Cellulose acetate layer effect toward aluminium corrosion rate in hydrochloric acid media

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Abstract. Corrosion occurs due to the oxidation and reduction reactions between the material and its environment. The oxidation reaction defined as reactions that produce electrons and reduction is between two elements that bind the electrons. Corrosion cannot be inevitable in life both within the industry and household. Corrosion cannot eliminate but can be control. According to the voltaic table, Aluminum is a metal that easily corroded. This study attempts to characterize the type of corrosion by using a strong acid media (HCl). Experiment using a strong acid (HCl), at a low concentration that occurs is pitting corrosion, whereas at high concentrations that occurs is corrosion erosion. One of prevention method is by using a coating method. An efforts are made to slow the rate of corrosion is by coating the metal with "cellulose acetate" (CA). cellulose acetate consisted of cellulose powder dissolved in 99% acetic acid, and then applied to the aluminum metal. Soaking experiments using hydrochloric acid, cellulose acetate is able to slow down the corrosion rate of 47 479%.

1. Introduction

Aluminium known as the second largest attractive materials next to the iron and widely applied in daily life and industrial process such as in automotive, aerospace, construction and electrical application due to lightweight, ductility, and good corrosion resistance. The good corrosion resistance of aluminium attributed to a protective thin invisible oxide film that forms on aluminium surface. When exposed, acid or alkaline conditions (systems) destroy the protective coating and corrosion of aluminium occurs, yielding Al³⁺ (trivalent aluminium) ions in the acid and Al₂O₃ (aluminate) ions in the alkaline medium Hence, it is needed to add some inhibitor to increase corrosion resistance which has low or zero environmental impact[1].

Nowadays, many researches have conducted to developed environmentally safe corrosion inhibitor for aluminium in acidic media. Abdulwahab et al. (2011) studied the inhibitor of an aqueous extract of bitter leaf on aluminum alloy in 0.5 M HCl[2]. Chaubey et al. (2015) studied about extract papaya peel as potential corrosion inhibitor for Aluminium alloy in 1 M HCl[3]. And Khadraoui et al. (2015) studied extract aromatic plant Thymus algeriensis as a new eco-friendly corrosion inhibitor for 2024 aluminium alloy in 1 M HCl[4]. Recently, most of the study to observe corrosion behaviour conducted in low concentration acidic media (not
more than 1M), in that case, this present study conducted not only in low concentration but also in higher concentration of acidic media (up to 3M).

In this study, we have attempted to prevent the corrosion of Al using cellulose acetate membrane. Cellulose acetate (CA) produced by the reaction of cellulose with acetic acid, the common material used for industrial acetylation of cellulose are wood and cotton. CA is widely applied in photographic film, textile, in cigarette filter and surface coating. But, the main application of CA is in production of membrane due to easy manufacture, cost effectiveness, environmental safety and strong mechanical properties [5-7]. The present paper is focused to evaluate CA inhibition effect due to corrosiveness behavior Al in HCl solutions which there is no study conducted on CA as corrosion inhibitor for Al in HCl solution.

2. Experimental

2.1. Material

Aluminum specimen with dimension 2cm x 2cm and thickness 0.1 cm was used for the study was obtained from beverage cans. It was sanded and cleaned with alcohol 70%. CA membrane were obtained by dissolving 5% cellulose powder with acetic acid.

2.2. Methods

Corrosion rate determined using weight loss method. It is the simplest and common conventional method for determining corrosion rate. The method involves the exposing of the specimen to a process environment for a given period, then removing the specimen for measurement. The basic measurement which determined from corrosion specimen, is weight loss, the weight loss taking place over the period of exposure being expressed as corrosion rate.

Specimen weight measured before and after specimen immersed in acidic media. The specimens immersed in HCl solution with concentration 0.5 M, 1M, 2M and 3M for 5 minutes in the present and absence of inhibitor. Corrosion rate are calculated from weight loss method with the formula:

\[
CR = \frac{W_{final} - W_{initial}}{D \times A \times T}
\]

Where: 
- \( W \) = weight loss (g),
- \( D \) = density (g/cm\(^3\))
- \( A \) = area of specimen (cm\(^2\)) and
- \( T \) = time (hr)[8].

The inhibition efficiency (%IE) were calculated using formula:

\[
%IE = \left(1 - \frac{W_1}{W_2}\right) \times 100\%
\]

Where: \( W_1 \) and \( W_2 \) are the corrosion rates in the absence and presence of the inhibitor[9].

