphate base influences the corrosion rate of carbon steel in the corrosion media of cooling water, sea water and PDAM water. The higher the inhibitor concentration, the corrosion rate of carbon steel decreases.
2. The chloride content in corrosive water will cause corrosion of carbon steel. Shows that the corrosion product of carbon steel in sea water has a relatively high composition of chloride and oxygen which leads to the formation of a corrosion product

in the form of $FeCl_2$ which is formed due to the reaction of Fe with chloride.

3. The efficiency of the zinc phosphate base inhibitor in cooling water corrosion media was 30.262% at a concentration of 40 ppm.
4. The zinc phosphate base carbon steel inhibitor is effective in reducing the corrosion rate of carbon steel in PDAM water and sea water. In sea water media without inhibitors, a drastic reduction in the corrosion rate was seen from 119.0457 mpy to 1.7754 mpy and in PDAM water media without inhibitors, a drastic decrease in the corrosion rate was seen from 18.5873 mpy to 3.4163 mpy, after adding inhibitors with a concentration of 60 ppm.

5. ADVICE

For further development of this research, the author hopes to carry out research on "Testing of zinc phosphate base as a corrosion inhibitor on carbon steel in the corrosion media of cooling water, sea water and PDAM water" as follows:

1. Using other variables such as temperature, amount of inhibitor concentration, soaking time and knowing the performance of the inhibitor.
2. Using other corrosive solutions to determine the performance of inhibitors in different corrosive solutions.

REFERENCES

Arifin, MZ 2020. Characteristics of ASTM A 36 Steel Plate Corrosion Rates Due to Bending with Varying Angles, Media and Corrosion Time. Department of Mechanical Engineering, Faculty of Engineering. Malang State University.

ASTM International. 2004. ASTM G31-72: Standard Practice for Laboratories *Immersion Corrosion Testing of Metals*. United States.

Callister, William. D.Jr. and Rethwisch, David. G. 2007. Materials Science and Engineering. 9th Edition. Wiley.

Fontana, Mars Guy. 1987. Corrosion Engineering, International. Third Edition. Mc. Graw Hill Inc.

Irmaya, AI and Yunita, L. 2020. Analysis of Corrosion Rates using Sea Water Media on Welding Results of Low Carbon Steel Metals Using the Heat Treatment Process. Offshore Journal, 4(37-43). e-ISSN: 2549-8681.

Jofalo, ZN and Tjahjanti, PH 2021.*Analysis of Corrosion Penetration Rates in Low Carbon Steel with Aluminum Coating***.**Procedia of Engineering and Life Science, 1 (01).

Marcus, P. and Oudar, J. 1995. Corrosion Mechanisms in Theory and Practice. Marcel Dekker Inc.

Nurani, L, et al. 2016. Study of Imidazoline Salt Based Corrosion Inhibitors in Brine Water in Crude Oil Distribution Pipes. LIPI Metallurgy and Metrial Research Center.

Ornelasari, R. 2015. Analysis of Corrosion Rates on Stainless Steel 304 Using the ASTM G 31-72 Method in Sugar Palm Water Media.JTM, 1 (01).

Pattireuw, KJ et al. 2013. Analysis of Corrosion Rates on Carbon Steel Using Sea Water and H_2SO_4.Mechanical Engineering, Sam Ratulangi University Manado.

Permadi, LB 2014. Analysis of Corrosion Rates in Mild Carbon Steel with Bending Treatment in Acid Solution Corrosion Media. Journal of Mechanical Engineering, 3(01).

Setiawan, A, et al. 2019. The Effect of Surface Treatment on the Corrosion

Resistance of Carbon Steel Coated with Zinc Phosphate in Sulfuric Acid Media. Journal of Technology, 11(01).

Tampubolon, M, et al. 2020. Corrosion Rate in Medium Carbon Steel Due to the Immersion Process in Sulfuric Acid (H2SO4) and Hydrochloric Acid (HCl) Solutions with Varying Times. E-ISSN 2685-8916. 2 (01).

Utomo, B. 2009. Types of Corrosion and Their Management. SHIP, 6 (2).

Wibowo, DA and Ghofur, A. 2021. The Effect of Water Salinity Levels on the Corrosion Rate of ST 60 Steel.ISSN: 2721-6225, 3 (02).

Widharto, S. 2004. Rust and its Prevention. PT. Pradnya Paramita, Jakarta.