The Effectivity of Oil Palm Inhibitor Processed by Aminolysis to Control Corrosion on Steel in Sodium Chloride Environment

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Abstract. A green inhibitor based on Palm kernel oil (PKO) was prepared to investigate its corrosion inhibition behaviour against steel ASTM A36 in sodium chloride solution. The aminolysis method was used to synthesize the green inhibitor and produced fatty acid diethanolamine. Afterwards, the mixture of PKO and diethanolamine of 1:6 and 1:20 were prepared. These mixtures were added into sodium chloride solution with concentration 50, 100, 500, and 1,000 ppm and they were used as working solution in corrosion testing. Corrosion testing was conducted using anodic polarization. The confirmation of microstructure of steels surfaces were done by optical microscope. The results obtained from corrosion testing showed that inhibitors of palm oil, especially palm kernel oil (PKO), provided a good corrosion protection effect. The present work provided very promising results in the preparation of green corrosion inhibitors.

1 Introduction

Mild steel has been widely used in industries, especially in the petroleum industry, as a storage tank or as pipe. A large number of mild steel usage due to its excellent mechanical properties, the high availability, and low cost [1]. Its strength and hardness is obtained from the addition of carbon in the iron matrix as much as 0.08%-0.30% [2]. Despite of their advantages, mild steel is prone to corrosion in the presence moisture or water.

One way to minimize the effects caused by corrosion is by the administration of corrosion inhibitors [3]. A corrosion inhibitor serves to lower the rate of a corrosion attack on a metal by forming a protective coating on a metallic surface [4]. In the application, a corrosion

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inhibitor is used for corrosion control within a closed system, as a cost efficient alternative [5]. Since the inhibitors become one of the important things to inhibit corrosion, it is necessary to do the selection according to the condition. The practical criteria in the selection of proper corrosion inhibitors are not only seen from the magnitude of its inhibition efficiency, but also seen from the safety of use, economic constraints, compliance with other chemicals in the system and environmental problems [6].

Palm oil has fatty acid amides content that plays an important role in its application as a corrosion inhibitor [7-8]. Before it can be used as a corrosion inhibitor, the palm oil must be processed in advance by synthesizing fatty acid amides. The process of synthesis is chemically done, for example aminolysis [9]. Aminolysis is usually used to convert palm oil into a surfactant for the Enhanced Oil Recovery process [10]. By looking at this success, aminolysis can also be used to convert palm oil into inhibitors, and it has been done in previous work from our group [11]. Therefore, this study was focused on the characterization and corrosion testing of these inhibitors.

2 Experimental

2.1 Materials

The working electrodes were mild steel ASTM A36 with dimensions of 20 mm (length) x 20 mm (width) x 3 mm (thickness). Furthermore, the specimens were ground with 400, 600, 800, and 1000 grit sandpaper. Afterwards, the working electrodes were cleaned using alcohol and then dried up. The composition of the specimen of mild steel ASTM A36 can be seen in Table 1.

| Chemical Composition (%) |
|---------------------------|
| C  | Cu | Mn | Si | P  | S  | Fe  |
| 0.26 | 0.2 | 0.8-1.2 | 0.15-0.4 | 0.04 | 0.05 | balance |

2.2 Corrosive Medium

In this study, a 3.5% NaCl solution employed as a part of the corrosive media (electrolyte) in corrosion testing. The 3.5% NaCl was known as the main component of seawater. Furthermore, sodium chloride solution was mixed with corrosion inhibitors from palm oil with concentrations of 50, 100, 500, and 1000 ppm.

2.3 Corrosion Testing

As for corrosion testing, anodic polarization method was used. The process was done using potentiostat and electrochemical cell with three electrodes configuration. The electrodes were consisted of reference, counter and working electrodes. The reference electrode was Ag/AgCl immersed in saturated KCl, counter electrode (CE) was platinum wire, and working electrode was mild steel ASTM A36. This method served to obtain the effectivity of green inhibitors
against corrosion of steel in simulated seawater. The testing method was referred to ASTM G-5 (Standard Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurement). As for the potentiodynamic polarization methods, the voltage was scanned at a potential range between -1 V to 1 V from open circuit potential (OCP), with the scanning rate of 10 mV/s. Lastly, the corrosion rate (CR) was obtained using EC-Lab software, and the percentage of inhibition efficiency (%) was calculated using the following equations:

$$\text{EI} \, (\%) = \frac{I_{\text{blank}} - I_{\text{inhibitor}}}{I_{\text{blank}}} \times 100\% \quad (1)$$

$I_{\text{blank}}$ is the corrosion current density with containing a corrosion inhibitor, and $I_{\text{inhibitor}}$ is the corrosion density without containing a corrosion inhibitor.

3 Results and Discussion

3.1 Potentiodynamic Polarization

In corrosion testing, a potentiodynamic polarization curve or tafel plotting was obtained. Polarization curves are used to determine the material resistance of general corrosion. Thus, corrosion current density ($i_{\text{corr}}$) and potential corrosion ($E_{\text{corr}}$) were obtained from polarization curves. The polarization curves as shown in Figure 1 and 2.

