WCEJ

WORLD CHEMICAL ENGINEERING JOURNAL

Journal homepage: http://jurnal.untirta.ac.id/index.php/WCEJ

Corrosion Analysis on Aluminum Metal (AMS 4050) Extreme Acid Rain Environment Method with Weight Loss

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ARTICLE HISTORY

Received 1 August 2021
Received in revised form 20 September 2021
Accepted 5 October 2021
Available online 4 November 2021

ABSTRACT

AMS 4050 aluminum metal which is a type of aluminum with no Zn content 5.7 - 6.7%Cu 2 - 2.6%, Mg 1.9 - 2.6%, Zr 0.15%, Si 0.15%and Mn 0.1% others 0.15% each. The advantage of aluminum is that it weighs only 2.7 gr / cm^3, corrosion resistant, good electrical and heat transmitter, easy to fabricate or forge. This AMS 4050 material is widely used in the expansion industry to be used as an aircraft frame. MS 4050 aluminum is more resistant to cracking than other types of aluminum, however cracks can still occur due to corrosion due to acid rain. The test method used to calculate the corrosion rate is the weight loss method. The corrosion rate test results obtained with mean values for immersion of 1, 2, 3, and 4 weeks were 0.03, respectively; 0.07; 0.1 and 0.12 mg / cm2 h. EDX test results showed that the aluminum content in AMS 4050 metal decreased by 18.18%.

Keywords: *Aluminum AMS 4050, weight loss method, corrosion rate*

1. INTRODUCTION

In today's rapid technological development, many innovations have been made, one of which is the aircraft industry. This innovation requires a lightweight, strong and durable metal alloy to be used as a component (Gapsari, F. 2017).

Aluminum alloys have several advantages over steel: they weigh lighter and are more resistant to corrosion. The use of aluminum alloys has advantages over other metals, such as stainless steel (too heavy), and titanium alloys (too expensive). The aluminum alloy used in the IFX aircraft is the AMS 4050 type because this type of aluminum is resistant to cracking, lightweight and corrosion resistant. However, throughout the period of operation, the aircraft is prone to corrosion due to environmental conditions such as exposure to acid rain (Davis, R. 2001; Sukiman, N. L. 2013).

Acid rain is defined as all types of rain with a pH below 5.6. Acid rain is caused by high levels of sulfur dioxide (SO_2) in the atmosphere. Sulfur Dioxide (SO_2) reacts with water (H_2O) to form sulfuric acid (H_2SO_4). Acid rain is divided into 3 based on its acidity level, pH 4-, 1 - 5.5 is normal acid rain, pH 3 - 4 is moderate acid rain and pH below 3 is extreme acid rain (BMKG). This research is the analysis of the corrosion rate value of AMS 4050 aluminum metal and the morphological analysis of AMS 4050 Aluminum metal. Corrosion on aluminum alloys is generally localized, due to the separation of anodic and cathodic reactions and the resistance of the solution in limiting the size of the galvanic cell. The basic oxidation reaction of aluminum in liquid media under normal conditions is written into the equation;

$$Al \rightarrow [\![Al]\!]^{3+} + 3e^-$$

Aluminum metal, in an oxidation state of 0, in solution changes to the cation Al^{3+} upon loss of three electrons. This reaction is offset by the simultaneous reduction of ions present in the solution which are free electrons. In liquid media with a pH close to neutral, such as ordinary water, seawater, and water vapor, it can be shown by thermodynamic calculations that only two reduction reactions can occur, namely: (NACE International. 2019) H + proton reduction: In acid medium:

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

At a temperature of 20 °C and below atmospheric pressure, the oxygen solubility in water is 43.4 mg.kg^{-2}. Decreases with increasing temperature and is not more than 30.8 mg.kg^{-2} at 40 °C and 13.8 mg.kg^{-2} at 80 °C. Generally the corrosion of aluminum in a liquid medium is the second sum of chemical reactions, oxidation and reduction:

$$Al + 3H_2O \rightarrow Al(OH)_3 + {}^3/_2\, H_2$$

This reaction is accompanied by a change in the oxidation field in aluminum, from 0 in the metal to the oxidation number of alumina (+3). By exchanging electrons, aluminum loses three electrons absorbed by 3H +. Aluminum corrosion is obtained in the formation of alumina $Al(OH)_3$ which is insoluble in water and precipitates as white cells where it is found to rust as white gelatin chips (Craig, B. D. 2007)

