The Effect of Environment Temperature and Humidity on Corrosion Rate of a Condensing Unit

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ABSTRACT

This study aims to determine the rate of corrosion of a condensing unit. Condensing unit is the main component of a split air conditioner which is installed outside a building (outdoor) and is always exposed to the elements as well humidity. Such conditions make the condensing unit vulnerable to corrosion. Further, the corrosion affects the performance of the air conditioner. Temperature and humidity (air velocity, hot and cold temperature) greatly affect the corrosion rate. This is an experimental study and data was based on observation and analysed using the formula corrosion rate. The results indicate that $FeFe_2O_4$ and FeO compounds affect corrosion rate. Specifically, the rate of corrosion on the metal plate of condensing units is 0.054 millimetres per year (mpy) at an ambient temperature of 30°C and 85% humidity.

Keywords: Atmospheric, condensing, corrosion, humidity, metal

INTRODUCTION

Condensing unit (or outdoor unit) of a split air conditioner is a main component installed outside a building. It is usually placed on the roof or wall of a building, which is exposed to sunlight, hot and cold air, and humid wind (Tidblad et al., 2016). Such conditions can potentially lead to corrosion of the condensing unit (Azwar, 2011). The metal plate which is exposed to outside air and affected by the temperature and humidity can cause corrosion (Simillion, Dolgikh, Terryn, & Deconinck, 2014). The quality of metal plate determines the rate of corrosion and its corrosion will affect the heat transfer process. Therefore, the heat must be removed from the room via conduction and convection. A delayed process of removing the heat will interfere with the phase change of the refrigerant in

the condensing unit. The refrigerant generated by the condensing unit contains liquid and gas phases. Supposedly, the phase of the refrigerant is in the form of liquid. Corrosion of the condensing unit degrades its performance and inefficient electrical consumption. The air it produces is also less cold.
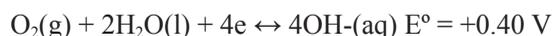
The rate of corrosion on each metal plate varies, depending on the quality, thickness and environment conditions. Plates which have good quality and thickness tend to have lower corrosion rate. Good environments also reduce the rate of corrosion of metal plates. The corrosion rate is influenced by the layer (coating) covering the plates. The quality and thickness of the layer tend to restrain the rate of corrosion of the metal plates. The corrosion rate of metal plates is also affected by the duration of contact with the environments. Environments containing high salt and moisture levels tend to accelerate the rate of corrosion (Mohammedi, Ismail, Rehamnia, Bensalem ,& Savadogo, 2015). Thus, the rate of corrosion of metal plates of a condensing unit is influenced by several factors, including: quality, thickness, layer (coating) and environmental conditions. No previous stuy has specifically measured the corrosion rate of a metal plate on a condensing unit. The current research focuses on corrosion in marine environments, steel pipes, copper pipes, aluminium, pollution and its inhibitors.

Environmental temperature and humidity accelerate the growth of microorganisms on a plate in the condensing unit. These microorganisms will accelerate the corrosion on the surface of the metal plate. The microorganisms that affect corrosion rate among others are bacteria, fungi, algae, and protozoa (Venzlaff et al., 2013). Corrosion has a major influence on the degradation of the material in the environment (Vasudevan & Sadananda, 2015). The effect of initiation or the rate of corrosion in an area and microorganisms are associated with the surface. Corrosion attaches to the metal surface in the form of a thin layer (bio deposit) and a thin film layer (biofilm). The film layer usually appears in a circle form with a certain diameter. If it is exposed to the environment, it can cause localised corrosion. Organisms in the deposit layers have a profound effect on chemicals in the environment between the surface of the metal/film or metal/deposit without considering the effect of the bulk electrolyte property (Dyah, Agung, & Bagusnovan, 2013).
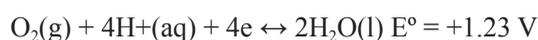
Corrosion is an electrochemical process. In corrosion on a metal plate, a certain part of the iron plates acts as anode, so that the metal plate experiences oxidation [22].

$$Fe(s) \leftrightarrow Fe^{2+}(aq) + 2e \quad E° = +0.44 \text{ V}$$
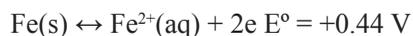
The electrons released by the anode flow to other parts of the iron which acts as the cathode, so that oxygen is reduced.

