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Corrosion rate of anodized AA 7075-T651 on H_2SO_4 electrolyte and voltage variation

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Abstract

Metal materials corrode because of an electrochemical process that damages or destroys them gradually. In addition to chemical reactions, high temperatures, mechanical operations, and rainfall exposure can all lead to corrosion. It is an experimental study with variation of voltage for AA 7075-T651. The voltage variation between 4 and 5 and 6 volts is the independent variable employed in this study. The rate of corrosion and the size of the pores are the dependent variables. One amp of current, thirty millimeters between the anode and cathode, one millimeter of sulfuric acid as the electrolyte concentration, and ten minutes of anodizing time are the controlled variables in this study. Variation in voltage throughout the anodizing process can regulate how quickly corrosion occurs via the oxide layer that is created. The 7075-T651 series aluminum alloy, when subjected to action anodizing at different voltages of 4 volts, 5 volts, and 6 volts, yields pore diameters measuring 0.273 µm, 0.436 µm, and 0.522 µm, respectively, according to SEM picture data.

***Keywords**: Corrosion; pores size, Tafel test; voltage, sulfuric acid*

1. INTRODUCTION

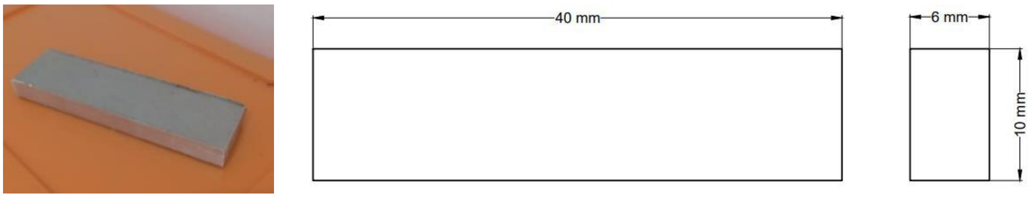
Aluminum is a material that has many applications in everyday life and is often used because it has advantages, including high strength to weight ratio, light weight, resistance to corrosion from various chemicals (resistance). to corrosion by many chemicals), high thermal and electrical conductivity (high thermal and electrical conductivity), non-toxic (nontoxicity), reflects light (reflectivity), easy to form and machining (easy of formability and machinability) and non-magnetic (no magnetic). Aluminum 7075-T6 has the advantage of higher strength than 2024, and has good corrosion characteristics. Aluminum 7075 is an alloy of Al-Zn-Mg-Cu which is a variant of the 7xxx series aluminum alloy. This alloy belongs to the group of alloys with the highest strength and has good mechanical properties and anodic reaction. With strong strength and corrosion resistance, 7075 Aluminum Plate is also commonly used for other high pressure structural components.

Bicycle gears have the potential to be exposed to corrosion. This corrosion is caused by an electrochemical process in metal materials so that they are damaged or destroyed gradually. Apart from chemical processes, corrosion can be caused by high temperatures and mechanical processes, and can also be exposed to rainwater. This is because rainwater is acidic which worsens the characteristics of bicycle chains. If the level of corrosion on bicycle gears gets worse, the bicycle gears will become inelastic and stiff, so they have the potential to break. Therefore, observation, treatment and early detection of corrosion is very important. One way to increase the corrosion resistance of aluminum is by increasing the oxide layer through the anodizing process. The anodizing technique basically uses the principle of electrolysis. In an electrolysis cell, the anode is connected to the aluminum metal that will be anodized and the cathode is connected to an anodizing conductor plate. This potential difference will trigger the growth of an oxide layer on the surface of aluminum metal. This oxide layer consists of two layers, namely the the thick layer is called the pore layer which is in the outermost layer and the thin one is not porous or is called the barrier layer (1).

