IOP Conf. Series: Materials Science and Engineering **732** (2020) 012089 doi:10.1088/1757-899X/732/1/012089

The effect of pH upon corrosion rate of aircraft component type MD 80 on fuselage part

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Abstract. Indonesia as one of the archipelagic countries with 16,055 islands and has been registered with PBB certainly requires transportation facilities that can reach all areas of the country. The most efficient and effective mode of transportation to reach all islands in Indonesia is aircraft. Along with the increasing number of users it will increase the number of requests in the level of comfort and safety of passengers one of which is in the feasibility of an aircraft. This research aims to study the effect of pH upon corrosion rate of aircraft metal material type of MD 80 on fuselage part. This study employed pH at 3.4; 3.8; 4.4; 4.8; 5.4; 5.8; 6.1; 7.5; and 12 at fixed temperature of 30°C. Weight loss of aircraft metal material were measured once every 1 hour. The results of this study conclude that the effect of pH upon corrosion rate of aircraft type MD 80 metal material on the fuselage part at a fixed temperature of 30°C in a span of 12 hours showed less significant results. This might be due to the corrosion rate of aircraft metal components running very slowly so that in the span of 12 hours, no significant results were obtained.

1. Introduction

Indonesia as one of the archipelago countries which has thousands of islands there are at least 16,056 islands that have been registered by Indonesia to the United Nations through the United Nations Conference on the Standardization of Geographical Names (UNCSGN) and United Nations Groups of Experts on Geographical Names (UNGEGN) [1]). A map of the Unitary State of the Republic of Indonesia is presented in figure 1.

Figure 1. The latest map of Indonesia launched in 2017 by the geospatial information agency [1].

In line with the increasing needs of the Indonesian people to travel from one island to another. It is needed an effective and efficient mode of transportation namely aircraft. According to the Central Statistics Agency 2019 data on the number of passengers departing on domestic flights at Indonesia's Main Airport 2006-2019 for January has increased as presented in table 1 below.

Table 1. Data on the number of passengers departing on domestic flights at Indonesia’s major airports for January 2006-2019 (persons).

Main Airport	Jan 2006	Jan 2007	Jan 2008	Jan 2009	Jan 2010	Jan 2011	Jan 2012
Polonia	169.652	178.255	202.989	175.756	208.514	253.516	278.080
Soe. Hatta	1.005.200	866.735	1.034.289	980.935	1.176.478	1.354.230	1.561.684
Juanda	329.764	301.274	328.446	331.528	388.819	457.763	530.692
Ng. Rai	136.457	151.069	179.548	176.843	207.334	266.295	309.625
Hasanudin	109.646	119.125	139.850	140.407	174.885	221.048	258.855

Main Airport	Jan 2013	Jan 2014	Jan 2015	Jan 2016	Jan 2017	Jan 2018	Jan 2019
Polonia	308.474	259.256	294.748	317.318	334.556	372.984	280.839
Soe. Hatta	1.534.744	1.712.529	1.478.308	1.746.840	1.704.606	1.751.059	1.569.630
Juanda	624.398	617.838	565.027	656.208	672.153	689.756	560.250
Ng. Rai	334.142	400.459	356.314	322.876	449.607	449.389	428.629
Hasanudin	280.711	287.815	263.245	376.967	352.303	369.341	299.845

Source: Central Bureau of Statistics Data. January 2006-2019 [2]

To increase the level of comfort and safety of aviation passengers it is necessary to conduct research on the rate of corrosion as part of consumer protection measures. Corrosion in the fuselage is a significant problem for commercial and military aircraft [3].

The fuselage as one of the components of an aircraft that is open and easily corroded. This is in line with research conducted by Malver et al. which explain that corrosion usually occurs in areas that are exposed to excessive humidity or are moistened with other liquids [4]. For example, fuselage which includes fuel area doors (including: cargo access) and landing gear doors and others. In addition, along

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with the age of the aircraft the aluminum alloy fuselage can experience corrosion that originates from salt water [5].

This study focuses on studying the effect of pH upon corrosion rate of aircraft component or metal material type McDonnell Douglas 80 (MD 80) on fuselage part. The pH in this study was obtained using the solution pH approach where this pH is a representation of the pH when the aircraft is airborne.

