Corrosion behaviour of 6063 aluminium alloy in acidic and in alkaline media

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Abstract The corrosion behaviour of 6063 aluminium alloy was investigated in different concentrations of phosphoric acid medium and sodium hydroxide medium at different temperatures. The study was done by electrochemical method, using Tafel polarization technique and electrochemical impedance spectroscopy (EIS) technique. The surface morphology was investigated using scanning electron microscope (SEM) with Energy-dispersive X-ray spectroscopy (EDX). The results showed that the 6063 aluminium alloy undergoes severe corrosion in sodium hydroxide medium than in phosphoric acid medium. The corrosion rate of 6063 aluminium alloy increased with an increase in the concentration of acid as well as with alkali. The corrosion rate was increased with an increase in temperature. The kinetic parameters and thermodynamic parameters were calculated using Arrhenius theory and transition state theory. Suitable mechanism was proposed for the corrosion of 6063 aluminium alloy in phosphoric acid medium and sodium hydroxide medium. The results obtained by Tafel polarization and electrochemical impedance spectroscopy (EIS) techniques were in good agreement with each other.

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1. Introduction

Corrosion, which is an inevitable problem faced by almost all industries can be considered as one of the worst technical calamities of our time. Besides its direct costs in dollars, corrosion is a serious problem because it definitely contributes to the depletion of our natural resources. Corrosion studies have also become important due to increasing awareness of the need to conserve the world’s metal resources (Stansbury and Buchanan, 2000). Now-a-days more attention has been paid to control the metallic corrosion, due to increasing use of metals in all fields of technology.

Corrosion studies of aluminium and aluminium alloys have received considerable attention by researchers because of their wide industrial applications and economic considerations (Christian Vargel, 2004; Kosting and Heins, 1931; Badaway et al., 1999; Paul and Sigwart Juniere, 1964). Aluminium and aluminium alloys have emerged as alternate materials in aerospace and in some chemical processing industries. Due to their wide applications, they frequently come in contact with acids or bases during pickling, de-scaling, electrochemical etching...
and extensively used in many chemical process industries. Most of the reported studies were conducted on corrosion of various metals and alloys in HCl and H₂SO₄ media (Paul and Sigwalt Juniere, 1964; Ating et al., 2010; Umoren et al., 2009; Obi-Egbedi et al., 2012; Nnanna et al., 2011).

Phosphoric acid medium is widely used for acid cleaning and elector polishing of aluminium (Christian Vargel, 2004). Even though dissolution rate of aluminium in phosphoric acid medium is lower, compared to the dissolution of the same in hydrochloric medium or sulphuric acid medium, it does corrode aluminium and its alloys. Phosphoric acid medium is also used in pickling delicate, costly components and precision items where rerusting after pickling has to be avoided. Sodium hydroxide is usually used for degreasing purpose. According to the available literature, not much study has been done regarding the corrosion behaviour of 6063 aluminium alloy in phosphoric acid medium as well as with sodium hydroxide medium. As part of our studies with corrosion behaviour of aluminium and aluminium alloys in phosphoric acid medium and sodium hydroxide medium and corrosion control of the same using green inhibitors (Deepa and Padmalatha, 2013a,b) we report herein the results of corrosion behaviour of 6063 aluminium alloy in phosphoric acid medium and sodium hydroxide medium of different concentrations at different temperatures.

2. Methods

2.1. Material

The experiments were performed with specimens of 6063 aluminium alloy. The composition of the 6063 aluminium alloy specimen is given in Table 1.

Cylindrical test specimens were sealed with Acrylic resin material in such a way that the area exposed to the medium was 1.0 cm². It was polished with 180, 280, 400, 600, 800, 1000, 1500, and 2000 grade emery papers. Further polishing was done with disc polisher using levigated alumina to get mirror surface. It was then dried and stored in a desiccator to avoid moisture before using it for corrosion studies.

2.2. Medium

A stock solution of phosphoric acid medium was prepared using analytical grade phosphoric acid medium (85%) and double distilled water. It was standardized by potentiometric method. Phosphoric acid medium of concentrations 1.0 M, 0.1 M and 0.01 M was prepared by appropriate dilution. A stock solution of sodium hydroxide was prepared by dissolving analytical grade sodium hydroxide pellets in double distilled water and standardized by volumetric method using phenolphthalein indicator. Solutions of required strengths 0.05 M, 0.25 M and 0.5 M were prepared by appropriate dilutions as and when required. Experiments were carried out using a calibrated thermostat at temperatures 30 °C, 35 °C, 40 °C, 45 °C and 50 °C (± 0.5 °C).

