UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

# WEAR BEHAVIOR AND CORROSION RESISTANCE OF NICKEL COATINGS ELECTRODEPOSITED ON ALUMINUM ALLOY 7075 SUBSTRATE VIA VARIOUS CURRENT DENSITY

Report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

by


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**BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA**

TAJUK: Wear Behavior And Corrosion Resistance of Nickel Coatings Electrodeposited on Aluminum Alloy 7075 Substrate Via Various Current Density

SESI PENGAJIAN: 2014/15 Semester 2

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| Date | : | 2th July 2015 |

# APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The member of the supervisory is as follow:

……………………………………..

(Official Stamp of Principal Supervisor)

……………………………………..

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# ABSTRAK

Lapisan nikel telah dienapkan atas aloi aluminium 7075 (AA7075) melalui ketumpatan arus. Tujuan kajian ini adalah untuk menentukan sifat haus dan ketahanan kakisan salutan nikel yang telah dienapkan pada AA7075. Proses pengenapan ini menggunakan larutan Watt nikel pada suhu 40 $^{o}$C dan nilai pH 3.0. Pelbagai ketumpatan arus telah digunakan iaitu 2.5, 5.0, 7.5, 10.0, dan 12.5 mA/cm$^2$. Di antara ketiga-tiga jenis ketumpatan arus, 7.5 mA/cm$^2$ memberikan hasil salutan yang terbaik. Morfologi salutan dianalisa menggunakan mikroskop imbasan electron (SEM) dan komposisi salutan telah dikenalpasti menggunakan x-ray pendafluoran (XRF). Morfologi dan struktur salutan nikel menjadi lebih padat dan tumpat seiring dengan peningkatan ketumpatan arus. Meningkatkan ketumpatan arus juga dapat memperbaiki saiz bijian. Sifat haus, dan kakisan bertambah baik dengan peningkatan ketumpatan arus.

# ABSTRACT

The nickel coatings are electrodeposited on aluminum alloy 7075 (AA7075) via various current density. The aim of this research is to determine the wear behavior and corrosion resistance of nickel coating electrodeposited on AA7075 substrate. The electrodeposition process was using a nickel Watt's bath as a solution at a temperature of $40^0$C and pH value of 3.0. Various current density have been used which are 2.5, 5.0, and 7.5 mA/cm$^2$. Amongs these three type of current density, 7.5 mA/cm$^2$ give the best results of coatings.The morphology of the coating are analyzed using scanning electron microscopy (SEM) and the composition of coatings was identified using x-ray fluorescence (XRF). The morphologies and structures of nickel coatings become more compact and denser as well as increasing in current density. Increasing the current density also refining the grain size. The wear, and corrosion resistance of coating improved with the increasing in current density.

# DEDICATION

This report is lovingly dedicated to my respective parents; Mr. Md Zahir Bin Zakaria and Mrs. Zaharah Binti Mohamad Jusoh, my supervisor; Dr. Intan Sharhida Binti Othman and Dr. Muhammad Zaimi Bin Zainal Abidin, my family's members and also to all my friends who have been supported and inspired me through this project.

# ACKNOWLEDGEMENT

Alhamdulillah, first of all, I would like to extend my gratitude to Allah S.W.T for blessing me with health, love, opportunity and mercy to complete this research.

Besides that, I would like to extend my sincere gratitude to my supervisor, Dr. Intan Sharhida Binti Othman who had given me guidance and support during the whole research period. My sincere thanks also goes to Dr. Muhammad Zaimi Bin Zainal Abidin as my co-suppervisor for his invaluable opinions during the research. Not to be forgotten, I would like to thanks to other lecturers, laboratories staffs, friends and inviduals who, directly or indirectly, give contribution towards my research progress.

Last but not least, I would like to thanks to my parents who always stand by my side to give moral support and never forget to pray for me. Further, I want to acknowledge UTeM especially Faculty of Manufacturing Engineering for giving me opportunity to gain experience and knowledge during this four year of my study.

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| | | |
|---|---|---|
| AA7075 | - | Aluminum Alloy 7075 |
| PVD | - | Physical Vapor Deposition |
| CVD | - | Chemical Vapor Deposition |
| HVOF | - | High-Velocity Oxygen Fuel |
| NaCl | - | Sodium Chloride |
| HCl | - | Hydrochloric Acid |
| XRF | - | X-Ray Fluorescence |
| XRD | - | X-Ray Diffraction |
| SEM | - | Scanning Electron Microscopy |
| $I_{corr}$ | - | Corrosion current |
| $E_{corr}$ | - | Corrosion potential |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Project

Aluminum alloy 7075 (AA7075) is commonly used as a structural material in aircraft application due to their attractive properties that have high strength to weight ratio. AA7075 have chemical composition roughly of zinc (Zn) 5.1-6.1 wt. %, magnesium (Mg) 2.1-2.9 wt. %, copper (Cu) 1.2-2.0 wt. %, and chromium (Cr) 0.18-0.28 wt. %. However, this material has a problem where it has low corrosion resistance. Therefore, to overcome this problem, a coating system has been introduced to the AA7075 in order to prevent corrosion.

