EFFECT OF HEAT TREATMENT ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF LOW CARBON STEEL

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"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Materials)"

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Date : 31 May 2013

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This report is done in order to fulfill the requirement of the Bachelor’s degree of Mechanical Engineering (Structure and Materials)

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature : ______________________

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Date : 31 May 2013

To my lovely parent,

Mr. Samat bin Othman and Mrs. Fatimah binti Moen

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ABSTRACT

A study of heat treatment of low carbon steel has been carried out in order to investigate the effect on its microstructure and mechanical properties. The study consists of metallurgy and mechanical investigation before and after heat treatment process. Various treatments were performed which were annealing, normalizing, quenching and carburizing at temperature 860, 900 and 940 ˚C with 1 hour soaking time. Metallurgical investigation was conducted and it was observed that quenched sample form a martensite microstructure due to rapid cooling. As for normalizing and annealing process, it formed pearlite and ferrite microstructure due to slow cooling rate. Then, hardness test was carried out highest hardness value was achieved by carburizing (water quenched) sample with 88.38 HRA at 940 ˚C. This is because of the existence of fine grain size and also the effect of carbon diffusion from the process. Meanwhile annealing process gave a lowest hardness value with 33.38 HRA compared to as-received sample with 53.62 HRA due to larger grain size. The grain size was measured according to ASTM E112, and its proof that annealed sample gave a coarse grain size while the quenched sample prompted ultrafine grain size since it gave more than 14 grain size number. Besides, the finding also found that heating energy and cooling rate effects the grain size where it became larger as increased in temperature thus it decreased the hardness value.

ABSTRAK

Kajian berkaitan proses rawatan haba ke atas besi rendah karbon telah dijalankan dengan tujuan untuk mengkaji kesannya terhadap sifat mikrostruktur dan mekanikalnya. Pembelajaran ini meliputi kajian berdasarkan metalurgi dan sifat mekanikalnya sebelum dan selepas proses rawatan haba. Pelbagai proses rawatan haba telah dijalankan seperti penyepuhlindapan, pengnormalan, lindapkejutan dan pengkarbonan pada suhu 860, 900 and 940 ˚C selama 1 jam. Siasatan logam telah dijalankan telah didapati bahawa sampel lindapkejutan membentuk mikrostruktur martensit kerana penyejukan yang cepat. Untuk proses pengnormalan dan penyepuhlindapan, ia membentuk mikrostruktur feritte dan pearlite kerana kesan daripada proses penyejukan yang lambat. Kemudian, ujian kekerasan telah dijalankan dan hasilnya menunjukkan nilai kekerasan yang tinggi untuk pengkarbonan (lindapkejutan) sampel dengan 88.38 HRA pada 940 ˚C. Ini adalah kerana kewujudan saiz butiran yang halus dan juga kesan penyerapan karbon daripada proses tersebut. Sementara itu, proses penyepuhlindapan memberikan nilai kekerasan paling rendah dengan 33.38 HRA berbanding sampel tanpa rawatan dengan 53.62 HRA kerana memiliki saiz butiran yang lebih besar. Saiz butiran ini diukur mengikut ASTM E112, dan ia terbukti bahawa sampel penyepuhlindapan memberikan saiz atom yang kasar manakala sampel lindapkejutan mendorong saiz butiran yang halus kerana ia memiliki lebih 14 nombor saiz butiran. Selain itu, kajian ini juga mendapati bahawa tenaga pemanasan dan kesan kadar penyejukan membentuk saiz butiran yang lebih besar lalu memberi kesan kepada penurunan nilai kekerasan.

CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

wt%	=	Weight percent
C	=	Carbon
Fe_3C	=	Iron Carbide
˚C	=	Degree Celsius
M_S	=	Martensite Start
g	=	Gram
γ	=	Gamma (austenite)
δ	=	Delta (ferrite)
cm^3	=	Volume
N	=	Newton
J	=	Joule
mm	=	Millimeter
A_{cm}	=	Above critical temperature
MPa	=	Mega Pascal
RPM	=	Revolution per minutes
HV	=	Vickers’s hardness unit
HRA	=	Rockwell hardness unit
HRB	=	Rockwell hardness unit
HRC	=	Rockwell hardness unit
HRF	=	Rockwell hardness unit
HB	=	Brinell hardness unit

LIST OF ABBREVIATION

AISI	=	American Iron and Steel Institute
ASTM	=	American Society for Testing and Materials
CNC	=	Computer Numerical Control
BCC	=	Body centered cubic
FCC	=	Face centered cubic
EDX	=	Energy Dispersive X-Ray
et. al.	=	et alii (and others)
etc.	=	Et cetera
NST	=	National Standard Thread
SEM	=	Scanning Electron Microscope
UTS	=	Universal Tensile Test

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Heat treatment is a combination of heating and cooling that applied to a particular metal in order to produce a certain microstructure and obtain the desired mechanical properties such as hardness, yield strength, percent elongation, Young's modulus, etc. Microstructures of steels are strongly related to its mechanical properties. It is an important process especially in manufacturing machine parts and tools. Heat treatment process such as annealing, normalizing, hardening and tempering are the most important process that often employed to modify the microstructure and mechanical properties of engineering materials particularly steels.

