EFFECT OF COATING CONDITION ON THE CORROSION PROPERTIES OF MILD STEEL SUBSTRATE

KHAIRUL NIZAM BIN ZAINUDDIN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) with Honours.

by

KHAIRUL NIZAM BIN ZAINUDDIN

FACULTY OF MANUFACTURING ENGINEERING

2009

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

JUDUL: **Effect of Coating Condition on the Corrosion Properties of Mild Steel Substrate**

SESI PENGAJIAN: **2009 Semester 2**

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TAJUK: EFFECT OF COATING CONDITION ON THE CORROSION PROPERTIES OF MILD STEEL SUBSTRATE

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Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka(UTeM)
Karung berkunci 1200, Ayer Keroh,
75450, Melaka

DECLARATION

I hereby declare that this report entitled **"EFFECT OF COATING CONDITION ON THE CORROSION PROPERTIES OF MILD STEEL SUBSTRATE"** is the result of my own research except as cited in the references.

Signature	:	.....
Author's Name	:	Khairul Nizam Bin Zainuddin
Date	:	22 May 2009

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (*Engineering Materials*) with Honours. The member of the supervisory committee is as follow:

.....

En. Mohd Yuhazri Bin Yaakob
(Principal Supervisor)

MOHD YUHAZRI BIN YAAKOB
Pensyarah
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka

ABSTRACT

Corrosion is a one problem that encountered in industry particularly against steel. There is much prevention and solution that researches and engineers applied in order to stop this problem from occurring in the future. In this project, the corrosion prevention of tin electroplating is carried out on the mild steel with several specimens. The implementation of this project is done with all the specimens are through surface preparation for electroplating, electroplating process with various coating parameters, determination of thickness coating, surface morphology examination before and after specimens corroded by using scanning electron microscope and followed by determination of corrosion rate based on Tafel extrapolation. The standard for preparation of tin electroplating is according to the ASTM B545, surface preparation referred to the ASTM B183 and corrosion rate measurement referred to the ASTM G102. The parameters that involved are current density of coating, times and constant of solution bath. As a result, the best parameter is determined which from current density of 6 A/dm^2 and 10 minutes of coating time. This parameter also capable to give a less of corrosion rate both condition of coating which are scratched coating and unscratched coating. The lower of current density is promoting the formation of tin whiskers and thin of coating but it gives a less of corrosion rate. The higher of current density promotes formation of cracking and worst of corrosion rate.

ABSTRAK

Kesan keadaan saduran terhadap sifat kakisan ke atas keluli lembut adalah tajuk bagi projek sarjana muda di mana kajian ini dijalankan untuk mengetahui keadaan saduran yang paling terbaik sekali berdasarkan pelbagai saduran parameter yang digunakan. Dalam kajian ini, kaedah saduran elektrik menggunakan bahan timah digunakan untuk menyadur ke atas keluli lembut. Proses yang dijalankan menggunakan beberapa spesimen. Perlaksanaan projek ini dilakukan di mana semua specimen melalui persediaan permukaan spesimen sebelum proses saduran elektrik, proses saduran elektrik, penentuan ketebalan saduran yang telah dibuat ke atas spesimen dengan menggunakan *scanning electron microscope*, pemerhatian mikrostruktur pada permukaan spesimen sebelum dan selepas proses kakisan berlaku dan akhir sekali spesimen-spesimen melalui proses penentuan kadar kakisan dengan menggunakan persisian Gamry. Piawaian yang digunakan dalam kajian ini terdiri daripada ASTM B545 untuk persediaan spesimen bagi proses saduran elektrik, ASTM B183 untuk persediaan permukaan spesimen dan ASTM G102 bagi untuk pengiraan kadar penentuan kakisan. Sebagai keputusan yang diperolehi, parameter yang terbaik dapat ditentukan iaitu pada ketumpatan arus 6 A/dm^2 dan 10 minit masa saduran. Pada parameter ini, ia berupaya untuk memberikan keseragaman saduran pada permukaan timah, tiada pembentukan rerambut dan menunjukkan kadar pengaratan yang kurang. Pada ketumpatan arus yang rendah, keputusan dan data menunjukkan pembentukan rerambut, saduran yang nipis tetapi menunjukkan kadar pengaratan yang kurang. Pada ketumpatan arus yang tinggi, saduran timah memberikan keputusan rekahan pada permukaan timah dan data pengaratan pada kadar yang teruk.

DEDICATION

To my beloved parents

Siti Zaleha Bt. Abdul Manaf

Zainuddin B. Karmani

ACKNOWLEDGEMENT

First of all I am grateful to ALLAH S.W.T for blessing me in finishing my final year project with success in achieving my objectives to complete this project. Secondly I want to thank my family for giving morale support and encouragement in completing my project and also throughout my study in UTeM as they are my inspiration to success. I also would like to thank my supervisor Mr. Mohd Yuhazri Bin Yaakob and Miss Siti Rahmah Binti Shamsuri for guiding and supervising my final year project throughout this semester. They have been very helpful to me in finishing my project and I appreciate every advice that they gave me in correcting my mistakes. I apologize to both of my supervisor for any mistakes and things that I done wrong while doing my project. I want to thank all my friends that have given me advice and encouragement in completing my project. Thank you very much to all and May ALLAH bless you.

