UNIVERSITI TEKNIKAL MALAYSIA MELAKA

COMPARISON STUDY ON THE MICROSTRUCTURE AND CORROSION RATE OF Ti-6Al-4V

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

By

YANG CHEE HENG

FACULTY OF MANUFACTURING ENGINEERING

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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SESI PENGAJIAN: 2009/2010

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DECLARATION

I hereby, declared this thesis entitled "comparison study on the microstructure and corrosion rate of Ti-6Al-4V" is the results of my own research except as cited in references.

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ABSTRACT

In this final year project, the aim of this thesis is to comparison of the Ti-6Al-4V alloy on the microstructure and corrosion rate. This thesis is mainly focus in how to find out the corrosion rate of metal alloy like Ti-6AL-4V alloy through some specific process and research. On the other hand, the microstructure for Ti-6AL-4V alloy is studying to different temperatures by using optical microscope for comparing the microstructures. For the sample preparation, there are 6 samples are prepared to heating up in furnace with different temperatures are setting. This is one of important test for cross-section the Ti-6AL-4V alloy to find out the oxidation of its coating surface after take the image microstructure. From the analysis, another focus to find the corrosion rate of the Ti-6AL-4V alloy is using the corrosion potential test and tafel technique. This technique measures the impedance of a system over corrosion potential measurements including to the sample area and graph of corrosion rate. Therefore, the study on the capability of corrosion potential standard technique and tafel technique are applying under the Gamry Instrument Framework Software to corrosion rate with more comprehensive and complete for making a professional and specific research. From the findings, analysis to the polarization curves is very important to find out the value corrosion rate and compare with different types of temperature.

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ABSTRAK

Bagi Projek Sarjana Muda (PSM) ini, tujuan untuk thesis ini adalah penyelidikan dalam pembezaan terhadap Ti-6Al-4V aloi pada mikrostruktur dan kadar kekakisan. Thesis ini juga lebih fokus terhadap bagaimana pencarian kepada kadar kekakisan bagi logam aloi seperti Ti-6Al-4V aloi melalui pelbagai jenis proses dan penyelidikan tertentu. Manakala, mikrostruktur bagi Ti-6Al-4V aloi juga perlu diselidik dan dibelajar terhadap perbezaan suhu yang berubah dengan mengunakan kajian "optical" mikroskop untuk membezakan mikrostruktur yang dapat. Dalam persediaan pengunaan bahan, terdapat 6 persediaan bahan yang digunakan untuk miningkatkan suhu dalam dapur leburan suhu yang tertentu. Kajian ini juga penting bagi membahagikan Ti-6Al-4V aloi kepada dua belah untuk dapat menyelidik pengoksidaan permukaan luaran aloi itu selepas mangambil gambaran mikrostruktur. Dalam thesis ini, focus yang lain dalam pencarian kadar kekakisan terhadap Ti-6Al-4V aloi adalah dengan pengunaan kajian "corrosion potential standard" teknik dan "tafel" teknik. Teknik-teknik ini untuk mengukur kadar "impedance" badi satu sistem yang dikenali kadar kekakisan kemungkinan pengukuran kepada luas contoh bahan dan graf kadar kekakisan. Oleh itu, perkembangan dalam kebolehan untuk kajian "corrosion potential standard" teknik dan "tafel" teknik adalah digunakan bawah "Gamry Instrument Framework Software" terhadap kadar kekakisan denagan lebih lengkap dan sempuran dalam penyelidikan yang professional dan spesifik. Dari keputusan itu, penafsiran "polarization curves" adalah penting untuk mencari nilai kadar kekakisan dan membeza dengan beberapa suhu yang berbeza.

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DEDICATION

To my beloved family

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I would like to thank for **Dr. Zulkifli Mohd. Rosli** be my final year project supervisor who has gracefully offered his time, attention, experience and guidance throughout the completion of the investigation thus far. Thanks to the university library for providing lots of sources which assistant to complete the report. Special thanks to university laboratory and technicians who have helped me for providing lots of sources to complete my final project with successful.

