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Experimental Study on the Corrosion Rate Influence Caused by Seawater on Aircraft Structures

Marga Dharma Prayoga[1*], Heru Susanto[1], dan Muhammad Luqman Bukhori[1]
[1] Sekolah Tinggi Teknologi Kedirgantaraan Yogyakarta
Jl. Parangtritis Km 4.5, Sewon, Bantul,
Yogyakarta
*E-mail: margadharma45@gmail.com

Abstract

Airplanes are a very fast and time efficient means of transportation. In Indonesia itself, because the country is an archipelago and has a tropical climate, rainwater and seawater are the main problems in the aviation world, this is evidenced by the corrosion that occurs in every aircraft maintenance. Factors that cause corrosion and corrosion rate are acidity, environmental conditions, and materials used. The material that is often used in aircraft is 2024 T-3 aluminum material which is strong, lightweight, and also resistant to corrosion, but because 2024 T-3 aluminum has several mixtures of other materials such as iron, copper, and copper,other materials, then aluminum can also be exposed to corrosion and corrosion rates. Corrosion and corrosion rate can be determined using the weight loss method which is used to measure the rate of corrosion that occurs, it is proven in 72 hours the material has experienced a corrosion rate of 0.002 mpy and the corrosion rate continues to increase every day, and to see the corrosion that occurs on the material used micro photos to see the type of corrosion. But the weight loss method is not very accurate because the weight loss that occurs from the material is the result of abrasion when sanded. In addition, seawater is the biggest influence on the corrosion rate problem when compared to rainwater.

Keyword : Aircraft, Corrosion, Corrosion rate, Physical metallurgy, Materials processing

A. IntroductionIn

Aircraft Maintenance, several aspects, including corrosion, need to be addressed. It is undeniable that regardless of how comfortable and well-designed an aircraft is, corrosion remains a significant concern. Corrosion is most commonly found in the lavatory area of aircraft. In a study conducted by El Azmi (2018), the corrosion rate of Aluminium 2024-T4 and Aluminium 7075 was investigated using the weight loss method and the Tafel test. The metals were immersed in an acidic solution for a week, and the corrosion rate of Aluminium 2024 was found to be higher than Aluminium 7075. The corrosion rates of Al 2024-T4 were 43.79 mm/year and 2.90 mm/year using weight loss and Tafel test, respectively, whereas the corrosion rate of Al 7075-T6 was 18.48 mm/year and 1.54 mm/year, respectively.

The factors contributing to corrosion can be categorized into two aspects: the type of metal and the surrounding environment, which are highly relative. Certain metals exhibit corrosive behavior, while others do not, depending on the environmental conditions (Laksono, 2018). In a study conducted by Kalium et al. (2011), it was observed that several engine components made from Aluminium 2024-T3 experience corrosion attacks in a marine environment, leading to the degradation of the passive layer on the surface of the Al 2024 T-3 material. The corrosion encountered in the marine environment in this study is referred to as pitting corrosion.

Furthermore, research by Budi & Kurniawan (2012) revealed that the corrosion rate varies based on the corrosive media. Among the various media, seawater resulted in the highest corrosion rate, measuring 5.523 mpy (mils per year). The second highest corrosion rate was observed in rainwater at 3.535 mpy. Subsequently, the corrosion rates for well water, tap water (PAM), and river water were 2.651 mpy, 2.209 mpy, and 1.767 mpy, respectively. Rainwater exhibited the second highest corrosion rate due to its ability to absorb particles from the air during its journey to the ground.

In a

nother study conducted by Setiawan (2022), Aluminium material was used for Cessna aircraft firewall components, where the material required resistance to heat, corrosion, brittleness, and fatigue. One approach to enhance the material quality for Cessna aircraft firewall applications is through hot-dipping alumina coating treatment.

B. Research Methods

The tools and materials used in this research are Aluminium 2024-T3, pH meter, Analytical balance, Sandpaper, Microscope testing equipment, Vernier caliper, Seawater, Rainwater, and 60 ml bottles

The research stages conducted in this study are as follows:

1. Preparation of the necessary tools and materials.
2. Immersion of the specimens in seawater for 0 hours, 72 hours, 168 hours, and 336 hours. The seawater is placed in open bottles to allow air to mix with the seawater. After immersion, the seawater specimens are also exposed to the marine environment. Additionally, immersion in rainwater is performed in residential or community environments, with the same time duration for exposure and immersion.
3. After the exposure and immersion process, a weight loss test is conducted by comparing the weight loss of the specimens in seawater with the weight loss in rainwater.

4. Once the weight loss test is completed, the obtained data is processed and calculated to determine the corrosion rate. Subsequently, a microscopic examination is conducted on the seawater and rainwater specimens.
5. After gathering all the data from the initial specimen weight to the completion of the testing, data analysis is performed.

C. Results of Research and Discussion

Immersion and Exposure Effects

Figure 1 illustrates the results of immersion and exposure at seawater and rainwater locations, where the immersion process was conducted at different time intervals, specifically 0, 72, 168, and 336 hours.