![Polarization curves for specimens in 3.5% NaCl condition with PKO : Diethanolamine = 1:6.](image)

Figure 1 showed the polarization curve of the specimen tested using a mixture of PKO : Diethanolamine = 1:6 inhibitor in 3.5% NaCl condition. The curve explained that the more positive the potential value, the corrosion resistance increased. In case of current density, the more negative current density value, the rate of corrosion was lowered. Therefore, it was
expected that potential value ($E_{\text{corr}}$) to be more positive and the current density ($i_{\text{corr}}$) to be more negative. Thus, by looking at Figure 1, specimens exposed in inhibitors with ratio 1:6 at 100 ppm (blue line) have the highest corrosion resistance value. The inhibitor had a corrosion potential ($E_{\text{corr}}$) value of -691.2 mV and a corrosion current density ($i_{\text{corr}}$) value of 2.6 μA/cm². Meanwhile, the inhibitor with the lowest corrosion resistance was the inhibitor with ratio of PKO : Diethanolamine 1:6 at 50 ppm (red line) with the $E_{\text{corr}}$ value of -1021.5 mV and $i_{\text{corr}}$ of 22 μA/cm².

![Figure 2](image.png)

**Fig 2.** Polarization curves for specimens in 3.5% NaCl condition with ratio of PKO : Diethanolamine 1:20.

Figure 2 shows the polarization curve of the specimen tested using ratio of PKO : Diethanolamine 1:20 in 3.5% NaCl condition. Figure 2 showed that the corrosion potential after added with PKO : Diethanolamine 1:20 were quite similar with the corrosion potential of no inhibitor (3.5% NaCl only). Therefore, it is thought that this mixture of inhibitors could not give the protection against corrosion. It seemed the addition of Diethanolamine fatty acid gave not much improvement, it is even enhanced the corrosion commencement.

For the value of corrosion potential ($E_{\text{corr}}$), corrosion current density ($i_{\text{corr}}$), corrosion rate (CR), and percentage of inhibition efficiency (Ei) can be seen in Table 2.
Table 2. Data regarding the concentration of inhibitor, $E_{\text{corr}}$, $i_{\text{corr}}$, CR and EI of the PKO inhibitors

| Inhibitor     | Concentration (ppm) | $-E_{\text{corr}}$ (mV vs Ag/AgCl) | $i_{\text{corr}}$ (μA/cm²) | CR (mm/year) | EI (%) |
|---------------|---------------------|------------------------------------|-----------------------------|--------------|--------|
| No inhibitor  | 0                   | 927.2                              | 0.26 x 10²                  | 0.2304       | -      |
| PKO : Diethanolamine 1:6 | 50      | 1021.5                             | 0.22 x 10²                  | 0.1959       | 15.38  |
|                | 100                 | 691.2                              | 0.26 x 10                  | 0.0229       | 90     |
|                | 500                 | 809.5                              | 0.35 x 10                   | 0.0311       | 86.54  |
|                | 1000                | 994.9                              | 0.14 x 10²                  | 0.1293       | 46.15  |
| PKO : Diethanolamine 1:20 | 50      | 940.6                              | 0.67 x 10                   | 0.0600       | 74.23  |
|                | 100                 | 962.3                              | 0.18 x 10²                  | 0.1613       | 30.77  |
|                | 500                 | 987.3                              | 0.21 x 10²                  | 0.1914       | 19.23  |
|                | 1000                | 974.9                              | 0.19 x 10²                  | 0.1692       | 26.92  |

Figure 3 describes the graph of the corrosion rate as the function of concentration of inhibitors. From the chart, the effectiveness of inhibitors with ratio of 1:6 showed the decreased corrosion rate as the concentration increased. It seemed that this ratio worked quite effectively in this mixture. At 100 ppm, the corrosion rate reached its lowest value. A similar result was obtained at 500 ppm. However, corrosion rate increased 0.13 mm/year as the concentration of mixed inhibitors was given at 1000 ppm. In another hand, mixture of PKO:Diethanolamine 1:20 was not sufficient to inhibit the corrosion process and it was even increased the corrosion rate much faster rather in mixture of 1:6.
This behaviour was suggested due to the difference of Diethanolamine fatty acid concentration. The ratio of 1:6 was much thicker than that of 1:20 and produced a much thicker inhibition layer and later inhibit the corrosion rate. This mixture also provided a better hydrophilic property of inhibitors, so that the inhibitors could dissolve completely in the water.

4 Conclusions

From this research, the following conclusions were obtained: Firstly, an organic inhibitor based on palm oil can inhibit corrosion that occurs by forming a layer of inhibition on the metal surface and reduced the corrosion rates. Then, inhibitors with maximum protection on the surface of mild steel ASTM A36 are produced by PKO : Diethanolamine1:6 inhibitors with a concentration of 100 ppm. These inhibitors had corrosion rate (CR) of 0.0229 mm/year and inhibition efficiency (EI) reaches 90%.

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