UNIVERSITI TEKNIKAL MALAYSIA MELAKA

The study of Corrosion on Surface Metal of Aluminum Alloy (6063) at Windows & Doors Frame

Thesis submitted in accordance with the partial requirements of the Universiti Teknikal Malaysia Melaka for the Degree of Bachelor of Manufacturing Engineering (Engineering Material) with Honours

By

MOHD SHAHRUL BIN MOHD NOOR

Faculty of Manufacturing Engineering

Apr 2008

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS TESIS*

JUDUL: **THE STUDY OF CORROSION ON SURFACE METAL OF ALUMINUM ALLOY (6063) AT WINDOWS AND DOOR FRAME**

SESI PENGAJIAN: 2/2007-2008

Saya **MOHD SHAHRUL BIN MOHD NOOR**

mengaku membenarkan tesis (PSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hak milik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☑	TIDAK TERHAD	

(TANDATANGAN PENULIS)

Alamat Tetap:
63R, Rumah Murah Kos 3,
Jalan Merbuk,
23000 Dungun, Terengganu.

Tarikh: 20/5/08

Disahkan oleh:

(TANDATANGAN PENYELIA)

Cop Rasmi:

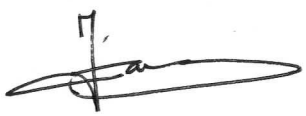
MOHD FAIRUZ DIMIN
PENSYARAH
JABATAN [illegible]
FAKULTI KEJUR[illegible]N
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Tarikh: 20/5/08

* Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

APPROVAL

This thesis submitted to the senate of UTeM and has been accepted as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Material). The members of the supervisory committee are as follow:



..... 20/5/08

Main Supervisor

(Official Stamp and Date)

MOHD FAIRUZ DIMIN
PENSYARAH
JABATAN PROSES PEMBUATAN
FAKULTI KEJURUTERAAN PEMBUATAN
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DECLARATION

I hereby, declared this thesis entitled "The Study of Corrosion on Surface Metal of Aluminum Alloy (6063) at Windows and Door Frame" is the results of my own research except as cited in references.

Signature	:	... ...
Author's Name	:	MOHD SHAHRUL BIN MOHD NOOR
Date	:	5 MAY 2008

ABSTRACT

In this study, the corrosion behavior of Aluminum Alloy 6063 for window and door frames is investigated. Besides that, the implementation of this research is to identify the effect of concentration of aggressive ion or environment, pH and exposure times to the corrosion rate. The purpose of doing this project is to measure the corrosion rate of aluminum alloy 6063 used for window and door frame of residential house constructed nearby the sea. In order to study the corrosion of the aluminum alloy 6063, the immersion testing is used. The corrosive medium used in this study is Natrium Chloride (NaCl) with the various concentrations. The specimen is fully immersed in the beaker with NaCl solution in concentration range of 0.1M to 5M against period of 7, 14, 21, and 28 days. Prior to any test, the samples were mechanically polished on a range of abrasive paper to a 1000 grit finish and washed in distilled water. The mass of the specimen is weighted before and after the test to measure the mass loss and further the corrosion rate. The micrographic analysis showed that the alloy suffered from pitting attack on its surface. The corrosion rate of the alloy increased with an increase in test concentration with the higher corrosion rate for the 5M concentration. Result indicated that the intensity of corrosion attack is influenced by concentration and pH of solution but not for the exposure times.

