UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EFFECT OF DIFFERENT HEAT SENSITIZATION TEMPERATURE ON TYPE 304 STAINLESS STEEL

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

TAY SHIN YOON

FACULTY OF MANUFACTURING ENGINEERING

2010

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Effect of Different Heat Sensitizaton Temperature on type 304 Stainless Steel**

SESI PENGAJIAN: 2009/2010

Saya TAY SHIN YOON(B050610149)

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM 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	

Disahkan oleh:

_____ (TANDATANGAN PENULIS)

_____ (TANDATANGAN PENYELIA)

Alamat Tetap:
725, JALAN BAKEK
82000 PONTIAN
JOHOR

Tarikh: 09th APRIL 2010.

Cop Rasmi:

Tarikh: _____

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

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 (Manufacturing Material) with Honours. The member of the supervisory committee is as follow:

(Signature of Supervisor)

……

(Official Stamp of Supervisor)

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 (Manufacturing Material) with Honours. The member of the supervisory committee is as follow:

(Signature of Priciple Supervisor)

……

(Official Stamp of Principle Supervisor)

(Signature of Co-Supervisor)

……..

(Official stamp of Principle Supervisor)

DECLARATION

I hereby, declared this thesis entitled " Effect of Different Sensitization Temperature on type 304 Stainless Steel" is the results of my own research except as cited in references.

Signature	:	…….
Author's Name	:	TAY SHIN YOON
Date	:	09th APRIL 2010

ABSTRACT

Nowadays, stainless steel is one of the most important materials. Stainless steel resistance to corrosion and staining, low maintenance, relatively low cost and familiar luster make it an ideal base material for a host of commercial applications. The material usage in this project is type 304 stainless steel. This project will present the effect of different heat sensitization temperature toward microstructure, corrosion and hardness of stainless steel. Type 304 stainless steel is suit to make all types of dairy equipment such as Kitchen sink, storage tank and piping. So it always use in industry equipment that has corrosive or chemical process. Sodium chloride solution was used in cyclic polarization test. The microstructure was determined by Optical Microscope and the hardness was determined by Vicker's Hardness Tester. Besides that, the present of some elements in the stainless steel was determined by x-ray diffraction machine. In addition, the corrosion test used was cyclic polarization. Next, a discussion, conclusion and recommendation were constructed from the result obtained. The microstructure was showed the precipitation of chromium carbide and precipitation of chromium carbide was proved by x-ray diffraction results. The hardness of the specimens was not had much different although corrosion was reduced the strength of the specimens. This is because chromium carbide is a hard phase. Lastly, the effect of sensitization was reduced the corrosion resistance of type 304 stainless steel.

ABSTRAK

Kini, “Stainless steel” adalah satu bahan yang penting. “Stainless steel” penentangan karat, tahan lama, harga murah dan permukaan yang kilat telah manjadi bahan ini sebagai bahan asas kegunaan. Bahan yang mangunakan dalam projek ini ialah jenis 304 “Stainless steel”. Projek ini akan manunjukkan kesan-kesan pelbagai mikrostruktur, kekakisan dan kekerasan dengan pelbagai suhu “sensitization” proses. 304 “Stainless steel” adalah sesuai digunakan untuk manbuat benda harian. Pelbagai unsur dalam “Stainless steel” akan ditentukan dengan mangunakan “X-ray Diffraction” analisis. Selain itu, mikrostrutur akan ditentukan dengan “Optical Microscope dan kekerasan akan ditentukan dengan “Vicker’s hardness machine”. Selepas itu, perbincangan, kesimpulan dan cadangan akan dibuat dengan merujukkan data. Mikrostruktur akan menunjukan kemunculan “chromium carbide” dan kemunculan itu dapat ditentukan dengan “X-ray diffraction” keputusan. Kekerasan bahan itu akan kekal lebih kurang sama kerana “chromium carbide” adalah keras fasa. Akhirnys, “sensitization” proses akan membawa keturunan kakisan rintanga kepada bahan.

