Identification of corrosion product on medium carbon steel under the exposure of Banda Aceh's atmosphere

Sulaiman Thalib[1], Muharil Ikhsan[1], Syarizal Fonna[1], Syifaul Huzni[1], Syahrir Ridha[2]

[1]Department of Mechanical and Industrial Engineering, Faculty of Engineering, Syiah Kuala University, Jl. Tgk. Syech Abdur Rauf No. 7 Darussalam – Banda Aceh 23111, Indonesia.
[2]Petroleum Engineering Department, Universiti Teknologi PETRONAS, 32610, Bandar Seri Iskandar, Perak Darul Ridzuan, Malaysia.

E-mail: syarizal.fonna@unsyiah.ac.id

Abstract. This research was conducted to study the form of corrosion products of medium carbon steel under the exposure of Banda Aceh's atmosphere. The medium carbon steel samples which the size based on ASTM G 50 were exposed in open areas around the Engineering Faculty, Syiah Kuala University, Darussalam - Banda Aceh, Aceh province, Indonesia. The study was carried out from January through December 2016. The corrosion product formed on the surface of the samples was studied using X-ray Diffraction (XRD) and Scanning Electron Microscope (SEM) method. Measurements of weight loss due to atmospheric corrosion as a basis for calculating corrosion rates was referring to ASTM G1. Corrosion product found based on XRD analysis was *lepidocrocite* (FeO_2, γ-FeOOH) and *goethite* (FeO_2, α-FeOOH). The results agreed with SEM analysis that also indicates to *lepidocrocite* and *goethite*. The corrosion rate for twelve months showed that the highest rate occurs in the period of March-April that was 0.024 mpy. During twelve months exposure, the corrosion products consist of *lepidocrocite* and *goethite*. Significant changes began to occur in the eighth month, where the product of corrosion was almost entirely *goethite*.

1. Introduction

Atmospheric corrosion is a degradation of metal due to contaminating with the surrounding air and the result of pollutants contained in the liquid [1]. Corrosion or commonly called rust formed on carbon steel consists of various oxides such as hydrated oxides, oxyhydroxides, miscellaneous crystalline and other elements as a result of the reaction of iron with the environment [2]. The corrosion products need to be studied to understand how corrosion can be controlled or can be prevented.

Many investigations have been conducted on corrosion products which formed in various atmospheres using XRD and Raman spectroscopy. The corrosion products obtained are *lepidocrocite* (γ-FeOOH), *goethite* (α-FeOOH) and *magnetite* (Fe_3O_4) [3-8]. *Lepidocrocite* is usually formed at the beginning of exposure time, then with the increasing of time, this phase turns into *goethite* [4].

The corrosion product of steel is generally a compound of iron oxide, hydroxide, and oxide-hydroxides in the form of crystals [9]. The structure and size of the crystals that are formed depending on the variable condition where crystals grow. The chemical compositions of some atmospheric corrosion products are shown in table 1. However, the information of the atmospheric corrosion product for Banda Aceh city of Aceh province, Indonesia, is still limited. Hence, the purpose of this

study is to identify atmospheric corrosion products formed on the surface of medium carbon steel using XRD and SEM in Banda Aceh.

Table 1. The chemical composition of atmospheric corrosion products [9].

Iron oxide	Composition	Crystal structure
Goethite	α-FeOOH	Orthorhombic
Lepidocrocite	γ-FeOOH	Orthorhombic
Akaganeite	β-FeOOH	Monoclinic
Hematite	α-Fe$_2$O$_3$	Hexagonal
Feroxyhyte	δ-FeOOh	Hexagonal
maghemite	γ-Fe$_2$O$_3$	Cubic

2. Experimental procedure

The medium carbon steel samples, that the size based on ASTM G 50, were exposed in open areas around the Engineering Faculty Syiah Kuala University, Darussalam, Banda Aceh, Aceh province, Indonesia. The calculation of atmospheric corrosion rate refers to ASTM G1. Characteristics of the atmospheric corrosion products were identified by XRD. The morphology of corrosion product was observed by SEM. The preparation of powder sample for XRD is conducted by grinding the atmospheric corrosion products using a mixer. The composition of medium carbon steel used in the study is shown in table 2.

