EFFECT OF HEAT TREATMENT ON THE MICROSTRUCTURES AND MECHANICAL PROPERTIES OF HIGH 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 and Material)

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Thesis submitted in fulfillment of the requirements
for the award of degree
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DECLARATION

“I hereby declare that the works in this report is my own except for summaries and quotations which have been duly acknowledge.

Signature	:	....
Author	:	....
Date	:	....

DEDICATION

This report is dedicated to my beloved family.

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ABSTRAK

Kajian ini meliputi terutamanya kesan rawatan haba pada mikrostruktur dan sifat mekanik SK3 keluli karbon tinggi. Terdapat empat jenis proses rawatan haba terdiri daripada penyepuhlindapan, pelindapkejutan, penormalan dan pembajaan. Analisis komposisi dijalankan ke atas spesimen untuk mencari komposisi kimia bahan sebelum proses rawatan haba. Spesimen dipanaskan pada suhu pengaustenit 760ºC, 840°C, 920°C, 1000°C dan 1080ºC dan bertahan selama satu jam rendaman masa. Spesimen disejukkan dengan tiga medium penyejukan iaitu pelindapkejutan minyak, penyejuk udara dan penyejukan relau. Proses pembajaan pada suhu 500ºC dengan 10minit masa rendaman dan disejukkan pada suhu bilik. Analisis kajian ini adalah ujian mekanikal dan penyiasatan logam sebelum dan selepas proses rawatan haba. Keputusan ujian kekerasan adalah 6.96HRC untuk spesimen asal. Peningkatkan kadar penyejukan menghasilkan nilai kekerasan yang lebih tinggi. Penyejukan pantas pada specimen pelindapkejutan menghasilkam nilai kekerasan yang tertinggi iaitu 56.34HRC. Kadar penyejukan sederhana di dalam spesimen penormalan menunjukkan nilai kekerasan pertengahan manakala kadar penyejukan perlahan pada specimen penyepuhlindapan menghasilkan nilai kekerasan terendah iaitu 4.28HRC. Selain daripada itu, kesan kadar penyejukan mempengaruhi saiz fasa mikrostruktur. Penyejukan perlahan menghasilkan saiz fasa kasar dan penyejukan pantas menghasilkan saiz fasa halus. Kekerasan dalam proses pembajaan adalah lebih rendah daripada proses pelindapkejutan disebabkan oleh perubahan mikrostruktur daripada martensit ke temper martensit. Selain itu, penyejukan perlahan menghasilkan mikrostruktur pearlit. Penyejukan sederhana membentuk mikrostruktur bainit. Manakala, penyejukan pantas menghasilkan fasa martensit.

ABSTRACT

This research covered mainly the effect of heat treatment on the microstructures and mechanical properties of high carbon steel SK3. There are four type of heat treatment process consist of annealing, quenching, normalizing and tempering. Composition analysis is conducted on the specimen to find the chemical composition. Specimen are heated at austenitizing temperature of 760ºC, 840ºC, 920ºC, 1000ºC and 1080ºC and hold for one hour soaking time. Specimens are cooled with three cooling medium which are oil quenching, air cooling, and furnace cooling. Tempering process is reheated the specimen at tempering temperature of 500 ºC with 10 minute soaking time and cool by normal temperature. The analyses for this research are mechanical test and metallurgical investigation before and after heat treatment process. Hardness result obtained 6.96HRC for as-received specimen. Increase in cooling rate produces to higher hardness value. Rapid cooling in quenched specimen shows highest hardness value of 56.34HRC. Moderate cooling rate in normalized specimen shows the intermediate hardness value whereas slow cooling rate in annealed specimen shows the lowest hardness value of 4.28HRC. Other than that, cooling rate effect to the grain size of the specimen. Slow cooling in annealed specimen produce coarse grain size and rapid cooling in quenched specimen produce fine grain size. Hardness in tempering process is lower than quenching process due to microstructural changes from martensite to tempered martensite. Besides, slow cooling form pearlite microstructure. Moderate cooling form bainite microconstituent. Whereas, rapid cooling produce martensite phase.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

1.1.1 HIGH CARBON STEEL.

High carbon steel has more than 0.6% C. Generally, high-carbon steel is used for application requiring strength, hardness and wear resistance. The applications of high carbon steel in industry are cutting tools, cable, music wire, springs and cutlery. Basically after being manufactured, the parts usually are heat treated and tempered. The higher the carbon content of the steel, the higher is its hardness, strength and wear resistance after heat treatment (Kalpakjian et al. 2010).