In the anodizing process, factors that influence the anodizing results include the amount of electrical voltage (voltage), the length of the process time, the strength of the electric current, the distance between the anode and the cathode, the concentration of the electrolyte solution, and the temperature of the solution. The morphology of the Al2O3 layer resulting from the anodizing process can also influence the corrosion rate that we will get if there are more layers of cracks resulting from anodizing, the resulting value of the corrosion rate will also increase as the number of cracks increases, this causes the opening of the AL2O3 layer which should cover the raw aluminum which causes a layer AL2O3 can be oxidized by the environment causing corrosion (2). Therefore, it is necessary to research the effect of voltage variations on the anodizing process to increase corrosion resistance so that it can maintain and extend service life.

2. METHODS

This research was conducted at the Basic Phenomena Laboratory of Mechanical Engineering Brawijaya University, Metallurgical Laboratory of Sepuluh Nopember Institute of Technology Surabaya, and the Industrial Metrology Laboratory of Mechanical Engineering Brawijaya University. The independent variable used in this research is the variation of voltage of 4 Volts, 5 Volts and 6 Volts. The dependent variable is the corrosion rate and pores sizes. The controlled variables used in this research are current of 1 Ampere, the distance between the anode and cathode of 30 mm, the electrolyte concentration (sulfuric acid) of 1M, and anodizing time of 10 minutes.



(a) (b)

Figure 1. Specimen for anodizing a) specimen as cut, b) dimensions of specimen

The specimens for anodizing process were prepared from Aluminum Alloys 7075 – T651 sheets with dimension of 10x6x40 mm as shown in Figure 1. After cutting, the specimens then paper sanded and cleaned by applying metal polish. The next preparation were cleaning, etching, and desmutting. The steps of preparation was shown in Figure 2 and was conducted before the specimen going into anodizing process. After anodizing process, the specimen then rinse to remove electrolyte and other impurity from anodized specimens. All the process was conducted by following typical anodizing process (3), (4), (5), (6).

a b c d e

Figure 2. Preparation and treatment of specimen: a) cleaning, b) etching, c) desmutting, d) anodizing, e) rinsing

The anodizing process was conducted on simple bath as depicted in Figure 3. Electrode was consisted of aluminum alloy as anode and carbon rod as cathode. The electricity for the process was supplied by DC power supply to gives voltage range from 4 to 6 Volts and current of 1 Amperes as depicted in Figure 3. After the specimens were anodized, then photograph of oxide layer were taken using Scanning Electron Microscope (SEM) to reveal the condition of oxide layer and the pore size. To have data on corrosion rate, a corrosion test using AUTOLAB PGSTAT204 were conducted. The equipment for data extraction of the research were shown in Figure 4.

(a) (b) (c)

Figure 3. Anodizing process in a) simple anodizing bath, b) DC power supply, c) carbon rod

(a) (b)

Figure 4. a) Scanning Electron Microscope (SEM) and b) AUTOLAB PGSTAT204

After data on pore size, condition of oxide layer, and Tafel diagram were obtained then analysis of corrosion rate and the correlation to pore size as functions of voltages was conducted.

3. Result and Discussion

Aluminum has been known to have good resistance to corrosion thank to the presence of natural passive oxide film in the form of alumina (Al_2O_3) with the thickness of several nanometers. The passive oxide film was spontaneously formed when it expose to media such as air or water. To enhance its corrosion resistance, a thicker oxide film by applying anodizing process to the aluminum (7), (8). The oxide film which deposited on the aluminum, depending on several factors, maybe formed into two type of anodic film i.e. barrier-type and porous type film (9), (10), (11), (12).

SEM (Scanning Electron Microscope) photo observations were conducted to determine the size of the pores formed in the 7075-T651 series aluminum alloy after anodizing with voltage variations of 4 Volts, 5 Volts and 6 Volts.

3.1 Barrier Type of Oxide Film

Figures 5 show SEM (Scanning Electron Microscope) photo images of 7075-T651 series aluminum alloy specimens with various treatments. Figure 5.a shows the 7075-T651 series aluminum alloy anodized with a voltage of 4 volts, Figure 5.b shows the 7075-T651 series aluminum alloy anodized with a voltage of 5 volts, and Figure 5.c shows the 7075-T651 series aluminum alloy anodized with a voltage of 6 volts. This anodizing process is conducted by using 7075-T651 series aluminum alloy specimens with the independent variable used being electrical voltage. The cathode used is a carbon rod, H_2SO_4 concentration is 10%. The distance between the anode and cathode is 3 cm, the current used is 1A and the processing time is 10 minutes. The aluminum oxide layer is formed due to the anodizing process which is similar to the corrosion process in metal. Aluminum will bind oxygen around it to form a layer of aluminum oxide.

