The Effect of Time Variations in the Pure Aluminium Anodization Process

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Abstract

Aluminium is a white non-ferrous metal and is easily oxidized. In the industrial world, aluminium was chosen because it has the advantages of light density, corrosion resistance, easy fabrication (forged), high thermal and electrical conductivity. However, aluminium also has disadvantages, namely having a low hardness value when compared to steel. Pure aluminum hardness is only around 50 VHN. Therefore anodizing is expected to improve the hardness value of aluminium. This study aims to determine the effect of time variation on the value of changes in mass, hardness, oxide layer thickness, and microstructure. This study used aluminium 1100 with a time variation of 60, 70, 80, and 90 minutes, a concentration of H_2SO_4 of 10%, a current density of 6 A and a voltage of 20 V. The results of the study using a time variation of 60, 70, 80 and 90 minutes obtained the change in value the smallest mass occurred at 60 minutes of 0.4 g and the largest occurred at 90 minutes of 1.09 g. The smallest hardness value occurred at 60 minutes at 72.8 VHN and the highest occurred at 90 minutes at 86.7 VHN. The lowest layer thickness value occurred at 60 minutes of 7.96 µm and the highest occurred at 90 minutes of 10.79 µm

Keywords: aluminium, anodization, hardness, vickers

Abstrak

Aluminium merupakan logam non ferro berwarna putih dan mudah teroksidasi. Dalam dunia industri aluminium sendiri dipilih karena memiliki kelebihan massa jenis ringan, tahan korosi, mudah di fabrikasi (ditempa), konduktivitas thermal dan listrik tinggi. Namun aluminium juga memiliki kekurangan yaitu memiliki nilai kekerasan yang rendah jika dibandingkan dengan baja. Kerasan aluminium murni hanya berkisar 50 VHN. Oleh karena itu anodisasi diharapkan bisa memperbaiki nilai kekerasan aluminium. Penelitian ini bertujuan mengetahui pengaruh variasi waktu terhadap nilai perubahan massa, kekerasan, ketebalan lapisan oksida, dan struktur mikro. Penelitian ini menggunakan aluminium 1100 dengan variasi waktu 60, 70, 80, dan 90 menit, konsentrasi H_2SO_4 sebesar 10%, rapat arus 6 A dan tegangan 20 V. Hasil dari penelitian menggunakan variasi waktu 60, 70, 80 dan 90 menit didapatkan nilai perubahan massa terkecil terjadi pada waktu 60 menit sebesar 0,4 g dan terbesar terjadi pada waktu 90 menit sebesar 1,09 g. Nilai kekerasan terkecil terjadi pada waktu 60 menit sebesar 72,8 VHN dan tertinggi terjadi pada waktu 90 menit sebesar 86,7 VHN. Nilai ketebalan lapisan terendah terjadi pada waktu 60 menit sebesar 7,96 µm dan tertinggi terjadi pada waktu 90 menit sebesar 10,79 µm.

Kata kunci: aluminium, anodisasi, kekerasan, vickers

1. Introduction

The development of the industrial world is increasingly growing rapidly, especially the world of manufacturing. Material selection is one factor that needs to be considered. A good material is a material that has high strength and toughness values. In the world of manufacturing, materials such as aluminium, iron, steel, zinc and bronze are examples of materials that are often used. Aluminium is the most widely used metal after steel. Aluminium was first discovered in 1827 by a scientist named Friedrich Wohler, then the name aluminium was carried out by H. Davy in 1808 and became the first person to carry out research on the separation of aluminium [1].

Aluminium is a white non-ferrous metal and easily oxidizes. In the world of industry, aluminium itself is chosen because it has the advantages of light density, corrosion resistance, easy fabrication (forging), high thermal and electrical conductivity. However, aluminium also has the disadvantage of having a low hardness value when compared to steel. The hardness of pure aluminium is only around 50 VHN [2], therefore pure aluminium is rarely used today because it is too soft. A small aluminium hardness value will cause the strength and toughness values to decrease. Seeing the shortcomings of aluminium, it is necessary to carry out special treatment to increase the hardness value. One way to increase the hardness value of aluminium is by carrying out an anodization process [3][4].

