The Effect of Paracetamol Inhibitor Concentration and Immersion Time to The Corrosion Rate and Toughness in 3% NaCl Media

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Abstract--*Corrosion is one of the main problems causing damage to metals. The occurrence of a reaction with the surrounding environment accompanied by several factors cause deterioration so that corrosion causes damage to the material. Therefore, researchers added inhibitors as a way to control corrosion. This study used paracetamol as an inhibitor against corrosion protection of AISI 1020 steel with 3% NaCl as the media. The method used for the corrosion test was the weight loss and toughness test using the Charpy method of impact testing. This study obtained the lowest corrosion rate value at the addition of 220 ppm inhibitor concentration with immersion time for 7 days of 1.078 mpy. The efficiency observed in this study showed that adding an inhibitor concentration of 220 ppm with the immersion time of 7 days had the highest value reaching 71.42%. Moreover, the impact test results got the highest value on the 220 ppm inhibitor variation with the immersion time of 7 days, reaching 0.0817 J/mm^2. The more inhibitors used, the lower the corrosion rate and the greater the impact strength value obtained. On the contrary, the lower the inhibitor used, the greater the corrosion rate that occurred, so the impact value decreased.*

Keywords*: AISI 1020, Corrosion, Weight Loss, Inhibitor, Paracetamol, Impact*

1. INTRODUCTION

In industrial scope, machinery and its equipment are an important part for the continuity of the production system. One of the inevitable problems in the machinery is corrosion. Corrosion or rusting is a phenomena of metal damage due to metallurgical factors in the material itself, and environmental factors that cause chemical reactions so that a decrease in the quality of a metal material can occur. The environmental factors are a corrosive environment, an environment where there are bacteria, differences in oxygen, temperature, and pH level [1].

Corrosion is part of the metal material cycle, corrosion cannot be discontinued or eliminated. The effort that can be done is to inhibit or slow down the corrosion process. One of the methods that can be used is applying inhibitors. Inhibitor is a chemical substance which, when added/introduced in small amounts into a corrosive environment, can effectively slow down or reduce the rate of existing corrosion [2].

The corrosion inhibitor is a substance added in the environment and can reduce the corrosion rate of metals [3]. Organic inhibitors are one of the most frequently used types of inhibitors, such as sodium nitrit, phosphoric, and carboxylic acid [4]. Additionally, green inhibitors are also rapidly developed from plant extract [5].

Besides, the organic substances in organic inhibitors are also present in drugs. Obot et al prove that the usage of antifungal drugs, such as Clotrimazole and Fluconazole effectively lower the corrosion rate of stainless steel [6]. Another study uses Atenelol and Nifidipine to decrease the corrosion rate of mild steel ini hydrochloric acid media [7]. Many researchers also apply Paracetamol to inhibit the corrosion rate. Their research proves that paracetamol is effective to decrease the corrosion rate in acid medium [8], [9].

Paracetamol is anti-inflammatory drug that generally used for relieving mild to moderate pain, treat headaches, and reduce fever. The broad benefits make the existence of this paracetamol drug easy to find in the market. Paracetamol or acetaminophen structure contains phenolic compounds that have phenyl and hydroxyl [9]. Those compounds are included in antioxidant compound that can inhibit or prevent the oxidation process on easily oxidized substrates [10].

The corrosion testing with the addition of inhibitor is carried out using low carbon steels. Low carbon steels are relatively soft, but have an excellent toughness and ductility [11]. Moreover, due to its low carbon content, this steel corrodes easier than carbon steel with high carbon content [12]. In order to represent the low carbon steel, AISI 1020 was used in this research with 0.2% carbon content. This research focused on using paracetamol as inhibitor with the variation of concentration and immersion time to the corrosion rate and toughness. The environment utilized to corrode is a salt solution with 3% NaCl with the exposure time of 7 and 14 days.