2.3. Electrochemical measurements

Electrochemical measurements were carried out by using an electrochemical work station, CH600D-series, U.S. Model with CH instrument beta software. The electrochemical cell used was a conventional three-electrode compartment having glass cell with a platinum counter electrode and a saturated calomel electrode (SCE) as reference. The working electrode was made up of 6063 aluminium. All the values of potential were measured with reference to the saturated calomel electrode. The polarization studies were done immediately after the EIS studies on the same electrode without any further surface treatment.

2.3.1. Tafel polarization studies

Finely polished 6063 alloy specimens with 1.0 cm² surface area were exposed to corrosion medium of different concentrations of phosphoric acid (0.01 M, 0.1 M and 1.0 M) and different concentrations of sodium hydroxide (0.05 M, 0.25 M and 0.5 M) separately at a temperature range of 303–323 K. The potentiodynamic current–potential curves were recorded by polarizing the specimen to −250 mV cathodically and + 250 mV anodically with respect to open circuit potential (OCP) at a scan rate of 0.01 V/s.

2.3.2. Electrochemical impedance spectroscopy (EIS) studies

Electrochemical impedance spectroscopy (EIS) measurements were carried out using a small amplitude ac signal of 10 mV over a frequency range of 100 kHz-0.01 Hz. Both techniques were repeated at least three times. The average value of best three agreeing values was reported.

Table 1 Composition of the 6063 aluminium alloy specimen (% by weight).

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>0.412</td>
</tr>
<tr>
<td>Fe</td>
<td>0.118</td>
</tr>
<tr>
<td>Cu</td>
<td>0.0570</td>
</tr>
<tr>
<td>Mg</td>
<td>0.492</td>
</tr>
<tr>
<td>Al</td>
<td>Balance</td>
</tr>
</tbody>
</table>

Figure 1 Tafel polarization curves for 6063 aluminium alloy in different concentrations of H₃PO₄ at 30 °C.
Corrosion behaviour of 6063 aluminium alloy

was studied using Tafel polarization technique. Figs. 1 and 2 represent the potentiodynamic polarization curves of 6063 aluminium alloy in different concentrations of phosphoric acid medium at 30 °C and in different concentrations of sodium hydroxide medium at 30 °C respectively. Corrosion parameters such as corrosion potential \(E_{corr}\), corrosion current density \(i_{corr}\), anodic slope \(b_a\) and cathodic slope \(b_c\) are obtained from the Tafel polarization curves. Results are tabulated in Tables 2 and 3. The corrosion rate was calculated using Eq. (1).

\[
\nu_{corr} (\text{mm y}^{-1}) = \frac{3270 \times M \times i_{corr}}{\rho \times Z^2},
\]

where 3270 is a constant that defines the unit of corrosion rate, \(i_{corr}\) is the corrosion current density in A cm\(^{-2}\), \(\rho\) is the density of the corroding material (g cm\(^{-3}\)), \(M\) is the atomic mass of the metal, and \(Z\) is the number of electrons transferred per atom (Fontana, 1987). The results of Tafel polarization measurements are reported in Tables 2 and 3 respectively.

The results indicate the increase in the corrosion rate \(\nu_{corr}\) with an increase in the concentration of phosphoric acid medium and sodium hydroxide medium. The positive shift in the corrosion potential \(E_{corr}\) with the increase in the concentration of phosphoric acid medium and sodium hydroxide medium indicates that the anodic process is much more affected than the cathodic process (El-Sayed, 1997). This observation is in accordance with Muralidharan (Muralidharan and Rajagopalan, 1979), who proposed dependence of \(E_{corr}\) and \(i_{corr}\) on solution parameters. Tafel slopes remained almost unchanged indicating that acid strength does not change the mechanism of the corrosion process. It is evident from data of Tables 2 and 3 that corrosion rate is more in case of sodium hydroxide medium than in phosphoric acid medium.

