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Study on Flow Velocity Effect to Corrosion Rate of Mild Steel

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ABSTRACT

The use of iron and steel as the main material for shipbuilding is still dominant. However, iron and steel are highly reactive and corrode in seawater and it has become the biggest causes of ship plate damages. In this study, the calculation of relatively fast corrosion propagation on low-carbon steel plates by comparing the corrosion rate on moving samples will be investigated. In this study, researchers examined the comparative effect of flow speed, time, pH, and salinity on specimens. Researchers used a method that looks at the initial mass of a sample before it is placed in a corrosive environment over a period of time, then reweighs the sample to measure the weight lost due to corrosion. Changes in flow velocity affect the corrosion rate of each specimen. The highest corrosion rate was found in specimens immersed with a flow speed of 0.3 m/s at 4.741 mm/year, and the lowest was found in specimens immersed with a flow velocity of 0.1 m/s at 0.244 mm/year. The faster the flow of water, the greater the corrosion rate. The variation of the corrosive media also affects the corrosion rate. The corrosion rate can increase as the pH decreases and the level of salt or salinity in the corrosive media increases. The highest corrosion rate value is found in specimens immersed in media with a pH of 5 and a salinity of 3.7% at 4.741 mm/year, and the lowest is found in specimens immersed in media with a pH of 9 and a salinity of 3.3% at 0.244 mm/year.

Keywords:
Capillary pipes; refrigeration system; COP

1. Introduction

So far, the use of iron and steel as the main materials for shipbuilding is still dominant. In terms of cost and strength, the use of iron and steel for shipbuilding is adequate. However, iron and steel are highly reactive and tend to be corroded by seawater. In constructions made of metal or non-metal, corrosion can cause huge cost losses. In ship steel, the technical losses that will be experienced due to corrosion are reduced ship speed, decreased fatique life, tensile strength and reduced mechanical properties of other materials [1]. Based on the structural aspects of the ship plate, the hull plate is the first area exposed to seawater, in this hull area the area below the water line or the area above the water line is very susceptible to corrosion. Corrosion of the hull plate can reduce the

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strength and life of the ship, reduce the speed of the ship and reduce the safety and security of cargo and passengers.

Corrosion in shipbuilding can only be slowed down and cannot be stopped completely. The causes of corrosion can jeopardize the safety of cargo and passengers, weaken the hull plates, and make the ship move more slowly [2]. Corrosion is a natural phenomenon that occurs in metal materials, where corrosion is a process of material damage due to chemical or electrochemical reactions with the environment. These environments are acidic environments, air, dew, fresh water, sea water, lake water, river water and groundwater. Seawater has corrosive properties relative to the particles it contains, including chloride ions, electrical oxygen conductivity, flow rate, temperature, pollution, stress, pollution, silt and suspended sediments, hull deposits [3]. Research on the effect of flow velocity variations on the corrosion rate of mild steel is very important, considering that mild steel is one of the most widely used materials in various industries, especially in piping systems and structures that are in direct contact with fluid flow. Fluid flow velocity can affect the corrosion rate by changing the condition of the steel surface, increasing the speed of electrochemical reactions, and removing the protective layer formed on the steel surface.

According to Fontana, “high flow velocities can accelerate the corrosion rate due to increased turbulence and mechanical abrasion of the metal surface” [4]. Therefore, understanding the relationship between flow velocity and corrosion rate in low-carbon steel will provide deep insights in corrosion control and selection of more durable materials, which can ultimately reduce maintenance costs and improve operational safety in industries that use steel as the main material. As for corrosion prevention efforts, namely, choosing the right metal or steel for the environment with its conditions, providing a protective layer so that the metal or steel layer is protected by its environment [5]. The occurrence of corrosion has prompted various studies. But analyzing and comparing corrosion rates on relatively moving samples is still rarely done, so researchers are interested in conducting experimental testing of corrosion rates on mild steel.