There are various techniques of coating which can be applied to AA7075 substrate, such as electrodeposition, ion implantation, laser beam deposition, chemical vapor deposition (CVD), physical vapor deposition (PVD), plasma and high-velocity oxygen fuel (HVOF). Among these techniques, electrodeposition has been identified as the most economical and superior techniques and technologically feasible with low residual porosity for production of nickel coating. Electrodeposition have various advantages such as, low cost and industrial applicability, can be easily control, and versatility and also has high production rates.

Further, nickel has been chosen as coating material in order to improve the corrosion resistance of AA7075. Moreover, nickel not only have good corrosion resistance but also high melting point, strength, and ductility.

This research aims to improve the corrosion resistance of AA7075 as well as the wear behaviors of the nickel coatings electrodeposited on AA7075 substrate. In order to get a good result for wear behavior, the grain size of nickel coating needs to be refined by increase the current density. Current density plays an important role on the modification of the grain size of electrodeposited coating. The grain size of the coating can be refined by applying a high current density during the electrodeposition process. The decreasing of the grain size of the coatings occur rapidly by increasing the current density (Rashidi and Amadeh, 2008).

The samples will be tested in several ways in order to determine the wear and corrosion behavior. Ball-on-disc wear tester will be used to determine the wear behavior. The corrosion test will be carried out by immersing the coating in a 3.5 wt. % of NaCl solution at room temperature.

## 1.2 Problem Statement

AA7075 is a type of material that can easily undergo corrosion process. Thus, this alloy needs to be coated with a coating system in order to prevent the corrosion. Previously in aircraft industry, cadmium (Cd) or chromium (Cr) were widely used as a coating material. However, these coatings materials are hazardous and contain a carcinogenic element which can cause cancer.

Due to this problem, Cd and Cr are replaced with others coatings materials such as polycrystalline nickel (Ni), nickel phosphorous (Ni-P), and zinc (Zn), even though the properties of these materials are not as good as Cd and Cr in term of wear and corrosion resistance.

One of the way to achieve a better wear resistance, and good corrosion resistance is by decreasing the grain size of nickel coatings. Therefore, this research is focused on increasing the surface properties of coatings by refining the grain size. According to El-Sherik and Erb (1997), the wear properties of nickel coating are influenced by the grain size of the coating. The challenge in this study is to produce coatings which can overcome the low wear and corrosion resistance of AA7075. In this research, the effect of the various current density applied in the electrodeposition process to the grain size of nickel coating will be studied.

## 1.3 Objectives

1. To produce nickel coatings electrodeposited on AA7075 substrate using various current density.
2. To analyse the corrosion resistance of nickel coatings electrodeposited on AA7075 substrate.
3. To determine the wear behavior of nickel coatings electrodeposited on AA7075 substrate.

## 1.4 Scope of Project

The focus of this study is to determine the wear behavior and corrosion resistance of nickel coating electrodeposited on AA7075 substrate. The coating process will be using electrodeposition method with suitable parameter such as current density. The function of current density is to control the grain size of nickel coating. After that, the samples will be test by using wear and corrosion testing. Finally, the result will be analyzed.

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 Electrodeposition of Nickel

#### 2.1.1 Introduction

Electrodeposition also known as electroplating is a process that using electrical current to reduce cations of desired material from a solution and deposits as a thin film onto a conductive substrate surface. Nickel electrodeposition is similar to other electrodeposition processes that deposits a thin layer of nickel onto a conductive substrate. Generally, the purpose of the nickel layer can make changes to the characteristics of a surface which are to improved appearance, corrosion resistance, wear resistance, or other desired properties. Nickel electrodeposition process is carried out in a solution bath which is Watts's solution.

### 2.1.2 Method of Electrodeposition

This process used a power supply to supplies a direct current that flow between two electrodes which are anode and cathode that immersed in conductive solution. The flow of direct current causes the anode electrodes to dissolve and the cathode electrode to become cover with nickel. In nickel solution contains positively charged nickel ions (cations) and negatively charged sulphate ions (anions). When current flows, the cations migrate to the cathode where they are discharged and deposited as metallic nickel, (Schlesinger and Paunovic, 2010).