DEDICATION

To my beloved family and friends

ACKNOWLEDGEMENT

First of all, I would like to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for the opportunity to pursue study in Bachelor of Manufacturing Engineering (Manufacturing Material) and to conduct and complete this "Projek Sarjana Muda". UTeM has provided many facilities such as machines and equipments to aid the success of this project.

Very special thanks to my supervisor Dr. Zulkifli Mohd. Rosli for his guidance, encouragement and contribution in this project. He has given me useful advices and motivation when I encountered problems and willingly shares the knowledge regarding this project.

Last but no least, I would like to thank my family for their continuous support and courage throughout the study and the project. Not forgettable, thanks to my friends that have been working side by side in completing this project.

TABLE OF CONTENT

Abstract		i
Abstrak		ii
Dedication		iii
Acknowledgement		iv
Table of Content		v
List of Tables		ix
List of Figures		x
List of Abbreviations		xii
1.0	**CHAPTER 1: INTRODUCTION**	**1**
1.1	Project overview	1
1.2	Problem Statement	2
1.3	Objective	4
1.4	Scope	4
1.5	Organization of report	4
2.0	**CHAPTER 2: LITERATURE REVIEW**	**6**
2.1	Introduction	6
2.2	Stainless steel	6
2.3	Austenitic stainless steel	7
2.4	AISI 304 stainless steel	10
2.5	Corrosion	10
2.5.1	Classification of corrosion	11
2.5.2	Type of corrosion	11
2.5.3	Causes of intergranular corrosion on austenitic stainless steel	11
2.6	Result studies on microstructure and mechanical properties of AISI 304 stainless steel	13
2.6.1	Effect of pH and chloride concentration on the corrosion of duplex	

	stainless steel	13
2.6.2	Sensitization study of Normalized 316L Stainless Steel	14
2.6.3	The size of the sensitization zone in 304 Stainless Steel welds	15
2.6.4	Pitting corrosion behaviour of Austenitic Stainless Steels-combining effects of Mn and Mo additions.	15
2.6.5	Effect of Mo and Mn addition on the Corrosion behaviour of AISI 304 and 316 Stainless Steel in H_2SO_4	16
2.6.6	Analyze from Microstructure, Corrosion and Mechanical Properties of 304 Stainless Steel containing copper, silicon and nitrogen	16
2.6.7	Effect of solution treatment conditions on the sensitization of austenitic stainless steel	17
2.6.8	XRD analysis of carbide phase n heat resistant steels	17
2.6.9	Microstructure and tribological behaviour of nano-structured metal matrix composite boride coatings synthesized by combined laser and sol gel technology	17
2.6.10	Austenitic stainless steel layer deposited by laser cladding on a mid steel realization and characterization.	18
2.6.11	Mechanical properties and corrosion resistance of burnished X5CrNi 18-9 stainless steel.	18
2.6.12	Austenitic stainless steels layer deposited by laser cladding on a mild steel realization and characterization.	19
2.6.13	Electrochemical evaluation of stainless steel in acidified sodium chloride solution	19
2.6.14	Susceptibility to localized corrosion of stainless steel and NiTi endodontic instruments in irrigating solution.	19
2.6.15	Effect of low temperature aging of type 316L austenitic stainless weld metal on transformation of ferrite phase.	20
2.6.16	Effect of H_2SO_4 addition on the corrosion behaviour of AISI 304 austenitic stainless steel in methanol.	21
2.7	Mirostructure	23
2.7.1	Martensite	23

2.7.2 Sulfides 23
2.7.3 Ferrite 23
2.7.4 Sigma 23
2.7.5 Chi phase 23
2.7.6 Laves 24
2.7.7 Carbide 24
2.7.8 Typical microstructure 26
2.8 Summary 31