Anodization is a coating of aluminium metal where the process is carried out by electrolysis on the surface so that a thin layer of oxide is formed on the aluminium surface [2]. The electrolysis process carried out on aluminium forms an oxide layer due to the electrochemical reaction between oxygen and aluminium which then produces a barrier layer and a porous layer. The layer formed will provide protection to aluminium, this will increase the hardness of aluminium but in the formation of the aluminium oxide layer the mass will decrease [5]. The hardness value of the oxide layer is relatively harder than aluminium before anodizing. The anodization process is influenced by many factors such as time, type of electrolyte solution, voltage and current strength [6][7].

Iqbal, D et al., (2018) [2] conducted anodization research by varying the current strength of 0.5 A, 1 A, and 1.5 A, time 5, 10, and 15 minutes on aluminium 1100. In this study the aim was to get better aluminium hardness values. The research results showed that the highest hardness value occurred at a variation of 1.5 A and a time of 15 minutes with a hardness value of 313.2 VHN. From the research results, it can be concluded that variations in current strength and time can significantly improve the hardness value from 50.3 VHN to 313.2 VHN.

Based on one of the disadvantages of aluminium that was mentioned previously, aluminium has a low hardness value. From previous research it is known that anodization can increase the hardness value of aluminium, so this research aims to determine the effect of time variations on the change value of mass, hardness and thickness of the oxide layer. When compared with previous existing research, the research I conducted will use a relatively higher variation in time, namely 60, 70, 80, and 90 minutes.

2. Methology

The material used in this research is 1XXX series aluminum or pure aluminum, where the aluminum element is 99% [8]. Meanwhile, the electrolyte solution used is H_2SO_4. Table 1 shows the results of aluminum tests carried out at the Ceper Polytechnic Laboratory and Figure 1 shows a schematic of the anodization process.

Table 1. Compositions

No.	Element	Rate (%)
1.	Aluminium (Al)	99
2.	Silicon (Si)	0,011
3.	Feron (Fe)	0,011
4.	Copper (Cu)	0,011
5.	Manganese (Mn)	0,011

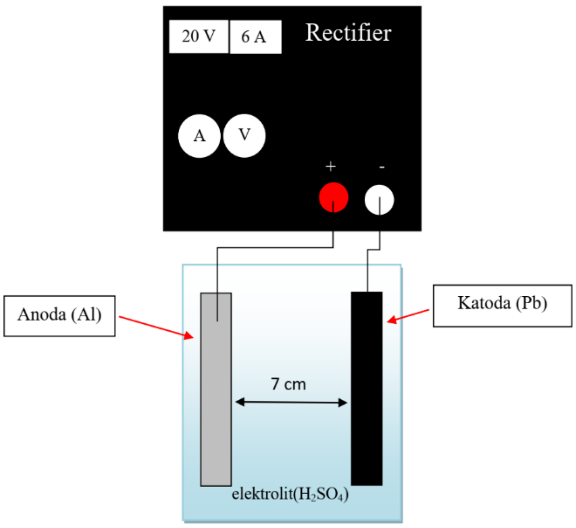

Figure 1. Anodization Process

Aluminum is cut to size 70x30x3 mm. After that, sanding is carried out from rough to fine. The next stage is chemical treatment, namely cleaning. The anodization process is carried out at the Mechanical Engineering Laboratory of the Sumatra Institute of Technology. Before the anodization process is carried out, a chemical treatment process is carried out which includes cleaning, rising, degreasing and pickling [9].

The cleaning stage is a stage that is carried out by cleaning the dirt that sticks to the surface. The cleaning stage is carried out using water and soap. The rinsing stage is a stage carried out by cleaning aluminum using distilled water. The rinsing stage is carried out before the degreasing stage. The degreasing stage is a stage that is carried out by cleaning aluminum using NaOH. Dyeing using NaOH solution aims to clean the oxide layer which was not previously removed during the cleaning and rinsing stages. After the degreasing stage, the specimen will be rinsed. The pickling stage is a stage carried out by dipping the aluminum in the H_2SO_4 solution. This stage aims to remove the thin layer of gray that formed during the degreasing stage. This stage is the final stage before the anodising process is carried out, but before that the specimen is rinsed first [7].

The anodization process uses time variations of 60, 70, 80, and 90 minutes. The anodization stage was carried out on a 1000 ml beaker containing 10% H_2SO_4 and 90% distilled water. Aluminium is used as the anode (+) and lead (Pb) as the cathode (-). The distance between the anode and cathode is 7 cm, while the current used is 5A and the voltage is 20 V. The temperature used is room temperature. Before testing, a rinsing process is carried out to clean the specimen [7].

