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RESEARCH ARTICLE

THE ASSESSMENT OF INHIBITIVE EFFECT OF CYMBOPOGON CITRATUS ON MARINE CORROSION OF MILD STEEL

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ABSTRACT

Numerous extensive efforts have been done to acquire the applicable green corrosion inhibitors in order to decrease the corrosion rate of the materials. The corrosion inhibition of mild steel is vital for technology due to the increased industrial applications of these materials. In this report, the inhibitive action of Cymbopogon Citratus on the marine corrosion of mild steel was evaluated. The inhibition efficiency was calculated using weight loss measurement method, electrochemical measurement and inhibitor mechanism analysis. It was found that, Cymbopogon Citratus exhibited a very good performance as a green corrosion inhibitor for mild steel corrosion in seawater. All the experimental methods used for this project show that the presence of Cymbopogon Citratus in the seawater significantly decreases the corrosion rates and further decreasing the corrosion rates as the concentration of Cymbopogon Citratus increases. To sum it up, the inhibition efficiency increases with an increase in Cymbopogon Citratus concentration.

KEYWORDS

Cymbopogon Citratus, corrosion inhibition, lemongrass, serai, mild steel, marine

1. INTRODUCTION

Corrosion is the deprivation and breakdown of a metal and its alloy due to chemical and electrochemical reactions with its environment. The effect of corrosion is touched in three extents of concern - economics, safety, and environmental loss. Corrosion is a drawback that affects every industry. The severe consequences of the corrosion process have become a problem of worldwide significance (Conshohocken, 2010). Therefore, preventing corrosion is an essential part of industrial and critical cleaning processes. There are several techniques used to control corrosion process. One such process is usage of corrosion inhibitors. Once, chromates were used as corrosion inhibitors. Nevertheless, environmental scientists do not encourage this since chromates are toxic in nature. Therefore, researchers are considering for green corrosion inhibitors such as extracts of plant resources.

Along the years, numerous extensive efforts have been done to acquire the applicable green corrosion inhibitors in order to decrease the corrosion rate of the materials. Research has been made to discover appropriate natural source to be carried out as corrosion inhibitor in adaptation with many corrosion media (Cymbopogon and Stapf, 2008). One of the efficient corrosion inhibitors is Cymbopogon Citratus (CC) based on its chemical properties that act as a corrosion inhibitor. CC will offer appealing potentials to be a corrosion inhibitor because it is renewable, cheap, safe use and mostly available in Southeast Asia especially Malaysia. Shortage of research on the effect of this inhibitor on the corrosion of mild steel in seawater has encouraged the author to explore this research area as contribution to the present interest on environmental- friendly and green corrosion inhibitors (Shaw and Kelly, 2006).

The key purpose of this research is to study the assessment of the natural inhibitor affecting the corrosion of the mild steel in the marine environment. In this research, the green corrosion inhibitor used is powder of CC. There are two experiments is carried out to determine the effectiveness of inhibitor which are weight loss and electrochemical measurement. The electrochemical measurement is conducted using Potentiodynamic Polarization (PP). The experiments in this research assess the corrosion rates and other results such as corrosion current and polarization resistance fromPP (Cymbopogon and Stapf, 2008). Next, the immersion in (CH3)2CO have been done in 2-3 minutes to remove the corroded parts. In addition, the specimen is immersed in H2SO4 for 5 minutes. Lastly, the samples have been washed by distilled water, dry and reweigh to ascertain the final weight.

The corrosion rate was calculated by using the following equation:

Furthermore, the inhibition mechanisms experiment also are carried out in order to determine the chemical properties of the inhibitor solution such as conductivity, salinity, Total Dissolved Solids (TDS) and Dissolved Oxygen (DO).

2. METHODOLOGY

Corrosion Rate (mm/y) = $\frac{87.6\times W}{\rho A T}$

mmpy: mm/year T: Time (hours)

A: Area of specimen (cm^2) ρ: Density (g/cm^3)

W: Weight loss (mg) (1)

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The mild steel specimen has been used as main element to determine the effectiveness of the CC powder for the research. The mild steel is used widely in marine applications. The size of the mild steel specimen is 30 × 24 × 2 mm. The samples are immersed in acetone, $(CH_3)_2CO$ for 2-3 minutes to remove corroded parts (Deyab, 2017). The samples further immersed in sulphuric acid, H_2SO_4 for 5 minutes. The samples then washed with distilled water. CC is the green corrosion inhibitor and can be considered as the head material of this research. CC was obtained from local market at Kijal, Terengganu (Rosliza and Nik, 2013). It has been cut into tiny sizes before grinded. The blender has been used as grinding medium to obtain the grinded specimen of CC. Then, the sample of CC has been dried for 1 day in an oven at 100. After that, the dried specimen has been sieved to obtain the size of 155 µm which is suitable as a solute for this experiment. The end product is the powder of CC with size of 155 µm.