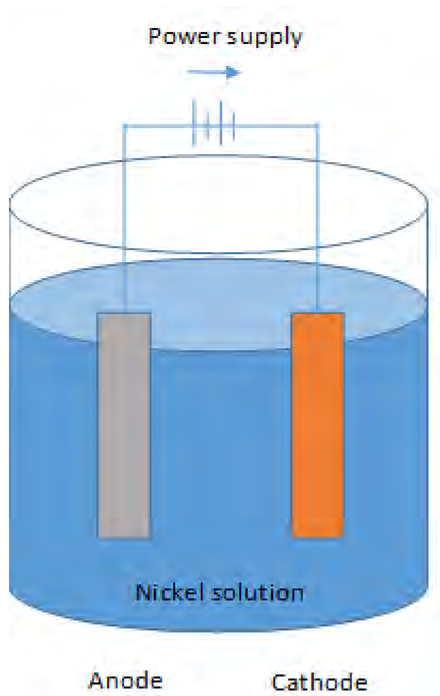


**Figure 2.1:** Electrolytic cell for the deposition of nickel from nickel sulphate solution.

### 2.1.3 Factor Influencing the Properties of Electrodeposited Material

#### 2.1.3.1 Nickel Solution

Professor Oliver P. Watts in the one that formulated an electrolyte in 1916 that combined nickel sulfate, nickel chloride, along with boric acid and optimized the composition of nickel electroplating solution, (Schlesinger and Paunovic, 2010). Nowadays, this Watts solution is widely used and caused the development of modern nickel electrodeposition technology.

Nickel sulphate plays an importance role in the Watts bath solution. This salt has least expensive salt of nickel with a stable anion that is not reduced at cathode, oxidized at the anode, or volatilized. The used of nickel sulphate now is not only to raises the limiting cathode current density but also decreases the resistivity, thus improving plate distribution.

On the other hand, the chloride ion is used to improve anode dissolution by reducing polarization and also increases the conductivity of the bath. It also raises the throwing power as a result of increasing cathode efficiency, electrolyte conductivity, and slope of the cathode potential curve.

For boric acid, it serves as a weak buffer in a nickel solution that controlling the pH in the cathode. Boric acid also is helpful in its smoothing action on the deposit, and very pure with inexpensive form.

Previous studies has found that the modern Watt's formula is more concentrated than the original, and can be represented well by nickel sulphate ($NiSO_4$) 240-340 g/l, nickel chloride ($NiCl_2$) 30-60 g/l, and Boric acid ($H_3BO_3$) 30-40 g/l, (Lowenheim and Schaefer, 1974). However, in other research difference composition of Watt's bath was studied, ($NiSO_4$) 250 g/l, ($NiCl_2$) 40 g/l, and ($H_3BO_3$) 35g/l (Hu, Lin and Wen., 1996).

#### 2.1.3.2 pH Solution

Range of pH in nickel solution usually can vary from 3 to 6. Keeping the pH out of this range might has some unwanted sequences. By increasing the pH solution, the deposition rate of alloy and nickel increased. While, when decreasing in pH, the deposition rate will decreased.

Figure below show the XRD patterns of the Watts Ni deposited using the plating solution at various of pH 3.8, 5.0, 5.5, and 6.0 for 30 minutes of plating time. Based on the result obtained, the preferred orientation of the deposits obtained in the nickel solution with pH less than or equal 5 is Ni (200), while Ni (111) is preferred orientation of the Watts nickel deposits when the plating solution pH is above 5 (Hu, Lin and Wen., 1996).

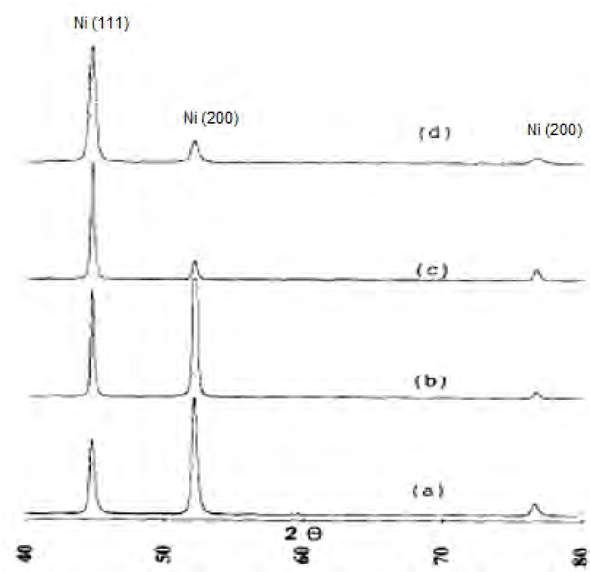


**Figure 2.2:** XRD patterns of nickel deposits from Watts plating solutions with pH values of (a) 3.8; (b) 5.0; (c) 5.5; and (d) 6.0, each at 30 min plating time (Hu, Lin and Wen., 1996).