3.2. Electrochemical impedance spectroscopy (EIS) measurements

The corrosion behaviour of 6063 aluminium alloy specimen was also investigated by EIS techniques in various concentrations of phosphoric acid medium and sodium hydroxide medium. The impedance spectra were recorded and displayed

\[
\begin{array}{cccccc}
\text{E}_{corr} (\text{V vs. SCE}) & b_a (\text{V dec}^{-1}) & b_c (\text{V dec}^{-1}) & \nu_{corr} (\text{mm y}^{-1}) & R_p (\Omega \text{cm}^2) & \text{CPE} (\mu \text{F cm}^{-2}) \\
0.01 & -0.72 & 2.99 & 3.73 & 5.40 & 0.32 & 1922.6 & 45 \\
 & -0.73 & 3.39 & 3.56 & 5.76 & 0.36 & 1767.8 & 57 \\
 & -0.74 & 3.42 & 3.50 & 6.04 & 0.37 & 1512.1 & 63 \\
 & -0.77 & 3.76 & 3.69 & 5.97 & 0.40 & 1324.8 & 74 \\
 & -0.78 & 4.29 & 3.78 & 5.94 & 0.46 & 993.5 & 83 \\
0.1 & -0.79 & 10.8 & 3.67 & 6.57 & 1.17 & 407.3 & 58 \\
 & -0.80 & 12.8 & 3.70 & 6.46 & 1.39 & 339.5 & 65 \\
 & -0.81 & 16.3 & 3.74 & 6.01 & 1.77 & 280.2 & 77 \\
 & -0.82 & 18.1 & 4.07 & 5.32 & 1.97 & 234.5 & 86 \\
 & -0.83 & 24.5 & 4.14 & 5.71 & 2.67 & 172.7 & 98 \\
1.0 & -0.76 & 38.6 & 3.34 & 6.72 & 4.20 & 101.70 & 69 \\
 & -0.77 & 50.5 & 3.43 & 6.68 & 5.50 & 75.90 & 78 \\
 & -0.78 & 69.2 & 3.50 & 6.43 & 7.54 & 54.00 & 90 \\
 & -0.80 & 96.0 & 3.69 & 5.97 & 10.46 & 36.80 & 117 \\
 & -0.81 & 135.4 & 3.79 & 5.60 & 14.75 & 24.20 & 129 \\
\end{array}
\]
as Nyquist plots as a function of acid strength. Nyquist plots for different concentrations of phosphoric acid medium and sodium hydroxide medium at 30°C are shown in Figs. 3 and 4 respectively. The EIS results are reported in Tables 2 and 3.

As can be seen from Figs. 3 and 4, the impedance diagrams show semicircles, indicating that the corrosion process is mainly charge transfer controlled (Wit and Lenderink, 1996; Lenderink et al., 1993). The depressed semicircles of the Nyquist plots suggest the distribution of capacitance due to inhomogeneous surface associated with the metal surface (Morad, 1999). The shapes of the curves are identical and it consists of a large capacitive loop at higher frequencies (HF), inductive loop at intermediate frequencies (IF), followed by a second capacitive loop at lower frequency (LF) values (Brett, 1990).

Similar impedance plots have been reported in the literature for the corrosion of aluminium and aluminium alloys in various electrolytes such as, sodium sulphate (Brett, 1992), sulphuric acid (Poornima et al., 2010), and sodium hydroxide (Shao et al., 2003; Abdel-Gaber et al., 2008; Reena Kumari et al., 2012). The HF capacitive loop is attributed to the presence of a protective oxide film covering the surface of the metal. According to Brett (Brett, 1992), the capacitive loop is corresponding to the interfacial reactions, particularly, the reaction of aluminium oxidation at the metal/oxide/electrolyte interface. The process includes the formation of Al$^+$ ions at the metal/oxide interface, and their migration through the oxide/solution interface where they are oxidized to Al$^{3+}$. At the oxide/solution interface, OH$^-$ or O$_2$ ions are also formed. The fact that all the three processes are represented by only one loop could be attributed either to the overlapping of the loops of processes, or to the assumption that one process dominates and, therefore, excludes the other processes (Morad, 1999). The other explanation offered to the high frequency capacitive loop is the oxide film itself. The origin of the