ABSTRAK

Di dalam penyelidikan ini, sifat kakisan bagi bingkai tingkap dan pintu Aluminum Aloi 6063 adalah di kaji. Selain itu, kajian ini adalah bertujuan untuk mengenal pasti kesan kepekatan ion, nilai pH dan masa kepada kadar kakisan. Tujuan kajian ini dijalankan adalah untuk menentukan kadar kakisan bingkai tingkap dan pintu Aluminum Aloi 6063 yang digunakan dalam kawasan perumahan yang berdekatan dengan laut. Untuk mengkaji kekakisan aluminum alloy 6063 ini, kaedah rendaman digunakan. Medium kakisan yang digunakan di dalam kajian ini adalah larutan natrium klorida dengan kepekatan yang berbeza-beza. Bahan sampel direndam sepenuhnya di dalam bikar yang mengandungi larutan natrium klorida dengan siri kepekatan 0.5M hingga 5.0M. Bahan sampel ini dikaji pada tempoh masa 7,14,21 dan 28 hari. Sebelum apa-apa ujian dijalankan, bahan sampel tersebut dibersihkan secara mekanikal iaitu menggunakan kertas pasir gred 1000 dan kemudiannya dibasuh menggunakan air suling. Berat sampel sebelum dan selepas ujian ditimbang untuk menentukan berat sampel yang telah berkurang dan seterusnya kadar kakisan sampel tersebut. Analisa mikrografik menunjukkan bahawa terdapat kakisan lubang pada permukaan sampel. Kadar kakisan sampel meningkat apabila kepekatan larutan natrium klorida tinggi di mana kadar sampel terkakis lebih cepat pada kepekatan 5M. Keputusan mendapati kekakisan sampel di pengaruhi oleh kepekatan dan juga nilai pH tetapi tidak dipengaruhi oleh tempoh masa.

DEDICATION

For all your advice and encouragement, this thesis is gratefully dedicated to my family and my friends. Thank you very much for your continuous support and effort towards the publication of this thesis.

ACKNOWLEDGEMENT

First of all, thanks to God for His blessing and guidance in accomplishing this research. With His mercy and bless, I was successfully complete this research as required.

Sincerely, I would like to express my appreciation towards my advisor, Mr. Mohd Fairuz Dimin for his supports, encouragement, and provides a lot of guidance and ideas for my project research. His knowledge and experience is really assisting me to accomplish this research successfully.

I also would like to send my grateful to Mr Ridzwan, Mr. Ismail, Mr Sharman, Mr Azhar and all technicians for their assistance during the laboratory testing of this research. I wish to express my appreciation to the workforce of Universiti Teknikal Malaysia Melaka (UTEM) especially the Faculty of Manufacturing Engineering staff for their cooperation and contribution.

In addition, big thanks to my lovely family for always give their support in terms financial, moral and motivation to me. Finally, I would like to express my thankful to my friend and to those who helped me to accomplish the research.

TABLE OF CONTENTS

Abstract i
Abstrak ii
Dedication iii
Acknowledgement iv

Table of Contents v
List of Figures viii
List of Tables x
List of Abbreviations, Symbols, Specialized Nomenclature xi

1. INTRODUCTION 1
1.1 Background 1
1.2 Statement of the Purpose 3
1.3 Problem Statements 4
1.4 Objectives 5
1.5 Scope of Study 5

2. LITERATURE REVIEW 6
2.1 Corrosion 6
2.1.1 Introduction 6
2.1.2 Electrochemical Concept 8
2.1.3 Corrosion Process 11

2.2 Corrosion of Aluminum Alloys 12
2.2.1 Introduction 12
2.2.2 Protective Layer 13
2.2.3 Alloying Composition Effect 14

2.2.4 Metallurgical and Mechanical Effect..... 14
2.2.5 Acidity/Alkalinity..... 15
2.2.6 Elevated Temperature..... 16

2.3 Pitting Corrosion..... 16
2.3.1 Characteristic Features..... 18
2.3.2 Mechanism..... 18
2.3.3 Shape of Pits..... 21
2.4 Aluminum Alloy..... 22
2.4.1 Introduction..... 22
2.4.2 Aluminum Alloy Element..... 23
2.4.3 Temper Designations System..... 25
2.4.4 6063 Aluminum Alloy..... 26
2.4.4.1 6063 Temper Designations System..... 26
2.4.4.2 Chemical Composition..... 27
2.4.4.3 Physical Properties..... 27
2.4.4.4 Mechanical Properties..... 28

3. METHODOLGY..... 30
3.1 Introduction..... 30
3.2 Sample Preparation..... 31
3.2.1 Surface Preparation..... 32
3.3 Immersion Test..... 32
3.4 Examining and Evaluation..... 34
3.4.1 Corrosion Rate Measurement..... 35

4. RESULT..... 37
4.1 The pH Measurement..... 37
4.2 General Appearance..... 38
4.3 Specimen Weight Measurement Data..... 39