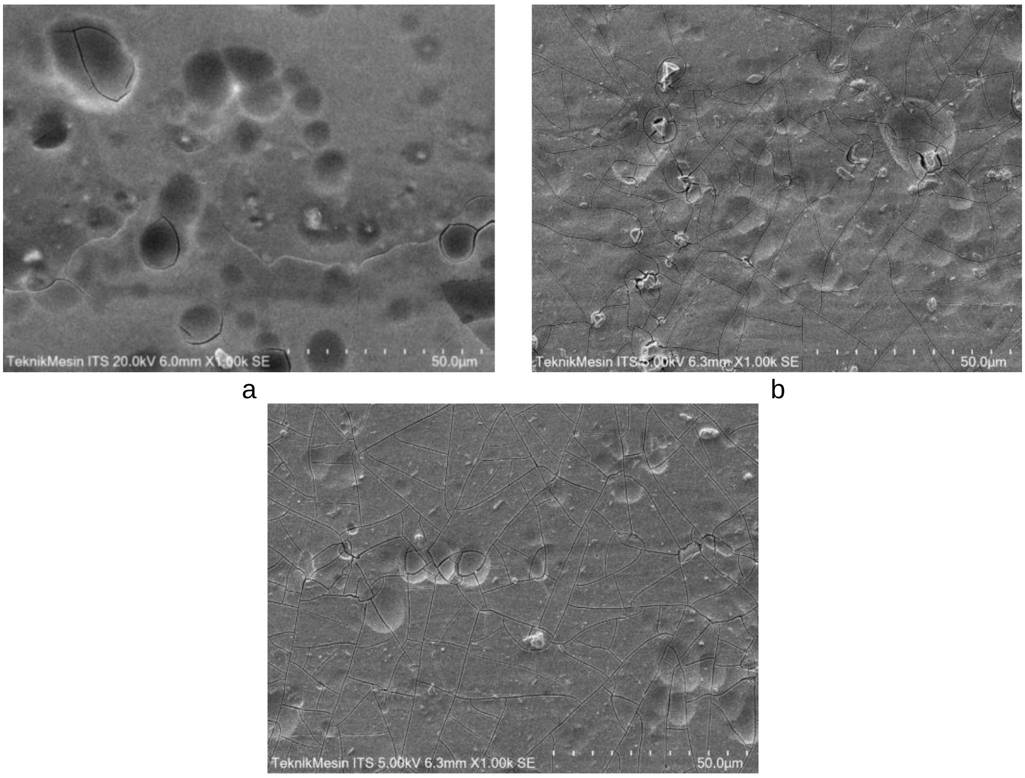
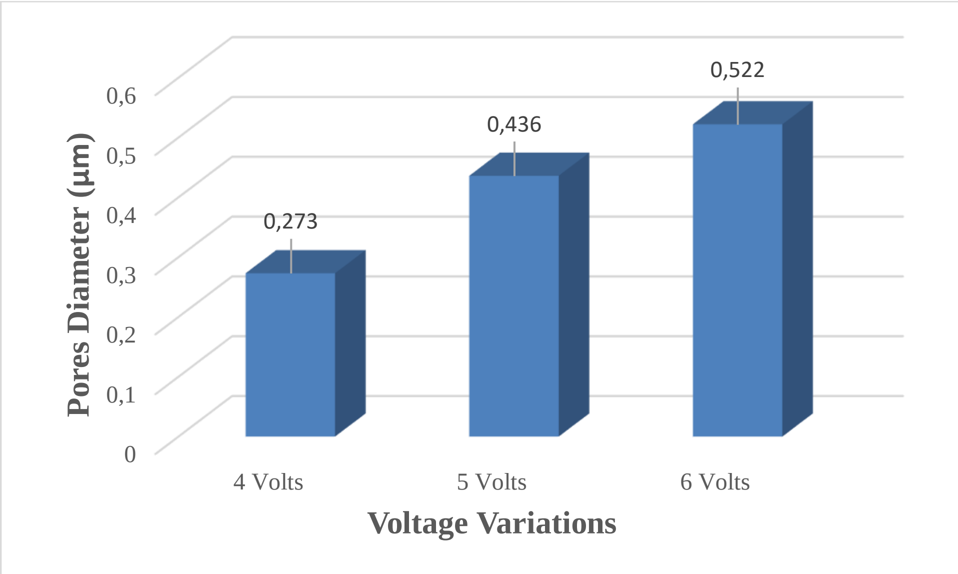


