UNIVERSITI TEKNIKAL MALAYSIA MELAKA

The Effects of Heat Treatments on the Mechanical Properties of Low Carbon Steel

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

By

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March 2008

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JUDUL: **THE EFFECTS OF HEAT TREATMENTS ON THE MECHANICAL PROPERTIES OF LOW CARBON STEEL**

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DECLARATION

I hereby, declared this thesis entitled "The Effects of Heat Treatments on the Mechanical Properties of Low Carbon Steel" is the results of my own research except as cited in references

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ABSTRACT

The research of the effects of heat treatments on the mechanical properties of carbon steel has been developed purposely to study on the microstructure with the relation of the mechanical properties of carbon steel. The study obviously emphasize on the research based on the metallurgy of the carbon steel. Low carbon steel and medium carbon steel has been chosen to be used as the type for this study. In carbon steel metallurgy, the important is to understand the phase diagram of iron carbon. In the diagram consists on the phase transformation that occurs as a result of heat treatment process. The basic iron phase such as austenite, ferrite, bainite, pearlite and martensite will be obtained from the results of the heat treatment. These microstructures will affect the mechanical properties of the carbon steel based on the theory. To accomplish this research, the method is to give the heat treatment on the carbon steel and observe the microstructure. After the microstructure of the metal obtained, the mechanical test was done on the heat treated steel such as tensile test, hardness test and impact test to determine the mechanical properties and its relation with the microstructures obtained. From mechanical test, the most brittle property is the specimen that undergone water quenching and the annealing heat treatment provide the most ductile property. While the tempering specimen has the most suitable properties since it has balance ductile and brittle properties.

ABSTRAK

Kajian mengenai kesan rawatan haba ke atas sifat mekanikal bagi besi karbon dibangunkan bertujuan untuk mendalami mikrostruktur berhubung dengan sifat mekanikal bagi besi karbon. Pembelajaran ini dengan jelasnya menekankan kajian berdasarkan metalurgi bagi besi karbon. Besi rendah karbon dan besi medium karbon telah dipilih sebagai bahan kajian untuk pembelajaran ini. Di dalam metalurgi besi karbon, ia adalah sangat penting untuk memahami diagram fasa bagi besi karbon. Diagram tersebut mengandungi perubahan fasa yang akan berlaku selepas proses rawatan haba. Fasa besi yang asas adalah seperti as austenite, ferrite, bainite, pearlite dan martensite akan diperolehi dari proses tersebut. Secara teorinya, perubahan mikrostruktur akan memberi kesan ke atas sifat mekanikal besi karbon tersebut Untuk menghasilkan kajian ini, adalah dengan memberi rawatan haba ke atas besi karbon dan pemerhatian mikrostrukturnya. Selepas itu, ujian mekanikal dilakukan seperti ujian terikan, ujian kekerasan dan ujian impak untuk mengetahui keputusan ujian samada ia kuat, keras, rapuh dan sebagainya serta hubungannya dengan mikrostruktur yang diperoleh. Berdasarkan ujian dibuat, spesimen yang mempunyai sifat yang paling rapuh adalah specimen yang menjalani celuran air dan rawatan haba menyepuh lindap memberi kesan yang paling mulur tehadap spesimen. Manakala 'tempering' membawa kesan rapuh dan mulur yang seimbang dan sesuai untuk pelbagai aplikasi.

DEDICATIONS

This thesis is gratefully dedicated to my parents, Mr Nik Ab Wahab and Habibatun Natifah, my beloved family, my respective lecturers, and my supported friends towards accomplishing this research.

ACKNOWLEDGEMENTS

Firstly, I want to gratitude to god, most gracious and merciful to show me guidance in accomplishing this research. Without His help and consent, I could not finish this project. I would also like to state my appreciation also to those individuals who involved whether directly or indirectly in assisting and aiding me throughout completing this project. Million of thanks to my project supervisor Mr. Mohamad Haidir Bin Maslan and my examiner Dr. Azizah Binti Shaaban for their time spending, encouragement, teaching, guidance and ideas for my research. Their contributions will not been forgotten. In this opportunity also, I wish to express my appreciation to the technicians involved in helping to complete this project. The most important is my appreciation to my parents and family. Lastly to all my friends who give their morale support and sharing this challenging time and beautiful life together.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