4.4 Mass Loss Measurement 41
4.5 Corrosion Rate 43
4.6 Corrosion Rate Calculation 44
4.7 Micrographic Observation 46

5. DISSCUSION 50
5.1 Mass Loss Analysis 50
5.2 Corrosion Rate Analysis 57
5.3 Microscopic Analysis 62

6. CONCLUSION 64
6.1 Conclusion 64
6.2 Suggestion for Future Work 65

REFERENCE 66

APPENDIX 68

LIST OF FIGURE

1.1	Aluminum alloy 6063 window frame	2
2.1	Corrosion process	7
2.2	Pourbaix diagram of alumina oxide film at 25°C	13
2.3	Passivity and film breakdown	15
2.4	Initiation of pitting corrosion	17
2.5	Pitting corrosion	20
2.6	Pits shape	21
3.1	Aluminum alloy 6063-T6 specimen	31
3.2	Immersion Testing	33
4.1	Specimen surface after 4 weeks immersion testing	38
4.2	The specimen surface which is immersed in 0.5M NaCl solution	46
4.3	The specimen surface which is immersed in 1.0M NaCl solution	47
4.4	The specimen surface which is immersed in 2.0M NaCl solution	47
4.5	The specimen surface which is immersed in 3.0M NaCl solution	48
4.6	The specimen surface which is immersed in 5.0M NaCl solution	48
4.7	Composition peak of specimen after immersion testing	49
5.1	Graph of mass Loss versus exposure time for 0.5M concentration	51
5.2	Graph of mass Loss versus exposure time for 1.0M concentration	51
5.3	Graph of mass Loss versus exposure time for 2.0M concentration	52
5.4	Graph of mass Loss versus exposure time for 3.0M concentration	52
5.5	Graph of mass Loss versus exposure time for 5.0M concentration	53
5.6	Graph of mass loss versus concentration	54
5.7	Graph of mass loss versus pH value	55

5.8	Typical example of acceptable cleanup of corrosion pits	56
5.9	Graph of corrosion rate versus exposure time for 0.5M concentration	57
5.10	Graph of corrosion rate versus exposure time for 1.0M concentration	58
5.11	Graph of corrosion rate versus exposure time for 2.0M concentration	58
5.12	Graph of corrosion rate versus exposure time for 3.0M concentration	59
5.13	Graph of corrosion rate versus exposure time for 5.0M concentration	59
5.14	Graph of corrosion rate versus concentration	60
5.15	Graph of corrosion rate versus pH values	61
5.16	Corrosion pits under 10x magnifications	62

LIST OF TABLE

2.1	6063 Alloy chemical composition	27
3.1	Variety of unit for corrosion rate	36
4.1	pH measurement	37
4.2	Specimen weight after 1 week immerse in different concentration	39
4.3	Specimen weight after 2 week immerse in different concentration	40
4.4	Specimen weight after 3 week immerse in different concentration	40
4.5	Specimen weight after 4 week immerse in different concentration	41
4.6	Mass Loss Measurement	42
4.7	Corrosion rate measurement data	43
4.8	Composition percentage of specimen after immersion testing	49

LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

g	-	Gram
m	-	Meter
cm	-	Centrimeter
cm^2	-	Centrimeter Cubic
mm	-	Milimeter
mm/y	-	Milimeter per year
^0C	-	Degrees Celsius
%	-	Percentage
T	-	Temper designation system
SEM	-	Scanning Electron Microscope
EDX	-	Energy Dispersive X -ray spectroscopy
Vs	-	Versus
Al	-	Aluminum
Cl	-	Chloride
H^+	-	Hydrogen Ion
NaCl	-	Natrium Chloride
M	-	Molarity
ASTM	-	American Standard Testing Material

CHAPTER 1
INTRODUCTION

1.1 Background

Aluminum alloy is one of the most abundant metals on earth and offer an extremely wide range of capability and applicability, with a unique combination of advantages that make it the material of choice for numerous products and markets. Generally, aluminum alloy has properties such as low density (light weight), high strength-to-density ratio, good corrosion resistance, good electrical/thermal conductivity, highly workable, naturally good looking, and eminently recyclable. It was widely use in variety application due to their excellent properties and natural advantages. Aluminum alloys are useful to us due to their light weight and good strength. Commonly referred to as the strength to weight ratio, high strength aluminum alloys are at the top of the list of choices for critical efficient structures. Aluminum alloys have one-third the density of steel and approximately 50% lower density than titanium alloys. However, they are not as strong as high strength steels or titanium, therefore more aluminum is needed to carry the same stresses.

