The Effect of Nickel Electroplating Time on Aluminum 2024 to Its Mechanical Property

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Abstract. Nickel plating is an excellent way to protect aluminum components from corrosion and wear. Nickel plating offers several advantages over other protective coatings for aluminum parts. It is extremely cost-effective compared to other options like powder coating or painting. The purpose of this research on nickel electroplating on aluminum was to determine the effect of time on the mechanical properties in the form of the hardness value of the specimen. The SEM-EDX test was carried out on the specimen with the highest hardness test value to determine the microstructure and elemental composition of the coating. The materials used in this study were nickel as a coating and aluminum 2024 as a coated material. Fixed variables used in this study include voltage (25 V), electrode distance (20 cm), water (2400 ml), salt (40gr), vinegar (1600 ml), aluminum 2024, and nickel. The independent variable is the variation of coating time, namely 10, 15, and 20 minutes. The results of this study showed that the highest hardness value was found in specimens with 10 minutes of immersion time with a value of 198.31 HV and the lowest hardness value was obtained by sample with 20 minutes of immersion time with a value of 132.81 HV. After the SEM-EDX test, it was found that the microstructure of the layer was containing pitting (defects) and highest element found in the layer was Nickel with a mass of 84.07% and an atomic number of 55.29%.

INTRODUCTION

The technique of depositing metals from aqueous solutions onto substrate without the use of an external current source is known as electroless plating, which is sometimes referred to as autocatalytic plating (1,2). Brenner and Riddel invented this procedure in 1946 for the deposition of nickel-phosphorous alloys (3), and it has several industrial uses (4–6). Electroless nickel-boron plating is an instance of that method that

utilizes either sodium borohydride (7,8) or dimethylamineborane (DMAB) (9,10) as a reducing agent. The resultant alloys contain a substantial quantity of co-deposited boron.

The ability to plate non-conducting materials as well as metals is one of the most essential characteristics of electroless nickel plating, as is the production of continuous coatings with completely homogenous thickness regardless of substrate shape (11). Therefore, the electroless nickel plating is the superior and interesting electroplating methods to produce high hardness (around 750 hv100 in the as-deposited state) (12,13), good wear resistance (14–16), good corrosion behavior (6,12–14,16,17)metal alloy. Due to this, electroless nickel-boron coatings are applicable in a wide range of industries, including those in the chemical and petroleum industries, plastic injection, optical, aircraft, weapons, automotive, and electronics (11,18).

Aluminum alloy 2024 is one of the metal alloys which is mostly utilized by aircraft manufacturers as a material for aircraft components due to its excellent mechanical property which has a high strength to weight ratio. Apart from airplanes, aluminum 2024 is also often used as a material for making motorcycle components. Electroless plating on Aluminum alloys gives them mechanical qualities (wear resistance) that enable their usage in mechanical applications. But it is difficult to use this method for plating aluminum since sodium borohydride is very unstable, save in very alkaline conditions. As a result, the plating bath typically has a pH greater than 9, which is unsuitable for aluminum. In addition, because they are conducted at temperatures that are too high for aluminum alloys, heat treatments created for electroless nickel coatings (typically at 400 °C for 1 h) are not appropriate (19). Therefore, specific methods for improving electroless nickel-boron coating characteristics without negatively affecting the resistance of the aluminum substrate were discovered (15,20).

There have been previous studies of the characteristics of electroless nickel coatings on aluminum alloys (17,19–22) , However, there aren't many works that specifically address how the properties of electroplating change with time. In addition, coating nickel on an aluminum mixture without harming the mixture's structure required a relatively complicated and complex approach, which was used in earlier studies.

In this study, a simple technique has been utilized to generate metal alloy structures with lower structural defects compared to previous work (23). This work introduces a straightforward technique for coating metal alloys that has an excellent rate of effectiveness in terms of diminishing structural imperfections. In this study, nickel plating on an alloy of aluminum was conducted at various coating times of 10, 15, and 20 minutes. The effect on the mechanical properties was then examined following the study of the structure..

RESEARCH METHODS

Electroplating is a process used to manipulate the properties of a substrate by coating it with another metal. The results obtained in the electroplating process are influenced by many variables, including the solution used, the temperature of the solution, the duration of the plating, the voltage between the two electrodes, the condition of the (23)electrodes used, and so on. Electroplating is made by passing an electric current through a solution between metals or other conductive materials. Two metal plates are the anode and cathode connected to the positive and negative terminals of the direct current (DC) source. The metal connected to the positive pole is called the

anode and the metal connected to the negative pole is called the cathode. When a voltage source is used in the electrolyte, the positive pole emits ions that move in solution (electrolyte) towards the cathode and are referred to as cations. The negative pole also gives off ions, moving towards the anode and is referred to as anion. The scheme of electroplating mechanism is shown in **Figure 1**.
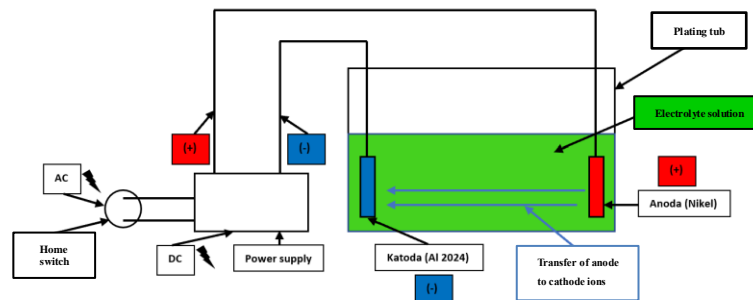