3.0 CHAPTER 3: METHODOLOGY 32
3.1 Introduction 32
3.2 Heat sensitizing process 35
3.3 Sample Preparation 36
3.3.1 Label 36
3.3.2 Mounting 36
3.3.3 Grinding 37
3.3.4 Polishing 37
3.3.5 Etching 38
3.4 Cyclic polarization 38
3.5 Microindentation Hardness Testing 39
3.5.1 Sample preparation 39
3.5.2 Testing parameters 39
3.6 Data record 40

4.0 CHAPTER 4: RESULTS AND DISCUSSION 41
4.1 Introduction 41
4.2 Microstructure 42
4.2.1 Result of microstructure 42
4.2.2 Comment 46
4.3 XRD result 47
4.3.1 Comment 50

4.4 Hardness 51
4.4.1 Hardness of type 304 stainless steel without any heat treated 51
4.4.2 Hardness of type 304 stainless steel with heat treated at 600ºC 51
4.4.3 Hardness of type 304 stainless steel with heat treated at 700ºC 51
4.4.4 Comment 52
4.5 Corrosion result 53
4.5.1 Information and calculation from Figure 4.8 53
4.5.2 Information and calculation from Figure 4.9 54
4.5.3 Information and calculation from Figure 4.10 55
4.5.4 Comment 57
4.5.5 Comparison of repassivation potential 57
4.5.6 Comparison of corrosion potential and current density 58
4.5.7 Comparison of pitting potential 60

5.0 CONCLUSION AND RECOMMENDATIONS 61
5.1 Conclusion 61
5.2 Recommendations 62

REFERENCES 63

APPENDICES 66

LIST OF TABLES

2.1	Composition of 304 stainless steel	10
3.1	Parameters for microindentation hardness testing	29
3.2	Vivker;s hardness value	40
4.1	Hardness value (original)	51
4.2	Hardness value (600ºC)	51
4.3	Hardness value (700ºC)	51
4.4	Critical potentials and protection intervals (original)	53
4.5	Analysis of Critical potentials and protection intervals (original).	53
4.6	Critical potentials and protection intervals (600ºC)	54
4.7	Analysis of Critical potentials and protection intervals (600ºC)	54
4.8	Critical potentials and protection intervals (700ºC)	55
4.9	Analysis of Critical potentials and protection intervals (700ºC)	55

LIST OF FIGURES

2.1	Austenitic stainless steel	13
2.2	The magnified of sensitization	15
2.3	Aging for 1000 hours	20
2.4	Optical microstructure of 304 stainless steel with different soaking time	26
2.5	Type 304 stainless steel etched with aqueous 10% ammonium persulfare	27
2.6	Delta ferrite	27
2.7	Carbide	28
2.8	Type 304 stainless steel etched with 20% NaOH	28
2.9	Austenitic grain boundaries of 304 stainless steel	29
2.10	Grain boundaries carbide etched with Ralph's reagent	29
2.11	Grain boundaries carbide etched by 10% ammonium persulfate	30
3.1	Process flow 1	33
3.2	Process flow 2	34
3.3	Heat sensitized at 600ºC	35
3.4	Heat sensitized at 700ºC	35
3.5	Sample label	36
3.6	Mounting machine	36
3.7	Grinding machine	37
3.8	Etching place	38
4.1	304 stainless steel with no heat treated	39
4.2	304 stainless steel with heat treated for 600ºC	44
4.3	304 stainless steel with heat treated for 700ºC	45
4.4	Original (chromium carbide)	46
4.5	600ºC (chromium carbide)	47
4.6	700ºC (chromium carbide)	49
4.7	Combination of XRD result	51

4.8	Cyclic polarization result for original	52
4.9	Cyclic polarization result for 600ºC	53
4.10	Cyclic polarization result for 700ºC	53
4.11	Combination of cyclic polarization result	55
4.12	Comparison of repassivation potential	55
4.13	Comparison of corrosion potential	57
4.14	Comparison of current density	57
4.15	Comparison of pitting potential	59