The testing process carried out is aluminium mass testing, hardness testing and layer thickness. Hardness testing using the Vickers micro method using the Zwickroell brand Universal Hardness Tester. With a load of 500 gf for 10 seconds. To find the Vickers hardness value, you can use equation 1.

$$\text{VHN} = \frac{1{,}854\,P}{d^2} \quad (1)$$

Information:

VHN : Vickers Hardness Number (kg/mm²)

P : Force (kgf)

d : Indentation (µm)

3. Results and Discussion

3.1 Mass Change

The mass change test results were obtained from weighing the specimen before and after anodization. The test was carried out to obtain the difference value and percentage change in mass after the anodization process. The results of the mass change test can be seen in Figure 2.

Figure 2 shows a graph of the influence of time variations on mass changes and their percentages. It is known that the weight of aluminium before anodization at 60 minutes was 16.3 g, at 70 minutes it was 16.5 g, at 80 minutes it was 16.6 g and at 90 minutes it was 16.3 g. After anodizing, at 60 minutes the mass of aluminium was 15.9 g, at 70 minutes it was 15.9 g, at 80 minutes it was 15.9 g, and at 90 minutes it was 16.3 g. From the data obtained and presented in graphical form in Figure 2 regarding the time variation graph of mass changes, it was found that the smallest mass change value occurred at 60 minutes of 0.4 g, while the largest mass change value occurred at 90 minutes of 1.09 g.

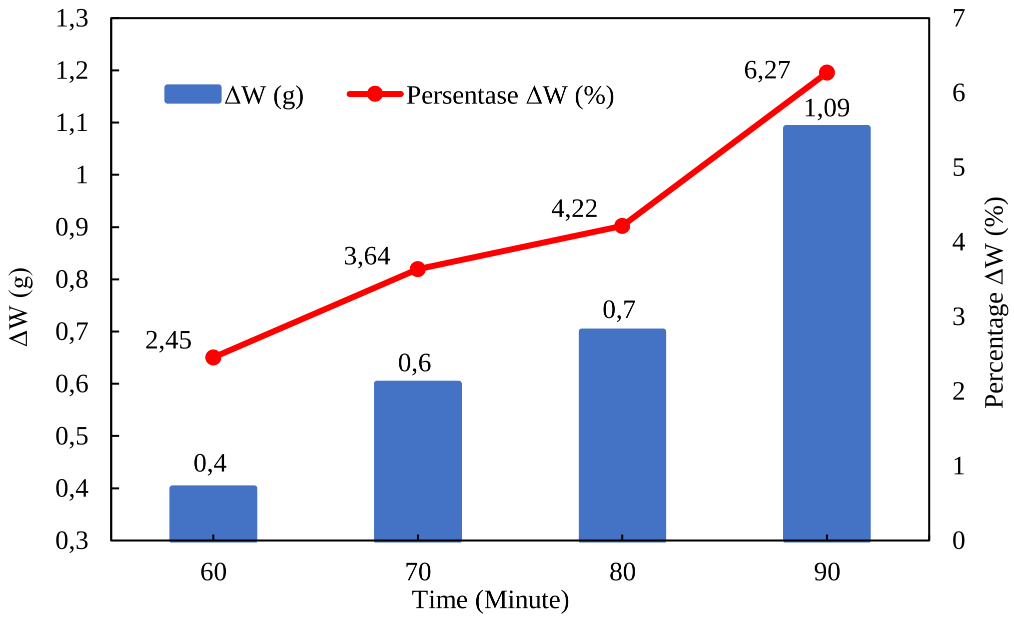

Figure 2. Mass Changer Graph

Faraday's Law 1 states "in electrolysis the mass released will be directly proportional to the amount of electricity and time used" [6]. Apart from voltage, current and time, the concentration of the solution will also affect the mass decay of aluminum. The electrolyte liquid used (H_2SO_4) will dissolve the film layer over time. The mass changes that occur are increasing over time and the peak mass change at 80 and 90 minutes shows a significant increase. This occurs because when the porous layer is formed with a porous structure, the mass decay occurs, where at 90 minutes the tension that occurs is greater and the time used is relatively over time this causes the mass to decrease more and more [10][11].