Figure 1 Electroplating mechanism scheme

Aluminum alloy 2024 is one of the metal alloys which is mostly utilized by aircraft manufacturers as a material for aircraft components due to its excellent mechanical property which has a high strength to weight ratio. Apart from airplanes, aluminum 2024 is also often used as a material for making motorcycle components. The element content of alumunium 2024 is shown in **Table 1**.

Tabel. 1 Aluminium 2024 element content

Element	Persentage (%)
Aluminium	90.7-94.7
Chromium	0.1
Copper	3.8-4.9
Ferrit	0.5
Magnesium	1.2-1.8
Mangan	0.3-0.9

The Vickers Hardness Test is to determine the resistance of the material associated with a smaller indenter, so that the results are more detail compared to using other hardness testing methods. The Vickers value is obtained using the formula 1 and 2:

$$D = \frac{(d1+d2)}{2} \qquad \text{Formula 1}$$

$$HV = \frac{1.854F}{D^2} \qquad \textit{Formula 2}$$

where:
D   : Mean diagonal tracking (mm),
d1   : Side diagonal tracking 1 (mm),
d2   : side diagonal tracking 2 (mm),
HV   : Hardness Vickers value (kgf/mm2), (HV), and
F   : Maximum force (Newton).

Scanning Electron Microscope (SEM) is an electron microscope designed to directly observe the surface of solid objects. SEM has a magnification of 10 – 3,000,000 times. Due to its combination of high magnification, large depth of field, good resolution, the SEM test is widely used to determine the composition and crystallographic information of a material surface.

This research was carried out by making electroplating tools. After carrying out the manufacturing process, all tools were calibrated both in the system and measuring instruments. After making sure everything is in good condition, the next step is to carry out the nickel-plating process on the aluminum base material and carry out hardness testing and SEM testing. Figure 2 shows the instruments used during the test:

(a)   (b)
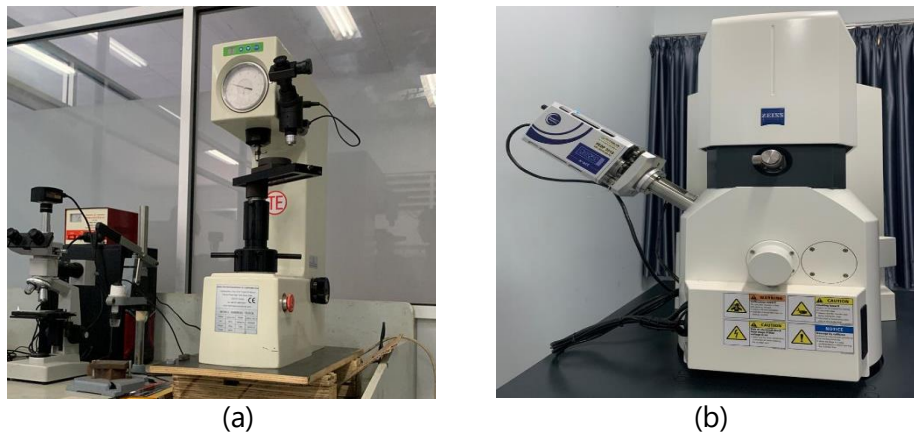
Gambar. 2 (a) Hardness testing instrument, (b) SEM-EDX instrument

RESULT AND DISCUSSION

The data from this study came from hardness tests on 3 electroplated specimens and SEM tests on specimens with the highest hardness values.

1. **Hardness analysis**

   Figure 3 shows the hardness Vickers values of samples with variation of nickel electroplating time.
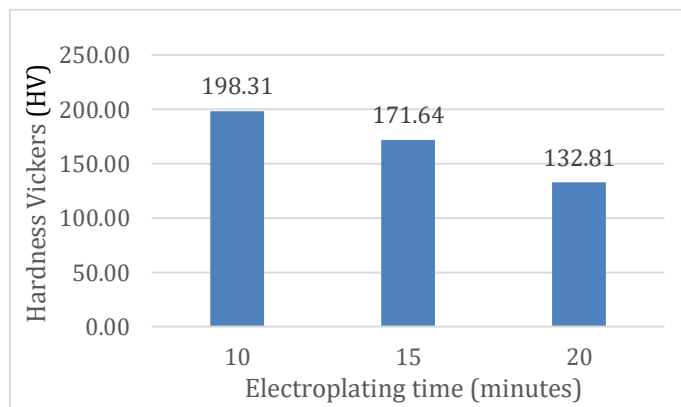

Figure 3 The Hardness result of samples with nickel electroplating time variations of 10, 15 and 20 minutes.