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 1 nm thick but is highly effective in protecting the aluminum from corrosion. 6xxx series aluminum alloys (*6063*) are widely used in the building and construction due to their extrudability and good corrosion resistance. The extrudability of this alloy making them the first choice for architectural and structural members where unusual or

particularly strength- or stiffness-criticality is important. In addition, it also has excellent corrosion resistance for normal environment condition compare to other metal. The architectural application of this alloy such as door and window frames. Figure 1.1 shows the window frame of aluminum alloy 6063 that are widely used in construction of residential house.

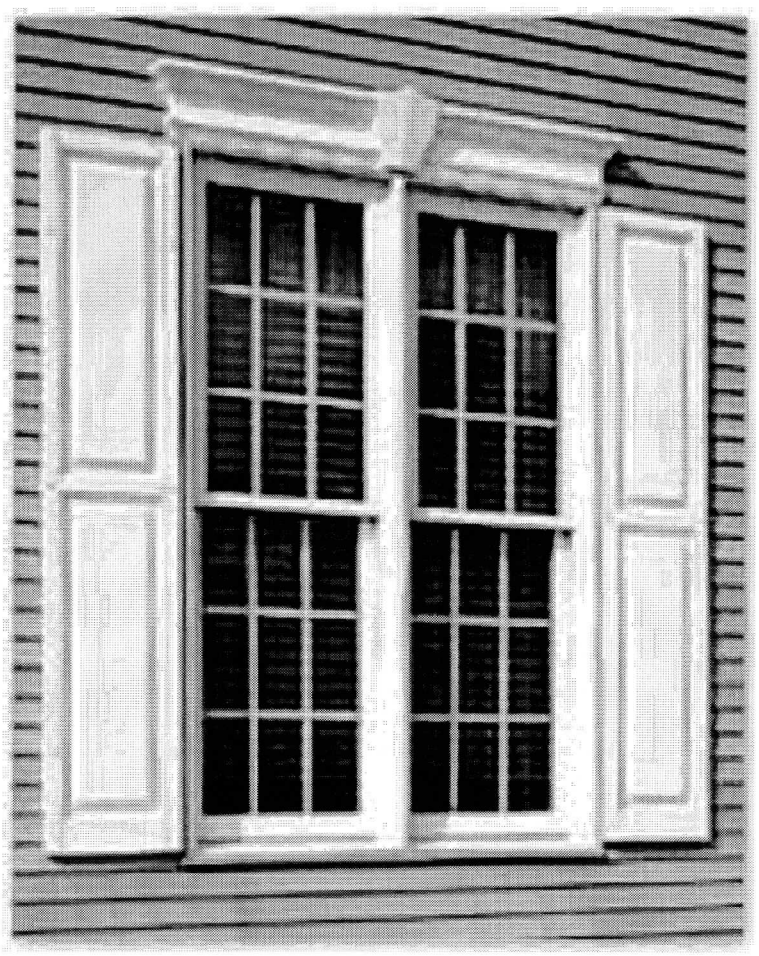


Figure 1.1: Aluminum alloy 6063 window frame

Although aluminum 6063 alloy has a large advantage when compared to other metals, it is not always completely resistant to corrosion. When exposed in extreme pH conditions its protective oxide layer can become unstable and broken. In environment which is highly acidic or basic, breakdown of the protective layer can occur and its automatic regeneration may not be fast enough to prevent corrosion. The oxide film of this alloy usually stable in the pH range of 4.5 to 8.5 but the nature of the compounds present is crucial which is certain soils tend to be corrosive to aluminum, particularly non-draining clay-organic mucks. As a general rule, contact with clay soil should be minimized unless special corrosion treatment measures are instituted. The following factors may affect the stability of the aluminum oxide and thereby cause corrosion:

- The oxide is not stable in acidic (pH < 4) or alkaline (pH > 9) environments
- Aggressive ions (chlorides, fluorides) may attack the oxide locally.
- Certain elements (Ga, Tl, In, Sn, Pb) may become incorporated in the oxide and destabilize it .