The seawater plays role as corrosion medium for the experiment. The seawater sample obtained from Pantai Teluk Kalong, Kemaman. The gravimetric analysis has been performed on the rectangular mild steel specimen with the dimension of 30 × 24 ×2 mm. The specimens of the mild steel in set of three corrosion inhibitor have been dipped in 6 beakers containing various solutions for 42 days (Fiori-Bimbi et al., 2014). The observation of the specimen have been repeatedly done every 7 days to reweigh the mild steel for the weight loss verification by recording the data in the table for weight loss measurement. The corroded parts of the mild steel specimens have been pulled out from the solution for cleansing process. The requirement in cleaning process of the specimen is distilled water and let the sample to dry.

The inhibition efficiency (%IE) was calculated by using the following equation:

$$\%IE = \frac{W_1 - W_2}{W_1} \times 100\% \tag{2}$$

W_1: Corrosion rate in the absence of the inhibitor
W_2: Corrosion rate in the presence of the inhibitor

The electrochemical test is done by using Potentiodynamic Polarization (PP). The NOVA software with AUTOLAB Corrosion Cell offers useful interface for creating Tafel plots, calculating Tafel slopes and corrosion rates. Using the markers, the anodic and cathodic Tafel regions are specified. When the regions are selected, the NOVA software automatically computes the Tafel slopes and the corrosion currents. The Tafel slopes are plotted automatically on the Tafel Plot (Garcia-arriaga et al., 2010). The Tafel slope analysis tool offers a quick estimation of the corrosion rate and the polarization resistance. The corrosion rate is computed from the estimated corrosion current, achieved from the intercept of the two linear segment of the Tafel slope. Choosing the Corrosion Rate Fit analysis tool from the Analysis menu accomplishes a similar analysis as with the Corrosion Rate Tafel Slope tool. The fit tool also makes a curve fit based on the Butler-Volmer expression which allows for a more accurate computation of the corrosion current, polarization resistance and corrosion rate (Hilti, 2015). The Corrosion Rate Fit tool mechanism is similar to Corrosion Rate Tafel Slope tool. Via markers the linear Tafel region is identified. Once the markers have been located on the plot, the software makes the curve fit and computes the characteristic corrosion values using the specified density, equivalent weight and surface area (Figure 1)

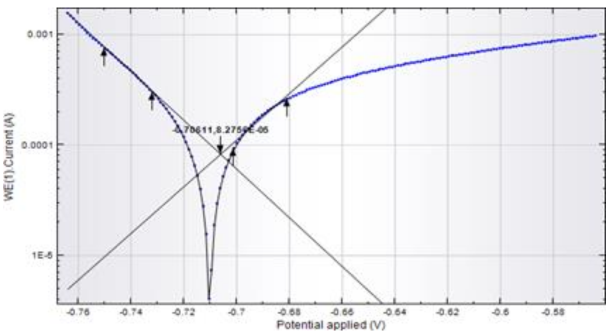

Figure 1: Corrosion Rate Fit

The inhibitor mechanism analysis has been completed by using conductivity meter, pH meter and DO meter.

3. RESULTS AND DISCUSSION

3.1 Weight Loss Method

The immersions of mild steels in seawater with different concentration of CC powder for weight loss measurement have been evaluated.

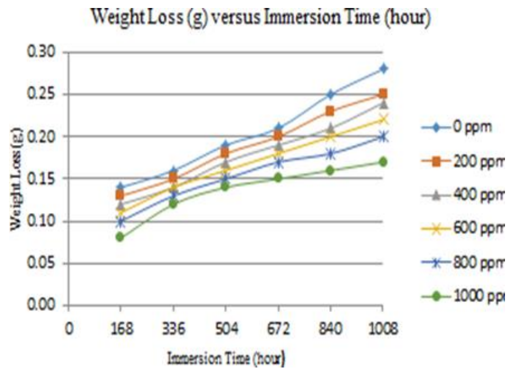

Figure 2: Graph weight loss of the mild steel versus the immersion time

Figure 3 shows the graph of weight loss of the mild steel versus the immersion time. Based on the graph, it is clearly indicating that there are differences between the samples of mild steel that exposed directly to seawater with different concentrations of CC. From the data obtained, the weight loss of the mild steel increases with time which shows that the weight loss is proportional to the immersion time (Matasyoh et al., 2011). Also, the weight loss of the mild steel in seawater with lower concentrations of CC is higher than that of in seawater with higher concentrations of CC. The mild steel with concentration of 1000 ppm CC gives the best result which has the lowest weight loss of mild steel samples with the immersion of time.

