http://jurnal.unmer.ac.id/index.php/jtmt
TRANSMISI
ISSN (print): 9-772580-228020
ISSN (online): 2580-2283

Effect of Cathode Distance, Anode and Electroplating Time on Aluminum Alloy Corrosion Rate

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ARTICLE INFORMATION

Received: 14 February 2023
Revised: 1 March 2023
Accepted: 7 March 2023
Published: 15 March 2023

ABSTRACT

The purpose of this study was to determine the properties of anodized cathode aluminum alloy and the required coating time. In this study, a quantitative experiment used 20 samples. The results showed that there were defects in the aluminum alloy lattice, but not too significant. Different corrosion rate values were shown using electrolysis periods of 30 minutes and 60 minutes combined with anode-cathode distances of 5 cm, 10 cm and 15 cm. The group with 30 minutes of coating time and 5 cm anode-cathode distance had the highest corrosion rate (0.853 mm/year), while the group with 30 minutes of coating time and 10 cm anode-cathode distance had the lowest corrosion rate (0.610). The group with 60 minutes of coating time and 10 cm distance between the anode and cathode had the highest corrosion rate of 1,564 mm/year, while the group with 60 minutes of coating time and 15 cm distance had the lowest corrosion rate. The anode-cathode distance partially affects the corrosion rate of electroplated aluminum alloys. The smaller the distance between the anode and cathode, the higher the corrosion rate of the aluminum alloy. The longer the coating lasts, the higher the corrosive rate of the Al alloy.

Keywords: Aluminum alloy, electroplating, anode, cathode

ABSTRAK

Tujuan dari penelitian ini adalah untuk mengetahui sifat paduan aluminium anodized katoda dan waktu pelapisan yang dibutuhkan. Dalam penelitian ini, eksperimen kuantitatif menggunakan 20 sampel. Hasil penelitian menunjukkan bahwa terdapat cacat pada kisi paduan aluminium, namun tidak terlalu signifikan. Nilai laju korosi yang berbeda ditunjukkan dengan menggunakan periode elektrolisis 30 menit dan 60 menit yang dikombinasikan dengan jarak anoda-katoda 5 cm, 10 cm, dan 15 cm. Kelompok dengan lama pelapisan 30 menit dan jarak anoda-katoda 5 cm memiliki laju korosi tertinggi (0,853 mm/tahun), sedangkan kelompok dengan lama pelapisan 30 menit dan jarak anoda-katoda 10 cm memiliki laju korosi terendah (0,610). Kelompok dengan lama pelapisan 60 menit dan jarak antara anoda dan katoda 10 cm memiliki laju korosi tertinggi yaitu 1.564 mm/tahun, sedangkan kelompok dengan lama pelapisan 60 menit dan jarak 15 cm memiliki laju korosi paling rendah. Jarak anoda-katoda sebagian memengaruhi laju korosi *electroplating* aluminium *alloy*. Semakin kecil jarak antara anoda dan katoda, semakin tinggi laju korosi paduan aluminium. Semakin lama lapisannya bertahan, semakin tinggi laju korosif pada Al *alloy*.

DOI: 10.26905/jtmt.v19i1.9650

Kata Kunci: Aluminium alloy, electroplating, anoda, katoda.

1. Introduction

Aluminum is one of the easiest metals to print, and has a very good type of resistance [1]. Aluminum can experience corrosion if it is in a place that is considered aggressive, especially in acidic and alkaline conditions [2]. Disadvantages of pure aluminum form is very fragile can not withstand heavy loads, has a soft texture. To develop pure aluminum, a lot of elements are added to improve it which is known as aluminum alloy.

Because pure aluminum is too brittle and does not have high strength under heavy loads, aluminum alloys are used more often than pure aluminum in daily life. Aluminum 6061 is used extensively in yacht construction, aircraft construction, flares, food packaging and auto parts such as alloy wheels and sharps for Audi A8 because of its good mechanical qualities [3]. In order to be used in other objects, aluminum alloys must have an attractive appearance. Therefore, in this study, aluminum alloy coating was carried out to improve the appearance of the metal and make aluminum resistant to corrosion. There are various processes for coating metals with the addition of other metals, such as electroplating, spray metallization, anodizing and plating. Electroplating offers a very uniform and good quality surface finish, because the careful process can be applied at various levels. In addition, the material to be coated is not heat treated, so there is no risk of affecting the mechanical properties of the material.