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LIST OF ABBREVIATIONS

NaCl	-	Natrium Chloride
Ohm	-	Measurements to Measure Resistance
µm	-	Micrometer
g/L	-	Gram per Liter
A/dm^2	-	Ampere per Decimeter Square
AC	-	Alternating Current
DC	-	Direct Current
mpy	-	Mils per Year
UTeM	-	Universiti Teknikal Malaysia Melaka
ASTM	-	American Society for Testing and Materials
SEM	-	Scanning Electron Microscope
PVD	-	Physical Vapor Deposition

LIST OF SYMBOLS

α	-	Ferrite
Fe	-	Iron
O_2	-	Oxygen
H	-	Hydrogen
H_2O	-	Water
Cl	-	Chloride
Ni	-	Nickel
OH	-	Hydroxide Molecule
Sn	-	Stannum
i_{corr}	-	Corrosion Current Density
SnO_2	-	Stannum Oxide

CHAPTER 1
INTRODUCTION

1.1 Background

Corrosion engineering is the application of science and art to prevent or control corrosion damage economically and safely. Corrosion is defined as the destruction or deterioration of a material because of reaction with its environment. Most of the corrosion prevention techniques are coating. This research is presented to identify which coating conditions on the mild surfaces are suitable due the selected environment as well as corrosion properties. According to the type of coating, the tin-electroplating was chosen to coat the materials (Fontana, M.G., 1987).

Now a day, corrosion matter must be prevented to ensure all the materials particularly made by metals are capable to extend the life span with approaches of various environments. In the world of engineering, corrosion and coating have a correlation. Typically, once the metals are fabricated and used for any application, its must be followed by coating method in order to prevent any corrosion or deterioration thus retain the mechanical behavior. According to the relation of work in the industrial field, the applications of electroplating techniques are widely used such as coating on the watch by using chromium electroplating (Fontana, M.G., 1987).

This research is implementing to enhance the understanding of how the tin electroplating is carried out. The thickness of coating is the most influences the corrosion properties. For example, the steels or metals that will immerse at the salt water needs undergo the extra protection in order to avoid the materials easy to damage and corrode (Fontana, M.G., 1987).

1.2 Problem Statement

Metal furnishing is the name given to a wide range of process to carry out in order to modify the surface properties of a metal, example by deposition of a layer of another metal, alloy, composite, or by forming the oxide film. Currently, the metal steel industry lay in desire to enhance the value of metal articles by improving their appearance and in the same time not forgetting the mechanical properties of each steel application. The trend now is towards surface treatment which will impart corrosion resistance.

According to the previous research at several industries, pure tin plating can cause a whisker mechanism on the plating. This is particularly in the electrical components which widely used tin plating in order to inhibit or prevent the corrosion during its application. In the HP (Hewlett Packard) products, tin plating is susceptible to the well-known reliability problem of tin whiskers. Whiskers may form as thin filaments of tin after plating and can cause electrical shorts and product failures. At this time, there are several critical and unresolved questions regarding tin plating and tin whiskers that need to be satisfactorily answered before all of HP can support the transition to tin plating and begin broadly accepting tin-plated parts (Yip, W. C., 2006).

In this regard, the plating process parameters and plating chemistries needed to control the tin plating in a repeatable "no whiskers condition" is not understood adequately by the plating industry. In order to make tin plating an industry-standard solution, the plating process parameters and conditions required to eliminate whiskering need to be widely understood. Thickness of tin plating is also affect tin whisker growth. Though very thin tin plating retards whisker growth and in reality very thin tin plating is not applied because tin plating with very thin thickness has poor corrosion resistance and solderability parts (Yip, W. C., 2006).

This project is basically to do some surface treatment via tin electroplating to form an optimum condition for the mild steel to sustain its properties. This process of electroplating would be emphasize the process parameters in order to form a best

coating to prevent corrosion particularly in electrical components, automotive parts such as fuel and brake line components, food beverage and aerospace industry.

1.3 Objectives

(a) Provide a tin coating on the mild steel substrate with various coating condition by using electroplating method.

(b) Investigate the corrosion properties of mild steel with various coating conditions once immersed in various corrosive environments.

1.4 Scopes

(a) Select an optimum coating conditions for obtaining corrosion protection via tin plating.

(b) Improve corrosion resistance of mild steel plate via tin coating.

(c) Identify the best route for coating and fundamental analysis on expected corrosion control technique.

(d) Compare the corrosion properties that occur on the tin coated mild steel with various process parameters.

1.5 Rational of Research

In constructing something technology, it must followed by the impact or damage that may occur. Thus, the project carried out have rational distinctive with a view to provide ease in the future. Each material according to very element of iron is tending to the nature of corroded and rust. Therefore, study is carried out with purpose to provide information on the state best tin plating to prevent corrosion nature when it use in solution NaCl. Its impact, this project will provide convenience to the future generation on the state best tin plating when in use something application.