$$O_2(g) + 2H_2O(l) + 4e \leftrightarrow 4OH^-(aq) \quad E° = +0.40 \text{ V}$$

or

$$O_2(g) + 4H^+(aq) + 4e \leftrightarrow 2H_2O(l) \quad E° = +1.23 \text{ V}$$

Iron ions formed on the anode are then oxidised to form ferric ion, which then forms the compound of hydrated oxide, $Fe_2O_3 \cdot xH_2O$, that is rust. The part of the iron that acts as an anode and acts as the cathode depend on various factors, such as impurities or density differences of the metal. Due to the migration of ions and electrons, rust is often formed in areas far from the surface of the corroded iron (Valeh-e-Sheyda & Rashidi, 2016). The colour of the s from yellow to brownish red and even black. The colour depends on the amount of H_2O molecules bound to rust. The rate of corrosion is defined as the amount of metal that is lost or removed from the area of the anode or the number of deposited metal (plating) on the cathode area (Cui, Li, Yang, & Wei, 2015; Kuang & Cheng, 2016).

MATERIALS AND METHODS

This is an experimental research to determining the rate of corrosion (weight loss) of a metal plate on a condensing unit (Baboian, 1995). The equation used (Priest, 1992) is:

$$\text{Corrosion rate} = \frac{W.K}{A.T.D}$$

Information:

The corrosion rate = millimetres per year (mpy)

W = weight loss (mg)

A = area expanded in the corrosion environment (cm^2)

T = soaking time (hours)

D = density (g/cm^3)

K = constant of corrosion rate = 534

The experiment was conducted on the metal plate of a split air conditioner condensing unit (Panasonic). The metal plate casing of the condensing unit was removed and two sample sizes were made: 40x20x0.75mm and 200x100x0.75mm. The first sample was soaked in a solution of NaCl and the second sample was used for the atmospheric environment. The metal plate sample surface was cleaned thoroughly using sandpaper 80, 240, 600, 800 and 1000 on a flat surface flowed with water. Surface cleaning was done on the samples mechanically, chemically, or both.

Every corner of the samples was cleaned to avoid any tension concentration that leads to corrosion due to cracking. The samples must be clean of all contaminants (dust, oil and rust products). Sanding must be done very carefully to avoid the high temperature on the surface as it can affect the microstructure of the sample. Data related to weight, dimensions and serial number of the samples were recorded and the surface was photographed prior to the experiment. The metal plates were later rinsed with distilled water and ethanol to ensure it did not damage their structure. The samples were later dried and stored in a desiccator to prevent contamination and later weighed and measured. Analytical scale was used to determine the difference in weight pre-and post-corrosion. Four samples were hung in atmospheric conditions. Four other samples were immersed in the solution of NaCl with NaCl concentration of 1.5%, 2.5% and

3.5% at different times. The NaCl concentration refers to the environmental conditions that may occur in Bandung.

The samples were soaked for 30 days. Cleaning and removal of corrosive products and all materials on the surface were done carefully before measuring the final weight. Information on location, time, depth measurement, surface profile (inflated or eroded) corrosive product or scale composition (the product formed because the soil had alkaline pH reacting with soil) and operating factors (inhibitors) were collated. In order to determine the corrosion rate with the weight loss method, pickling solution was required. The pickling solution was made of 5 grams of chloride lead and 2 grams of chloride antimony dissolved in 100 mL of concentrated hydrochloric acid.

The corroded samples were then inserted into the pickling solution for about 2 minutes, then washed with water, brushed with a soft brush so that the corrosive products disappeared, rinsed with distilled water and acetone, dried and weighed again. The difference in weight before and after corrosion is the weight loss. For each metal, this treatment was repeated three times before Then, the corrosion rate and efficiency of the inhibitor at the time variation and NaCl were determined (Van den Steen, Simillion, Dolgikh, Terryn, & Deconinck, 2016).

RESULTS AND DISCUSSIONS

Table 1 shows the value of the corrosion rate of the two samples in four conditions and corrosion time. The four samples were tested to determine the corrosion rate in two environments: sea water and atmosphere. They represent several conditions and duration. For the sea water condition, 1.5%, 2.5% and 3.5% NaCl respectively were used (Dwilaksono, Supomo, & Pribadi, 2013). Meanwhile, the atmospheric environment is the environment of Bandung with a temperature ranging from 20 to 31°C and humidity of 80-85%.