2. METHODS

2.1 Specimen

This study used AISI 1020 steel with the dimension of 55 x 10 x 10 mm and the notch on one side of the center of the specimen is 2mm deep and wide. This specification is according to ASTM E-23 for impact testing. As seen in Figure 1.

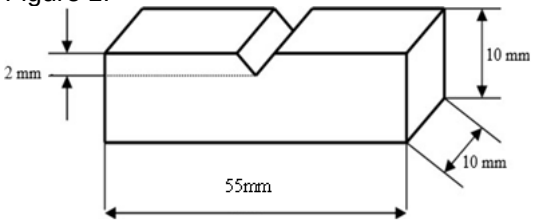

Figure 1. Specimen dimension of ASTM E-23

The specimen surface is cleaned using sandpapers so that it is not sharp and free from dust and light rust. After cleaning and before immersion, the specimens are weighted using the digital scales to determine the initial weight.

2.2 Specimen immersion

The corrosion media used is 3% of NaCl solution with the composition of 30 grams of NaCl and 1 liter of aquades.

The paracetamol used is the syrup type. The inhibitor concentration is varied at 0 ppm; 120 ppm (4.99 ml); 170 ppm (7.07 ml); and 220 ppm (9.15 ml). The ppm unit is calculated using a parameter that each 5 ml containing 120 mg acetaminophen.

Each concentration variation is immersed for 7 and 14 days. After the immersion, the specimens are dried and cleaned, then weighted to obtain the final weight.

2.3 Weight loss method

Weight loss method is a test performed to determine the corrosion rate of a workpiece by weighing the initial weight and final weight of the specimen after going through the immersion process. The corrosion rate calculation is carried out using Equation (1) [13]:

$$CR = \frac{K \cdot W}{A \cdot T \cdot \rho} \quad (1)$$

where, CR is corrosion rate (mpy), K is corrosion rate constant (3.45 x 10^6), W is weight difference (gram), A is specimen surface area (cm^2), T is immersion time (hour), and ρ is specimen density (g/cm^3).

The inhibitor effectiveness is calculated to determine the efficacy of the inhibitor. It is obtained using Equation (2) [13]:

$$EI(\%) = \frac{CR_{uninhibited} - CR_{inhibited}}{CR_{uninhibited}} \times 100\% \quad (2)$$

where, EI is the efficiency of inhibitor (%), $CR_{uninhibited}$ is corrosion rate without inhibitor, and $CR_{inhibited}$ is corrosion rate using inhibitor.

2.4 Impact testing

The impact testing is performed using Charpy Method. This testing is carried out to evaluate the specimen's toughness before and after the immersion process of corrosion, additionally, the test refers to the ASTM E-23 standard. The impact strength is obtained by dividing the energy absorb by specimen area (see Equation (3)).

$$IS\ (J/mm^2) = \frac{\Delta E}{A} = \frac{WL(\cos\beta - \cos\alpha)}{A} \quad (3)$$

where, IS is impact strength (J/mm^2), ΔE is energy absorbed by the specimen (J), A is area (mm^2).

3. RESULT AND DISCUSSION

3.1 Corrosion rate results

The corrosion rate results include the result of the specimen without inhibitor with 7 and 14 days of immersion time. From the research that has been done, the corrosion rates of AISI 1020 with all determined variables are displayed in Figure 2.

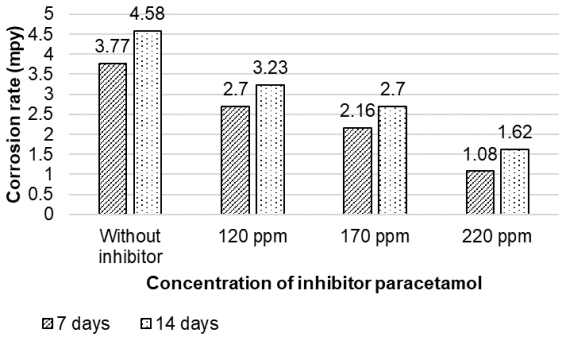

Figure 2. Corrosion rate results with variations of inhibitor concentration and immersion time

The specimens immersed without inhibitor achieve the highest corrosion rate up to 4.58 mpy. The longer immersion time results in the higher corrosion rate. Meanwhile, the immersion using the paracetamol inhibitor gives a significant difference because the addition of inhibitors can work in decreasing the corrosion rate of AISI 1020 steel due to the antioxidant content in paracetamol.