The nature of the copper construction is so soft that it is easy to shape because it is also electropositive, young copper is deposited with a large range of electromotive force [4] The properties of copper are used for corrosion protection and also enhance the appearance of copper used as a coating. Copper plating is very suitable as a base coat for subsequent plating. Corrosion rate is a measure of how quickly a material spreads or deteriorates over time. The corrosion resistance of the metal resulting from the coating process is also affected by the weight of the settling layer.

2. Methodology of Research

Raden Rahmat Islamic University's main laboratory, which houses the science and technology faculty, is where the corrosion rate test is conducted. A sample is required as a coating item to complete the electroplating procedure. The sample used measures 5 cm x 2 cm x 0.6 cm and is composed of 6061 aluminum alloy. As a conductor between the anode and cathode of the electrolyte solution, the preparation of the electrolyte solution is also useful. Depending on the anode used as a coating, the composition of the resulting electrolyte solution varies.

2.1. Materials preparations

1. Sand the surface of the Al sheet using coarse sandpaper until it is smooth and clean
2. Clean oil and grease,
   a) How to make an oil and grease cleaning solution: Mix 12.9 grams of NaOH with 25 grams of Na_2CO_3, then dissolve and melt in 1 liter of water.
   b) How to remove oil, grease, etc. The time required to soak an aluminum sheet that has been soaked in an oil and grease cleaning solution at 700°C is 15 minutes.
3. Remove rust by mixing 80 ml of distilled water with 20 ml of concentrated H_2SO_4 to make a rust cleaning solution.
4. After removing the rust, rinse it and weigh it using a digital scale.

2.2. Pretreatment process

1. Before soaking the sample, weigh the initial weight of the specimen with a balance (digital scale).
2. Soak the workpiece in zinc solution to increase the adhesion of the coating.
3. The cathode is closed to the negative valve and the anode is closed to the positive valve.
4. Use an aluminum plate (the item to be coated) as the cathode and copper as the anode.
5. For 30 minutes and 60 minutes, dip the anode and cathode into the electrolyte solution at intervals of 5 cm, 10 cm and 15 cm.
6. Unplug the device from the power source and remove the test piece.
7. After the test object is removed, let it dry before weighing it again on the scale

(digital scale).

The anode-cathode distance and the change in coating duration were used in this study to calculate the required deposition rate, corrosion rate, and coating mass. The difference between the original mass before sample coating and the post coating mass is the actual coating mass value. The deposition rate and corrosion rate values were derived from the deposition rate formulation and the corrosion rate formulation, respectively.

If the measurement of the corrosion rate and deposition rate is the data or results obtained, then the data is checked. Analysis of numerical data obtained from measurements of deposition rates and corrosion rates was used in this study using quantitative experiments; The collected data is then presented using a differentiating graph software in Microsoft Excel.

3. Result and Discussion

The results of this study are divided into several discussions which will be described as follows.

3.1. Corrosion rate

The speed of propagation or the rate of material deterioration over time is known as the corrosion rate. For this reason, a Weight Loss Technique is needed. This method calculates the weight loss caused by corrosion by using interval inspection. To calculate the weight loss due to corrosion, use the formula below [5].

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

CR= Corrosion rate (mm/*year*)
W = Losses weight (gram)
K = Factor constants (mm/*year* = 87,6)D
D = Metal density (gram/cm^3)
A = Surface area (cm^2)
T = Time (hour)

In this procedure, the actual weight of the test item—the object whose corrosion rate is to be determined—is measured; the lost weight is calculated from the original weight. The formula is modified to include the weight loss to get the object weight loss [6]. If this method is used repeatedly and continuously, it can be used as a guide to locate objects and assess the amount of corrosivity of the surrounding area. It can also be used to decide on the appropriate course of action to treat the object's location and condition [7].

