CORROSION RATE OF ALUMINUM ALLOY BY ANODIZING WITH EMPHASIS ON BODY PANEL APPLICATION

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Thesis submitted in accordance with the partial requirements of the University Teknikal Malaysia Melaka for the
Bachelor of Mechanical Engineering (Structure & Material)

By

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APRIL 2009

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Material)":

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I hereby declare that this thesis is the results of
my own research except as cited in references.

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DEDICATION

For My Family

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In the name of ALLAH, the Beneficent, the Merciful. It is with the deepest sense of gratitude of the Almighty ALLAH who gives me the strength and ability to complete this project and thesis as it is today.

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ABSTRACT

This research will be focused on the corrosion rate of aluminum alloy 6061 by anodizing for application of body panel. From the literature review, it is about the aluminum alloy and the metallurgy, corrosion and the applications, specified material and equipment and the mechanical behavior of the prototype which is reported in this study. From the literature review also, the methodology is designed based on similar research area which is the experiment samples will be anodized using Galvanic Cell application and will be anodized at a current density range from 0.012 A/mm^2 to 0.018 A/mm^2 . Then, the result will be compared between each current density. Factors that affected the variables of the result also discussed. The rate of corrosion is calculated from the mass losses that have been achieved by subtracting the mass before cleaning and after cleaning process that had been done. In this thesis, it also includes with, the calculation for the rate of corrosion and also the Scanning Electron Microscope images of the corrosion product under 1000X magnification, such as for images of 0.012 A/mm^2 and 0.018 A/mm^2 . We can see area corroded clearly on the microscope. The result of this research has been successful although that some improvement need to bee done in the future.

ABSTRAK

Penyelidikan ini akan menumpukan kepada kajian tahap perlindungan kakisan terhadap aluminum aloi 6061 kepada aplikasi panel kereta. Daripada kajian ilmiah, ianya menerangkan mengenai aluminum aloi 6061 dan bahagian kaji logam aloi tersebut. Selain itu, kakisan dan kegunaannya, peralatan dan bahan yang khusus dan tingkah laku mekanikal prototaip yg diceritakan dalam ulasan karya. Daripada kajian ilmiah tersebut, metodologi adalah direka-bentuk berdasarkan bidang penyelidikan yang sama, yang mana sampel ujikaji disalutkan dengan menggunakan aplikasi penyalutan Galvanic Cell. Di dalam menghasilkan projek ini, satu persekitaran kakisan yang di percepatkan telah dihasilkan dengan menggunakan perkakasan dan peralatan di dalam makmal kimia dengan menggunakan bahan aloi Al-6061 yang akan disalut-logamkan dengan arus pada kadar antara 0.012 A/mm^2 hingga 0.018 A/mm^2. Hasil-hasil ini kemudiannya akan dibandingkan untuk setiap arus yang berbeza. Faktor-faktor yang mempengaruhi penggunaan juga akan dibincangkan. Kadar kakisan dikira daripada kehilangan berat yang terhasil daripada penolakan berat sebelum dan selepas proses pembersihan dengan menggunakan kertas pasir pelbagai gred. Di dalam tesis ini juga menyentuh kepada pengiraan kadar kakisan bagi sampel ujikaji dan juga imej produk kakisan daripada Scanning Electron Microscope pada pembesaran 1000X. Secara kesimpulannya, kajian ini mendatangkan hasil yang memberangsangkan walaupun terdapat sedikit perubahan perlu dilakukan pada masa hadapan.

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CHAPTER 1

INTRODUCTION

1.1 Background

After the Steel had been dominant material used in building automobiles since the 1920's, Aluminum Alloy has been in the automotive industries structural applications later and it is the best material, which second only to steel as a major factor in the metal industry. The growth has been based on characteristic such as light weight, non-rusting properties, reasonably good strength and easy fabrication, modern metallurgical control of structure and properties, and favorable economics. Commonly, aluminum alloy comes with a wide range of properties and often used in engineering structures. Alloy systems are classified by a number system (ANSI) or by names indicating their main alloying constituents (DIN and ISO).

Selecting the right alloys for a given application entails consideration of several parameters such as strength, ductility, formability weldability, and also corrosion resistance. The growing demand for more fuel-efficient vehicles to reduce energy consumption and air pollution is a challenge for the automotive industry. The characteristic properties of aluminum, high strength stiffness to weight ratio, good formability, good corrosion resistance, and recycling potential make it the ideal candidate to replace heavier materials (steel or copper) in the car to the respond to the weight reduction demand within the automotive industry. (Polmear, 2006)

The corrosion resistance; is always defines as interpretation of the term is 'an attack on a metallic material by reaction with its environment'. Corrosion of metallic materials can be divided into three main groups (E. Bardal, 2003).