Figure 3 shows the results of the average hardness value of each time variation. The sample with an immersion time of 10 minutes has the highest hardness Vickers value of of 198.31 HV. Otherwise, the sample with longest immersion time (20 minutes) has the lowest hardness Vickers value of 132.81HV.

2. **SEM-EDX Analysis**

SEM test was carried out with a magnification of 1000 times. The microstructure of the electroplated layer obtained on the specimen with an immersion time of 10 minutes was obtained by Figure 4.
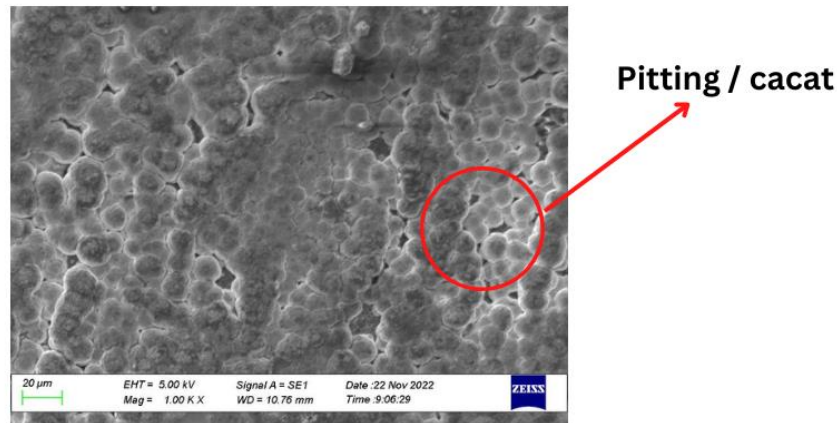

Figure 4 SEM image of sample with immersion time of 10 minutes

From the SEM result, it can be observed that the nickel was successfully coated to the Alumunium 2024. Nickel particles that stick to aluminum form bubbles that are layered and interrelated. However, there are also unrelated bubbles that form cavities in each of them. After carrying out the EDX test on the layer, it can be observed that it is these cavities that allow oxygen and carbon to be trapped in the layer. This can be caused by reactions that occur during the coating process.
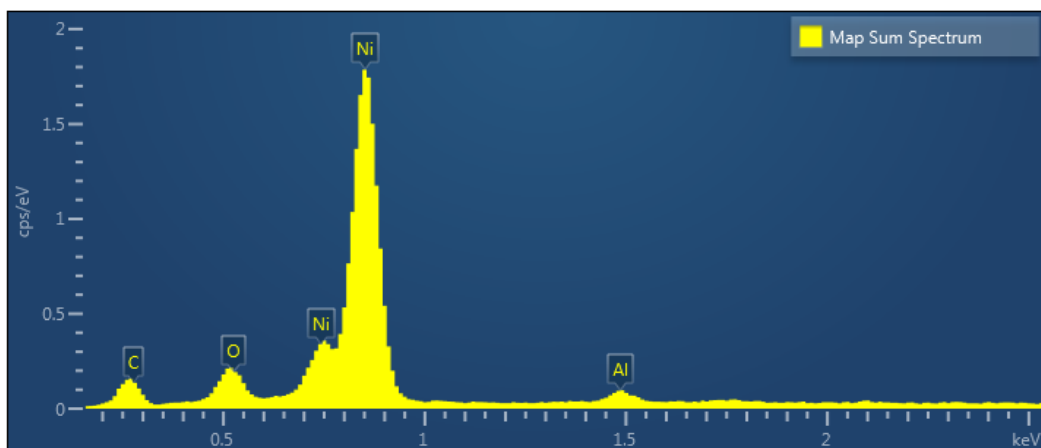

Figure 5 Elemental analysis result of sample with immersion time of 10 minutes

Figure 5 and Table 2 show the elemental analysis of sample with immersion time of 10 minutes. The largest element contained in the sample is nickel element with a composition of 84.07 wight % 55.29 atomic %.

Table 2. Elemental analysis of sample with immersion time of 10 minutes

Element	Weight %	Atomic %
Ni	84.07	55.29
O	4.86	11.73
C	9.60	30.87
Al	1.47	2.11

CONCLUSION

The nickel electroplating to alumunium 2024 was successfully performed with the immersion time variations of 10, 15 and 20 minutes. Hardness analysis result states that the immersion time variation affect the hardness property of samples. The shorter immersion time of 10 minutes shows the higher hardness value of 198.31 HV compared to the sample with the longer immersion time of 20 minutes which has the lower hardness value of 132.81 HV. The hardness value decreases along with the increasing immersion time due to the emergence of pitting (defects) on the electroplated layer. SEM image of 10 minutes immersion sample shows that the microstructure of the specimen layer is hollow and there are some impurities attached to it. The cavities and impurities are identified as oxygen and carbon analyzed from the EDX result. With the presence of pitting (defects), it causes the decrease of hardness value of the specimen and easily produce the brittle nickel coating on the specimen.

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