2.3. Scanning electron microscopy (SEM)

Surface morphology of specimen immersed in HCl solution with presence and absence of inhibitor were analysed by recording SEM image using HITACHI SU3500.

3. Result and Discussion

Corrosion research on Al is very interesting to learn, considering Al is a material that is often used in various fields. In this study we studied the effect of CA membrane coating on Al on corrosion rate. Corrosion rate measurement was done by using 2 methods namely weight loss
method and using imaging with FE / SEM. Media test solution used is HCl with concentration 0.1M, 0.5M, 1M, 2M, and 3M. The corrosion rate of aluminium in HCl solution has shown in table 1. Corrosion rate were determined at room temperature after 5 minutes immersion period.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{HCl (Molar)} & \textbf{Corrosion rate (mm/y)} & \textbf{Corrosion rate (mm/y)} \\
\hline
0.1 & 0.05324 & 0.02904 & 45.45 \\
0.5 & 0.11132 & 0.10648 & 4.35 \\
1 & 0.21781 & 0.19844 & 8.89 \\
2 & 0.72119 & 0.31945 & 55.71 \\
3 & 1.67956 & 0.80831 & 51.87 \\
\hline
\end{tabular}
\caption{Corrosion rate by weight loss method.}
\end{table}

Based on tables 1 and 2 above, it is seen that the higher concentration of HCl solution then the corrosion rate will be faster [10] This is because HCl is a strong acid solution and so can damage the surface of Al metal more quickly. Through reaction:

\begin{equation}
2\text{Al} + 6\text{HCl} \rightarrow 2\text{Al}^3+ + 3\text{H}_2 + 6\text{Cl}^{-}
\end{equation}

The effect of the addition of CA membrane as inhibitor tested at different concentration of HCl solution studied by weight loss measurement. The value of percentage inhibition efficiency and corrosion rate obtained from weight loss method at different concentration of HCl solution summarized in Table 1. it was observed that the increasing corrosion rate associated with the increasing of HCl concentration solution shown in figure 1. By using CA as an inhibitor it can decreased corrosion rate with efficiency up to 50%. Although coating has performed the corrosion rate still occurs in proportion to the concentration. This is inseparable from the morphological changes of cellulose acetate on HCl acid media, as seen in FE / SEM, the higher the porosity of the CA the more enlarged due to the deacetylation in CA. (yamashita et al, 2003)[11].

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{chart.png}
\caption{The corrosion rate of Aluminium in various concentration of HCl}
\end{figure}
Table 2. Corrosion thickness.

| HCl  (Molar) | Blank Thickness | CA Inhibitor Thickness |
|--------------|----------------|------------------------|
| 0.1          | 6.41           | 0.038                  |
| 0.5          | 9.615          | 5.769                  |
| 1            | 22.435         | 6.538                  |
| 2            | 74.358         | 7.435                  |
| 3            | 91.025         | 8.974                  |

It’s observed that corrosion started occur in HCl solution with 1M represent from morphological aluminium surface recorded by SEM in figure 2.
The increase of the HCl immersion concentration on the CA inhibitor membrane can still be resolved well up to 3 M concentration in the sample by coating. This could be proven in SEM surface view morphology, where membrane shows relatively similar porous morphology in all conditions. Figure 2. Nevertheless, the increasing in HCl concentration affected to the adhesivity of the inhibitor to the Al substrate. Although the ability to protect the sample against acid corrosion can still be remedied even when under strong acid conditions with high concentrations (3 M).

As for the sample without the CA inhibitor, SEM morphological shows clearly differences when compared with the sample using CA inhibitor. Under conditions of 0.1 and 0.5 M, corrosion growth is not significant when compared to 1, 2 and 3 M., although there is some corrosion (oxide) on the surface under condition of 0.1 and 0.5 M. However, with increasing acid concentrations starting from 1 M to 3 M, the corrosion layer (oxide) begins to cover the metal surface and diffuses into the Al metal substrate affected degradation on Al substrate especially under condition of 2 and 3 M as evidenced by the SEM cross section [8,10].

4. Conclusion
Cellulose acetate acts as a good inhibitor for the corrosion of aluminum metal in HCl solution with concentration 0.1, 0.5, 1, 2 and 3 M. The inhibition efficiency increases 55.71% under condition of 2M HCl solution and 51.87 % under condition of 3M HCl solution. CA can be considered as corrosion inhibitor due to easy manufacture, cost effectiveness and environmental.

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