The general similarity for aluminum and alloys is that they both have corrosion resistance in aggressive aqueous environments. The protective oxide layer demonstrates the thermodynamic stability of the aluminum alloy in a corrosive environment - it acts as a physical barrier and is able to repair itself in an oxidizing environment if damaged. The thermodynamic principles for explaining and predicting the passive phenomena that control the corrosion behavior of aluminum are summarized by Pourbaix -type analysis. This produces a potential vs. pH plot based on the type of electrochemical reaction involved, a picture known as the Pourbaix diagram (Roberge, P. R. 2000; Oger, L., E, ET.AL.2020). as shown in Figure 1

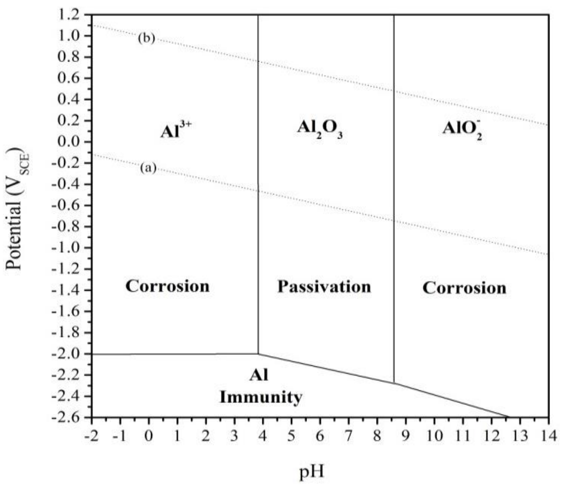


Fig. 1. Diagram of Pourbaix E-pH Fe – H_2O

Corrosion is the process of decreasing material quality due to chemical reactions with the environment (Hilti, 2015). Corrosion can be said to be material damage because it is not purely mechanical. It can be seen that metals that are left alone in the open air can corrode due to the reaction between the metal and its environment. Therefore, there are three aspects of corrosion, namely: material, reaction and environment (Gapsari, 2017). When viewed from the interactions that occur, corrosion is the process of transferring electrons from metal to its environment. The metal acts as an electron donating cell (anode) and the environment acts as an electron acceptor (cathode). While the decrease in quality caused by physical interaction is not called corrosion, but is referred to as corrosion.

Calculating the magnitude of the corrosion rate can use the equation (Dalo, 2012):

$$CR = (m_1 - m_2) / (A.t)$$

where:

CR	= Corrosion Rate (mg / cm2h)
m1	= Initial Mass (mg)
m2	= final mass (mg)
A	= Specimen Surface Area (cm2)
t	= Immersion Time (hours)

Meanwhile, to calculate the efficiency value of the inhibitor using the equation (Dalo, 2012)

% IE = (CRblank - CRinh) / CRblank x 100%

Where:

CRblank = Corrosion rate without inhibitor (mg / cm2 h)

CRinh = Corrosion rate with inhibitor (mg / cm2 h)

% IE = inhibitor efficiency (%)

2. MATERIALS AND METHODS

The metal sample used was AMS 4050, cut to the size of 40 mm x 20 mm x 5 mm. The sample is cleaned with acetone to remove impurities that remain on the metal surface. The process of sanding the sample with 200, 400, 600, 1000 and 2000 grid sandpaper in wet conditions to clean up the remaining dirt. The treatment on metal surfaces refers to the ASM Handbook, Volume 5. Surface Engineering. Rinse the sample with distilled water then dry using a hair dryer. Sterilize the sample by dipping the sample in 70% alcohol and dry it using a hair dryer. Corrosion testing using weight loss methode metal surface testing using SEM-EDX (Carl Zeiss Evo machine, model MA10 type)