3.2. Effect of anode-cathode distance with coating time of 30 minutes electroplating aluminum alloy corrosion rate

After testing the corrosion rate by analyzing the difference in weight between the samples before and after coating and testing the corrosion rate by immersing the samples in a corrosion solution for a certain time, the next step is to analyze the effect of the distance between the anode and cathode.

3.2.1 Analysis of the results of the corrosion rate test with a coating time of 30 minutes

Immersing in a corrosion solution and measuring reduction before and after a predetermined time, the corrosion rate is evaluated using the weight loss method. HCL concentration of 37% was used as a corrosion solution. To determine the mass loss due to corrosion, samples were taken and weighed every 20 minutes during the 60 minute immersion period.

Corrosion rate test results on aluminum alloy after 30 minutes of electroplating, and corrosion rate and mass after 20 minutes, 40 minutes and 60 minutes of immersion in a corrosion solution. The average corrosion rate value for 5 cm electroplating distance is 0.853 mm/year at 5 cm anode-cathode distance, where specimens (A), (B), and (C) are known to have a corrosion rate of 0.958 mm/year, respectively respectively 0.818 mm/year, and 0.785 mm/year. It is known that the corrosion rate is 0.639 mm/year for specimen (A) at a distance between the anode and cathode of 10 cm, a corrosion rate of 0.644 mm/year is known for specimen (B), and a corrosion rate of 0.548 mm/year is known for specimen (C). As a result, the average corrosion rate for this distance is 0.610 mm/year. The average corrosion rate for an electroplating distance of 15 cm is 0.701 mm/year at an anode-cathode distance of 7 cm. Specimens (A), (B), and (C) are known to have corrosion rates of 0.758 mm/year, 0.685 mm/year and 0.660 mm/year, respectively.

Figures 1 and 2 show that the anode-cathode distance of 5 cm has an average initial mass of 14.049 grams, the average mass loss after 20 minutes is 1.104 grams and the mass decreases to 15.153 grams. After 40 minutes, the average mass loss was 0.955 grams and the mass had reduced to

14.198 grams. After 60 minutes, the average mass loss was 0.116 grams and the mass had reduced to 14.082 grams.

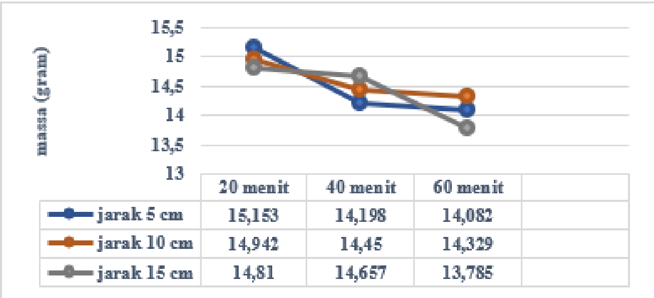

Figure 1 Graph of 30 Minute Electroplating Mass Reduction

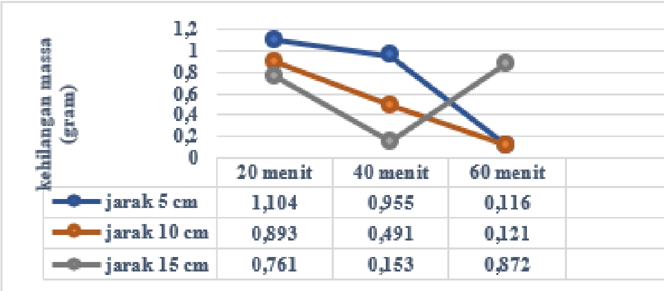

Figure 2 Graph of 30 Minute Electroplating Mass Loss

At an anode-cathode distance of 10 cm, the average initial mass was 14.049 grams, the average mass loss after 20 minutes was 0.893 grams and the mass decreased to 14.942 grams. After 40 minutes, the average mass loss was 0.491 grams and the mass had reduced to 14.450 grams. After 60 minutes, the average mass loss was 0.121 grams and the mass had reduced to 14.329 grams.