The XRD data retrieval was performed every six month and corrosion rate calculations were done every two months from January to December. The weight losses of the specimen were measured using a digital scales with precision 0.001 gr.

Table 2. The composition of medium carbon steel used in the study

Elements	C	Si	Mn	P	S	Ni	Cr	Mo	Co	Al	Fe
Composition	0,310	0,062	0,729	0,002	0,010	0,049	0,051	0,029	0.019	0,014	6,256

3. Results and discussion

3.1. XRD analysis

The result of corrosion products identification using XRD after six-month period exposure is shown in Figure 1 (A label). The first peak of the angle 2Θ is 14.33° and corrosion product formed is lepidocrocite (FeO$_2$). The second peak of the angle of 2Θ is 26.97° and the corrosion products formed Fe (III) oxide hydroxide lepidocrocite (γ-FeOOH). The third highest peak which formed goethite (FeO$_2$) at an angle of 2Θ 36.33°.

Corrosion or commonly referred rust formed on carbon steel consists of various oxides, as a result of the reaction between iron and the environment. The corrosion product of lepidocrocite is usually formed at the beginning of exposure. With the increasing of exposure time, the lepidocrocite might turn into goethite. This is in accordance with the results obtained by other researchers with using x–rays and Raman spectroscopy [3-8, 10]. The identification using SEM verified the corrosion products formed after six months exposure was lepidocrocite as seen in figure 2(a).

The corrosion product after twelve month period of exposure was also identified using XRD. The result is shown in figure 1 (B label). Corrosion product of lepidocrocite (FeO$_2$) was formed at the first peak with 14.05° of 2Θ angle. The second peak with 27.01° of 2Θ angle corresponded to the corrosion products of Fe (III) oxide hydroxide lepidocrocite (γ-FeOOH). Corrosion product of goethite (α-FeOOH) was formed at the third peak with 36.31° of 2Θ angle.

The verification was also performed using SEM for the corrosion products in a period of six months to twelve months. It was obtained lepidocrocite and goethite phases. However, goethite is

dominant than lepidocrocite as shown in figure 2(b). The changes of corrosion product morphology might be affected by the presence of hydrogen on metal surfaces with the increased exposure time.
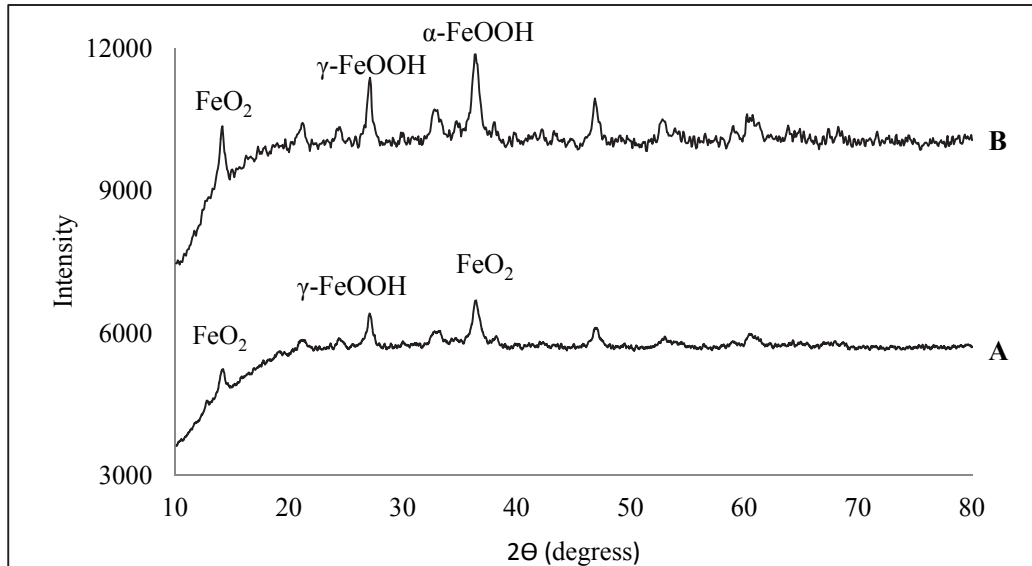