2. Theoretical Background

2.1 Definition of Corrosion

Corrosion is defined as the deterioration of metals due to electrochemical reactions with. In corrosion, metal is oxidized and oxygen (air) is reduced. Corrosion itself is an electrochemical process, which is a process (chemical change/reaction) in which electricity is present. Some parts of the metal act as the negative pole (negative electrode, anode), while other parts of the metal act as the positive pole (positive electrode, cathode). Electrons flow from the anode to the cathode, resulting in a corrosion event [6]. In general, corrosion can be said to be a decrease in the quality of a material caused by the surrounding environment. The interaction in question is an electrochemical interaction [7].

2.2 Corrosion Process

The corrosion process can be broken down into anodic and cathodic reactions. If one of these reactions is controlled then the overall corrosion rate will be affected. It is important to understand the electrochemical nature of corrosion. If the corrosion of carbon steel is considered very simply it can be explained as follows. Steel is not homogeneous and at the onset of corrosion anodic and cathodic sites are formed on the alloy surface. In the presence of electrolyte, small corrosion cells are installed on the surface and in the anodic area iron enters the solution as iron ions, i.e. steel corrosion. Various reactions can occur at the cathode. The cathodic reaction in ordinary atmosphere or submerged conditions results in the production of hydroxyl ions and the two reactions can be written as follows). The two reactions below together form iron hydroxide which eventually oxidizes and rusts [8].

Anode: $2Fe \rightarrow 2Fe^{2+} + 4e^{-}$ (1)

Cathode: $O_2 + 2H_2O + 4e^{-} \rightarrow 4OH^{-}$ (2)

$Fe^{2+} + 2OH^{-} \rightarrow Fe(OH)_2 \rightarrow FeOOH$ (rust) (3)

2.3 Effect of Flow Velocity

Flow velocity plays an important role in corrosion. Velocity often strongly influences the corrosion reaction mechanism by showing a high amount of mechanical wear effect especially, when the solution is corrosive. Flow at very high velocities can cause erosion corrosion on metal surfaces. Conversely, low velocity fluid flow can trigger under deposit corrosion [9]. The high currents and waves in the sea can cause an increase in the corrosion rate, because they can damage the anti-rust layer, produce a lot of oxygen, and accelerate penetration so that the cavities on the steel surface will be exposed. Turbulent seawater may destroy the rust barrier layer and invite more oxygen. In addition, impact collisions accelerate penetration while cavities increase the number of exposed steel surfaces so that corrosion continues [10].

2.4 Seawater Salinity

Seawater contains 3-4% salt content which equals a salinity of 30-40 0/00. Meanwhile, the temperature found on its surface ranges from 0-30°C [11]. However, based on the theory of passivity, at certain salt levels, i.e. with high salt content, the corrosion rate will be reduced. Passivity is the process of reducing an element's reactivity to corrosion, or it can also be referred to as a metal's resistance to certain environmental conditions. When the corrosion rate decreases at a certain salt content, this condition is referred to as passivity. Thus, salt solutions can function both as catalysts (triggers or boosters) and as inhibitors (blockers) [12].

2.5 Acidity (pH) Seawater

It is very important to remember that at low pH, the effect of pH on steel corrosion is very complex because the kinetic equation correlates with the corrosion rate. Therefore, the influence of pH variables on the corrosion process is very complex [13]. In aggressive environments, the corrosion rate is higher, especially in acidic environments because the material interacts with various environments (air and water), and during the interaction the material will undergo a corrosion process [14].

2.6 Corrosion Rate

Corrosion rate is the rate of material degradation over time. In the weight loss measurement method, the amount of corrosion is expressed as the amount of weight loss of the tested metal coupon per unit surface area per unit time. The general formula can be written as follows [15]:

$$CR = \frac{87.6\,W}{DAT} \tag{4}$$

where CR is corrosion rate (mm/year), D is density (gram/cm^3), W is Weight lost (gram), A is surface area (cm^2) and T is time (hour).