Studied the phenomenon of galvanic corrosion attacks causing aircraft nose landing gear fractures. The results of the study concluded that failure in the bushing area of the nose landing gear is a characteristic of the shape of the fracture surface as a result of excessive load (impact load) during landing and the presence of defects caused by galvanic corrosion attacks [6].

Studied an experimental study of corrosion control on Al 2024-T3 in seawater environments through the addition of Potassium Chromate inhibitors (K_2CrO_4). The results of the study concluded that Al 2024-T3 corrosion in the seawater environment was 0.0216 mm/year. The addition of K_2CrO_4 inhibitors can reduce the corrosion rate by 0.0134 mm/year (a decrease of 38% under optimal conditions of 0.5% K_2CrO_4) [7].

Studied the determination of low carbon corrosion rates with ultrasonic tests. The results of the study concluded that the determination of the corrosion rate using the ultrasonic method has a weakness in detecting the depth of corrosion, which is smaller than 1 millimetre so that it requires a long time to corrode [8].

Monitors aircraft for climate and corrosion. Data obtained in each monitoring in the form of ambient air humidity relative air humidity ambient air temperature surface air temperature, surface humidity and corrosion using a corrosion sensor [3]. Here Ganther W D et al. describes a brief process of corrosion and establishes a mathematical model for estimating conditions in various aircraft spaces that can cause corrosion to occur [3].

Studied the corrosion resistance of aircraft brackets with Mg_4AlZn alloys produced through a new forging method. The results showed that the Mg_4AlZn alloy produced from the forging method was then corroded in a 5% NaCl solution for 170 hours at 35°C. Corrosion test results show that there is a dominant local corrosion pit. Weight reduction in the test sample varies and depends on the forging method used [9].

Examining the effect of volcanic ash on aircraft components, where both the chemical composition of volcanic ash, volcanic ash particle size and the size distribution of volcanic ash is possible to influence the aircraft's metal components. The aircraft components studied in this study are in the McDonnel Douglas 80 (MD 80) fuselage section. In addition, the value of hardness and metal roughness shows the results that the aircraft's metal characteristics are quite good, so it is expected to be able to withstand the influence of volcanic ash [10].

The results of this study are expected to be beneficial for the development of science, which is to develop the treasury of corrosion in metal components especially for the aerospace field. As for the development of the Nation and State this research is expected to increase the amount of research on corrosion especially in the aerospace field.

2. Aircraft fuselage

Explains that aluminum alloys are used for frames or fuselage, wings and skin. The thin aluminum skin and fuselage frame function as protectors (such as cable panels) between cabin crew passengers and potential hazards [5]. Medium according to Malver et al. explained that corrosion usually occurs in areas that are exposed to excessive humidity or moistened with other liquids. For example, fuselage which includes fuel area doors (including: cargo access) and landing gear doors and others [4].

As the plane's life goes on aluminum alloy fuselage can experience corrosion that comes from salt water. Corrosion that can cause damage to the skin and stress on the joints of the skin panel. These cracks can cause rapid decompression and aircraft accidents [5].

3. Corrosion rate

Corrosion is a chemical or electrochemical reaction of metal with components from the environment. Environmental components that can cause corrosion such as: pH; temperature; and the presence of organisms. Corrosion can cause damage to buildings motor vehicles; ships; aircraft; and others [11]. In addition, corrosion is a phenomenon of material damage due to interacting with the environment [6].

The method of determining the effect of pH upon corrosion rate in this study uses the method of weight loss (mass loss) by measuring the weight loss of aircraft metal material that has been subjected to treatment (immersion) as a result of corrosion. Weight reduction method is a common method in studying corrosion on metals. Where this method is done by measuring the weight of the specimen and the geometry of the specimen before and after exposure to the corrosive environment for a certain period of times [12].

The formula for calculating the corrosion rate is presented in the Equation (1) as follows:

$$mpy = \frac{543.W}{D.A.T} \tag{1}$$

where:

mpy : Mils Per Year (thousandths of an inch per year);
W : Weight loss (mass loss) (mg);
D : Density of speciment (g/cm^3);
A : Area of speciment (m^2);
T : Exposure time (hour).

4. Research methodology

The method of determining the corrosion rate in this study uses the method of weight loss by measuring the weight loss (mass loss) of aircraft metal material that have been subjected to treatment (immersion) as a result of corrosion.