LIST OF ABBREVIATIONS

SEM	-	Scanning Electron Microscope
EDX	-	Energy Dispersive X-ray
SS	-	Stainless steel
ASTM	-	American Society for Testing and Materials International
ASM		American Society for Metals
Mn	-	Manganese
MnS	-	Manganese sulphide

CHAPTER 1
INTRODUCTION

1.1 Project overview

This project is to obtain the effect of different sensitization temperature on corrosion, microstructure and hardness of type 304 stainless steel. The heat treatment processes is sensitizing process. The specimens are heat in different sensitizing temperature. The whole project is focus on how the different heat treatment processes affect the corrosion, microstructure and hardness of type 304 stainless steel. In this project, understanding the effect of sensitizing temperature is the main thing need to be done. Sensitizing heat treatment is whether accidental intentional or incidental. Corrosion is the chemical transformation of metal due to chemical reactions. Stainless steel is susceptible to intergranular corrosion if heat treating is not performed correctly. Intergranular corrosion is a selective attack of a metal at or adjacent to grain boundaries. There are three mechanisms that have been identified as causing intergranular corrosion in various situations. One of the mechanism causes intergranular corrosion is due to the local depletion of an alloying element. This form of attack can occur in many stainless steel. It is called sensitization. Many stainless steels rely on a combination of nickel and chromium for their corrosion resistance. Nickel and chromium are expensive so they are added only in amounts necessary to obtain the necessary corrosion resistance. Another element which is commonly present in stainless steel is carbon. In stainless steels, carbon atoms tend to concentrate at the grain boundaries as an impurity during solidification. Chromium carbides can form adjacent to the grain boundaries during heat treatment. When these compounds form, the chromium is

removed from the alloy adjacent to the grain boundaries and the resulting alloy does not have enough chromium content to remain passive. There is a very unfavourable anode/cathode area ratio and rapid attack can occur. Besides that, understanding the applications and properties of type 304 stainless steel is also needed in order to be more understand the purpose of this project. Stainless steel is high alloy steel which has been added by some elements in order to improve its properties such as resistance to corrosion. Stainless steel can be divided into three groups which are austenitic, ferritic and martensitic. The names of these classes reflect the microstructure of which the steel is normally composed. Type 304 stainless steel is austenitic grade. Austenitic stainless steels are non-magnetic non heat-treatable steels and FCC metal. In austenitic steels the grain boundaries are narrow straight lines. Grade 304 is the basic 18-8 alloy (18% chromium, 8% nickel) and most common of the 300 series with the excellent corrosion resistance in most applications. 304 stainless steel is especially suited for all types of dairy equipment such as milking machines, containers, homogenizer, sterilizers, storage tanks, piping, milk truck and railroad cars.

1.2 Problem statement

Austenitic stainless steel with excellent corrosion resistance and good weldability has used in various scientific and engineering applications like chemical and pharmaceutical industry such as food and beverage industry, petrochemical industry, oil and water pipe lines, ship and naval structures, architectural applications, water supply and desalination. Type 304 stainless steel is the basic 18Cr8Ni austenitic stainless steel and is so widely used that it accounts for about 50% of all stainless steel production. Corrosion can weakening the material and may lead to crack growth or failure. Hence it is critical importance to any engineer designing components or structure that use metal. Atmospheric contaminants often responsible for the rusting of structural stainless steels are the chlorides and metallic rust. Chlorine can be introduced into a piping system in

many ways but most common seen in food industry applications are as sodium chloride. The structure of a material is related to its composition, properties, processing history and performance. Therefore, studying the microstructure of a material will provides information linking with its composition to its properties and performance. Hardness is the property of a material that enables it to resist plastic deformation, penetration, indentation and scratching. Therefore, hardness is important properties for a material because resistance to wear by either friction or erosion by steam, oil and water. Besides that, the hardness value also can determine the brittleness of the material. Moreover, hardness value can be converting to tensile strength. So, raw material can be save due to small quality of material needed for hardness test if compare with tensile test.