Figure 5. SEM Photograph with 1,000x Magnification of Anodized Aluminum Alloy 7075-T651 Series with a Voltage of a) 4 Volts, b) 5 Volts, and c) 6 Volts

It can be seen in Figure 5.a that the results of anodizing using a voltage of 4 Volts have begun to form a layer of pores that are relatively small in size, and not evenly distributed on the surface of the aluminum layer, and there are small cracks on the surface of the oxide layer. In Figure 5.b, which is the result of anodizing using a voltage of 5 volts, quite a lot of pore layers have formed with a larger diameter, and there are cracks on the surface of the oxide layer. In Figure 5.c, which is the result of anodizing with a voltage of 6 Volts, the pore layer has begun to form, with the dominant pore diameter being relatively large, and more and more cracks forming. These cracks can result in an increase in the corrosion rate value of a specimen, because the flowing electric current should be blocked by the Al_2O_3 layer but can synchronize directly with the aluminum surface. This indicates that it is easy to increase the corrosion rate.

These cracks can arise due to several factors, including: the difference in the coefficient of expansion between the aluminum and the oxide layer that will form. This is caused by the influence of temperature on the aluminum surface which rises unstable which results in the formation of Al_2O_3 being disturbed and the thin layer of Al_2O_3 breaking due to unstable temperature changes. Cracks can also be caused by the relatively weak strength of the aluminum layer which means that when it binds to Al_2O_3 it is not strong enough, causing cracks on the surface.



Graph 1. Effect of Voltage on the Pore Diameter of the Aluminum Surface Anodizing 7075-T651 Series Alloy

Graph 1 shows the effect of voltage variations on pore diameter the surface of the 7075-T651 series aluminum alloy is anodized. It can be seen in the results anodizing using a voltage of 4 Volts, the pore size formed is 0.273 µm. In the results of anodizing using a voltage of 5 Volts, the size of the formed pores of 0.436 µm and the anodizing results using a voltage of 6 Volts has pore size of 0.522 µm. This is in accordance with the research on the research on the an increase in voltage will cause an increase in pore diameter [13]. This is caused by the amount of voltage affects the strength of the current so that it will become more and more oxygen quickly oxidizes and sticks to the aluminum layer which causes the larger the pore size.

3.2 Electrochemical Corrosion Rate Testing

Electrochemical corrosion rate testing aims to test the corrosion rate value of aluminum alloy series 7075-T651 after anodizing with varying voltages of 4V, 5V, and 6V. Figure 6 and Figure 7 shows the results of corrosion rate testing on aluminum anodizing results 7075-T651 series alloy. It can be seen that the 7075-T651 series aluminum alloy with 4 volt anodizing treatment has a corrosion rate of 0.001434 mm/year, aluminum 7075-T651 series alloy with 5 volt anodizing treatment has a corrosion rate of 0.000819 mm/year, and aluminum alloy 7075-T651 series with anodizing treatment 6 volt has a corrosion rate of 0.000632 mm/year. This is because with the voltage increases, the current density will also increase. With the current density increases, the time required for the formation process increases the oxide layer will become shorter, resulting in a dissolution process (re-dissolving of the layer). Oxide formed on the metal surface by the electrolyte solution will be less occurs, so that the alumina structure formed will become denser and harder. This explains the phenomenon that increasing the voltage will cause the corrosion rate drop.