The high carbon steels normally having carbon content between 0.60wt% and 1.4wt%, are the hardest, strongest and yet least ductility of carbon steel. Basically, they are used in hardened and tempered condition such as related to wear resistant and capable of holding a sharp cutting edge. These steels are utilized as cutting tools and dies for forming and shaping materials as well as in several applications in industry. Examples of high carbon steel usage are knives, razors, hacksaw blades, spring and high strength wire (Callister 2007).

Steel content approximately 0.6-0.99% carbon is called high carbon steel. This steel is very strong, as the carbon content in steel increases, it becomes harder and stronger with the sacrifice of its ductility. Thus the heat treatment operation is adopted (Danda 2011).

Figure 1.1 : High carbon steel application in industry.

1.1.2 HEAT TREATMENT

Heat treatment can be defined as a combination of heating and cooling operations applied to a metal or alloy in solid state. It is important manufacturing process, which controls the mechanical properties of metals, therefore contributes to the quality of the product. By construct the heating process in furnace, it will change the microstructure and mechanical properties and most of energy is consumed (Zhang et al. 2007).

Heat treatment is an industrial process, used to alter the physical, chemical, and metallurgical properties of a material. Heat treatment process involves the use of heating or chilling, normally to extreme temperatures to achieve desire result such as hardening or softening. In overall process of heat treatment, the specific purpose of altering properties intentionally (Choudhury et al. 2001).

Heat treatment is a heating-treating process whereby the steel are exposed to elevated temperature and cooled of which transform or changes the mechanical properties. Transformation in the solid state can be obtained using heat treatment process that can affect the changes on microstructure result (Totten et al. 2004).

1.2 PROBLEM STATEMENT

How does heat treatment affects the microstructures and mechanical properties of high carbon steel?

1.3 OBJECTIVES

The objectives of this research are

1. To identify the effect of heat treatment on the microstructure of high carbon steel.
2. To identify the effect of heat treatment on mechanical properties of high carbon steel SK3.

1.4 SCOPE OF STUDY

The scope of study are:

1) To conduct heat treatment process on high carbon steel.
2) To conduct hardness on the material before and after heat treatment process.
3) Metallurgical investigation and material characterization before and after heat treatment process.

CHAPTER 2

LITERATURE REVIEW

2.1 CARBON STEELS

Carbon steel or plain carbon steel is a metal alloy with the combination of carbon and iron. Carbon steels are classified by the percentage of carbon content. As general, carbon steel is classified into three groups which are low carbon steel also called as mild steel, medium carbon steel and high carbon.