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LIST OF ABBREVIATIONS

ASM	-	American Society for Metals
ASTM	-	American Society for Testing and Materials International
BCC	-	Body-Centered Cubic
EDS	-	Energy Dispersive X-Ray Spectroscopy
EIS	-	Electrochemical Impedance Spectroscopy
FYP	-	Final Year Project
HCP	-	Hexagonal Close-Packed
HF	-	Hydrofluoric Acid
HNO_3	-	Nitric Acid
MEK	-	Methyl Ethyl Ketone
NaCl	-	Sodium Chloride
R & D	-	Research and Development
SCC	-	Stress-Corrosion Cracking
SEM	-	Scanning Electron Microscope
Ti-6Al-4V	-	Titanium 6-Aluminum 4-Vanadium
UTeM	-	Universiti Teknikal Malaysia Melaka
XRD	-	X-Ray Diffraction

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Chapter 1
INTRODUCTION

This chapter is contains the objectives, scope of the study and background of the problem statement. Overall in this chapter, I will explain and discuss about the aims of the whole project.

1.1 Project Overview

In this final year project (FYP), the title is comparison study on the microstructure and corrosion rate of Ti-6Al-4V. Therefore, the main material is used in this project is Titanium Alloy, Ti-6Al-4V. Inside the Ti-6Al-4V is including composition of several metal alloys like titanium oxide, aluminium oxide, vanadium and other small composite alloys. In this FYP, there is some of the methodology methods had been progressed in the project. First for preparing sample section, then is to heat treatment section, then comparison on the microstructure in different temperature are set, after that turns to the corrosion test section, there are two types of corrosion testing are made includes corrosion potential test and corrosion rate test - tafel techniques.

For the chapter two – literature review part, inside this part is introduce to titanium alloys for Ti-6Al-4V, their mechanism, form of corrosion and chosen test methods for corrosion rate test. All analysis to compare and proven theory are come from the finding journal and some electronic journal form website. In the introduction of Ti-6Al-4V alloy, all types of characteristic and composition of this alloy have been showed. This is includes introduce to their chemical composition of the titanium alloy. Then for analysis

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to their microstructure part, optical microscope is used for capture the image of microstructure and comparison between the original and specific microstructure in different temperature. Then is study in the capability of the corrosion rate with same material and differ in temperature. This corrosion test can be applied by the Gamry Instrument Framework software with compare the corrosion rate in the graph format.

For the Methodology part, inside this part is describe about the project research methods and progression ways should be continued. In this part also include to the predicting and drafting steps to be progressed for the result and discussion part. All flow chart in this overall project had been showed and some consumption to be made before goes through second phases of the project.

For result and discussion part, all results and discussion had been recorded to show the experiment was progressed from time to time. The comparing results between the materials applied had been assisting from some of analysis data and graph. This may explain the research and thesis are complete with proven in the findings like journal and guiding by project supervisor.

For conclusion part, the definite conclusion had been made for the whole project to show the obeying objectives and scopes are definitely to achieve.

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1.2 Problem Statement

The study and knowledge of corrosion rate testing to all the local university are inadequate by making a professional and specific researching on it. This is due to the cost titanium alloys problem in making the Research and Development (R & D) time-consuming become slow and long way to step forward for our country by comparing with other Modern countries like Europe, Japan, United State of America and etc. The application of corrosion test for Titanium alloys like Electrochemical Impedance Spectroscopy (EIS) are more important for biomaterial in the surgical implant human body. Titanium alloys are chosen for their inherent mechanical properties are highly corrosion resistant, biologically inert and capable of being fabricated as an implant if suitable design at a reasonable cost. However, due to high cost factor and difficulties in machining, titanium alloys always are not regarded a competitive material for these applications. Therefore, applying to corrosion testing under Gamry Instrument Framework Software are easier and advance to use and reasonable to buy for saving more investment equipment in R & D departments.

On the other hand, the problems for applying electrochemical test is real issue to settle as some of the limitations have discontinue researching and progressing to the process. For example, the Cyclic Potentiodynamic Polarization methods are complex to apply in the corrosion testing process. This is because the limitation and problems of the Cyclic Potentiodynamic Polarization methods are predominately related to the induction time required for pitting, the repassivation rates and the complications arising from allowing too much pitting propagation to occur along with the accompanying chemistry changes before the reversal in the scan direction. Therefore, application under the Gamry Instrument Framework Software which is very easy way in control and calculate to the corrosion rate whether in different or materials or parameter are setting.

Therefore, this project will study on the capability of the corrosion potential and tafel techniques under the Gamry Instrument Framework Software to corrosion rate with more comprehensive and complete for making a professional and specific research.