3. Methods

3.1 Experiment Tools and Design

In this study, the researcher examined the comparison of the effect of flow velocity, time, pH, and salinity on the specimen. Analyzing data in real-time and systematically to find patterns, determine the parts between parts, and the whole in this case is testing the comparison of treatment variations on specimens. In this research, the components used include an aquarium measuring 80x15x15 cm, cleaning container, digital flow meter, digital microscope, pump, abrasive paper, measuring cup, pH meter, refractometer, as shown in Figure 1.

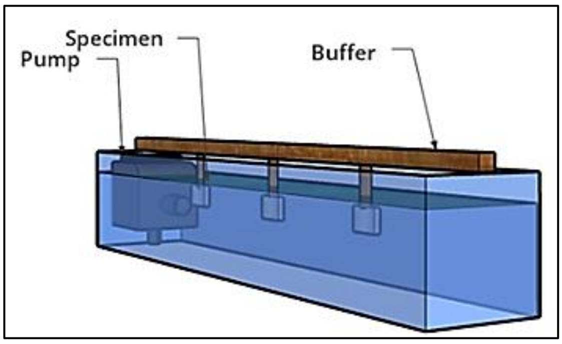

Fig. 1. Specimen arrangement

3.2 Data Collection Method

Researchers conduct real-time and systematic testing to look for patterns, determine the parts between parts, and the whole in this case is testing the comparison of treatment variations on specimens. The researcher used a method that considers the initial mass of the sample before it is placed in a corrosive environment for a certain period, then reweighs the sample to measure the weight lost due to corrosion. The experiment involved immersing the mild steel plates for 48 hours, 144 hours, 240 hours in 10 liters of seawater with the help of a pump with a capacity of 2000 L/H. The mild steel test plates used in this study have dimensions of 4 cm in length, 3 cm in width, and 0.8 cm in thickness, as shown in Figure 2.

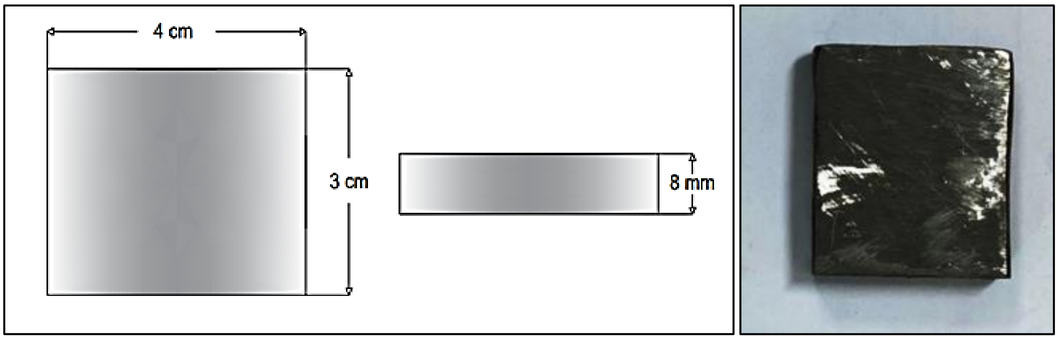

Fig. 2. Specimen dimension

4. Results and Discussion

4.1 Effect of Flow Velocity on Corrosion Rate of Mild Steel

4.1.1 Graph in 48 hours

It was found that the corrosion rate value at a speed of 0.3 m/s had the highest corrosion rate value with an immersion time of 48 hours, respectively 0.659 mm/year, 0.408 mm/year, 0.290 mm/year. From the table results, a diagram can be drawn showing the increase in corrosion rate values as the flow velocity generated by the pompa shown in Figure 3.