1.3 Objective

I. To study the effect of different sensitizing heat treatment process for type 304 stainless steel on microstructure.
II. To study the effect of different sensitizing heat treatment process for type 304 stainless steel on hardness.
III. To study the effect of different sensitizing heat treatment process for type 304 stainless steel on corrosion.

1.4 Scope

I. The microstructures of the specimens are obtained by optical microscope.
II. The hardness of the specimens is test by Vicker hardness test machine.
III. Use XRD to determine the characteristic and crystal structure of that metal.
IV. Cyclic potential dynamic is use to obtain the corrosion level of the specimen.

1.5 Organization of report

This report is divided into six chapters which are Introduction, Literature Review, Methodology, Results, Discussion, and Conclusion.

I. Introduction

This chapter contains the background and problem statement of this project. Besides that, the understanding of this project will also be shown in this chapter.

II. Literature Review

This chapter contains the sources find out from book, journal, articles and internet source. Any information which is related to this project is studied and summarized.

III. Methodology

This chapter contains the experimental procedure of this project. A flow chart of this project will be shown in this chapter.

IV. Results & Discussion

This chapter contains some table, figure and graph which is plotted base on the result obtained during lab session. Besides that, this chapter also presents the most important results and commenting on results. Moreover, the result obtained from the lab session and the theoretical results are compared. In addition, the results obtained are concluded.

V. Conclusion

This chapter summary all the finding from this project and give some suggestion or recommendation for the further study. Besides that, this chapter will also review the significant findings and explain the significant for the findings.

CHAPTER 2

LITERATURES REVIEW

2.1 Introduction

This literature review is to find out all the necessary information and unknown knowledge in the research of the effect of different sensitization temperature towards AISI 304 stainless steel microstructure, corrosion and hardness. The objective of literature review is to use the sources found out to support the research. The sources found out will explain the properties and the effect of different sensitizing temperature toward microstructure, corrosion and hardness of AISI 304 stainless steel. The sources include book, journal, articles and internet sources.

2.2 Stainless Steel

Stainless means non-corrosion. Stainless steels are considered as ferrous alloys which containing more than 12% to 30% of chromium. The corrosion resistance of the stainless steel is due to the formation of chromium rich oxide passive film on the surface in oxidized environment. The stainless steel can be classified into three types that are ferritic stainless steel, martensitic stainless steel and austenitic stainless steel (Chen, M.L. 2006).

2.3 Austenitic Stainless Steel

This type of steel requires the austenite stable at the application temperature and it has the best corrosion resistance among the three classes of stainless steel. Thus large amount of alloying element is required especially Ni and Mn. The base composition is 0.1%C-18%Cr-8%Ni. The steels is face centered cubic crystal lattice so it exhibit excellent workability and low temperature toughness. The properties of austenitic stainless steels can be modified by addition or reduction of the alloying elements (Chen, M.L. 2006). For example,

i. Corbon

High carbon content will produce higher ultimate strength and hardness but may lower ductility and toughness. Carbon also increases air-hardening tendencies and weld hardness. Increasing carbon content lessens the thermal and electrical conductivities of steel (Mohinder, L. 2007). Copper is another primary corrosion resistance element used in steel (Bjorhovde, R. 2001).

ii. Phosphorus

In general, increasing phosphorus content has an undesirable effect on the properties of carbon steel, notably on shock resistance and ductility. However, phosphorus will improve machinability (Mohinder, L. 2007).

iii. Silicon

In general, silicon increases the tensile strength of steel without increasing brittleness when limited to less than about 2 percent. Besides that, silicon also increases resistance to oxidation, increase electrical resistivity and decreases hysteresis losses. Adding silicon may reduce creep rupture strength (Mohinder, L. 2007).