1) Wet corrosion, where the corrosive environment is water with dissolved species. The liquid is an electrolyte and the process is typically electrochemical.
2) Corrosion in other fluids such as fused salts and molten metals.
3) Dry corrosion, where the corrosive environment is a dry gas. Dry corrosion is also frequently called chemical corrosion and the best-known example is high-temperature corrosion.

1.2 Problem Statement

Corrosion protection of aluminum alloy by anodizing for application body panel is the problem when reacted with liquids. Although that aluminum offers a wide range of corrosion resistance and its usage as one of the primary metals in the automotive industries, the material also will undergo different type of corrosion by depending on the situation and the chemical properties involves.

By according to the standard test for corrosion of Saltwater Acetic Acid Test (SWAAT) which is to aim at the reproducing lifetime performance of the material, the different automotive heat exchangers, radiator, charge air cooler, evaporator, oil cooler, are subjected to different corrosion environment. This means that for every application the right alloy has to be selected to obtain maximum corrosion resistance. This implies that every application has to be specifically tested under condition that simulated real life exposure.

These studies are mainly to use an anode, a cathode and a conducting circuit to see the corrosion resistance of uncoated and coated aluminum by salt spray test. This is because, the study involves the reactions with liquids which are the corrosion in liquids is electrochemical and requires those materials. The anode is the area that is corroded away, and the cathode receives the electrons from the conducting circuit, which includes the metal and the liquids surrounding it. However, that it is not necessary for the metal to be totally immersed, a single drop of conducting liquid is sufficient for a corrosion reaction to happen.

The aluminum plate that will undergo testing will be cut into pieces of 30mmx30mmx1.695mm and 30x10mm1.695mm. Then, the material will be anodize for coated and after that, the data will be taken after 10 days or more. The weight and type of corrosion involves in this studies are also going to be taken.

1.3 Objectives

The objectives of this project are:

- i. To set up an experiment for anodizing aluminum alloy.
- ii. To investigate the rate of corrosion for uncoated and coated aluminum alloy.
- iii. To analysis the atmospheric corrosion testing by Salt Spray Test.

1.4 Project Scope

The scopes of this project are:

- i. Particularly, material use is aluminum 6061.
- ii. Study the effect of current density on the corrosion resistance of coated aluminum alloy.
- iii. The small scale dimensions and will be done in laboratory environment.

1.1 Table of Gantt Chart For PSM I

ACTIVITIES	WEEK													
i. PSM Proposal: Corrosion Protection of Aluminum Alloy by Anodizing (application for body panel)														
Introduction: i. Gantt Chart ii. Background and Problem Statement iii. Objective and Project Scope														
Literature Review i. Aluminum Alloy Metallurgy ii. Type of Corrosion														
Methodology i. Experiment Equipment ii. Experiment Procedure														
Submit Chapter 1: Introduction														
Submit Chapter 2: Literature Review														
Submit Chapter 3: Methodology														
Submit Chapter 1,2,3														
Submit Full PSM Report and Presentation														

1.2 Table of Gantt Chart For PSM II

ACTIVITIES	WEEK
Material Selection: Corrosion Protection of Aluminum Alloy by Anodizing for Application for Car Body Panel	
Sample Preparation: i. Cut into requested dimensions ii. Preparing Samples iii. Anodizing Process	
Samples Solution & Testing: i. Salt Spray Test ii. Atmospheric Exposure	
Samples Inspection: i. Visual Inspection ii. Optical Microscope Inspection iii. Scanning Electron Microscope	
Samples Data: i. Weighting Samples Using Weight Measurement Unit of 4 Decimal	
Submit Chapter 4 and 5	
Submit Chapter 6: Conclusion	
Submit Full Report PSM II	

CHAPTER 2

LITERATURE REVIEW

2.1 Aluminum Alloy and Metallurgy

Aluminum alloys are widely used in the aerospace and automotive industries in structural applications. Although most metals will alloy with aluminum, comparatively few have sufficient solid solubility to serve as major alloying additions.

Wrought aluminum alloys which those are used for rolled sheet or shapes, forgings or extrusion, have standard alloy composition and temper designation systems. A four digit numerical system developed by the Aluminum Association has traditionally been used to identify composition and it is still used as the common language among the industry. The International Unified numbering System has adopted a five digit designation for aluminum with an A prefix. In this chapter, the only material focuses are the 6000 series aluminum alloy which then focuses only to Aluminum Alloy 6061.

The major alloying elements used in aluminum are silicon, magnesium, and copper. Aluminum as indicated by its position on electromotive force (EMF) series is a thermodynamically reactive metal; among structural metals, only beryllium and magnesium are more reactive. Aluminum owes its excellent corrosion resistance and its usage as one of the primary metals of commerce to the barrier oxide film that is bonded strongly to its surface and that if damaged, re-forms immediately in most environments. On a surface freshly abraded and then exposed to air, the barrier oxide film is only 1nm thick but is highly effective in protecting aluminum from corrosion.