3.2.1 Tafel corrosion test

Figures 6 and Figure 7 show graphs of corrosion test results on anodizing results Aluminum alloy 7075-T651 series. Corrosion testing on anodized Aluminum Alloy 7075-T651 series alloy uses a potentiostat. This test also uses 3 Types of electrodes which are counter electrode, reference electrode and working electrode.

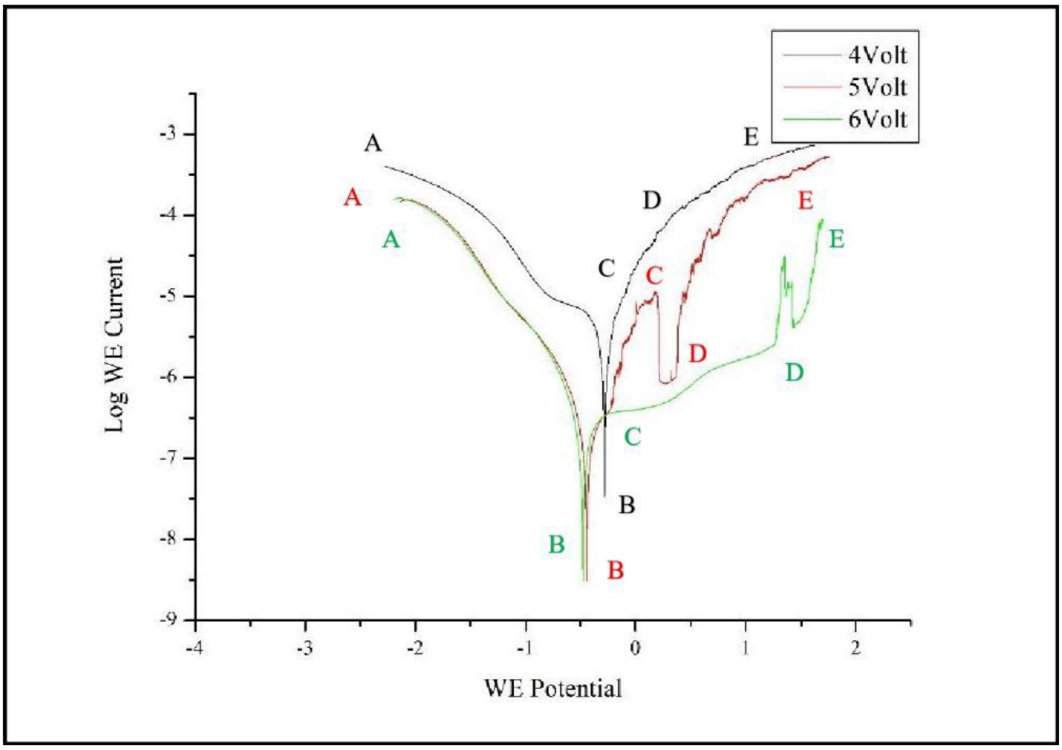
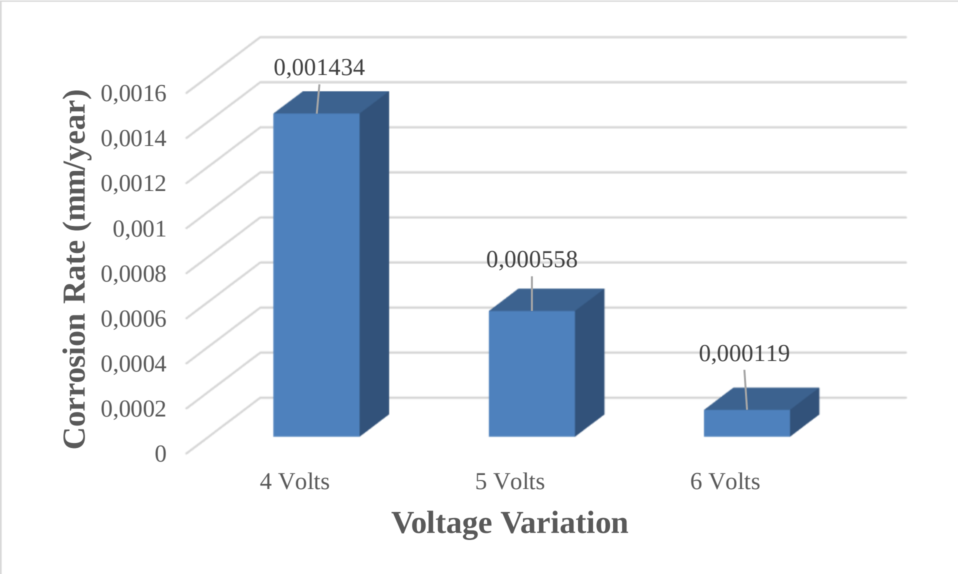