| Table 3 | Results of Tafel polarization studies and EIS studies of 6063 aluminium alloy in NaOH. |
|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| NaOH (M) | $T$ (K) | $E_{corr}$ (V vs. SCE) | $i_{corr} (\times 10^{-3} \text{A cm}^{-2})$ | $b_a$ (V dec$^{-1}$) | $b_c$ (V dec$^{-1}$) | $\delta_{corr} (\text{mm y}^{-1})$ | $R_p (\Omega \text{cm}^2)$ | CPE ($\mu$ F cm$^{-2}$) |
| 0.05 | 303 | −1.55 | 40.4 | 4.84 | 4.86 | 4.40 | 101.8 | 66 |
| | 308 | −1.56 | 46.9 | 4.87 | 4.83 | 5.11 | 82.5 | 72 |
| | 313 | −1.57 | 52.6 | 5.21 | 5.31 | 5.73 | 80.2 | 75 |
| | 318 | −1.58 | 57.2 | 4.83 | 5.33 | 6.23 | 77.3 | 79 |
| | 323 | −1.59 | 59.8 | 4.45 | 5.44 | 6.51 | 75.6 | 85 |
| 0.25 | 303 | −1.57 | 209 | 5.04 | 4.84 | 22.78 | 24.9 | 76 |
| | 308 | −1.59 | 244 | 4.90 | 4.92 | 26.59 | 18.3 | 84 |
| | 313 | −1.60 | 281 | 5.11 | 4.47 | 30.62 | 17.3 | 96 |
| | 318 | −1.61 | 307 | 4.80 | 4.70 | 33.46 | 15.0 | 107 |
| | 323 | −1.62 | 331 | 4.93 | 4.73 | 36.07 | 14.4 | 114 |
| 0.5 | 303 | −1.59 | 326 | 4.92 | 4.71 | 35.53 | 12.2 | 83 |
| | 308 | −1.60 | 374 | 4.92 | 4.91 | 40.76 | 11.5 | 95 |
| | 313 | −1.61 | 424 | 5.03 | 4.88 | 46.21 | 9.9 | 101 |
| | 318 | −1.62 | 437 | 4.67 | 4.84 | 47.63 | 9.7 | 111 |
| | 323 | −1.63 | 455 | 4.92 | 4.96 | 49.59 | 8.3 | 123 |

**Figure 3** Nyquist plot for 6063 aluminium alloy in different concentrations of H$_3$PO$_4$ at 30 °C.

**Figure 4** Nyquist plot for 6063 aluminium alloy in different concentrations of NaOH at 30 °C.
The inductive loop has often been attributed to the surface or bulk relaxation of species in the oxide layer (Morad, 1999). The LF inductive loop may be related to the relaxation process obtained by adsorption and incorporation of phosphate ions and hydroxide ions into the oxide film (Lorenz and Mansfeld, 1981).

An equivalent circuit of nine elements depicted in Fig. 5a was used to simulate the measured impedance data of the 6063 aluminium alloy, as shown in Fig. 5b. In this equivalent circuit, $R_s$ is the solution resistance and $R_t$ is the charge transfer resistance. $R_L$ and $L$ represent the inductive elements. This also consists of constant phase element; CPE (Q) in parallel to the series capacitors $C_1$ and $C_2$ and series resistors $R_1$, $R_2$, $R_L$ and $R_t$. $R_L$ is parallel with the inductor $L$. The polarization resistance $R_p$ and double layer capacitance $C_{dl}$ are calculated from Eqs. (2) and (3):

$$R_p = R_L + R_t + R_1 + R_2,$$

$$C_{dl} = C_1 + C_2.$$  

The measured value of polarization resistance decreased with increase while the CPE value increased with increasing concentration of the phosphoric acid medium and sodium hydroxide medium, indicating that the rate of corrosion increased with increasing concentration of the phosphoric acid medium and sodium hydroxide medium. This is in agreement with the results obtained from potentiodynamic polarization data.

### 3.3 Effect of temperature

The effect of temperature on the corrosion rate of the 6063 alloy was studied by measuring the corrosion rate at the temperature range of 303–323 K. Figs. 6 and 7 represent the potentiodynamic polarization curves of 6063 aluminium alloy in 1.0 M phosphoric acid medium and 0.5 M sodium hydride medium at temperature range of 303–323 K. Figs. 8 and 9 represent Nyquist plots for the same. From both figures it is...
obvious that the corrosion rate increased with an increase in temperature. This results in the rapid dissolution of the oxide film, thereby enhancing the corrosion rate. This is attributable to the enhanced chemical film dissolution due to enriched phosphate ions, \(\text{OH}^-\) ions and depleted Al(\(\text{OH}\))\(_2^-\) ions at the film/solution interface. Thus with the increasing temperature the oxide passive film becomes thin, porous and less protective as a result of dissolution of the film by the electrolyte (Foley and Nguyen, 1982).

The energy of activation of corrosion of 6063 aluminium alloy was calculated from Arrhenius Eq. (4). The Arrhenius plot (\(\ln(CR)\) vs. \(1/T\)) at all the concentrations of phosphoric acid medium and sodium hydroxide medium is represented in Figs. 10 and 11.

\[
\ln(\tau_{\text{corr}}) = B - \frac{E_a}{RT},
\]

where \(B\) is a constant, \(R\) is the universal gas constant, and \(T\) is the absolute temperature.

