Oxidation Behavior of SAE-1053 Alloy in Presence of Seawater

M. Misbahul Amin, Khairel Refazie Ahmad, Habsah Md. Ishak and Neelofar Amin

School of Materials Engineering, PPK Bahan Taman Muhibah UniMAP, University Malaysia Perlis, 02600 Jejawi, Perlis, Malaysia

Abstracts: The oxidation behavior of steel SAE-1053 alloy were investigated in presence of seawater at atmospheric condition. The rate of corrosion was varied with the water movements and the aeration. The scale morphologies were determined by SEM. After immersed in seawater, the alloy surface of incomplete recrystallisation shows thick, loose and porous deposits. The various elements were characterized by using energy-dispersive X-ray spectroscopy (EDS) analysis. The main constituents were found such as FeO, in addition to Na$_2$O, MoO$_3$ and MnO.

Key words: Corrosion, SAE-1053 alloy, Seawater, SEM, EDS.

INTRODUCTION
Corrosion specifically refers to any process involving the deterioration or degradation of metal components. The seawater with varying degree of pollution are regarded as a gradually increasing aggressiveness in the environment, aggravated by increase in flow rates and changes in the temperature and oxygen content of the water. The influence of chloride salts separately or in combination with transition metal sulfates has been studied but not in so much details[1-5]. The oxidation behavior of alloys is strongly dependent on their composition and microstructure, on the other hand, the environmental characteristics namely composition, temperature and degree of aeration, influence of drastic behaviors[6-8].

Very large amounts of carbon steels are used in marine application, such as construction, nuclear and fossil fuel power plants, chemical processing, mining and transportation. Carbon steels are primarily affected by general corrosion and there are prone to deleterious corrosion by seawater[9,10]. In this work, the oxidation characteristic of carbon steel SAE-1053 alloy were investigated based upon oxidation kinetics and morphologies of scales.

MATERIALS AND METHODS
The present study were carried out using SAE-1053 alloy in plate having composition in Wt.%: 0.50-C, 0.15-Si, 0.8-Mn, 0.04-P, 0.05-S, and remaining Fe were obtained commercially. The SAE-1053 alloy in sheet plates were cut into coupons of rectangle sizes, 26 X 14 X 2 mm, and then grounded with silicon carbide abrasive papers of 320, 600 and 800 grit sizes respectively and finally degreased in acetone. The coupons were rinsed with distilled water, dried and then weighed before exposure.

The weighed test specimens were totally immersed in two tanks (A & B), pumped from south china seawater of Malaysia near sea shore and were investigated for period of 90 days at atmospheric condition. Tank A containing static condition without aeration while tank B is also static condition with aeration.

Variation in mass changes were recorded at 30 days intervals throughout the 90 days and the corrosion rate were calculated by using following expression:

\[
\text{Corrosion rate} = \frac{\text{weight loss (g)}}{\text{Panel area of specimen (cm$^2$)} \times \text{Exposure period (days)}}
\]

The investigation was based upon oxidation kinetics and morphologies of scales were determined by using SEM and oxidized coupons were characterized by Energy-dispersive X-ray Spectroscopy (EDS) analysis.

RESULTS AND DISCUSSION
Variation of corrosion rate and consequently 30 days to 90 days of SAE 1053 alloy in seawater is presented in Fig. 1. The seawater predominantly...
consists of sodium chloride (about 3.5%) and many other constituents in ionic forms. Chloride ions are very strong, and could easily penetrate passive films. Some of the factors affecting the corrosion of metals and alloys in the seawater are temperature, salinity, marine organism, bacteria, dissolved oxygen in seawater and relative velocity.

As the dissolved oxygen content is higher, it increases the risk of corrosiveness. It means higher oxygen content is accompanied by an increase in the rate attack. This can explained why specimens immersed in test B showing the higher corrosion rate. Metals also sensitive as air bubbles are present, it may impingement attack. The corrosion of Fe-C alloy under seawater conditions is also due to deposition of foulants or brackish water and/or attack of bio-fouling, covering multifarious aspects of this type of corrosion.

Fig. 2(a & b) showing Scanning Electron Microscope (SEM) micrographs of SAE 1053 alloy immersed in seawater of different tests for 90 days. After exposure to seawater, the film deposited on the alloy surface coupons show thick, loose and porous on the surface of alloy. The scales showed complex microstructures and compositions, exhibiting deleterious effect on the surface of alloy. The alloy is heavily corroded due to the scales are separated from the alloy and there is fragmentation of the alloy.

The result of Energy-dispersed X-ray Spectroscopy (EDS) analysis is presented in Table 1 and the EDS spectra are shown in Fig. 3 (a & b). The constituents identified by EDS were rich FeO, followed species such as Na₂O, MnO, SiO₂ and Cl. seawater for 90 days: (a) specimen A & (b) specimen B.

Table 1: Compositions of metallic oxides/chlorides films of specimens SAE-1053 alloy by using EDS (in mass%) analysis.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Test A</th>
<th>Test B</th>
</tr>
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<tbody>
<tr>
<td>C</td>
<td>2.00</td>
<td>0.71</td>
</tr>
<tr>
<td>F</td>
<td>2.99</td>
<td>1.99</td>
</tr>
<tr>
<td>Na₂O</td>
<td>3.15</td>
<td>0.31</td>
</tr>
<tr>
<td>SiO₂</td>
<td>0.34</td>
<td>0.15</td>
</tr>
<tr>
<td>SO₃</td>
<td>0.08</td>
<td>0.34</td>
</tr>
<tr>
<td>Cl</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>CaO</td>
<td>0.01</td>
<td>-</td>
</tr>
<tr>
<td>MnO</td>
<td>0.23</td>
<td>0.38</td>
</tr>
<tr>
<td>FeO</td>
<td>90.62</td>
<td>95.76</td>
</tr>
<tr>
<td>MoO₃</td>
<td>0.41</td>
<td>-</td>
</tr>
<tr>
<td>SnO₂</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>RuO₂</td>
<td>-</td>
<td>0.18</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Formation of rich FeO, exhibiting the presence of dissolved oxygen and is believe that FeO₃ also occur in the oxidation process. Some of the ferrous ions will react with hydroxide ions to formed iron hydroxide, which is dissolved in the water medium and give rise to light green solution.

Fe^{2+} + 2OH⁻ → Fe(OH)₂

(1)
The ferric ions combine with oxygen to form ferric oxide (III).

$$4 \text{Fe}^{3+} + 3\text{O}_2 + 12\text{e}^- \rightarrow 2\text{Fe}_2\text{O}_3$$

The oxide formed does not firmly adhere to the surface of the steel and flakes off easily causing “pitting”. The ferric oxide formed precipitate of orange brownish color into the seawater. The dissolved sulfates to sulfides in the course of which they are able to depolarize cathodes areas of steel and sulfite is identified in the scales.

**Fig 3:** Energy-dispersed X-ray Spectroscopy profiles of elements of deposits on SAE-1053 immersed in seawater for 90 days: (a) specimen A & (b) specimen B.
**Conclusion:** The influence of seawater on the corrosion of SAE-1053 alloy were investigated in seawater environment at atmospheric condition for the period of 90 days. In the exposure to seawater, the film deposited on alloy coupons shows thick, loose and porous deposits on the surface of alloys. The deposit scales showed complex microstructures and compositions, exhibiting deleterious effect on the surface of alloy. The alloy of incomplete recrystallisation is perforated by seawater due to supplying aeration.

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**REFERENCES**