The tools in this study were measuring flasks; measuring cups; watch glasses; beaker cups; glass funnels; measuring pipettes; bubbles; tongs; squid spoons; analytical scales; calipers; hair dryers; and aluminum foil.

The material in this research is aircraft component or metal material type MD 80 on fuselage part which has been cleaned from paint; Sodium Acetate; Acetic Acid; and Aquades.

5. Research results and discussion

5.1. The effect of pH upon corrosion rate of aircraft components type MD 80 on fuselage part

Data of delta weight loss of aircraft component or metal material type MD 80 on fuselage part with pH variations presented at every 1 hour presented in table 2 below.

Table 2. Data of Delta Weight Loss (ΔW) of aircraft metal material type MD 80 on fuselage part with pH Variations.

Times	Weight Loss (ΔW) (mg)								
(Hour)	pH 3.4	pH 3.8	pH 4.4	pH 4.8	pH 5.4	pH 5.8	pH 6.1	pH 7.5	pH 12
1	4.800	0.150	2.650	8.400	-0.300	7.800	4.450	-14.800	29.550
2	4.500	-0.150	3.050	8.500	0.200	8.400	5.050	-14.500	51.750
3	4.500	-0.550	2.350	8.800	0.300	8.300	5.150	-14.600	63.450
4	5.000	-0.350	2.750	8.900	0.200	8.900	5.350	-14.900	67.150
5	5.000	-0.550	2.550	8.800	0.300	8.400	5.450	-14.600	67.650
6	4.900	-0.150	2.850	8.600	-0.500	8.600	5.650	-14.700	67.550
7	4.600	0.150	2.950	8.500	0.300	8.800	5.750	-14.200	68.650
8	4.800	-0.150	2.950	8.700	0.600	9.000	5.850	-14.200	68.850
9	4.900	0.350	3.850	10.100	1.500	8.500	6.050	-15.600	68.050
10	5.200	0.250	3.350	6.600	0.800	8.900	5.850	-14.000	68.050
11	5.900	177.450	3.050	9.000	0.400	9.000	5.950	-13.800	68.550
12	4.600	-0.450	2.650	8.700	130.100	9.000	5.750	-14.300	66.950

From table 2 the weight loss per area of aircraft metal material type MD 80 on fuselage part with pH variations presented in table 3 is then arranged.

Table 3. Data of delta weight loss per area of aircraft metal material type MD 80 on fuselage part with pH variations.

Times	Weight Loss/Area of Speciment (ΔW/A) (mg/m^2)								
(Hour)	pH 3.4	pH 3.8	pH 4.4	pH 4.8	pH 5.4	pH 5.8	pH 6.1	pH 7.5	pH 12
1	2398.843	70.462	1324.361	4008.886	-142.648	3736.339	2179.626	6653.883	14795.307
2	2248.915	-70.462	1524.265	4056.611	95.098	4023.750	2473.508	6519.007	25910.562
3	2248.915	-258.360	1174.433	4199.786	142.648	3975.848	2522.488	6563.966	31768.602
4	2498.794	-164.411	1374.337	4247.511	95.098	4263.259	2620.449	6698.842	33621.145
5	2498.794	-258.360	1274.385	4199.786	142.648	4023.750	2669.429	6563.966	33871.489
6	2448.818	-70.462	1424.313	4104.336	-237.746	4119.553	2767.390	6608.925	33821.420
7	2298.891	70.462	1474.289	4056.611	142.648	4215.357	2816.370	6384.131	34372.176
8	2398.843	-70.462	1474.289	4152.061	285.295	4311.160	2865.351	6384.131	34472.313
9	2448.818	164.411	1924.072	4820.209	713.238	4071.651	2963.311	7013.553	34071.763
10	2598.746	117.436	1674.192	3149.839	380.394	4263.259	2865.351	6294.214	34071.763
11	2948.577	83356.233	1524.265	4295.235	190.197	4311.160	2914.331	6204.297	34322.107
12	2298.891	-211.385	1324.361	4152.061	61861.503	4311.160	2816.370	6429.090	33521.008

From table 2 above the weight loss data of aircraft component or metal material type MD 80 on fuselage part is displayed every hour for 12 hours where the results shown for each pH vary. The 12-hour time was chosen as the initial parameter in measuring the rate at the laboratory scale.

