Bio-Inhibitor on Corrosion Rate of ASTM A53 Steel in Marine Environment

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Abstract. There are many methods to prevent the corrosion process. One of them is corrosion inhibitors usage. Inhibitor divided into two types, there are organic inhibitor and non-organic inhibitor. Organic inhibitor could be obtained by extracting some materials which exist in nature. In this research, bio-inhibitors were made from rambutan (*Nephelium lappaceum*) peel, banana (*Musa acuminata Colla*) peel, mango (*Mangifera indica L.*) leaves and papaya (*Carica papaya*) leaves. The determination of corrosion rate used weight loss method. The material of carbon steel ASTM A53 was used in the research. The salinity of artificial seawater was 35 ‰. The results showed that corrosion rate on carbon steel ASTM A53 was 0.2172 mpy at mango leaves and the efficiency of those inhibitor was 44.5%. The corrosion rate carbon steel ASTM A53 was 0.2436 mpy for corrosion rate and 37.8% of inhibitor efficiency when it used papaya leaves as bioinhibitor. Meanwhile, it reached 0.2739 mpy and 0.2812 mpy of corrosion rate for banana peel and rambutan peel, respectively. The efficiency of inhibitor were 30% and 28.2% for banana peel and rambutan peel, respectively. The corrosion rate on carbon steel ASTM A53 without inhibitor was 0.3914 mpy. Based on the microstructure results, all specimens in all variation of treatments showed pitting corrosion and uniform corrosion on specimen. In conclusion, mango leaves, papaya leaves, banana peel and rambutan peel have potentially to be used as bio-inhibitor to decrease the corrosion rate in marine environment.

1 Introduction

Corrosion can cause disastrous damage to metal and alloy structures causing economic consequences in terms of repair, replacement, product losses, safety, and environmental pollution. Due to these harmful effects, corrosion is an undesirable phenomenon that ought to be prevented [1]. There are several steps to inhibit the process of corrosion, one of them is the inhibitors. The inhibitor may be either organic or inorganic. It serves to add to the metal material in a corrosive environment so that it will inhibit and lower the rate of corrosion. In recent days, many alternative ecofriendly corrosion inhibitors have been

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developed, and they range from rare earth elements to organic compounds [2] Organic inhibitors can be obtained by extracting some of the ingredients found in nature. Some examples of natural materials that can be used as an organic inhibitor of banana peel, orange peel, dragon fruit peel, mangosteen peel, mango leaves, papaya leaves, and so forth. The concentration of nature inhibitor obtained results that vary depending on the type of material used. Inhibitors decrease or prevent the reaction of the metal with the media. They reduce the corrosion rate by (i) adsorption of ions/molecules onto metal surface, (ii) increasing or decreasing the anodic and/or cathodic reaction, (iii) decreasing the diffusion rate for reactants to the surface of the metal, (iv) decreasing the electrical resistance of the metal surface. (v) inhibitors that are often easy to apply and have in situ application advantage [3].

Some of the ingredients were in nature inhibitor include tannins, alkaloids, saponins, amino acid pigment, catechins, and proteins that have the ability to reduce the rate of corrosion. Tannins and their derivatives can be used to protect steel, iron, and other tools from corrosion [4]. Extracts of tobacco from twigs, stems, and leaves can protect steel and aluminium in saline solutions and strong pickling acids [1,5]. According to Paul and Koley [2], corrosion inhibition of carbon steel by few green inhibitors viz. garlic, yeast, pepper, and coffee or green inhibitors have been found to decrease the acid corrosion of mild steel by several folds with about 70–90% adsorption on the surface. The other study reported that watermelon extract has been found to have strong effect on corrosion of mild steel in HCl and H₂SO₄ [6]. The inhibition efficiency increases with the concentration of the extract increases.

Although, some research reported the usage of many nature inhibitor but it is rare for carbon steel in marine environment. The aim of the research were to determine of corrosion rate and inhibitor efficiency of ASTM A53 steel after add with natural inhibitor from banana peel extract, rambutan peel, mango leaves, and papaya leaves.