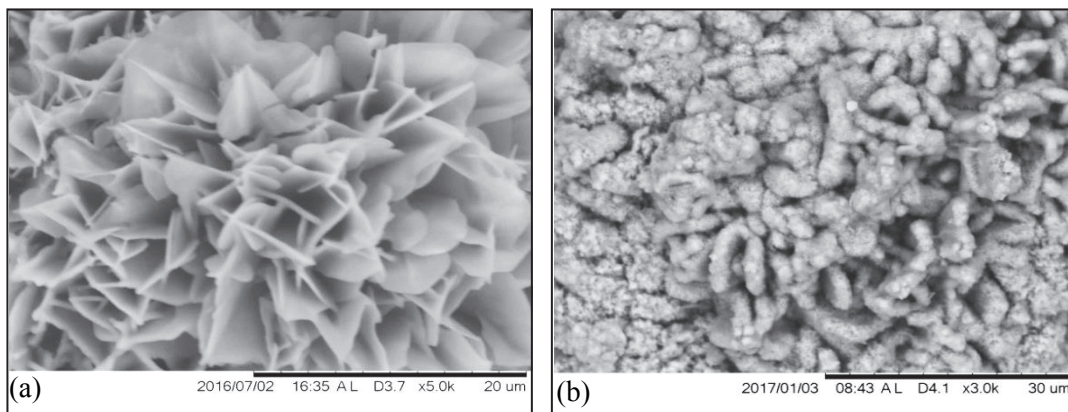**Figure 1**. The results of the identification of corrosion products using XRD.

Figure 2. (a) Corrosion products of lepidocrocite that formed after six months of exposure; (b) Corrosion products of goethite that formed after twelve months of exposure.

3.2. Corrosion rate
Atmospheric corrosion rate was calculated over the last twelve months using an equation based on ASTM G1. The highest corrosion rate of 0.024 mpy occurred in the period of March-April, as shown in Figure 3(a). The lowest corrosion rate that occurred in the period July-August was 0.0125 mpy. It was suggested that the rain became a major factor for the occurrence of such a low corrosion rate. However, the corrosion rate around Engineering Faculty, Syiah Kuala University, Darussalam, Banda Aceh, Aceh province, Indonesia, is still in the outstanding categories.
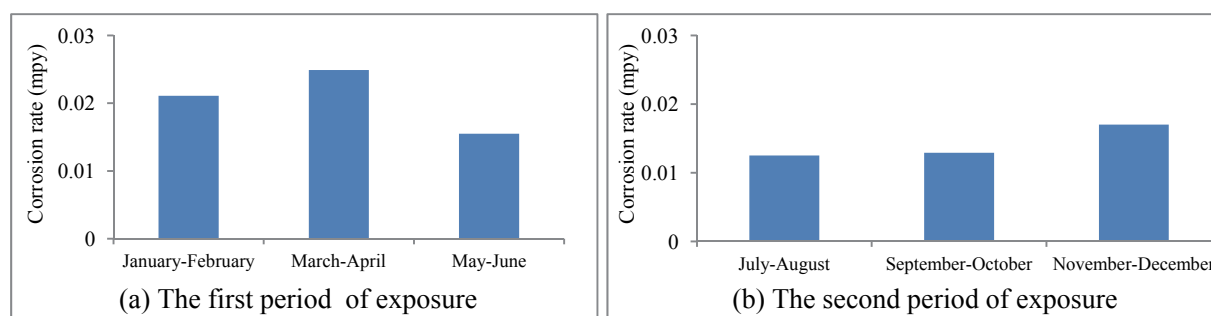
Figure 3. The corrosion rate for all periods of exposure.

4. Conclusions

The results of the identification of the corrosion products using SEM and XRD shows that in general, the corrosion products formed on medium carbon steel which exposed in the open area of Engineering Faculty, Syiah Kuala University, Banda Aceh were lepidocrocite and goethite. A chemical compound that was formed after six months exposure was FeO_2, γ-FeOOH, and FeO_2. Whereas after twelve months of exposure, the product was FeO_2, γ-FeOOH, and α-FeOOH. The highest corrosion rate in the area was 0.024 mpy during March-April. While, the lowest corrosion rate occurred in the period of July-August, i.e. 0.0125 mpy. However, the corrosion rate level in the area was still found as outstanding.

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