3. PURPOSE RESULTS AND DISCUSSION

3.1. Testing Corrosion Rate With Weight Loss Method

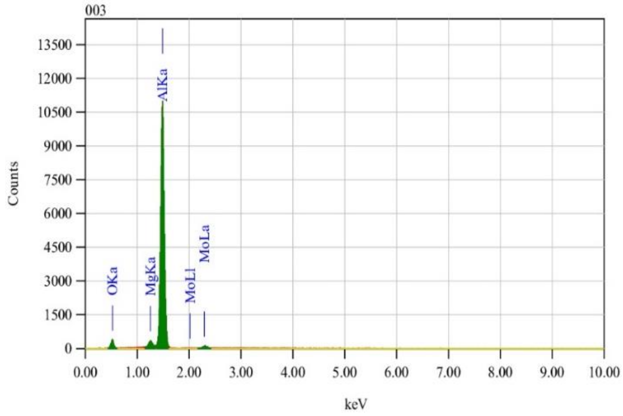
Corrosion rate analysis using weight loss rate method by immersing 12 samples of Aluminum AMS 4050 in 0.005 M H_2SO_4 environment in sample time 1-3 for 1 week, sample 4 - 6 for 2 weeks, Sample 7 - 9 for 3 weeks and sample 10 - 12 for 4 weeks are summarized in table 1 below; In the table it is clear that the immersion of AMS 4050 Aluminum metal samples in an environment of 0.005 M H_2SO_4 for 168 hours (1 week) has a corrosion rate of 0.03 mg/cm2hours, at 336 hours (2 weeks) the corrosion rate is obtained and at a longer immersion time of 504 hours (3 weeks) 0.07 mg/cm2h the corrosion rate increased when the metal sample was immersed for 672 hours (4 weeks) the value was 0.12 mg/cm2h, so it can be concluded that the longer the immersion the corrosion rate will increase. For more details on the metal surface can be seen using the SEM-EDX tool

Table 1. Yield data of AMS 4050 Aluminum Corrosion Level in 0.005 M H_2SO_4 environment Immersion table for 4 weeks Meanwhile, through EDX testing, it is seen that the

No Sample	m1 (mg)	m2 (mg)	Immersion Time (Jam)	Corrotion Rate (mg/cm^{2}jam)
1	2060	2050	168	0,03
2	2080	2070	168	0,03
3	2950	2940	168	0,03
average weight				**0,03**
4	2110	2060	336	0,07
5	2130	2080	336	0,07
6	3000	2950	336	0,07
average weight				**0,07**
7	2160	2070	504	0,09
8	2180	2080	504	0,10
9	3050	2950	504	0,10
average weight				**0,10**
10	2220	2070	672	0,11
11	2240	2080	672	0,12
12	3110	2950	672	0,12
average weight				**0,12**

3.2. Ams 4050 Metal Surface Morphological Test With Sem-Edx

Metal surface analysis using scanning electron microscopy (SEM-EDX) was observed on AMS 4050 without immersion and AMS 4050 metal after immersion in H_2SO_4 solution. Test results of both samples showed differences in surface morphological structure in AMS 4050 metal. From the results of surface morphology testing with 1000x magnification, it can be seen that on the metal surface of AMS 4050 metal, the grooves are seen in the same direction and the surface is brighter, indicating that there is no decrease on the metal surface of AMS 4050. The aluminum content has decreased when compared to the aluminum content before immersion



ZAF Method Standardless Quantitative Analysis
Fitting Coefficient : 0.5826

Element	(keV)	Mass%	Error%	Atom%	Compound	Mass%	Cation	K
O K	0.525	14.26	2.87	22.45				12.2246
Mg K	1.253	4.13	1.05	4.27				4.3348
Al K	1.486	77.27	1.15	72.14				80.4584
Mo L	2.293	4.35	5.24	1.14				2.9823
Total		100.00		100.00				

Fig. 2. EDX AMS 4050 test results before immersion in 0.005 M H_2SO_4 immersion environment for 4 weeks