From these tests it is known that the longer the anodization process is, the more the mass of aluminum will decrease [12]. The amount of mass decreased, where at 60 minutes there was a mass reduction of 2.45% and the largest mass change occurred at 90 minutes of 6.27%.

3.2 Hardness

Vickers hardness testing aims to obtain the surface hardness value of aluminum after anodizing. The test results can be seen in Figure 3.

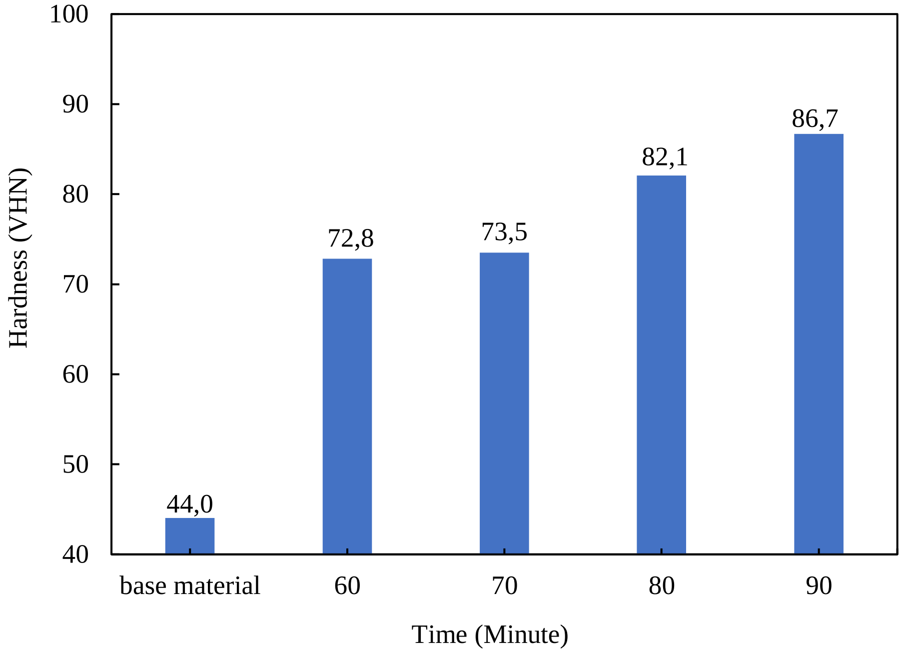

Figure 3. Hardness Graph

Figure 3 shows that the hardness value of aluminum before anodizing was 44.0 VHN and after anodizing for 60 minutes it produced an average hardness value of 72.8 VHN, at 70 minutes the average hardness value obtained was 73.5 VHN, at 70 minutes. At 80 minutes the average hardness value obtained was 82.1 VHN, and at 90 minutes the average hardness value obtained was 86.7 VHN. From this data, the lowest hardness value occurred at 60 minutes with a hardness value of 72.8 VHN and the highest hardness value occurred at 90 minutes at 86.7 VHN.

The test results show that aluminium 1100 has a low hardness value, after anodizing for 60 minutes it appears to have experienced a significant increase. The increase in hardness value is due to the growth of the oxide layer which gets thicker as time increases. This oxide layer has a surface consisting of millions of pores. An oxide layer is formed when current from the rectifier flows to the anode, aluminium will release electrons so that aluminum can bond with oxygen to form an oxide layer. This oxide layer causes the hardness of aluminium to increase thereby increasing the strength and toughness values of aluminium [13][14]. So, the hardness value of each surface point has a different hardness. Surfaces that have many pores tend to have high hardness values. At 60 minutes and 70 minutes there was a slight increase because the time interval used was not too far apart, this meant that the structure of the porous oxide layer was not too different. At 80 and 90 minutes, there was an increase in the aluminium surface hardness value, this occurred because the time interval used was longer, which resulted in the formation of a more even porous oxide layer on each surface [3][10]. The results of the research I conducted can be concluded that the higher the time used in anodizing, the harder the aluminium hardness value produced, this is because the growth of the oxide layer increases over time.