It can be seen that at an anode-cathode distance of 15 cm, the average initial mass was 14.049 grams, after 20 minutes the average mass loss was 0.761 grams and the mass had decreased to 14.810 grams. After 40 minutes, the average mass loss was 0.153 grams and the mass had reduced to 14.657 grams. After 60 minutes, the average mass loss was 0.872 grams and the mass had decreased to 13.785 grams.

Figures 1 and 2 show the highest mass loss experienced by a distance of 5 cm. This is because in the electroplating results at a distance of 5 cm there are several layers of copper that do not stick perfectly to the aluminum. This problem can result when the electroplated specimen is immersed in a corrosion solution, the solution will quickly attack the aluminum layer so that the copper layer that protects the layer inside will peel off resulting in a large loss of mass [8].

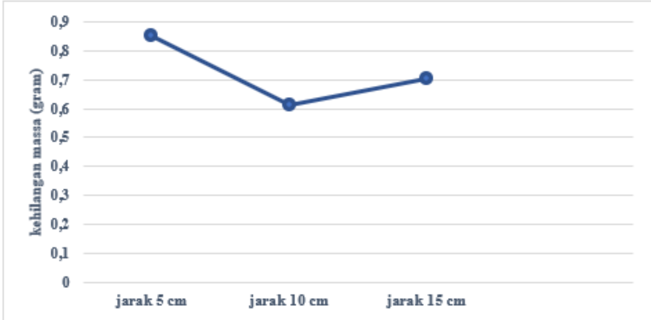

Figure 3 Graph of 30 Minute Electroplating Corrosion Rate

Figure 3 shows the results of the corrosion rate of aluminum alloy that has been electroplated for 30 minutes with various anode-cathode tests, the results are known and averaged. In Figure 3 it is known that the results of the highest corrosion rate at a distance of 5 cm with a value of 0.853 mm/year, and at a distance of 10 cm have the lowest corrosion rate results with a value of 0.610 mm/year.

Variations in the anode-cathode distance also affect the results of the corrosion rate of aluminum alloy. It is shown that the results of the tests show that some have the highest and some the lowest corrosion rates.

Because there was a significant loss of mass at a distance of 10 cm which increased the value of the corrosion rate, Figure 3 shows that the corrosion rate decreased from a distance of 5 cm to a distance of 10 cm and then increased at a distance of 15 cm. Conversely, at a distance of 5 cm and 15 cm, the loss of mass when immersed in the corrosion solution is smaller than the loss of mass at a distance of 10 cm. This is in accordance with the weight loss method of calculating the corrosion rate which states that the greater the mass loss value, the higher the corrosion rate value [5].

Specimens that were not electroplated, the corrosion rate was 6.236 mm/year, from these results the relative corrosion resistance was very low. This can be explained that aluminum alloy 6061 has a very low level of corrosion resistance because the alloy mixed with this aluminum can reduce its corrosion resistance [9].

3.3. Effect of anode-cathode distance with coating time of 60 minutes electroplating aluminum alloy corrosion rate

Electroplating aluminum alloy against corrosion rate. After testing the corrosion rate by immersing the sample in a corrosion solution for some time, the next step is to study the effect of the anode-cathode distance.

3.3.1 Analysis of the results of the corrosion rate test with a coating time of 60 minutes

Methods of weight loss or immersion in the corrosion solution for a long time to calculate the mass loss before and after immersion in the corrosion solution are both used to test the corrosion rate. HCL concentration of 37% was used as a corrosion solution. Samples were weighed every 20 minutes during the 60 minute immersion period to determine mass loss due to corrosion.

The results of testing the corrosion rate of aluminum alloy after 60 minutes of electroplating, as well as the corrosion rate and mass after 20 minutes, 40 minutes and 60 minutes of immersion in a corrosion solution. The average corrosion rate of 5 cm electroplating spacing is 1.367 mm/year because specimens (A), (B), and (C) have known corrosion rates of 1.490 mm/year, 1.379 mm/year and 1.233 mm/year. years, respectively, with a distance between the anode and cathode of 5 cm. The average corrosion rate for 10 cm electroplating distance is 1.564 mm/year at 10 cm anode-cathode distance, where specimens (A), (B), and (C) are known to have corrosion rates of 1.594 mm/year, 1.579 mm/year, and 1,519 mm/year. The average corrosion rate of 15 cm electroplating distance is 0.754 mm/year at an anode-cathode distance of 15 cm, where specimens (A), (B), and (C) are known to have a corrosion rate of 0.813 mm/year, 0.799 mm/year, and 0.650 mm/year.