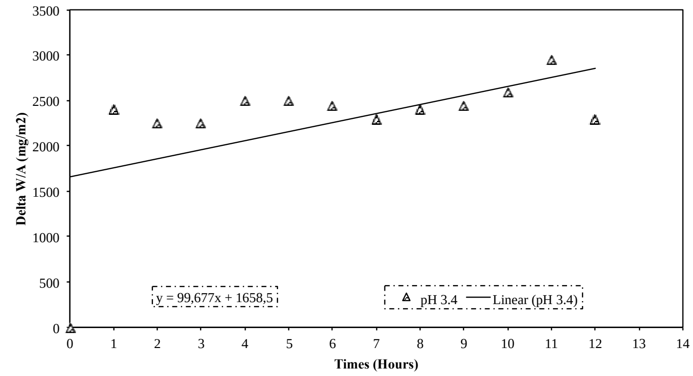
At pH 3.8; 4.4; 5.4; and 7.5 in table 2 shows the weight loss from 0 to negative mg; this might be due to the pH solution used in this study is still less stable where in this study there were changes in pH at each hour so that the directly cause the measurement results from 0 to negative mg.

In the pH variations 4.8 and 5.8 presented in table 2 above shows that the weight of the metal material after testing increases compared to the initial weight of the metal material which is 5.5655 and 5.5392 mg. This is because the corrosion process has occurred in the metal material causing the addition of weight of aircraft components type MD 80 on fuselage part of the initial weight of the metal. This is evidenced by the change in colour from the aircraft component or metal material type MD 80 to black. Where the initial colour of the metal is shiny white.

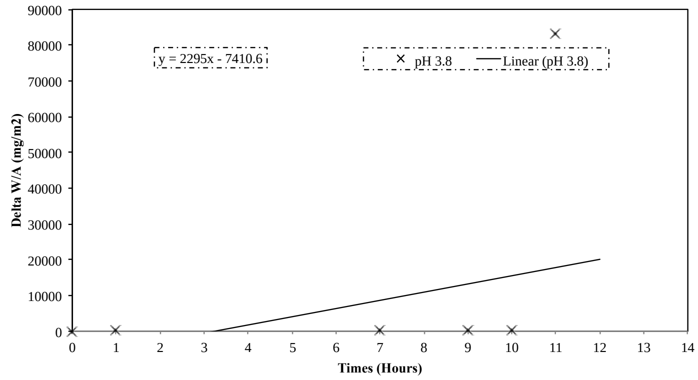
However, this additional weight should be followed by an elimination step (reduction in metal weight due to corrosion) through scraping corrosion on the metal before the metal is tested for a time of 2 to 12 hours. As explained by Esmaily et al. that before measuring mass after immersion, the sample needs to be cleaned to remove corrosion products from the sample surface because it can cause inaccuracies from the corrosion rate. This is done so that the weight of the same metal returns to the initial weight and reduces measurement error [12].

For variations in pH 3.4 and pH 6.1 in table 2 it is presented that the weight loss of aircraft component or metal material type MD 80 on the fuselage part is 4.5000 to 5.9000 mg and 4.4500 to 6.0500 mg where this value still in a range that is not too far from the initial weight of the metal material before treatment namely 5.3640 and 5.2899 mg. But it is clear that the corrosion process at pH 3.4 and 6.1 does occur.

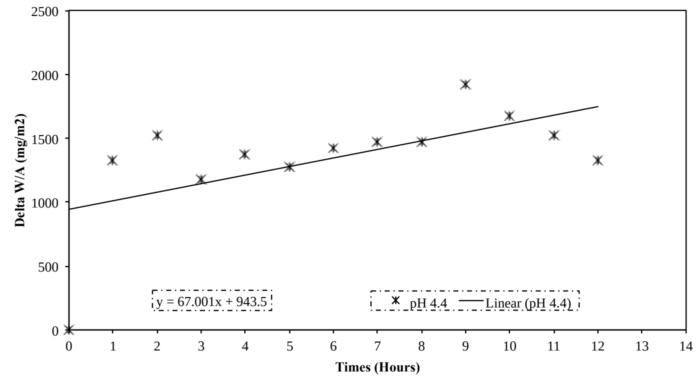
The data in table 3 above then makes the relationship curve between Delta W/A and Times (hours) presented in figure 2 and 3.