In the case of window and door frame for the construction of residential house, there are susceptible to more corroded in environment nearby the sea. This is because the sea water has contained chlorides which are can corroded the aluminum alloy 6063. The moisture and evaporate of seawater combined with the presence of chloride in atmosphere will attack the window and door frame of aluminum alloy 6063 thus corroded that frame.

1.2 Statement of the Purpose

The purpose of this research is to study and analyzed the corrosion behavior of window and door frame of aluminum alloy 6063 used for construction of residential house. The corrosion behavior is such as pitting corrosion and the corrosion rate is analyzed to predict the weight loss of the frame in the real conditions.

1.3 Problem Statements

The use of aluminum alloy 6063 as a material for window and door frame in the building construction especially for construction of residential house has create much potential in recent years. In the earlier period time, another material is used in application of window and door frame. The advantages of aluminum alloy over another metal are acceptable as good corrosion resistance, low density, and extrudability and this make the aluminum alloy is the most suitable material for construction application. In the construction application, they need the material that is good corrosion resistance and thus the lifetime of the equipment will be long. In normal condition or environment, the aluminum alloy is very good corrosion resistance due to their natural protective oxide layer that can prevent the corrosion from occur.

Although aluminum alloy are good corrosion resistance but in certain condition or environment it will become damage due to the corrosion process. For example, residential house using the frame constructed nearby the sea will be more easily corroded due to the salty air surrounding the sea. This environment with presented of chloride are able to attack and damage the surface of aluminum alloy 6063 window and door frame. The chloride is one of the halide ions that are able to damage the protective oxide layer of aluminum alloy. Even though, the break down protective layer can renewal but with the aggressive ions attack it are unable to prevent the corrosion.

Studies on the corrosion behavior of aluminum alloy 6063 window and door frame have been done include the properties, electrochemical reaction, environment aspect, corrosion type and the corrosion rate of the material. In this project, the corrosion behavior is simulated within the laboratory test.

1.4 Objectives

The purpose of this project is:

i) To study and analyze the corrosion behavior of aluminum alloy 6063 at window and door frame

ii) To identify the corrosion type of aluminum alloy 6063 at window and door frame

iii) To measure the corrosion rate of aluminum alloy 6063 used for window and door frame of residential house constructed nearby the sea.

iv) To study the effect of solution concentration, pH and exposure time to the corrosion rate.

1.5 Scope of study

The laboratory test is used to accelerate the corrosion testing for the aluminum alloy 6063 window and door frame. The immersion techniques of the specimen in the sodium chloride solution with various concentrations were carried out to determine the corrosion behavior and corrosion rate. A part from that, the metal weight loss measurement is used to measure the corrosion rate.

CHAPTER 2
LITERATURE REVIEW

2.1 Corrosion

2.1.1 Introduction

Corrosion is the deterioration or destruction of materials due to chemical reaction with their environment. Generally, the term of corrosion is refers to the metal but sometimes also applied to the degradation of plastics, concrete and wood. Metals are obtained from their ores and oxides, and the extraction of metals from their ores requires a considerable amount of energy. In nature, aluminum is found as alumina oxide and commercially be alloying with other element such as magnesium or silicon. These metals can be regard as being in a metastable state and will tend to lose their energy thus tendency to return to their natural state (corrosion) as show in figure 2.1.

Corrosion can be classify into eight forms which is general corrosion, galvanic or two-metal corrosion, pitting, crevice corrosion, intergranular corrosion, dealloying or selective leaching, erosion corrosion and stress corrosion cracking (SCC).

General corrosion is corrosion that proceeds at approximately the same rate (uniformly) across the entire exposed surface, galvanic corrosion is defined as when two dissimilar metals are in contact or electricity connected in the same electrolyte, one of them is preferentially corroded whereas the other remains free from corrosion, crevice corrosion as define as intensive localized form of corrosion usually

associated with stagnant solution occurs within crevice or shielded areas on metal surfaces. While pitting is localized corrosion of a surface usually a metal confined to a point or small area that is in the form of a cavity and it is associated with the formation of pits. Intergranular is defined as preferential attack on the grain boundary phases or the zones immediately adjacent to them. Dealloying is the removal of one of the components of the alloy by corrosion and erosion corrosion is the deterioration due to relative movement between a corrosive fluid and metal surface. SCC is defined as the delayed failure of alloys by cracking when exposed to certain environments in the presence of static tensile stress.