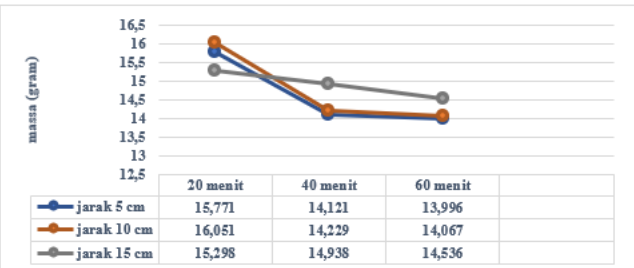

Figure 4 Graph of 60 Minute Electroplating Mass Reduction

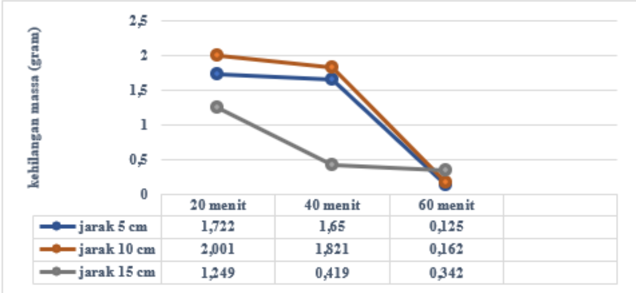

Figure 5 Graph of 60 Minute Electroplating Mass Loss

Figures 4 and 5 show that the anode-cathode distance of 5 cm has an average initial mass of 14.049 grams, the average mass loss in the 20th minute is 1.722 grams and the mass decreases to 15.771 grams. After 40 minutes, the average mass loss was 1.650 grams and the mass had increased to 14.121 grams. After 60 minutes, the average mass loss was 0.125 grams and the mass had reduced to 13.996 grams.

Figures 4 and 5 show that an anode-cathode distance of 10 cm has an average initial mass of 14.049 grams; after 20 minutes, the average mass loss was 2.001 grams and the mass had decreased to 16.051 grams. After 40 minutes, the average mass loss was 1.821 grams and the mass had reduced to 14.229 grams. After 60 minutes, the average mass loss was 0.162 grams and the mass had reduced to 14.067 grams.

Figures 4 and 5 show that the anode-cathode distance of 15 cm has an average initial mass of 14.049 grams; after 20 minutes, the average mass loss was 1.249 grams and the mass had decreased to 15.298 grams. After 40 minutes, the average mass loss was 0.419 grams and the mass had reduced to 14.938 grams. After 60 minutes, the average mass loss was 0.342 grams and the mass had reduced to 14.536 grams.

Figure 5 shows the highest mass loss experienced by a distance of 10 cm. This is because in the electroplating results at a distance of 10 cm there are several layers of copper that do not stick perfectly to the aluminum. This problem can result when the electroplated specimen is immersed in a corrosion solution, the solution will quickly attack the aluminum layer so that the copper layer that protects the inner layer will peel off resulting in large mass loss [10][11].

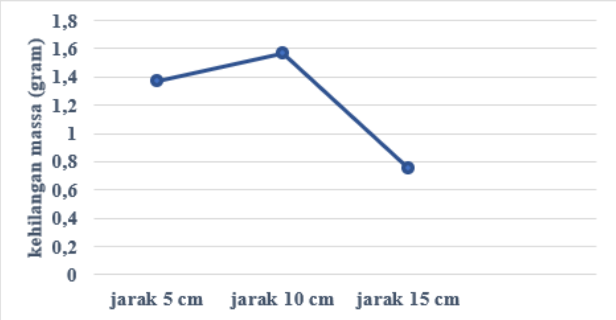

Figure 6 Graph of 60 Minute Electroplating Corrosion Rate

The line diagram in the graph of Figure 6 shows the results of the analysis of the corrosive rate of electroplated aluminum alloy for 60 minutes with variations in the anode-cathode distance, the results are known and averaged. In figure 6 the line diagram shows that the highest corrosion rate results at a distance of 10 cm with a value of 1.564 mm/year, and at a distance of 15 cm has the lowest corrosion rate result with a value of 0.754 mm/year. Variations in the anode-cathode distance also affect the results of the aluminum alloy corrosion rate from the test, with some having the highest and some lowest corrosion rates [11].