%	-	Percent
σ_y	-	Yield Strength,
σ	-	Tensile Strength
ASTM	-	American Society for Testing and Materials
AISI	-	The American Iron and Steel Institute
e	-	Permanent increase in depth of penetration
E	-	A constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter
HR	-	Rockwell hardness number
Q	-	Heat input
V	-	Voltage
I	-	Current
S	-	Welding speed
μ	-	Shear modulus
b	-	The Magnitude of the Burgers vector.
^{0}C	-	Degrees Celsius
K	-	Kelvin
D	-	Diameter
E	-	Modulus of Elasticity
M	-	Mega
Mm	-	Milimeter
Pa	-	Pascal
s	-	Second
SEM	-	Scanning Electron Microscope
EDX	-	Energy-dispersive X-Ray spectroscopy
TTT	-	Time Temperature Transformation

HAZ	-	Heat Affected Zone
UTM	-	Universal Testing Machine
C	-	Carbon
wt%	-	Weight percentage
Cl	-	Chlorine
Al	-	Aluminium
Si	-	Silicon
Fe	-	Ferum
PCS	-	Plain Carbon Steel
etc.	-	Etcetera
α	-	Alfa
γ	-	Gamma
Fe_3C	-	Carbide
Lab	-	Laboratory
FKP	-	Faculty of Manufacturing Engineering
max	-	Maximum

CHAPTER 1

INTRODUCTION

1.1 Research Background

The effects of heat treatments on the mechanical properties of carbon steel are the research developed to study the effects of heat treatments on the mechanical properties of carbon steel. It emphasizes the study on the metallurgy of the carbon steel since in depends on the study of the metal grain size and microstructure. The metallurgy is a domain of materials science that studies the physical and chemical behavior of metallic elements, their intermetallic compounds, and their mixtures, which are called alloys. It is also the technology of metals where the way in which science is applied to their practical use.

The carbon steel type used for this research is the low carbon steel (mild steel) since the metal is easier to obtain and fabricate. Besides, it is also lower in cost. The low carbon steel is the carbon steel that has less than 0.25wt% of carbon in the steel. In

matter of lower carbon content, it is lower in terms of strength since the composition of carbon will increase the strength in alloying element. Besides, the carbon steel is steel that easily corrode if exposed to mineral acids even when they are very dilute (pH less than 5).

The most vital part on understanding this research, the basic understanding of iron carbon phase diagram is required. Phase diagram consist on the transformation of iron-carbon phase based on the heat treatment results. The basic iron phases are the austenite, ferrite, pearlite, bainite, cementite and martensite. All these microstructure will give some effect on the mechanical properties theoretically. As well as the grain size of the steel will also give effect on the mechanical properties. The heat treatment process such as annealing, quenching and tempering will be carried out to obtain the expected microstructures after applied the metallurgical techniques.

To determine the mechanical properties, several tests will be observed such as the tensile test, hardness test, impact test and fracture toughness test. These tests will determined the strength, toughness, hardness and other properties related. All the tests involved will be done according to the ASTM references.

The outcome of the study were consequently related with the welding practice where the welding parameter such as temperature will affect the grain size and the microstructure of the welded steel which accordingly will give the effect on the performance of the material in terms of mechanical properties. Therefore, the best formula for the better welded parameters relation with the mechanical properties has to be obtained.

1.2 Statement of the Purpose

The purpose of this research is to investigate the resultant microstructure of steel when subjected to different type of heat treatments. The mechanical properties parameters will be observed are such the tensile, hardness, fracture toughness and impact properties. This research also deals with a few of the important mechanical properties and describes some of the innovative treatments under development for the production of better welds.

1.3 Hypotheses

i). The different microstructure of carbon steel will affect the mechanical properties of the carbon steel.

ii). Varying the heat treatment will change and transform the microstructure and grain size of carbon steel.

1.4 Problem Statements

It has been possible for some time to estimate the microstructure of steel weld metals from their chemical composition and welding parameters. This is extremely useful in the development of alloys, given a broad understanding of what constitutes a good microstructure. The methodology cannot, however, be used directly in engineering design because that requires specific values of mechanical properties.

1.5 Objectives

The purpose of this project is:

i) To investigate the resultant microstructure of low carbon steel when subjected to different type of heat treatments.

ii) To investigate the effect on the microstructures of low carbon steel when subjected to different type of heat treatments.

1.6 Scope of study

This study will focus on the effect of heat treatment with the microstructure and how it is related to the mechanical properties of carbon steel. It will include the literature review on the metallurgy of the carbon steel, the preparation for the various microstructures and grain sizes using several main heat treatment processes and several mechanical testing such as tensile, hardness, and impact test. The microstructure of the steel will be observed under the microscope and the fracture surface using SEM. While the composition for the carbon steel is using EDX.