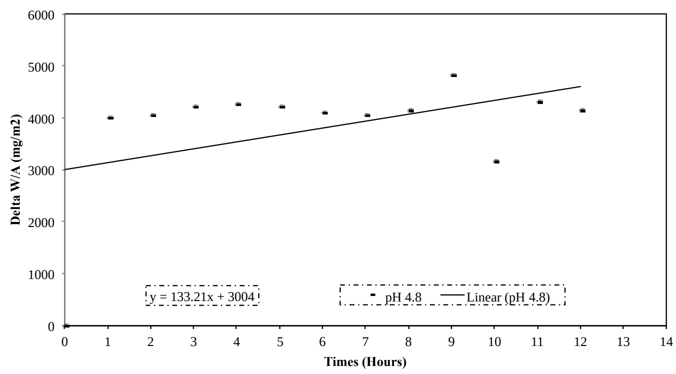
(**a**)



(**b**)



(c)



(**d**)

Figure 2. Relationship curves between delta W/A and times (hours) (a–d).

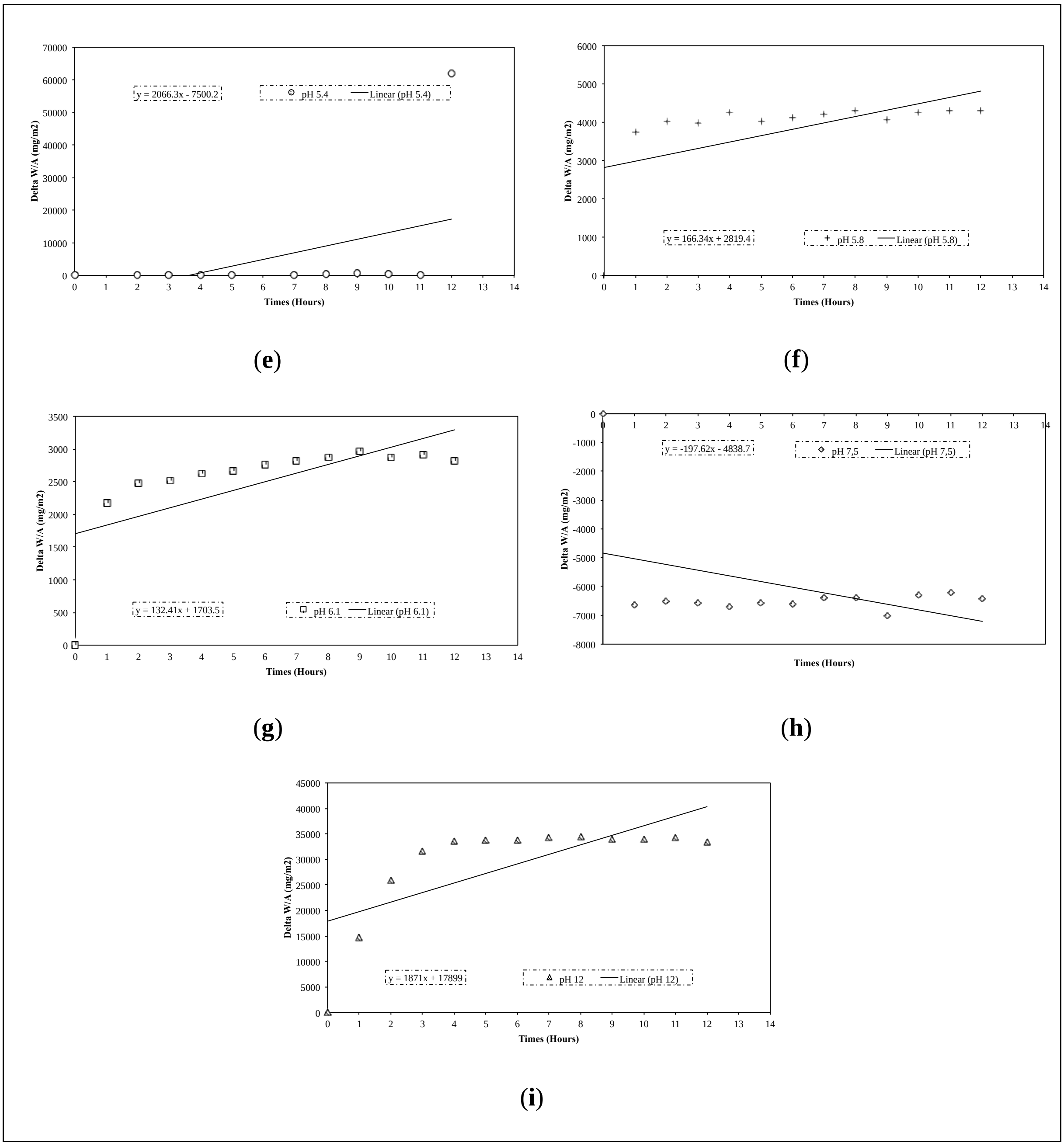


Figure 3. Relationship curves between delta W/A and Times (hours) (e–i).

From figure 2 and 3 the slope value (a) is then taken for each variation of pH which is summarized and presented in tabel 4 below.

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Table 4. The value of the delta W/A slope with respect to time for each pH variation.

pH	slope
3.4	99.677
3.8	2295.000
4.4	67.001
4.8	133.210
5.4	2066.300
5.8	166.340
6.1	132.410
7.5	-197.620
12	1871.000

Based on table 4 above then the relationship curve between the W/A delta slope and the pH is presented in figure 4.

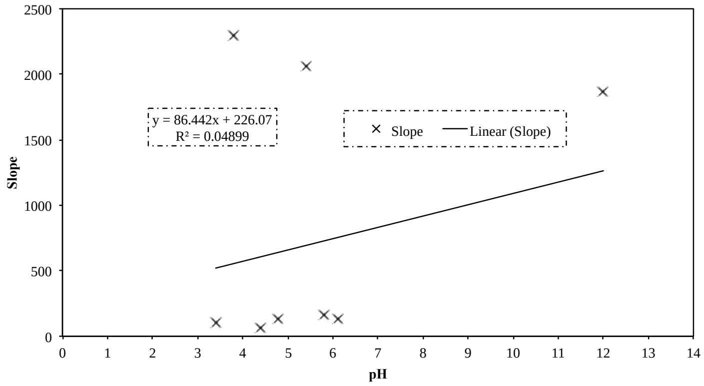

Figure 4. Relation curve between the W/A delta slope and the pH.

Based on figure 4 above shows the relationship curve between the W/A delta slope to pH where the slope value of 86.442 cm/hour is obtained. This value represents the speed of corrosion rate of aircraft component type MD 80 on fuselage part which in mpy units (thousandths of an Inch per year) yields of 298.349 in/year with value of R-squared is 0.04899. Thus it can be concluded that the effect of pH upon corrosion rate of aircraft type MD 80 component on fuselage part is less influenced by pH or less significant results. This might be due to the effect of pH upon corrosion rate of aircraft metal component running very slowly so that in the span of 12 hours, no significant results were obtained. The results of this study are in line with Rupprecht et al. where corrosion is a chemical or electrochemical reaction of metal with components from the environment. Environmental components that can cause corrosion such as: pH; temperature; and the presence of organisms [11].