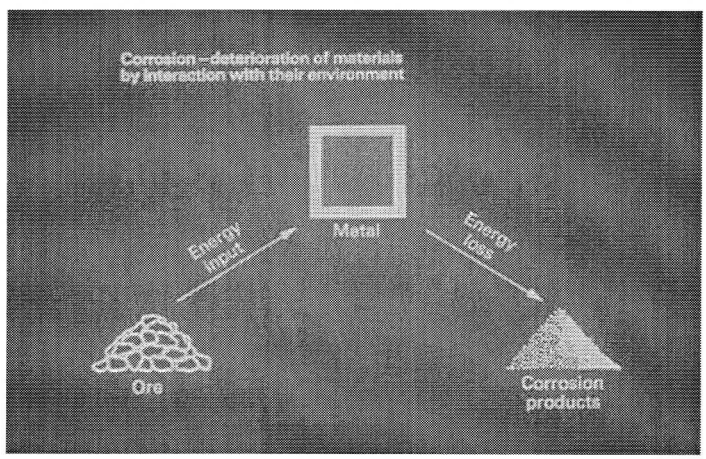


Figure 2.1: Corrosion process

2.1.2 Electrochemical Concept

Usually all corrosion reactions an electrochemical process which is required anodes and cathodes in electrical contact as well as an ionic conduction path through an electrolyte. The chemical nature of this electrolyte may be acidic, alkaline, or neutral. The electrochemical process can be exemplified by the attack on aluminum in acidic electrolyte which is by hydrochloric acid. When aluminum is exposed in dilute hydrochloric acid, vigorous reactions occur with the creation of alumina chloride and evolved of hydrogen gas. The reaction is:

$$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2 \qquad (2.1)$$

This equation can be simplified due to consideration that the chloride ion is not involved and it becomes:

$$Al + 2H^+ \rightarrow Al^{3+} + H_2 \qquad (2.2)$$

From the equation above, it can be seen aluminum undergo oxidation and forming aluminum ion while hydrogen ions undergo reduction and forming hydrogen gas during the reaction. The basis of this reaction is charge transfer; therefore it can be represented into two partial reactions:

$$Al \rightarrow Al^{3+} + 3^{e-} \qquad \text{Oxidation}$$

$$2H^+ + 2e^- \rightarrow H_2 \qquad \text{Reduction}$$

In term of electrochemistry, a production of electron or an increase in valence as represented in equation above is called an *oxidation or anodic reaction* and an electron consumption or decrease in valence charge as represented in equation above is called as *reduction or cathodic reaction*. The site for oxidation or anodic reaction is identifying as anode while the site for reduction or cathodic reaction is identify as cathode. At anode site, the aluminum goes into solution as aluminum ions, this

constituting the anodic reaction. The negative charge will rapidly create up in the metal when aluminum atoms was oxidized to ions which they release electron and prevent further anodic reaction, or corrosion. Therefore this dissolution will only persist if the electrons released can go by to a site on the metal surface where a cathodic reaction is possible. At a cathode site, the electron removed from the metal due to the reaction with some reducible component of the electrolyte. The corrosion of aluminum in hydrochloric acid is therefore an electrochemical process which is occurring due to charge transfer by anodic and cathodic reaction. The rates of the anodic and cathodic reactions must be equivalent (in terms of electron production and consumption) according to Faraday's Laws and being determined by the total flow of electrons from anodes to cathodes which is called the "corrosion current", I_{cor}.

The anodic reaction is the oxidation of a metal into the solution and form as ions. In general form, the anodic reaction in every metal corrosion process can be written as:

$$M \rightarrow M^{n+} + ne^{-} \qquad (2.3)$$

Where; M = type of metal

n = valence of metal involved

Cathodic reaction varies from medium to medium but here also some generalization is possible. There are some type of cathodic reaction usually come across in metal corrosion process. The most common are:

- Hydrogen Evolution
    - Occur if the corrosive medium is an acid solution
    - The reaction $2H^{+} + 2e^{-} \rightarrow H_2$ (2.4)