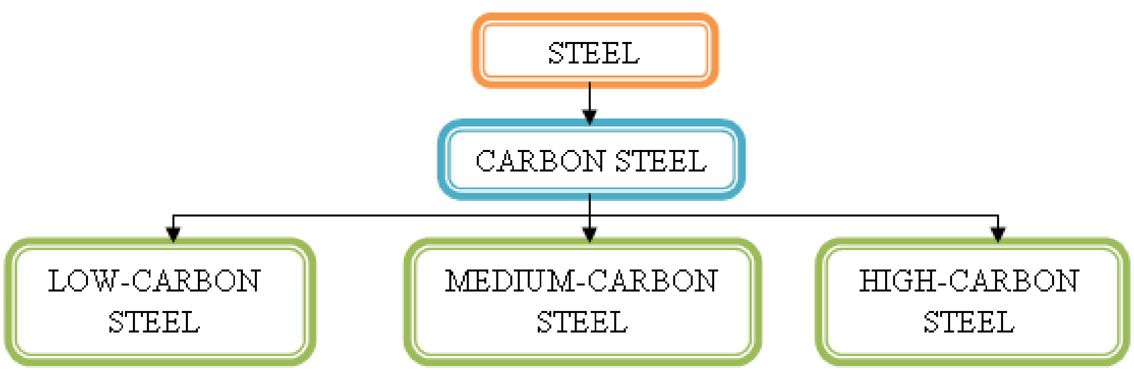

Figure 2.1 : Carbon steel chart

According to Kalpakjian et al. (2010), these three different groups of carbon steels have specific carbon percentage and the applications in industries. For low carbon steels also known as mild steels has less than 0.30% C. It is used commonly in industrial product such as nuts, bolts, sheets, plates and tubes. These metals are not suitable for high strength especially in machine components. For medium-carbon steel has 0.30% to 0.60%C. The application is requiring high strength such as in machinery, automotive and agricultural equipments parts. Other applications of medium carbon steels in industries are gear, axles, connecting rods and crankshaft. For high carbon steels has more than 0.6%C. generally, high carbon steels is used for applications requiring strength, hardness and wear resistance such as cutting tools, cable, music wire, springs and cutlery.

2.2 PHASE DIAGRAM

Phase diagram or similar as equilibrium or constitutional diagram shows the relationship among temperature, composition and phase present. Based on Kalpakjian et al. (2010), in iron-carbon phase diagram shown in figure 2.2 the range in significantly to engineering applications is up to 6.67%C, because Fe_3C is a stable phase. Pure carbon steel melts at a temperature of 1538°C as iron-carbon cools, the first phase form delta ferrite, followed by austenite and final stage would be alpha ferrite.

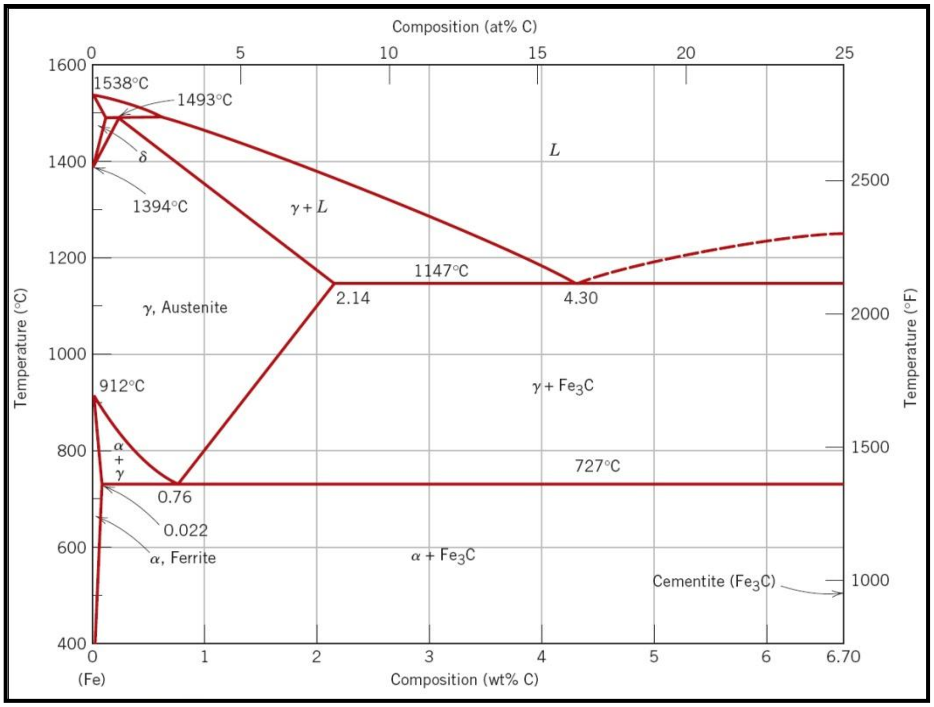

Figure 2.2 : The iron-iron carbide phase diagram

(Source: Kalpakjian et al. 2010)

2.2.1 FERRITE

Ferrite is a solid solution of body-centered cubic iron it has a maximum solid solubility of 0.022%C at temperature of 727°C. Ferrite is soft and ductile in the range of temperature at 27°C (room temperature) to 768°C. Although very a small amount of dissolve carbon, but the amount of carbon can significantly affect the result of mechanical properties. Delta ferrite is a form that is stable at high temperature (Kalpakjian et al. 2010).