1.6 Research Methodology

The methodology chapter is the way of the project from the preparation of specimens until carry out the testing. The experiment used 15 specimens from mild steel and coated by tin. In this experiment, NaCl, HCL and NaOH act as the exposure corrosive. The experiment is done by using the electroplating technique. Electroplating technique is the process of using electrical current to reduce cations of a desired material from a solution and coat a conductive object with a thin layer of the material, such as a metal. The experiment is carried out with various coating condition and each of specimen will observed to determine the best coating condition that capable to inhibit corrosion in NaCl. All the specimens will carry out with Tafel extrapolation to determine the corrosion penetration rate based on the linear polarization.

1.7 Thesis Frame

This project is done with five main chapters which are introduction, literature review, methodology, result and discussion. Chapter one briefly explained the objective, scope, problem statement, rational of research, research methodology and chapter arrangement. Chapter two is a literature review which consist the definition of corrosion, theory of corrosion and electroplating, electroplating process and some of the previous research for tin electroplating. Chapter three is mentioned about the way of project being done whereas stated the method that will be used from beginning process until final process. The chapter also included the data of coating parameters. In chapter four, all the gathered result based on coating and corrosion properties is attached and also analyzed the data itself. Here, the data of thickness coating, surface examination and corrosion rate measurement is determined. In chapter five, it explained the conclusion for overall of this research and recommendation for the improvement in the future for this research.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Corrosion is a destruction or deterioration of a material because of a chemical attack with its environment. The corrosion behavior represents a tremendous economic loss. The most techniques to prevent the corrosion are by coating or plating on the surface of materials (Fontana, M.G., 1987).

Mild steel is a type of steel that contains about 0.1% of weight carbon. Mild steel also called high carbon steel and the microstructure has two major constituents, which are pearlite and ferrite. Figure 2.1 mentioned that the light colored region of the microstructure is the ferrite. The dark regions are the pearlite. It is made up from a fine mixture of ferrite and iron carbide. Pearlite has a lamellar (plate-like) structure consisting of alternating plates of α ferrite and cementite (Callister, W.D., 2005). Ferrite or alpha iron (α-Fe) is a materials science term for iron or a solid solution with iron as the main constituent with a body centered cubic crystal structure (Henkel, D. et al., 2002). It is the component which gives steel and cast iron their magnetic properties. The properties of the steel depend upon the microstructure. Decreasing the size of the grains and decreasing the amount of pearlite improves the strength, ductility and the toughness of the steel (Anonymous, 2000).

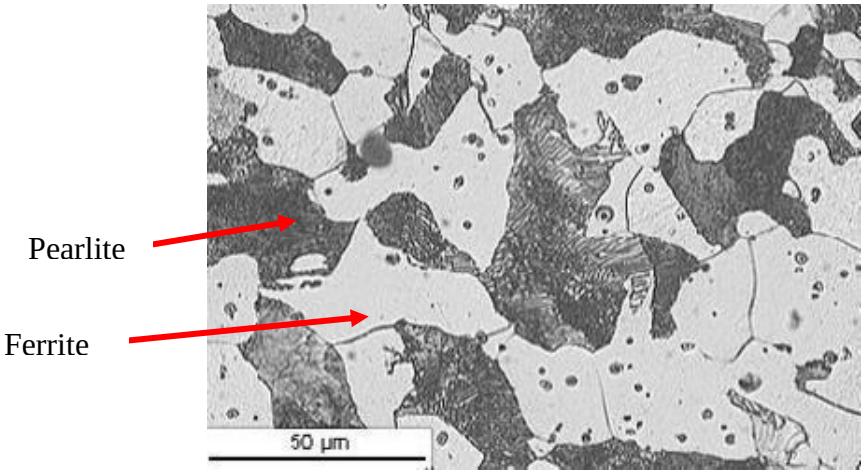

Figure 2.1: Microstructure of Mild Steel (Anonymous, 2000).

2.2 Theory of Corrosion

Most corrosion phenomena are of electrochemical nature and consist of at least two reactions on the surface of the corroding metal. One of the reactions is the oxidation also referred to as the anodic partial reaction. The other is a reduction reaction is referred to as the cathodic partial reaction. Figure 2.2 show the phenomenon of chemical reaction for metal in electrolytic. For example, the corrosion of iron to form rust proceeds according to the overall reaction (2.1, 2.2 2.3) (Tullmin, M., 2000). The reaction is initially formed which the Fe will release $2e^-$. The electron which released will combine with oxygen and hydrogen to form hydroxide molecule ($4OH^-$) (Tullmin, M., 2000).

This reaction includes the dissolution of iron, the reduction of oxygen and formation of rust:

$$Fe \rightarrow Fe^{2+} + 2e^- \text{(anodic)} \quad (2.1)$$

$$2H_2O + O_2 + 4e^- \rightarrow 4OH^- \text{(cathodic)} \quad (2.2)$$

$$2\,Fe + 2H_2O + O_2 \rightarrow 2Fe^{2+} + 4(OH)^- \quad (2.3)$$