(a)

(b)

Fig. 1. (a) Dimension of specimen and (b) the specimen was ready to be used

2 Materials and methods

2.1 Preparation of Specimen

A steel pipes of ASTM A53 specifications were used in this research [7] and the preparation of specimens was conducted based on the American Society of Mechanical Engineers (ASME). Figure 1 showed the demension of specimen (20 x 20 x 4 mm) and the appearance of specimen after it through some process of preparation based on ASME. The following steps were conducted:

- a. Cut-shaped material with dimensions of 20 mm x 20 mm x 4 mm.
- b. Drilling was carried out on the upper side portion of the specimen.
- c. Finishing the surface of the specimen with grade # 80 sandpaper to # 2000.
- d. The process of pickling the specimen was soaked using low grade HCl with ASTM A380 standard.
- e. After that, the specimen was cleaned by rinsing with running water then dried and ready for use.

2.2 Preparation of Bio-Inhibitor

About 300 grams of every basic ingredients of natural inhibitor put on erlenmeyer. For extraction solvents using N-Hexan as much as 500 ml of each ingredient. The method for the manufacture of inhibitors was reflux or upright coolant. The preparation of the extract started by mixing the material with the solvent on the erlenmeyer tube. After that, it installed an upright cooling extraction tool and heated the mixture of the ingredients and solution over the hotplate for approximately 1 hour. The color of solution changed due to the mixing of the compound in the inhibitor with the solvent. After that, the solution was filtered with filter paper to separate the liquid and solids of the inhibitor material. The solution was cooled by kept it in room temperature. Then the resultant solution was heated to evaporate the N-Hexan solution to obtain a concentrated inhibitor extraction. After obtaining a thicker solution, the next step was cooled by immersion for some time. The inhibitor was ready to be used on the specimen.

2.3 Preparation of Artificial Seawater

In this research, the artificial seawater with salinity of 35 ‰ was used due to the salinity was a salinity in the depths of the intermediate ocean. The standard to preparation of artifisial seawater was ASTM D1141-98 [8].

2.4 Immersion Testing

The specimen was tested by immersion tehnique in a prepared seawater solution with salinity 35‰ using ASTM G31-72 standard [9]. There were two different treatments, namely treatment with bio-inhibitor addition and treatment without addition of bio-inhibitor to the specimens. Testing was carried out for 2 weeks. The specimens were be sprayed with each solution extraction of rambutan peel, banana peel, mango leaves and papaya leaves. One specimen was be sprayed with 10 mL of solution extraction. Immersion testing was conducted in plastic glass with size of 300 mL and the artificial seawater was 250 mL for each plastic glass.

2.5 Calculation of Corrosion Rate and Efficiency of Inhibitor

Running rate of corrosion is a rapid propagation of material quality decline against time. There is a formula for calculating the corrosion rate based on the ASTM G1-03 standard [10] as follows:

$$\text{Corrosion Rate (mpy)} = \frac{K \times W}{A \times T \times D} \quad (1)$$

Where :

K = Constanta

T = Time of exposure (h)

A = Surface area (cm²)

W = Weight loss (gram)

D = Material density (gram/cm³)

In addition, the efficiency of inhibitors is also one of the important aspects of this study. It is the value that determines how optimal an inhibitor works. Efficiency of inhibitors can be calculated using the following equation:

$$\text{Efficiency of inhibitor(\%)} = \frac{V1}{V0} \times 100 \quad (2)$$

Where :

V1 = Corrosion rate with addition of inhibitor

V0 = Corrosion rate without inhibitor

2.6 Microstructure Testing

After corrosion testing was conducted, the microstructure of specimens were determinated using a microscope for detailed morphology of the specimen structure. It was used for documentary evidence and it can be known that the specimen differences between before and after testing.

3 Results and Discussion

3.1 Extract of Rambutan Peel, Banana Peel, Mango Leaves, and Papaya Leaves

Rambutan peel extraction had a physical feature of a yellowish solution. The smell of rambutan peel extraction was also not too strong. The application of bio-inhibitor to the specimen was conducted using spray method. The solution extraction of rambutan peel was sprayed to the surface of specimen. The bio-inhibitor color after it was sprayed to the specimen was not very visible.

Banana peel extraction had the physical characteristics of brownish yellow solution. However, when compared with rambutan peel extraction solution, the color of banana peel extraction had more concentrated. There was a distinctive aroma from banana peel extraction. However, there was a sap in banana peel extraction due to the specimen was sticky when it held.

Solution of mango leaves extraction had the physical characteristics of dark green solid solution. When compared with other extractions, the color of mango leaves extraction was concentrated. The aroma of mango leaves extraction was quite strong. The appearance of color was dark green when the extraction of mango leaves was sprayed to the specimen.