Table 1
Calculation of corrosion rate

Sample Code	Surface Area (in^2)	Initial Weight (g)	Final Weight (g)	Difference of Weight (g)	Corrosion Rate (mpy)
			NaCl 1,5%		
A1	2.671	4.451	4.434	0.017	0.107
A2	2.732	4.393	4.377	0.016	0.049
A3	2.876	4.650	4.633	0.018	0.034
A4	2.755	4.518	4.501	0.017	0.027
			Average	0.017	0,054
			NaCl 2,5%		
B1	2.950	4.797	4.780	0.017	0.097
B2	2.684	4.371	4.355	0.016	0.051
B3	3.001	4.894	4.876	0.018	0.034
B4	2.922	4.743	4.727	0.016	0.023
			Average	0.017	0.051

Table 1 *(continue)*

NaCl 3,5%					
C1	3.078	5.012	4.996	0.016	0.087
C2	2.908	4.617	4.603	0.014	0.039
C3	3.011	4.903	4.887	0.016	0.030
C4	2.758	4.465	4.453	0.012	0.018
			Average	0.015	0.044
Atmospheric Environment					
D1	63.322	110.042	109.673	0.370	0.0493
D2	62.759	109.014	109.013	0.001	0.0001
D3	63.399	110.239	110.242	0.003	0.0003
D4	62.867	108.996	109.001	0.005	0.0003
			Average	0.095	0.0013

The metal corrosion rate (Figure 1) in the 30 day-corrosion test has the highest value on any test conditions with 1.5% NaCl. Meanwhile, the longer the corrosion test took in each of the test conditions, the lower the rate of corrosion. This is due to the formation of a layer of oxide iron Fe_2O_3 which can inhibit the corrosion rate. The addition of 3.5% NaCl concentration caused the corrosion rate of carbon metal to decrease (Karthikeyan, Raja, Balan, & Jeeva, 2015). This means that the greater the concentration of NaCl, the slower the rate of corrosion. This is due to increased viscosity of the solution so that the movement of ions in the solution is reduced. Consequently, the conductivity of the solution and the corrosion current density decreases.
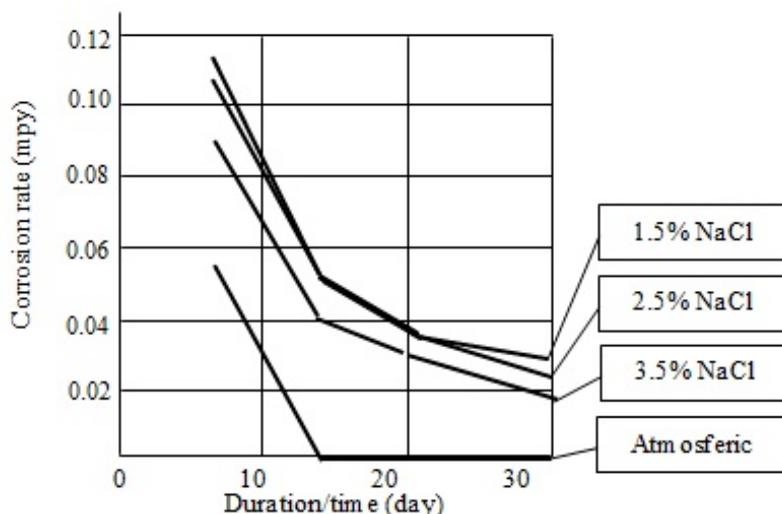

Figure 1. Corrosion rate based on duration in four NaCl conditions

The results show that the corrosion rate in NaCl 1.5% is higher and faster than in any other solutions (Khireche, Boughrara, Kadri, Hamadou, & Benbrahim, 2014), based on the same duration but with a different concentration of the solution. Testing at atmospheric conditions shows that the corrosion rate tends to decrease during longer periods. The value of the corrosion rate in the atmospheric conditions is smaller than in salt water environments. The corrosion rate becomes stable after reaching a certain time. This is due to the resistor of the corrosion rate and residue from the previous corrosion.

Morphological characterisation test was also done to the metal plates whereby those which had not been subject to corrosion were characterised using SEM EDS. The results were compared to carbon metal plates which had been corroded (Hadi & Jumarlis, 2013). Characterisations of the metal plates before and after preparation were obtained. The test was done to observe the surface of the metal plates, which was compared to the corroded ones.