3.3 Layer Thickness

The layer thickness test aims to obtain the oxide layer thickness value from time variations of 60, 70, 80, and 90 minutes. Figure 4 shows the layer thickness which continues to increase with each variation used. Where the smallest layer thickness value occurred at 60 minutes at 7.96 µm and the highest layer thickness occurred at 90 minutes with a thickness of 10.79 µm, meaning that the higher the time used, the thicker the oxide layer formed [3][7]. The oxide layer formed after the anodization process consists of a barrier layer (base layer) and a porous layer. This porous layer increases the hardness of aluminum. Where the formation of an oxide layer occurs when the rectifier passes current to the aluminum which results in the release of electrons and binding with oxygen to form an oxide layer [12][15]. The layer thickness value at each point is different, even the average deviation value (Standard Deviation) has a value of 4.07 at 60 minutes and 2.38 at 90 minutes. Differences in deviation values for each oxide layer occur because the voltage is unstable and the time used has an influence on the formation of the oxide layer. This was also mentioned in research conducted by Muzaki., et al (2022) [13], he stated that the influence of tension affects the distance between pores and the time used can increase the layer thickness. From the anodization process, it can be seen that the longer the anodization time, the thicker the oxide layer produced. The difference in layer thickness is influenced by unstable stress during the anodization process which causes the distance between the pores to widen. This is what causes each oxide layer to have a different thickness.

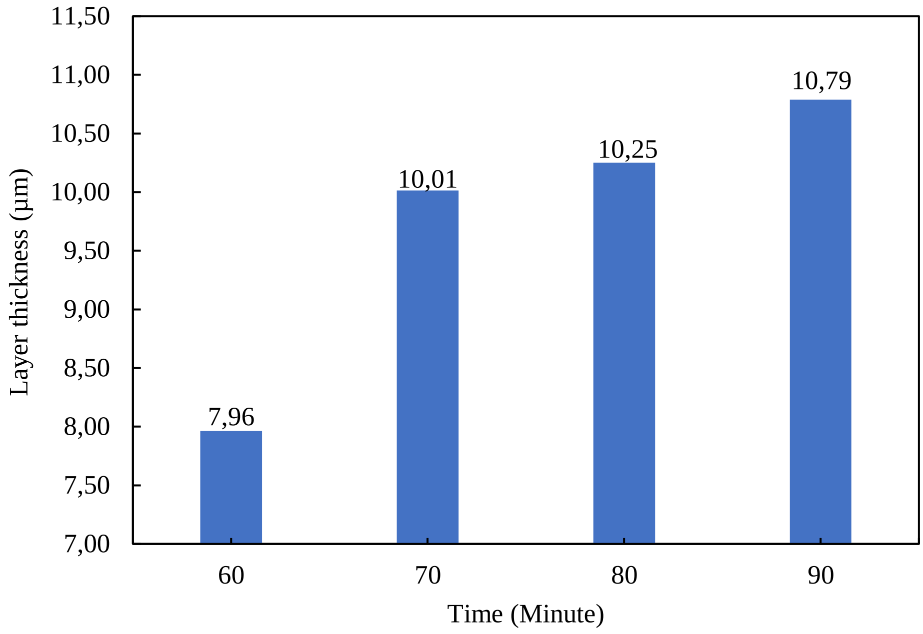

Figure 4. Layer Thickness Graph

4. Conclusions

After testing the mass change, the mass change values at 60, 70, 80 and 90 minutes were respectively 0.4 g, 0.6 g, 0.7 g and 1.09 g. Where the smallest mass change value occurred at 60 minutes of 0.4 g and the largest mass change occurred at 90 minutes of 1.09 g. This proves that the longer the anodization process, the aluminum mass will decrease. Furthermore, after testing the hardness using the micro vickers method, the average hardness values at 60, 70, 80 and 90 minutes were 72.8 VHN, 73.5 VHN, 82.1 VHN and 86.7 VHN respectively. Where the smallest hardness value occurred at 60 minutes at 72.8 VHN and the highest hardness value occurred at 90 minutes at 86.7 VHN. This proves that the longer the anodization process takes, the harder the aluminum will increase. And then, after testing the layer thickness, the layer thickness values at 60, 70, 80, and 90 minutes were respectively 7.96 µm, 10.01 µm, 10.25 µm, 10.79 µm. Where the lowest layer thickness value occurred at 60 minutes at 7.96 µm and the highest thickness value occurred at 90 minutes at 10.79 µm. This proves that the longer the anodization process, the layer thickness increases.

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