Figure 6. Corrosion Rate Test Tafel Graph

Figure 6 shows a graph of the corrosion rate test on aluminum anodizing results 7075-T651 series alloy. Area A – B is the area where cathodic protection occurs, where the applied potential has no effect on the material. At point B, namely the E_{corr} point shows the potential value required by the material so that the material can corroded. Areas B – C are areas that show the material before it reaches potential required for the protective layer to occur. At point C, that is the point shows where the material reaches the protective layer stage. Areas C – D is an area that shows the material at the protective layer stage. On this layer useful for preventing continued corrosion of the material. At point D that is, the dot indicates the protective layer of the material has been damaged, and the material is starting corrodes freely. Areas D – E are areas that show where the material is has corroded freely.

3.3 The Effect of Voltage on the Corrosion Rate of Anodizing Aluminum Alloys Series 7075-T651

Graph 2 shows a graph of the influence of voltage on the rate of surface corrosion of anodized aluminum alloy series 7075-T651. It can be seen in the product of anodized aluminum alloy using 4 Volts has a high corrosion rate of 0.001434 mm/year. The results of anodizing using 5 Volts have a corrosion rate which is lower than before at 0.000819 mm/year. And on the anodizing results by using 6 Volts, the corrosion rate decreases by 0.000632 mm/year. It can be concluded that the anodizing voltage has an impact on the rate corrosion, which means that the rate of corrosion can be controlled by the voltage in the anodizing process.



Graph 2. Effect of Voltage on Corrosion Rate of the Aluminum Surface Anodizing 7075-T651 Series Alloy

From the graph, it is known that the higher the voltage used in the process anodizing will result in a lower corrosion rate. This is caused increasingly voltage used in the anodizing process will increase the sizes of the pores or pore diameter. This is in accordance with the statement by other research in which the higher the voltage, the larger the pore size and distance between pores (13). The larger the pore size and pore distance will increase the corrosion resistance of aluminum alloy series 7075-T651 which is characterized by lower rate values resulting corrosion. This is in accordance a research which state that higher voltage will produce larger pore size and will affect the corrosion resistance (14).

4. Conclusion

From the analysis and discussion of data which was conducted on the effect of voltage variations in the anodizing process on the rate of corrosion using concentration of sulfuric acid (H2SO4) as an electrolyte in Aluminum alloy series 7075- T651, then the following conclusions can be drawn. Voltage variations in the anodizing process can control the corrosion rate through the oxide layer formed as a result of the anodizing process. SEM photo results (Scanning Electron Microscope) on 7075-T651 series aluminum alloy with action anodizing with varying voltages of 4 volts, 5 volts, 6 volts produces pore diameter with sizes respectively 0.273 µm; 0.436 µm; and 0.522 µm. It was concluded that the greater the voltage applied, the greater the pore diameter the greater it is 2. The results of the electrochemical corrosion rate test produce a corrosion rate value of aluminum alloy series 7075-T651 anodized using varying voltages 4 volts, 5 volts, 6 volts respectively equal to 0.001434 mmpy; 0.000558 mmpy; 0.000119 mmpy. It can be concluded that the greater the voltage applied to the anodizing process, the corrosion rate will decrease further.

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