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1.3 Objectives

The objectives of this final year project:

- To compare the microstructure for titanium oxide and aluminium oxide under optical microstructure with the different temperature.
- To test corrosion rate by the corrosion tests under the Gamry Instrument Framework software and immerse with some solutions are prepared.
- To analysis and interpret the results of corrosion rate and graph are getting from the corrosion test.

1.4 Scope of Study

The emphasis to the FYP project is comparison study on the microstructure and corrosion rate of Ti-6Al-4V. This can be elaborated in specimen preparation in conventional procedures, but deformation and overheating must be avoided when put in furnace as they can both cause changes in microstructure. The investigation includes laboratory model tests on the cross section to titanium alloys like Ti-6Al-4V and taking the microstructure of that alloys under optical microscope. The small size of materials are prepared have make the problems for cross-section part. This is because the hard properties of the titanium alloy are difficult to cut and soften face of the surface of material are difficult to hold when cut. Besides that, the high corrosion resistances properties of titanium alloys have make the difficulties of corrosion test. Therefore, the preparation material steps must be done in good condition for getting the best corrosion results.

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CHAPTER 2
LITERATURES REVIEW

This chapter is explaining and deriving all of relevant information which is related to the project is studied and summarized it. For example, introduction to the titanium alloys materials, some of introduction for heat treatment process and corrosion process. Many kind of information are summarized in a literature review with mention to sources either from book, journal, conference proceedings or internet (electronic journals).

2.1 Background of Titanium Alloys

Titanium alloys were originally developed in the early 1950s for aerospace applications, in which their high strength-to-density ratios were especially attractive. Although titanium alloys are more used for the aerospace industry for these properties, recognition of the excellent resistance of titanium to many highly corrosive environments, particularly oxidizing and chloride-containing process streams, has led to widespread nanoaerospace industrial applications. This is because of the decreasing cost and the increasing availability of titanium alloy products, many titanium alloys have become standard engineering materials for a host of common industrial applications. In case, a growing trend involves the use of high-strength aerospace-founded titanium alloys for industrial service in which the combination of strength to density and corrosion resistance properties is critical and desirable (Cramer *et al.* 2005).

The history of titanium is the ninth most abundant element in the earth's crust and is primarily found in the minerals Rutile (TiO_2), Ilmenite ($FeTiO_3$) and Sphene ($CaTiSiO_5$).

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Titanium makes up about 0.57% of the earth's crust. The word titanium comes from the Greek word Titans the mythological "first sons of the earth". The pure elemental metal was not made until 1910 by Matthew A. Hunter, who heated $TiCl_4$ together with sodium in a steel bomb at 700-800°C (Davis *et al.* 1990).

2.2 Introduction of Titanium Alloys

Titanium alloys are metallic materials which contain a mixture and other chemical elements. In case, alloying elements can act as stabilize either the alpha or beta phase. Through the use of alloying additions, the beta phase can be sufficiently stabilized to coexist with alpha at room temperature. This fact forms the basis for creation of titanium alloys that can be strengthened by heat treating. This alpha-beta alloy is the workhorse alloy of the titanium industry because it is by far the most common Ti alloy, accounting for more than 50% of total titanium usage. It is an alpha combine beta alloy that is heat treatable to achieve moderate increase in strength. For the lattice parameters, α-titanium actually are as follows in a = 2.9504 Å, C = 4.683 Å; at 25^0C (as obtained by extrapolation) a = 3.282 Å. In fact, the properties of titanium and its alloys depend to a great extent in the content of inevitable gas impurities, which get into the metal from the initial raw material, spongy titanium. Impurities, mainly oxygen, determine the useful property of titanium as it has high mechanical strength (Valentin, N. M. 2006).

In theoretical, characteristic of alloying is increase the strength of material but also is reduces the ductility of alloys. Therefore, the initial material, in this case titanium, should have maximum ductility. The more alloying is to be done, the more ductile and, thus, freer of impurities, the initial titanium should be. Usually, it is not advantageous to increase strength by using impurities, as it is accompanied by a considerable loss of ductility, because the major impurities like oxygen, nitrogen and carbon form interstitial solid solutions with titanium. Besides, these impurities have an adverse effect on other important characteristics of titanium alloys in the properties like thermal stability, creep resistance and notch sensitivity. An increase of the purity of the initial titanium would

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