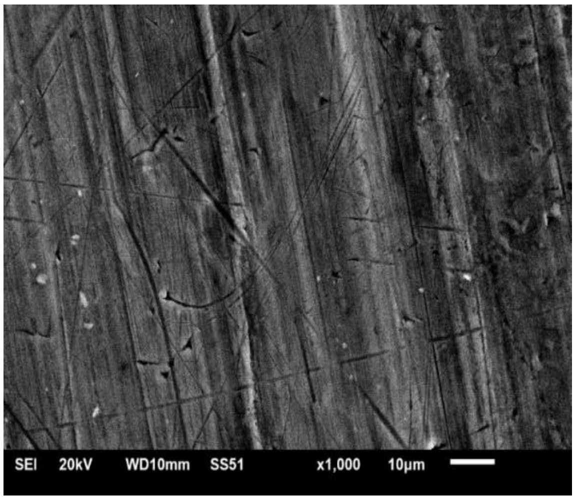


Fig. 3. Morphological test results of AMS 4050 before immersion

In the SEM-EDX test for untreated metal samples, it can be seen in Figure 2 that the composition of the aluminum content is about 95.45%, if you look at the morphology on the metal surface, it looks homogeneous and shiny, it can be seen in Figure 3, while the metal samples after immersion in 0.05 M media H_2SO_4 after being soaked for 4 weeks shows the dissolution of the aluminum metal with evidence of a reduction in the composition of aluminum to 77. 27%, as shown in Figure 4 and the metal surface is damaged in the form of cracks and there are holes which indicate that the AMS 4050 metal has been corroded, as shown in figure 5.

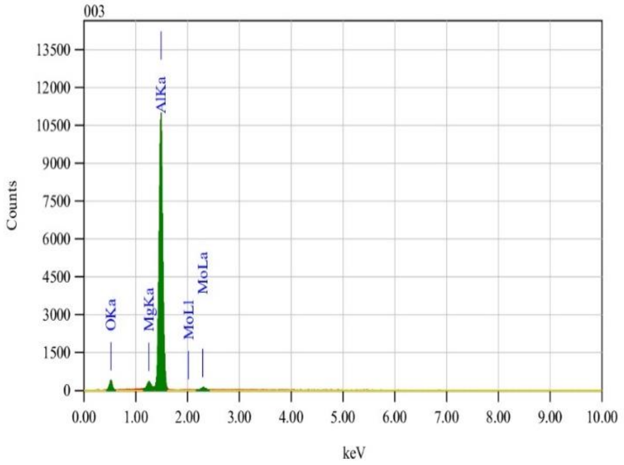


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Fig. 4. EDX AMS 4050 test results after immersion in 0.005 M H_2SO_4 immersion environment for 4 weeks

From the results of SEM-EDX test, it is known that there is a change in the surface morphology of the sample and a decrease in aluminum content from 95.45% to 77.27 % (18.8%). The decrease in the percent composition of aluminum is due to the oxidation of the metal in sulfuric acid media (0.005M H_2SO_4) causing the metal to corrode, this is clearly seen in the morphology of the metal surface.

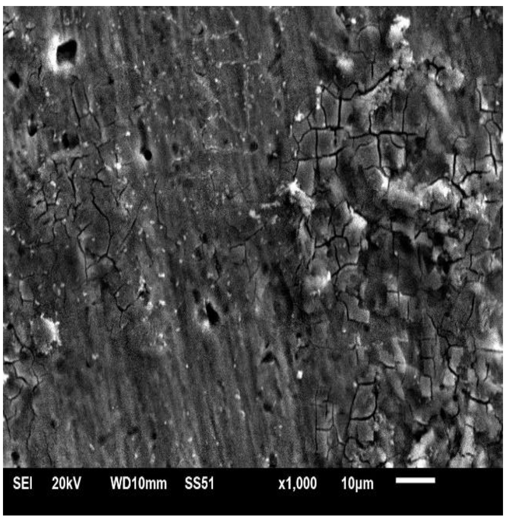

Fig. 5. Morphological test results of AMS 4050 after immersion in sulfuric acid media (0.005M H_2SO_4)

4 CONCLUSION

Based on the study conducted, it can be concluded that the results of this study are;

1. The results of corrosion rate test performed on AMS 4050 metal using weight loss method, in testing AMS 4050 metal samples, corrosion rate results were obtained with mean values for immersion of 1, 2, 3, and 4 weeks respectively 0.03; 0.07; 0.1 and 0.12 mg / cm2 h
2. EDX test results show that the aluminum content in AMS 4050 metal decreased by 18.18%

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