Carbon metal plates that had been corroded were characterised using SEM EDS. Figure 2a and 2b shows the metal plates which were corroded and not corroded. The damage was significant which also saw formation ofcracks. The occurrence of corrosion cracks on the surface of the metal samples indicate. the metal plates have lost their strength and influenced the heat transfer process (Nasrazadani & Nakka, 2016). As the casings are always exposed to vibration from the compressor, the cracks caused the plates to break and chip easily.
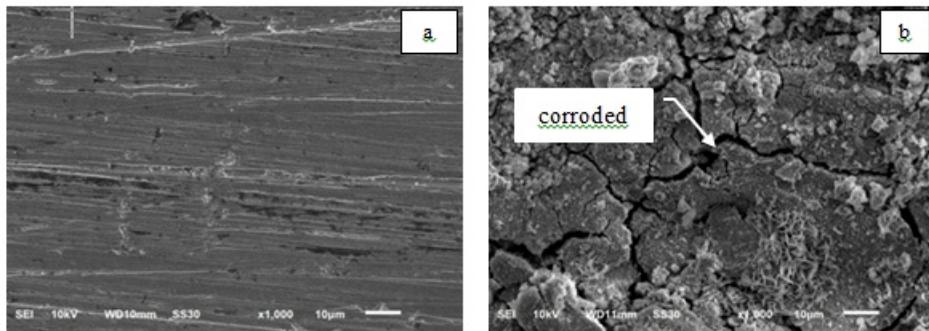

Figure 2. SEM images of surface before (a) and after (b) corrosion process

The results of EDS (energy dispersive x-ray spectroscopy) of the metal specimens are presented in Table 2. It was observed that there was a weight loss of 6.1% (5.7 grams) of FeO oxide compound in the initial specimens before the corrosion. At the beginning, the specimen contained 93.9% FeO. After the corrosion, it decreased to 88.2%. This suggests that Fe reacted to its aggresive environments during the test and turned into corrosion products (Finšgar & Jackson, 2015).

Table 2
Results of metal EDS API 5L X52 M PSL 2 in the form of oxide

Compound	Weight pre corrosion (%)	Weight post corrosion (%)
C	4,14	0,23
FeO	93,89	88,16
SiO_2	0,57	0,71
N	-	10,40
P_2O_5	0,11	-
MnO	0,95	0,15
SO_3	-	0,34
Nb_2O_5	0,20	-
Ti_2O_3	0,13	-
V_2O_5		0,00
Total	100,0	100,0

The analysis using XRD was aimed to determine the types of compounds generated by the corrosion on the metal plates. Metals analysed using XRD are those which had been corroded and had the largest corrosion rate (Araban, Kahram, & Rezakhani, 2016). The XRD analysis results indicate (Figure 3) the formation of corrosive products of $FeFe_2O_4$ and FeO. Both have the highest peak at 44.6 indicating the presence of Fe as the most dominant metal compound. The two compounds have the highest corrosion rate or the most vulnerable compounds to corrosion (Zeng, Lillard, & Cong, 2016).
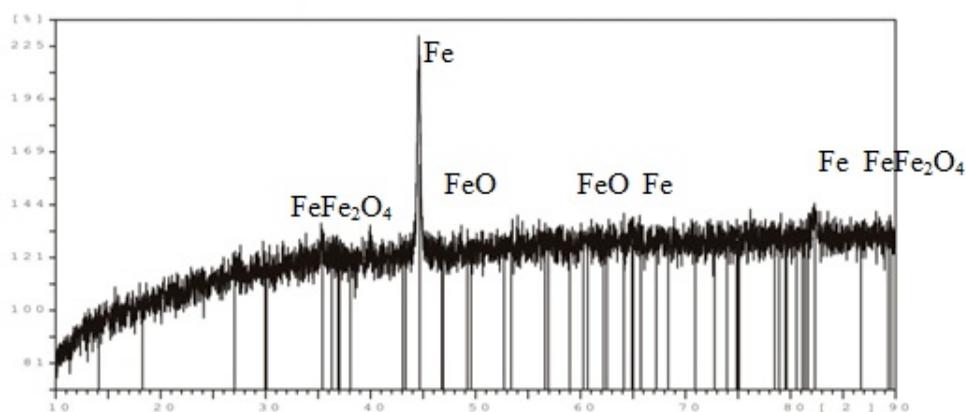

Figure 3. Metal XRD diffractograms after corrosion

CONCLUSION

It can be concluded that the metal plate of the split AC casing is subject to rapid corrosions in environments with 1.5% NaCl concentrations but not in humid environments. The results of SEM EDS analysis of the damage level caused by corrosion is characterised by the presence of cracks on the surface of the samples. The compound corrosion products are $FeFe_2O_4$ and

FeO. These compounds have the highest corrosion rate or are the most vulnerable to corrosion. The corrosion rate of a condensing unit metal plate is 0.054 mpy in environments containing 1.5% NaCl. The value of the corrosion rate is acceptable because it does not quickly damage the coating of metal plates. A corrosion rate of 0.1 mpy or more will quickly damage the metal plates. Thus, it is recommended that the metal plates are cleaned and coated with anti-rust.

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