The 6000 Series Aluminum Alloy is moderately high strength and very good resistance to corrosion make the heat-treatable wrought alloys of the 6xxx series (aluminum-magnesium-silicon) highly suitable in various structural, building, marine, machinery, and process-equipment applications. The 6xxx series is heat-treatable Mg-Si alloys. AA6061 is used widely for hot extrusions.[1] For example, window and door frames.

2.1.1 Aluminum Alloy

Although aluminum is now the second most used metal, it is a comparative newcomer among the common metals because of the difficulty in extracting it forms its ores. Unlike iron, for example, it combines so strongly with oxygen that it cannot be reduced with carbon. An impure form of aluminum was first isolated in 1809 in England by Sir Humpry Davy which he produced from alum, its bisulphate salt. He called this new metal 'aluminum', which is the name still used in the United States, whereas it is now known as 'aluminium' in Europe and most other countries.[1]

Aluminum owes its excellent corrosion resistance and its usage as one of the primary metals of commerce to the barrier oxide film that is bonded strongly to its surface and that, if damaged, reforms immediately in most environments. On a surface freshly abraded and then exposed to air, the barrier oxide film is only 1nm thick but is highly effective in protecting the aluminum from corrosion.

The oxide film that develops in normal atmospheres grows to thicknesses much greater than 1nm and is composed of two layers. The inner oxide next to the metal is a compact amorphous barrier layer whose thickness is determined solely by the temperature of the environment. Wrought aluminum alloys those used for rolled sheet or shapes, forgings, or extrusions, have standard alloy composition and temper designation systems.

2.1.2 Heat-Treatable Aluminum Alloys

Aluminum alloys are not allotropic, they do not undergo a phase or structure change like steels when heating. But if the right alloying additions are present they can be heat treated by solution heat treating and precipitation hardening. In the early days of 1930's solution heat treatment was referred to as ST, and many times precipitation hardening was referred to as aging. Solution heat treatment involves temperatures very close to the melting point of the aluminum alloy, usually 200°F to 300°F below the melting point. The purpose is to provide enough thermal energy to dissolve in a solid solution when the alloy elements present. In the case of 6061, the major alloy element is magnesium, and by taking the part to 920°F, the magnesium present within the 6061 will dissolve or disperse uniformly throughout the solid aluminum part.

Table 2.1: Properties of principal age-hardenable aluminum alloys for 1/16-in sheet in several tempers

Alloy	Composition	Temper	Tensile Strength, MPa	Yield Strength, MPa	Elongation in 50mm, %
2014	4.4 Cu, 0.8 Si, 0.8 Mn, 0.4 Mg	0	190	100	22
		T4	440	280	18
		T6	490	420	10
2024	4.5 Cu, 0.6 Mn, 1.5 Mg	0	190	80	20
		T4	475	330	20
		T6	480	400	10
		T86	525	495	6
6061	**1.0 Mg, 0.6 Si, 0.2 Cr**	**0**	**125**	**55**	**25**
		T4	**245**	**150**	**25**
		T6	**315**	**280**	**12**
		T91	**410**	**400**	**6**
7075	5.5 Zn, 2.5 Mg, 1.5 Cu, 0.3 Cr	0	230	105	17

Without getting into the solid state physics of the metallurgical reactions, dissolution does occur but only at this high temperature. However, if the parts are slowly cooling down, the copper wants to come back out of solution. Quenching is a very rapid cooling down, using water on the order of 500°F to 600°F per second. Quenching locks in place all alloy elements that have been dissolved at the high solution heat treating temperature. Before the alloy additions can think about changing places and moving back out of solution, they are already locked in place by the rapid quench cool down. The result is called a "super saturated solid solution" an unstable condition. Quenching is critical to proper solution heat treatment.

Aging Precipitation Hardening can now happen under the right conditions. In the case of natural aging of 6061, or aging at room temperature, the dissolved copper slowly comes back out of solution over an extended time (96 hours minimum), forming CuAl precipitants. The word precipitant comes from the weather term precipitation meaning to separate and fall from solution (clouds). Precipitated particles in heat treatable aluminum alloys strengthen the alloy by pinning or locking up numerous microstructure features in the aluminum. Other heat treatable alloys like 2024 and 7075 undergo very similar precipitation reactions, with the actual precipitated particles differing depending on whether zinc, magnesium, manganese, silicon or copper additions are present. The way that metallurgists control the formation of these precipitants will determine the mechanical and corrosion properties.

In the case of artificial aging or precipitation hardening, the previously solution heat treated and quenched parts are subjected to elevated temperatures (instead of room temperature) in the range of 225°F to 375°F over extended periods of time (4-24 hours). The precipitants formed and grown here are more controlled and substantial in nature, resulting in higher mechanical properties as compared to naturally aged conditions.