In terms of the paracetamol addition, the lowest corrosion rate is obtained with the value of 1.08 mpy in the variation of 220 ppm inhibitor

concentration and 7 days immersion time. Moreover, the highest corrosion rate 3.23 mpy occurs with the variation of 120 ppm inhibitor concentration and 14 days immersion time.

The corrosion rate obtained with paracetamol inhibitor is much lower compared to the use of an organic coffee extract inhibitor with the same steel and corrosive medium. In this study, the addition of a minimum of 120 ppm alone is capable of reducing the corrosion rate by up to 2.7 mpy. Meanwhile, in Simanjutak's 2019 research, the use of coffee extract with the highest concentration could only decrease the corrosion rate to 4.94 mmpy (equivalent to 194.6 mpy) [13].

The longer immersion time, the higher the corrosion rate results. This is due to the media have longer time to oxidize the metal for the first two weeks. The results is in line with previous study [14]. Moreover, the higher inhibitor concentration leads to a decrease in the corrosion rate. The amount of acetaminophen is higher, sufficient to inhibit the oxidation process on the metal surface. These similar results are also stated by Maidhah, 2018 [15].

The corrosion rate results with the inhibitor application can obtain the inhibitor efficiency. The efficiency is calculated from the corrosion rate without inhibitor and with inhibitor. The results are shown ini Table 1.

Table 1. Efficiency of inhibitor results

Inhibitor concentration (ppm)	Immersion time (days)	Efficiency of inhibitor (%)
120	7	28.57
	14	29.41
170	7	42.85
	14	41.17
220	7	71.42
	14	64.70

The efficiency results of paracetamol inhibitor application shows that the excellent result achieves at 71.42% with 220 ppm of concentration. The efficiency values obtained are higher compared to the results obtained in Maidhah's 2018 study, which only achieved an efficiency of 54.32% [15].

These results are correlated with the corrosion rate results. A decrease in corrosion rate leads an increase in efficiency. Malfinora et al. explain in their study that an addition of inhibitor will lower the corrosion rate and rise the inhibition value [16]. The higher addition of inhibitor concentration gives higher efficiency, but, oppositely, the longer immersion time leads to a decrease in the efficiency value.

The corrosion rate and efficiency of the inhibitor are supported by visual observations. The observation is taken after the specimen immersion with the quantity of 2 samples per variable as seen in Figure 3.