2.2.2 AUSTENITE

Austenite structure has a solubility of up to 2.11%C at temperature of 1148°C. The solid solubility of austenite is about two orders of magnitude higher than ferrite. Austenite is denser than ferrite and the structure is ductile at elevated temperatures, consequently and posses good formability (Kalpakjian et al. 2010).

2.2.3 CEMENTITE

Cementite contain 100% iron carbide Fe_3C having percentage of carbon content 6.67%. cementite is hard and brittle intermetallic compound (Kalpakjian et al. 2010).

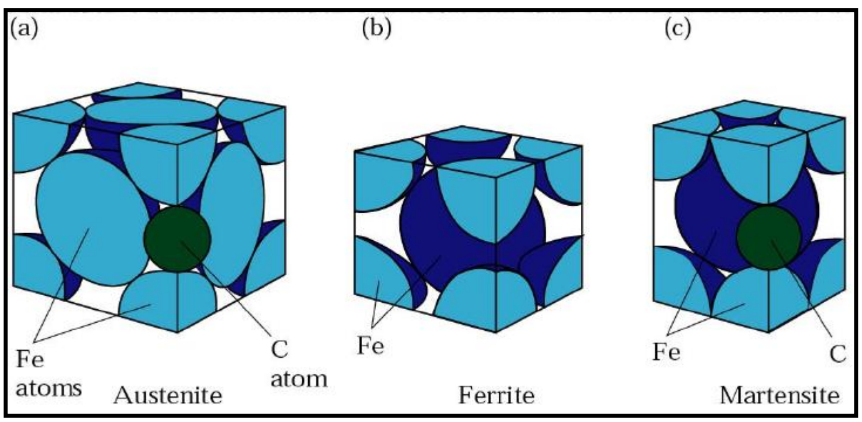

Figure 2.3 : Unit cells for autenite, ferrite and martensite.

(Source: Kalpakjian et al. 2010)

2.3 HEAT TREATMENT

Heat treatment process is widely used in industries to achieve better mechanical properties of material. Major requirements of high carbon steel are high yield strength, high hardness and high wear resistance. The properties of high carbon steel can achieve by adding suitable alloying elements by heat treatment process. Heat treatment is a combination of timed heating and cooling applied to a particular metal or alloy in the solid state to produce certain microstructure and desire mechanical properties including of hardness, toughness, yield strength, ultimate tensile strength, Young's modulus, percentage elongation and percentage reduction. Annealing, normalizing, hardening and tempering are the most important process of heat treatment that often used to modify the microstructure and mechanical properties of engineering materials particularly steels (Motagi et al. 2012).

2.3.1 ANNEALING

Annealing is one of the heat treatment processes to soften iron or steel materials and refines its grains due to ferrite-pearlite microstructures. It is used where the elongations and appreciable level of tensile strength are required in engineering materials.

In annealed Carbon steel with the percentage of carbon less than 0.8%, the carbon content increases the tensile strength increases but ductility decreases. The increase in strength is due to the increase in the proportion lamellar pearlite with increasing carbon content. Thus the carbon content increases the proportion of proeutectoid ferrite phase in soft ductile phase decreases leading to the reduction in ductility. Whereas in hypoeutectoids steels of higher carbon content between 0.6 to 0.8%C the spheroidizing techniques is applied to break lamellar cementite into cementite spheroids. This provides improve ductility of the metals with a microstructures consisting of cementite spheroids in the matrix of ferrite (Atanu et al. 2012).