Figure 1.
Results of immersion and drying of seawater

In Figure 1, the longest exposure duration is 168 hours, and visually, the surface of the Aluminium appears to have corrosion, as it shows a brownish tint. However, at this point, it cannot be confirmed whether it is indeed corrosion or not. Therefore, a microscopic examination was conducted to closely observe the surface of the Aluminium and determine whether corrosion has occurred or not.

In Figure 2, it can be observed that there is no visible corrosion on the surface of the Aluminium.

Figure 2
Results of soaking and drying rainwater

Corrosion rate with respect to time and weight loss.

In Table 1, it is evident that the time intervals used were 0, 72, 168, and 336 hours, with the initial weight of the specimen being 5.960 grams. After the immersion process, the results can be observed in the table above. In each time interval, there is an indication of corrosion, which is attributed to the weight reduction of the material due to the immersion and exposure in the marine environment.

Table.1
Reduction in weight by seawater

Air Laut			
Waktu	Massa (gr)	w setelah perendaman (gr)	Kehilangan berat (gr)
0	5,960	5,960	0
72	5,960	5,959	0,001
168	5,960	5,672	0,288
336	5,960	5,003	0,957

In Table 2 above, it can be observed that there is a weight reduction due to the immersion and exposure process in the marine environment. The indication of corrosion occurs because of the weight reduction of the material. However, at the 72-hour mark, the material experiences a weight increase of -94 grams. This is attributed to the rainwater containing H^2O or hydroperoxides, where the material undergoes reduction and oxidation. In the reduction process, the material experiences a weight increase, making it seem like the material gains weight due to the reduction process. However, at 168 hours and 336 hours, the material undergoes oxidation again, leading to weight reduction once more.

Table.2 .
Weight reduction by rainwater

Air Hujan			
Waktu	Massa (gr)	w setelah perendaman (gr)	Kehilangan berat (gr)
0	5,960	5,960	0
72	5,960	5,959	- 0,94
168	5,960	5,672	0,002
336	5,960	5,003	0, 308

The corrosion rate calculation used to determine the corrosion rate on aluminum can be seen in the following equation:

$$CR = \frac{W \times K}{D \times A \times T}$$

Where :

CR = Corrosion rate (mpy)
W = Berat (gram)
K = Konstanta
D = Densitas (gr/cm)
A = Area
T = Time

The constant that will be used in this calculation is 8.75 x 104, the weight is 5.9560 gr, where it is the initial weight of the specimen, the density for Al 2024 is 794.67 g/cm³, the area is 7.5 cm³, and the time used is 168 hours

$$CR = \frac{8{,}76x104 \quad \times 0.0288}{794{,}67 \times 7{,}5 \times 168}$$
$$= 0{,}025 \text{ mpy}$$

Table.3
Comparison of seawater weight loss

Air Laut		Air Hujan	
Waktu	laju korosi (mpy)	Waktu	laju korosi (mpy)
0	0	0	0
72	0,02	72	-0.01
168	0,02	168	0,01
336	0,4	336	0,01

From Table 3 above, the results of weighing and calculations using the weight loss method indicate that the corrosion rate of seawater is higher compared to the corrosion rate produced by rainwater. This difference is attributed to the higher acidity level and pH of seawater compared to rainwater.

After conducting the corrosion rate calculation, a microscopic examination was carried out to determine the corrosion on the aluminum material.

Figure 3
Results of micro-aluminum photographs with seawater media

From the microscopic examination in Figure 3, it was initially indicated that there might be corrosion at the red circle; however, after conducting the microscopic analysis, it was confirmed that there is no corrosion at that point. Therefore, the weight reduction observed in the aluminum during the weight loss test is a result of abrasion on the surface of the aluminum. This is because Aluminium 2024-T3 contains certain compounds, one of which includes iron or other metals, leading to the occurrence of corrosion in the aluminum mixture. This is further supported by the very minimal corrosion rate observed in this research.

Furthermore, the microscopic examination conducted on specimens treated with rainwater also yielded the same result, indicating no corrosion on the surface of the material. This can be observed in Figure 4. Additionally, the white lines on the image represent the traces of sanding on the aluminum, as sanding is performed to smoothen the material's surface before weighing it.

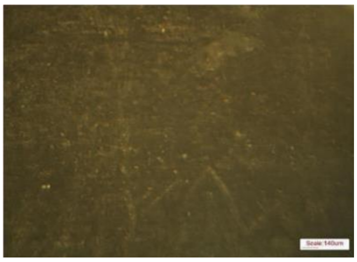

Figure 4
results of micro aluminum photos with rainwater media

Conclusion

From the results of the weight loss and microscopic examination, the following findings were obtained:

1. The immersion and exposure process caused corrosion effects on Aluminium 2024-T3 when visually observed on the surface of the aluminum, particularly when exposed to seawater. However, there was no indication of corrosion when exposed to rainwater.
2. The aircraft structure made of Aluminium 2024-T3 is susceptible to corrosion. The corrosion rate can occur daily, but its spread is minimal. The influence of seawater significantly outweighs that of rainwater concerning the corrosion rate.
3. Regarding the two methods used in the testing, it was found that the weight loss method can determine the corrosion rate, but it may not be visible in the microscopic examination. Hence, it can be concluded that the use of the weight loss method is less accurate in determining the corrosion process and corrosion rate.

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