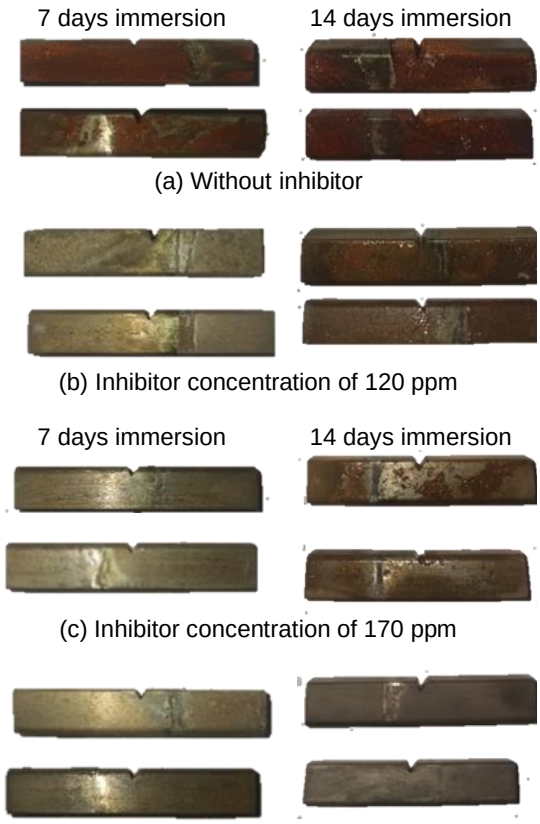

Figure 3. Visual observation of the corrosion testing with inhibitor addition

The visual observation of AISI 1020 surfaces after the immersion support the corrosion rate and efficiency of the inhibitor results. The longer immersion time results in the darker rust, additionally, the higher inhibitor concentration shows the lighter rust. The application of paracetamol inhibitor significantly changes the surface appearance of the metals. The less rust in the visual observation correlates with a lower corrosion rate and higher efficiency. The results prove that the addition of paracetamol as an inhibitor affects the oxidation on the metal surface both in corrosion rate value and metal appearance.

3.2 Impact test results

The toughness results are determined from the impact strength value. The testing is performed to the specimens after the immersion corresponding to the inhibitor concentration and immersion time variation. The impact strength value is shown in Figure 3.

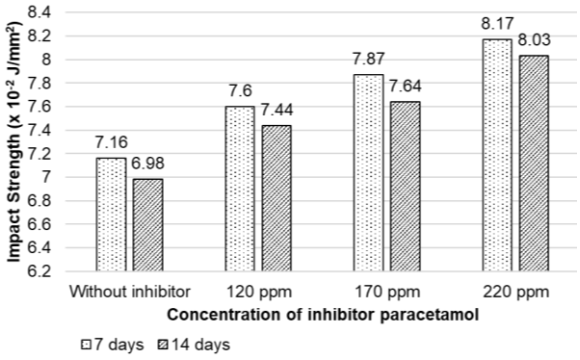

Figure 3. Impact strength results with variations of inhibitor concentration and immersion time

The impact strength results exhibit that the lowest value is 6.98 x 10^{-2} J/mm^2 without inhibitor and immersion time of 14 days. The addition of paracetamol notably enhances the impact strength values. The highest value 8.17 x 10^{-2} J/mm^2 achieves with 220 ppm concentration and 7 days of immersion time. Moreover, the addition of 120 ppm paracetamol gives narrow effect on the impact strength value.

The higher concentration of paracetamol leads to a higher impact strength. This is due to a decrease in the corrosion rate after the inhibitor addition. Paracetamol inhibitor indicates its capability to protect the metals, so the metals gain their mechanical property better. Moreover, the longer immersion time leads to a reduction of the impact strength due to the higher corrosion rate that damages the metals. This also can be confirmed through the visual observation results that show the deterioration with the longer immersion time. The linear results is also seen in the previous study that the higher inhibitor concentration gives an increase in the mechanical property of the metal [17].

4. CONCLUSION

Based on the results of testing and research, as well as, analysis carried out on AISI 1020 steel specimens in NaCl media using variations in the concentration of the drug paracetamol inhibitor and without inhibitors, the following conclusions can be drawn:

1. The corrosion rate with the paracetamol addition shows a significantly lower value than the immersion without paracetamol addition. The higher inhibitor concentration exhibits the lower corrosion rate at 1.08 mpy with 220 ppm concentration and 7 days of immersion. In opposite, the longer immersion time gives the higher corrosion rate.
2. The efficiency of paracetamol inhibitor reaches 71.42% with 220 ppm concentration and 7 days of immersion time. The higher inhibitor concentration results in the higher efficiency, but the longer immersion shows a decrease in the efficiency.
3. The impact strength of the metals reaches the highest at 8.17 x 10^{-2} J/mm^2 with 220 ppm concentration and 7 days of immersion time. The paracetamol inhibitor addition notably affects an increase in the steel's impact strength. The higher inhibitor concentration is able to more protect the metal. In the results, the higher inhibitor concentration gives a higher value of impact strength.

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