#### 2.1.3.3 Temperature

Generally, in the electroplating process, the range of temperature usually is 30 to 65 C. But the most practical given range is 40 to 60 C which is perfect. Minimum temperature is 40 C and below than that temperature should be avoided. If the temperature lower than 40 C, any measurable effect can be seen. According to ASTM B 343-92a, an electroplating process is operated at a temperature between 25 to 50°C.

#### 2.1.3.4 Effect of Current Density on the Grain Size of Nickel Coating

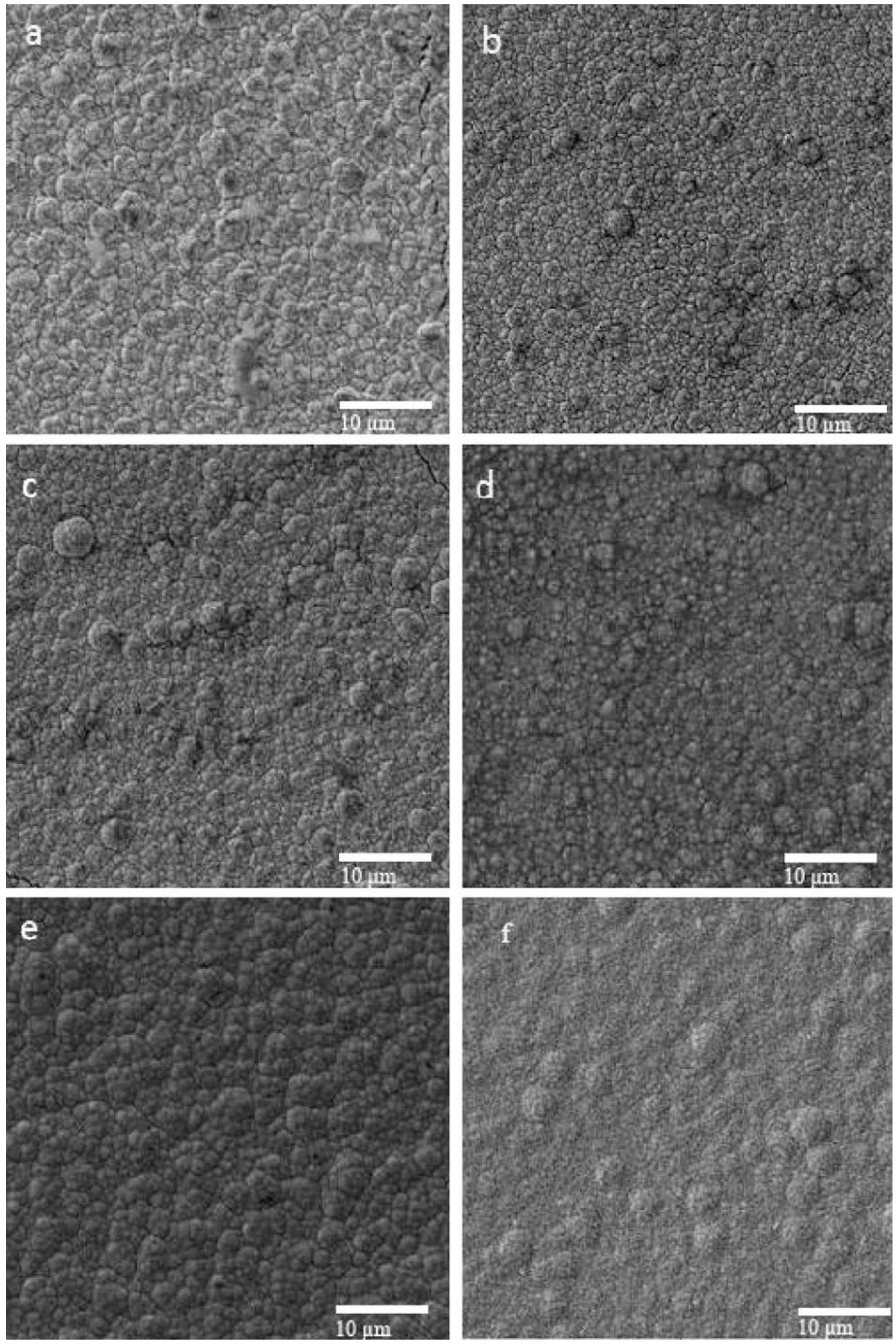


**Figure 2.3:** SEM micrographs of Ni–Co–W coatings produced at (a) 2.5mA/cm$^2$, (b) 5 mA/cm$^2$, (c) 7.5 mA/cm$^2$, (d) 15 mA/cm$^2$, (e) 50 mA/cm$^2$ and (f) 70 mA/cm$^2$ (Farzaneh, Raeissi and Golozar, 2010).