Enthalpy of activation (\(\Delta H_a\)) and entropy of activation (\(\Delta S_a\)) were calculated from the transition state theory Eq. (5),

\[
\tau_{\text{corr}} = \frac{RT}{Nh} \exp\left(\frac{\Delta S_a}{R}\right) \exp\left(\frac{\Delta H_a}{RT}\right)
\]

where \(h\) is Plank’s constant and \(N\) is Avagadro’s number.

A plot of \(\ln(\tau_{\text{corr}}/T)\) vs \(1/T\) gives a straight line with slope = \(-\Delta H_a/T\) and intercept = \(\ln(R/Nh) + \Delta S_a/R\). The plots of \(\ln(\tau_{\text{corr}}/T)\) vs \(1/T\) for the corrosion of 6063 aluminium alloy in the presence of different concentrations of phosphoric acid medium and sodium hydroxide medium are shown in Figs. 12 and 13.

The values of energies of activation, enthalpy of activation and entropy of activation are listed in Tables 4 and 5.

As indicated in Table 4, except for 0.01 M phosphoric acid medium, value of energy of activation is greater than 20 kJ mol\(^{-1}\). This suggested that at higher strengths of acid, the whole process is controlled by surface reaction (El-Neami et al., 1995). This phenomenon may be due to the fact that the activation energy for the corrosion reaction is independent of concentration polarization (Oguzie, 2007) and mainly due to activation polarization. However, in case of sodium hydroxide medium, energy of activation at all studied concentrations was less than 20 kJ mol\(^{-1}\) and \(E_a\) decreased with an increase in sodium hydroxide medium concentration, which is suggestive of concentration polarization as a main reaction at electrode–electrolyte interface.

The entropy of activation is large and negative. This implies that the activated complex in the rate determining step represents association rather than dissociation, indicating that a decrease in disorder takes place, in going from reactant to the activated complex (Trowsdale et al., 1996). The value of \(\Delta S_a\) decreased with an increase in acid concentration reveals that dissolution of alloy is facilitated as the concentration of the acid medium increases.
3.4. Scanning electron microscopic study

The SEM images of freshly polished surface of 6063 aluminium alloy are given in Fig. 14 which shows polished surface with few scratches due to polishing. The surface morphology of the 6063 aluminium alloy sample was examined by SEM immediately after corrosion tests in 1.0 M phosphoric acid medium and 0.5 M sodium hydroxide medium. The SEM image of corroded sample given in Figs. 15 and 16 shows the degradation of alloy, with more or less uniform attack in phosphoric acid medium and sodium hydroxide medium. Fig. 17 represents EDX spectrum of the polished sample of the 6063 aluminium alloy. The spectrum shows peaks for aluminium and oxygen suggesting the presence of aluminium oxide/hydroxide. Fig. 18 depicts the EDX spectrum for the corroded sample in the presence of phosphorous indicating the attack of phosphoric acid medium.
For aluminium there is deposition of aluminium phosphate precipitate on the surface and for 6063 aluminium alloy due to the alloying elements, it may be attributed to deposition of the phase $\text{Mg}_5\text{Al}_8$ which makes an anodic phase in the aluminium matrix and Si acts as cathode and contributes to the intergranular corrosion resulting in uniform attack and making it an optimum region of dissolution (Scamans et al., 1987). Close observation of SEM metal images indicates the deposition of precipitates of aluminium phosphate and magnesium phosphate on 6063 aluminium alloy.

Fig. 19 depicts the EDX spectrum for the corroded sample in the presence of sodium hydroxide medium. The spectrum reveals the presence of sodium hydroxide medium, the increase in the amount of oxygen can be attributed to the presence of aluminium hydroxide film formed due to the attack of hydroxide ion on the surface of metal.

3.5. Mechanism of corrosion process

Aluminium and its alloys have air formed oxide film of amorphous $\gamma$ alumina which initially thickens on exposure to neutral aqueous solution with the formation of a layer of crystalline hydrated alumina (Hart, 1957).