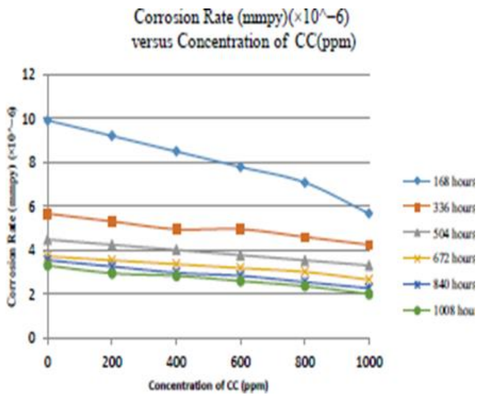

Figure 4: Graph of corrosion rate versus concentration of CC

Figure 4 shows graph of corrosion rate versus concentration of CC. There are differences in corrosion rates between the samples of mild steel that immersed in the seawater with different concentrations of CC where the corrosion rate decreases as the concentration increases. This reflects that CC is capable to slow the rate of corrosion.

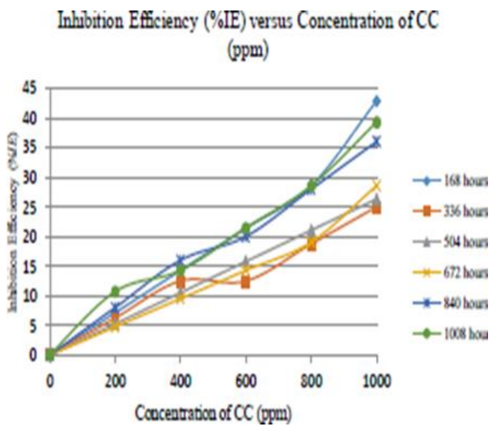

Figure 5: Graph of inhibition efficiency versus concentration of CC

Figure 6 shows graph of inhibition efficiency versus concentration of CC. The graph indicates that the inhibition efficiency increases with time and concentration. The concentration of 1000 ppm of CC gives the highest inhibition efficiency with 39.29%.

3.2 Electrochemical Measurement

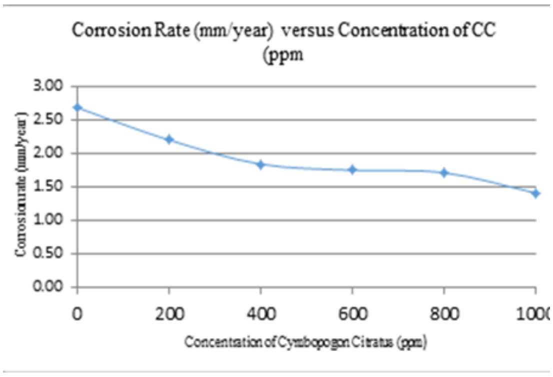

Figure 6: Graph of corrosion rate versus concentration of CC

The change in cathodic and anodic Tafel slopes (ba and bc) shown in Table 4.9 indicates that the adsorption of CC modifies the mechanism of the anodic dissolution and cathodic hydrogen evolution. This shows CC is a mixed type of inhibitor where it reduces both the rate of anodic or cathodic reaction (Metrohm, 2011). Figure 3.4 shows graph of corrosion rate versus concentration of CC. As expected and same trend as weight loss method, the rate of reaction undergoes decrement when concentration of CC increases. The 1000 ppm concentration of CC records the lowest corrosion rate of 1.408 mmpy where the 0 ppm concentration of CC records the highest corrosion rate of 2.6777 mmpy.