6. Conclusions

The results of this study concluded that the effect of pH upon corrosion rate of aircraft metal material type MD 80 on fuselage part at a fixed temperature of 30°C in a span of 12 hours showed less significant results. This might be due to the corrosion rate of aircraft metal components running very slow in the span of 12 hours, no significant results were obtained. The pH which quite good in testing the corrosion rate is pH 3.4 and 12 both of which are able to represent changes in the weight of aircraft component or metal material type MD 80 on fuselage part clearly.

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7. Suggestion

For future research a standard pH solution can be used so there is no need to make a pH variation solution. In addition, the pH solution should be constant at each measurement time to obtain better and more accurate measurement or test results. In addition, every 1-hour measurement of metal scraping is needed to reduce errors in measurement or testing. It is necessary to compare the corrosion rate measurements using standard tools.

Acknowledgment

Our thanks go to Marsda TNI (Purn.) H. Udin Kurniadi. S.E. M.M. as the Chairperson of the Sekolah Tinggi Teknologi Kedirgantaraan (STTKD) Yogyakarta for the Grant Aid of the STTKD Permanent Lecturer Research Program in 2018. Mr. Yunus as a laboratory assistant in the Polymer Technology Laboratory, Chemical Engineering Department, Faculty of Engineering, Universitas Gadjah Mada.

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