Steel is basically an iron alloyed with carbon and other alloying elements. It can be heat treated to a wide range of strengths, toughness and ductility. Carbon is the most important alloying element in order to improve the mechanical properties of steel. Most heat treatments of steel are based primarily on controlling the distribution of carbon. Furthermore, steel offers good formability due to its low yield strength, ease in fabrication, good strength, toughness, nice weldability and it is relatively cheaper compare to other alloy.

1.2 OBJECTIVE

The objectives of this study are:

a) To identify the effect of various type of heat treatment on the microstructure of low carbon steel.

b) To identify mechanical properties of low carbon steel before and after heat treatment process.

1.3 PROBLEM STATEMENT

Many industrial applications such as car bodies require steel with excellent properties. The steel especially low carbon steel has a good strength and does not end up brittle when it comes out of the press. Additionally, when low carbon steel car bodies get into an accident, it can bend, folds and deforms more than other steel. In addition it also helps to absorb the energy of the crash.

However, this low carbon steel still needs some improvement before comes out as a product. Hence, the effects of heat treatment on the microstructure and mechanical properties of low carbon steel need to be studied in order choose the best heat treatment method to improve its properties in order to produce a high quality of car bodies.

In order to overcome the problem of low carbon steel, heat treatment techniques which are annealing, carburizing and quenching were chosen to improve its properties.

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1.4 SCOPE OF STUDY

The scopes of the research are:

a) To conduct various process of heat treatment on the material which are carburizing, annealing, normalizing and quenching.

b) Metallurgical investigation and material characterization of low carbon steel before and after heat treatment process.

c) To conduct hardness test on the material before and after heat treatment process.

CHAPTER 2

LITERATURE REVIEW

2.1 METALLURGY

Metallurgy is a field of materials science and materials engineering that studies the physical and chemical behavior of metallic elements, intermetallic compounds and its mixtures, which known as alloys. Besides, it is also a technology of metals where science is applied to their practical use.

2.1.1 Introduction to Steels

Steels are alloy of iron and carbon that normally have less than 1.0 wt% content of carbon. It may contain with or without other alloying elements that have different compositions and/or heat treatment (Callister et al., 2008). American Iron and Steel Institute has defined carbon steel as steel is considered to be carbon steel when no minimum content is specified or required for chromium, cobalt, molybdenum, nickel, titanium or any other element to be added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40%; or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65, silicon 0.60, copper 0.60 (Key to metal, 2001).

Steels may be broadly classified into two types; carbon and alloy where some of common carbon steels are classified according to its carbon concentration as shown in Figure 2.1. They are frequently called low, medium and high carbon types. Besides, subclasses also exist within each group based on concentration of other alloying elements such as manganese, silicon, phosphorus and sulfur.

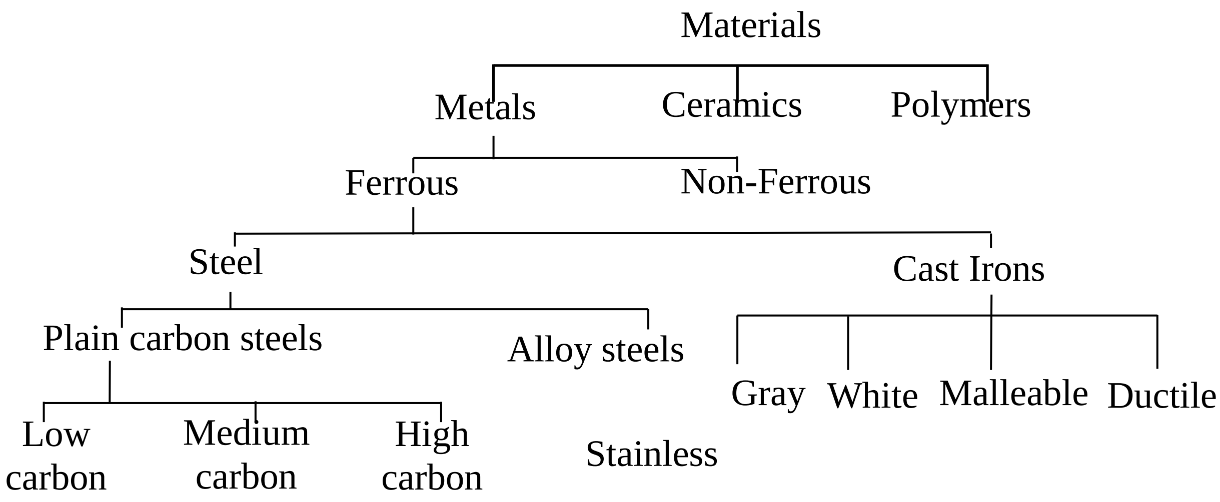

Figure 2.1: Classification scheme for various ferrous alloys

(Source: ecourses.vtu.ac.in)

2.1.2 Low Carbon Steels

Low carbon steel is widely used and produced in all applications because it is cheaper than other steel. Normally it contains less than 0.25 wt% and divided into two groups plan carbon steels and high-strength, low alloy (HSLA) (Jaypuria, 2008). The microstructure of low-carbon steel consists of ferrite and pearlite. As a consequence, these alloys are soft, malleable and weak but have a good ductility and toughness. Furthermore, plain low-carbon steel also machinable, weldable and low cost to produce. Generally plain low-carbon steels used in automobile body components, structural shapes and sheets that are used to form tin cans, wire, pipelines and etc.

For HSLA, they contain other alloying elements such as nickel. Copper, molybdenum and vanadium in combined concentration as high as 10 wt%. Thus, it