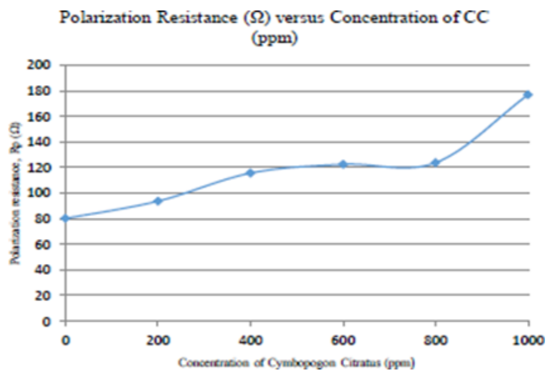

Figure 7: Graph of PP versus concentration of CC

Figure 3.5 shows graph of Polarization Resistance versus concentration of CC. Polarization Resistance increases with increasing concentration of CC which means that CC are able to increase the resistivity of the electrolyte surrounding the electrodes. The 1000 ppm concentration of CC the highest Polarization Resistance of 177.06 Ω where the 0 ppm concentration of CC records the lowest Polarization Resistance of 80.26 Ω.

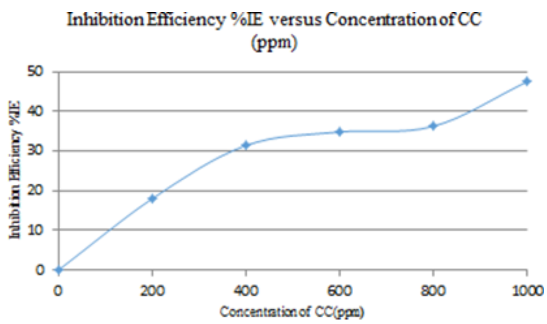

Figure 8: Graph of Inhibition Efficiency %IE versus concentration of CC

Figure 8 shows the graph of Inhibition Efficiency %IE versus concentration of CC. Inhibition Efficiency %IE increases with increasing concentration of CC which show that CC is an effective corrosion inhibitor (Migration, 1986). The concentration of 1000 ppm of CC gives the highest inhibition efficiency with 47.42%.

3.3 Inhibitor Mechanism Analysis

All the values of conductivity, salinity, TDS and DO undergo decline as the concentration of CC increases. The concentration of 1000 ppm of CC gives the best result which has the lowest value in conductivity (39500 µs/cm), salinity (25.84572 ppm), TDS (26465 ppm) and DO (78.5 %). On the other hand, the concentration of 0 ppm of CC gives the worst result which has the highest value in conductivity (53000 µs/cm), salinity (35.6089 ppm), TDS (35510 ppm) and DO (83.8 %).

Table 1: Inhibitor Mechanism Analysis

Concentration (ppm)	Conductivity (µs/cm)	Salinity (ppm)	TDS (ppm)	DO %
0	53000	35.61	35510	83.8
200	44900	29.72	30083	82.5
400	43200	28.50	28944	81.7
600	41900	27.56	28073	80.6
800	41500	27.28	27805	79.3
1000	39500	25.85	26465	78.5

4. Conclusion

CC can be considered as a wellspring of generally cheap, eco-accommodating, biodegradable and successful green corrosion inhibitor. From this research, it was found that the corrosion rate of mild steel decreases with increasing CC concentration. This means the inhibition efficiency increases with increasing CC. The inhibition efficiency achieved from the gravimetric analysis which is weight loss method, electrochemical measurement using PP and inhibitor mechanism analysis are all in good agreement and provides valuable and superb analysis. In the weight loss method, the weight loss is proportional to the immersion time. Also, the weight loss and the rate of corrosion decrease as the concentration of the CC increases. This trend of decrease in weight loss with an increase in concentration of CC is because of the adsorption amount and the coverage of CC on the mild steel increase which leads to the formation of thin layer that act as a layer of protective barrier that inhibits corrosion.

The electrochemical measurement using PP records the decrement in the value of corrosion rate and increment in the value of polarization resistance as the concentration of CC increases. This indicates the CC effectively inhibits the corrosion by reducing the anodic and cathodic reaction of corrosion. For the corrosion to occur, the number of electrons lost at the anode must equal to the number of electrons gained at the cathode. Decreasing the rate of anodic or cathodic reaction or both increases the corrosion inhibition behavior. CC inhibits the corrosion via mixed inhibition mechanism, affecting both the anodic metal dissolution reaction and the cathodic hydrogen evolution reaction. The measurement of inhibitor mechanism analysis indicates the parameter of conductivity, salinity, TDS and DO undergo decrement in value as the concentration of CC increases. This is because the free electrons available in the redox reactions decrease as these parameters' values decrease which obviously will decrease the corrosion rate.

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