The corrosion rate decreased from a distance of 5 cm to a distance of 10 cm; up to 10 cm distance, significant mass loss occurs, increasing the corrosion rate value; between 5 cm and 15 cm, there is less mass loss when immersed in the corrosion solution than below 10 cm. This is in accordance with the corrosion rate formula for the weight loss method, which states that the higher the mass loss value, the higher the corrosion rate value [12].

For specimens that were not electroplated, the corrosion rate was 6.236 mm/year, from these results the relative corrosion resistance was very low. This can be explained that aluminum alloy 6061 has a very low level of corrosion resistance because the alloy mixed with this aluminum can reduce its corrosion resistance [13].

3.4. The difference in the results of the 30 minute and 60 minute electroplating corrosion test

Comparison of the results of the corrosion rate test for Electroplating 30 minutes and 60 minutes can be seen in Figure 7.

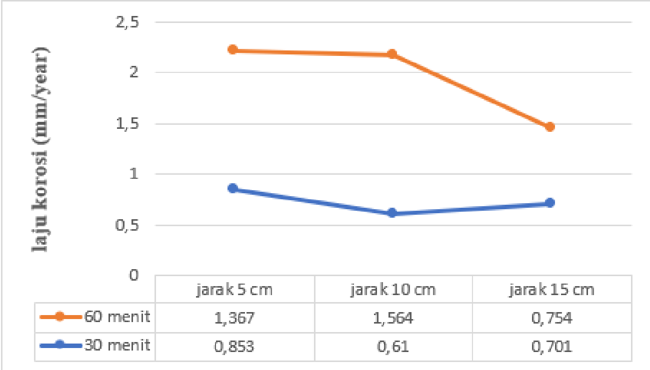

Figure 7 Comparison Diagram of Corrosion Rate Results

Combining the results of the corrosion test between 30 minutes and 60 minutes of electroplating produces the data shown in the line graph of Figure 7. Based on the line graph above, the corrosion value for electroplating with a coating time of 30 minutes and an anode-cathode distance of 15 cm has the lowest corrosion value of 0.334 mm/year and the highest deposition rate is 0.549 mm/year for electroplating. with a coating time of 60 minutes and a distance of 5 cm between the anode and cathode. It is known that the corrosion test findings reveal differences between the corrosion rates at 30 and 60 minutes after electroplating. The copper layer will be thicker and heavier the longer the wet coating time, this is what causes the coating results with a coating duration of 60 minutes showing the highest relative corrosion resistance. As a result, it can be shown that the corrosion rate is lower than the corrosion rate of aluminum alloy without electroplating. For example, in the case of this study, the corrosion rate of raw material for aluminum alloy 6061 is 7.3878 mm/year.

The data in the line diagram above is the average result between groups of corrosion rate values. From these results it can be seen that there is a difference in the value of the corrosion rate between the starting groups from the highest to the lowest.

4. Conclusion

Based on the data that has been collected and the research that has been done, the findings of this study can be summarized as follows:

1. The anode-cathode gap intentionally reduces the corrosion rate during electroplating within 30 minutes. Therefore, this is evident

from the narrowing of the anode and cathode distance and the heating up of the corrosion rate. This indicates that the 5 cm gap has a tight corrosion rate.

2. The interaction between anodized and cathodized aluminum alloy during the electric dipping process takes 60 minutes. The highest corrosion rate was recorded at an anode-cathode distance of 10 cm within 60 minutes.
3. The results of the corrosion test showed that the corrosion rate was different between 30 minutes and 60 minutes of electroplating time. So this can be clearly seen if the copper layer becomes thicker and heavier with increasing coating time, resulting in a coating with the highest relative corrosion resistance at 60 minutes.

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