Solution of papaya leaves extraction had physical characteristics similar to mango leaves extraction. Solution of papaya leaves extraction was dark green. When compared with other extractions, the color of the papaya leaves extraction was concentrated. The aroma of the papaya leaves extraction was quite strong as the aroma of green tea. Figure 2

showed the appearance of solution extraction of mango leaves, banana peel, papaya leaves and rambutan peel.

Fig. 2. the appearance of solution extraction of mango leaves, banana peel, papaya leaves and rambutan peel.

3.2 Corrosion Rate

Figure 3 showed that mango leaves has the lowest corrosion rate on ASTM A53 in 35‰ of salinity after immersion test for 14 days. It reached 0.2172 mpy. The corrosion rate on ASTM A53 with addition of papaya leaves, banana peel and rambutan peel solution extraction were 0.2436, 0.2739, and 0.2812 mpy, respectively. The corrosion rate on ASTM A53 without nature inhibitor or bio-inhibitor addition was 0.3914 mpy. Based the results, it showed that solution extraction of mango leaves, papaya leaves, banana peel and rambutan peel potentially to be used as bio-inhibitor to decrease the corrosion rate on ASTM A53 material in salinity of 35‰. Mango leaves extract and papaya leaves can inhibit corrosion rate better than rambutan peel extract and banana peel extract. This due to solution extraction of mango leaves and papaya leaves have stronger adhesion on the surface of the specimen. Besides that, solution extraction of banana and rambutan peel were more easily react with corrosive media testing i.e. NaCl solution 35 ‰ so that those were more quickly decomposes.

Fig. 3. Comparison of corrosion rate on ASTM A53 material.

Fig. 4. Comparison of inhibitor’s efficiency on ASTM A53 material

3.3 Efficiency of Bio-Inhibitor

The efficiency of mango leaves as inhibitor was 44.5% (Figure 4). Meanwhile, others nature inhibitor i.e papaya leaves, banana peel and rambutan peel can be used as inhibitor although the efficiency were below the mango leaves. The reduction of corrosion rate was be predicted the inhibitor or solution extraction coated the surface of the metal surface so that it could inhibit the occurrence of redox reactions in the corrosion process. According to Rani and Basu [3], one of mechanism of reduction corrosion rate was decreasing the anodic and/or cathodic reaction. The ability of mango

leaves, papaya leaves, banana peel and rambutan peel were as inhibitor on corrosion due to those plants contained tannin and saponin. According to Ningsih et al. [11], extract of mango leaves contained tannin and saponin. However, papaya leaves, banana peel and rambutan peel also contained tannin and saponin, but it suggested the concentration below the mango leaves. It indicating that mango leaves has a high potentially to be used as a corrosion inhibitor on ASTM 53 in marine environment.

Fig. 5. Microstructure on ASTM A53 material after addition with microstructure (a) solution extraction of mango leaves (b) solution extraction of papaya leaves (c) solution extraction of banana peel (d) solution extraction of rambutan peel (e) control or without any addition of bio-inhibitor.

3.4 Microstructure

The microstructure in the following figure with 100x magnification consists of

light-colored ferrite grains and dark pearlit grains. Grain ferrite was a structure in steel that tends to be subtle. The characteristics of pearlit grains tend to be more rough when compared to grains ferlit. Figure 5 showed the microstructure of specimens in control or without addition of solution extraction and in various of bio-inhibitors with 100x magnification. There was a difference in the microstructure of the intermediate specimen when it compared between control and with addition of solution extraction. The corrosion on specimen could be detected through black holes or dark patches in photo of microstructure. The photo of microstructure can identify the type of corrosion that occurs in a specimen. The majority of corrosion types that were occurred on the test specimens were pitting corrosion or corrosion hole. This pitting corrosion was depicted a dark hole in the microstructure. In addition, uniform corrosion were detected on some surface of specimen. However, the microstructure results showed only a part of specimen. Based on Figure 5, all specimens in all variation of treatments showed pitting corrosion and uniform corrosion on specimen.

4 Conclusion

Solution extraction of mango leaves, papaya leaves, banana peel and rambutan peel can be used as nature inhibitor on preventing of corrosion on ASTM A53 in salinity of 35‰. The efficiency of solution extraction of mango leaves, papaya leaves, banana peel and rambutan peel as bio-inhibitor on corrosion were 44.5; 37.8; 30 and 28.2%, respectively.

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