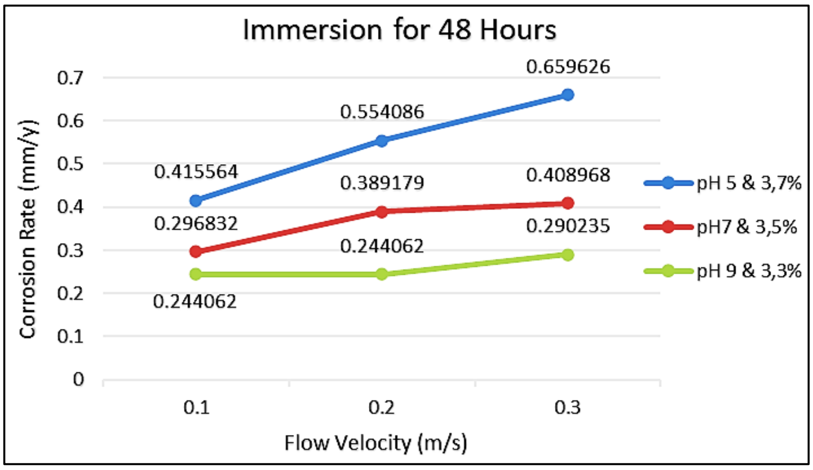

Fig. 3. Corrosion rate test results with 48 hours immersion

4.1.2 Graph in 144 hours

In Figure 4, it is found that the corrosion rate value at a speed of 0.3 m/s has the highest corrosion rate value with an immersion time of 144 hours, respectively 2.869 mm/year, 2.104 mm/year, 1.398 mm/year. From the results of the table, a diagram can be drawn showing the increase in the corrosion rate value as the flow velocity generated by the pump increases.

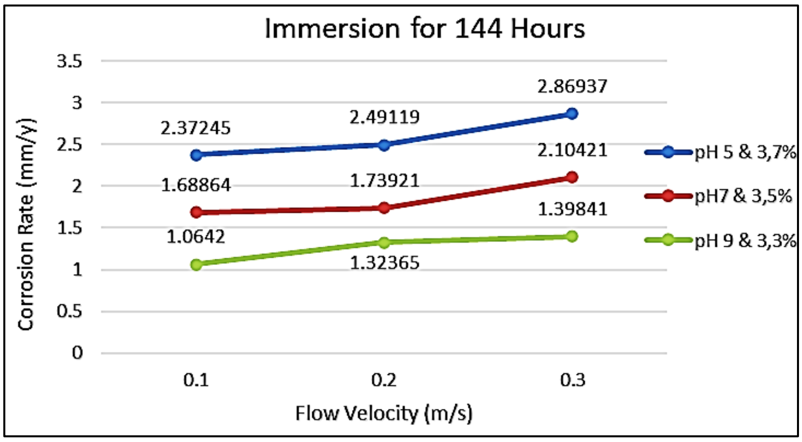

Fig. 4. Corrosion rate test results with immersion for 144 hours

4.1.3 Graph in 240 hours

Figure 5 shows that the corrosion rate value at 0.3 m/s speed has the highest corrosion rate value with 240 hours of immersion time, respectively 4.741 mm/year, 2.292 mm/year, 1.218 mm/year.

From the table results, a diagram can be drawn showing the increase in corrosion rate values as the flow velocity generated by the pump increases. when compared to previous research [16] explains that steel immersed in a corroding medium with an acidic solution or a high percentage of HCL will make the corrosion rate increase with a value of 3.687 mm/y.