In acid solution the mechanism of dissolution of aluminium is as follows (Obot et al., 2010):

$$\text{Al} + \text{H}_2\text{O} \rightarrow \text{AlOH}_\text{(ads)} + \text{H}^+ + \text{e}^-,$$

$$\text{AlOH}_\text{(ads)} + 5\text{H}_2\text{O} + \text{H}^+ \rightarrow \text{Al}^{3+} + 6\text{H}_2\text{O} + 2\text{e}^-,$$

$$\text{Al}^{3+} + \text{H}_2\text{O} \rightarrow [\text{AlOH}]^{2+} + \text{H}^+,$$

$$[\text{AlOH}]^{2+} + \text{X}^- \rightarrow [\text{AlOHX}]^{+}.$$

Thus soluble complex ion formed leads to the dissolution of the metal.

In case of sodium hydroxide medium corrosion of metals is known to proceed by the action of local cells, which are established by metals, comprising a partial anodic reaction and a partial cathodic reaction occurring simultaneously on the metal surface (Uhlig and Revie, 1991). So, in order to
follow the mechanism underlying the corrosion of metals, it is necessary to explore which partial anodic reactions and partial cathodic reactions involve and to determine which of them prevails in the gross corrosion reaction to a greater extent. In addition, the presence of the native surface oxide film should be considered in studying the corrosion mechanism of aluminium in alkaline solution. The anodic aluminium dissolution reaction in the presence of the oxide film can be classified into a direct metal dissolution reaction by the movement of aluminium ions through the film and an indirect metal dissolution reaction by consecutive oxide film formation and dissolution (Moon and Pyun, 1998; Moon and Pyun, 1999).

It is generally accepted (Wernick et al., 1987; Brock and Wood, 1967) that the film formation proceeds electrochemically by the incorporation of hydroxide ions into the film and migration through the film towards the aluminium/film interface in the presence of a thick oxide film on the surface of aluminium as (11):

\[
\text{Al} + 3\text{OH}^- \rightarrow \text{Al(OH)}_3^- + 3\text{e}^- \tag{10}
\]

The aluminium hydroxide film formed electrochemically will be dissolved chemically by OH- attack at the film/solution interface:

\[
\text{Al(OH)}_3^- + \text{OH}^- \rightarrow \text{Al(OH)}_4^- \tag{11}
\]

where Al(OH)$_4^-$ represents the aluminate ions. A partial anodic dissolution reaction of aluminium in alkaline solution can be obtained by combining electrochemical film formation (10) and chemical film dissolution (11), which can be written as:

\[
\text{Al} + 4\text{OH}^- \rightarrow \text{Al(OH)}_4^- + 3\text{e}^- \tag{12}
\]

The electrons produced by the partial anodic Reaction (12) will be consumed immediately by such partial cathodic reactions as the oxygen reduction reaction:

\[
3/4\text{O}_2 + 3/2\text{H}_2\text{O} + 3\text{e}^- \rightarrow 3\text{OH}^- \tag{13}
\]

and/or the water reduction reaction:

\[
3\text{H}_2\text{O} + 3\text{e}^- \rightarrow 3/2\text{H}_2 + 3\text{OH}^- \tag{14}
\]
The short-circuited corrosion reaction of pure aluminium in alkaline solution can be obtained by combining Reactions (12) and (13):

\[
\text{Al} + \text{OH}^- + 3/4 \text{O}_2 + 3/2 \text{H}_2\text{O} \rightarrow \text{Al(OH)}_4^- \quad (15)
\]

and/or by combining Reactions (12) and (14):

\[
\text{Al} + 3\text{H}_2\text{O} + \text{OH}^- \rightarrow 3/2 \text{H}_2 + \text{Al(OH)}_4^- \quad (16)
\]

As a consequence of the overall corrosion Reaction (15), aluminium metal dissolution occurs. On the other hand, hydrogen evolution takes place simultaneously with the dissolution of aluminium metal as a result of the overall corrosion Reaction (16). The observation of gas bubbles on the corroding aluminium surface shows that the corrosion of aluminium in alkaline solution proceeds mainly by water reduction (Pyun et al., 1999) according to Reaction (16).

Therefore, it is concluded that the overall corrosion reaction of aluminium in alkaline solution can be divided into two substeps of a partial anodic reaction comprising the electrochemical formation and chemical dissolution reactions of the film, and a partial cathodic reaction of water reduction reaction.

4. Conclusions

- 6063 aluminium alloy undergoes corrosion both in phosphoric acid medium and in sodium hydroxide medium.
- The corrosion rate increases with an increase in the concentration of phosphoric acid medium as well as sodium hydroxide medium.
- The corrosion rate increases with an increase in temperature.
- The corrosion of 6063 aluminium alloy is more severe in sodium hydroxide medium than in phosphoric acid medium.

References