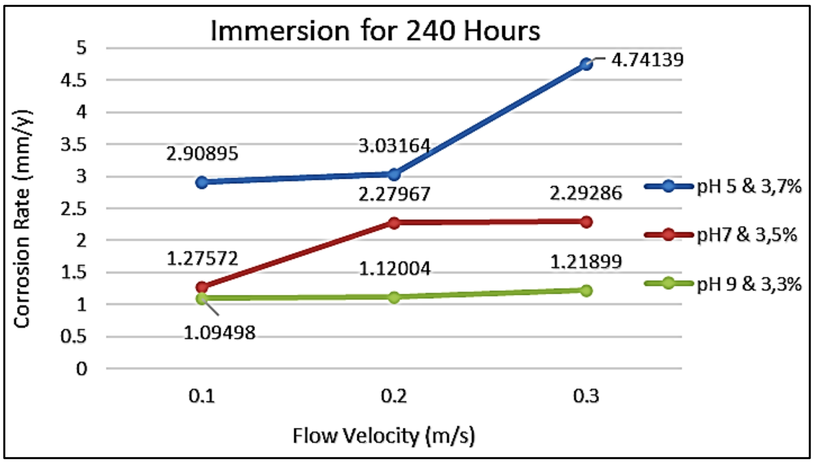

Fig. 5. Corrosion rate test results with 240 hours of immersion

4.2 Effect of Variation of Corroding Media on Corrosion Rate

In Figure 6, the corroding medium having pH 5 & 3.7% is the most corrosive medium with the highest average corrosion rate of 3.560 mm/y, and the corroding medium having the lowest average corrosion rate is in the medium having pH 9 and 3.3% with an average corrosion rate of 0.259 mm/y. This is because solution concentration also plays an important role in determining the corrosion rate. From the above data, we can see that in general, the lower the pH of the solution and the higher the salinity level, the higher the corrosion rate. For example, at pH 5 and 3.7% salinity, the corrosion rate at 48 hours reaches 0.543 mm/y, while at pH 9 and 3.3% concentration, the corrosion rate at the same time is only about 0.259 mm/y. Thus, it can be said that the solution pH and salinity level can significantly affect the corrosion rate.

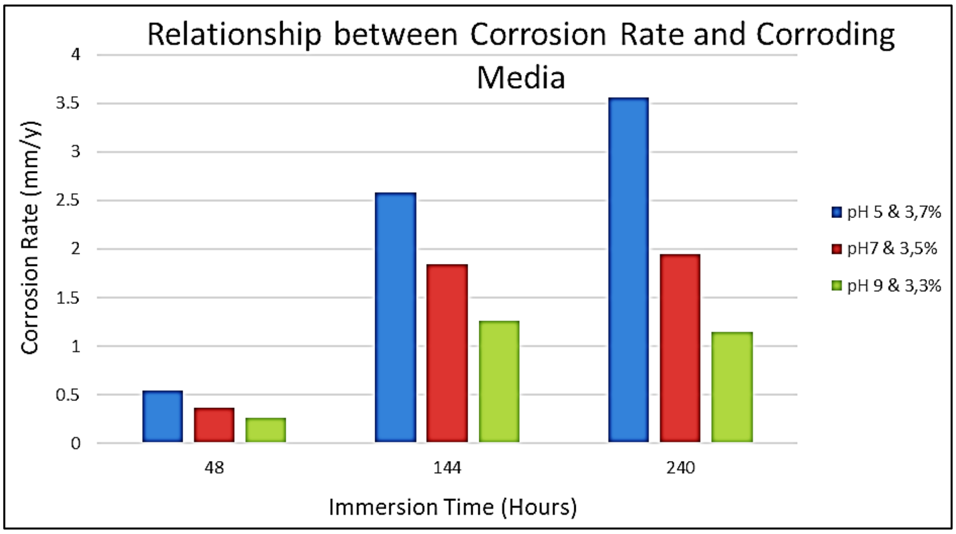

Fig. 6. Diagram of relationship between corrosion rate and corroding media

4. Conclusions

Changes in flow velocity affect the corrosion rate of each specimen. The highest corrosion rate is found in specimens immersed with a flow velocity of 0.3 m/s at 4.741 mm/year and the lowest is obtained in specimens immersed with a flow velocity of 0.1 m/s at 0.244 mm/year. The faster the water flow, the greater the corrosion rate. The variation of corrosion media also affects the corrosion rate, where the corrosion rate can increase as the pH decreases and the level of salt content or salinity increases in the corrosion media. Where the highest corrosion rate value is found in specimens immersed in media that have a pH of 5 and a salinity of 3.7% of 4.741 mm/year and the lowest is found in specimens immersed in media that have a pH of 9 and a salinity of 3.3% of 0.244 mm/year.

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