'We admit that had read this work and in our view this work was satisfy from scope and quality aspect to be awarded for Bachelor of Mechanical Engineering (Structure&Material)'

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EFFECT OF MARTEMPERING PROCESS ON PLAIN CARBON STEEL

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This report is produce to complete the requirement of the Bachelor of Mechanical Engineering (Structure & Materials) award.

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APRIL 2009

"I admit that this report is my own work

except for summary and quotation that has been stated the resources."

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ASBTRAK

Tujuan untuk perawatan keluli karbon biasa E8M-04 ialah untuk perubahan sifat mekanikal keluli seperti kemuluran, kekerasan, kekuatan alah dan lain- lain. Kekerasan bertambah apabila bilangan karbon dalam keluli bertambah tetapi kemuluran berkurangan. Martensit pembajaan digunakan untuk mengatasi kelemahan proses pelindapkejutan dan pembajaan yang biasa. martensit pembajaan merupakan pemindahan daripada austenit ke martensit pada masa yang sama pada seluruh struktur keluli. Ini dilakukan dengan gangguan kitaran pelindapkejutan iaitu penyejukan dihentikan pada suhu diatas daripada kawasan pemindahan martensit dimana masa untuk suhu titik tegah menyejuk adalah sama dengan masa penyejukan permukaan. Penyejukan berterusan sehingga kawasan martensit diikuti dengan pemanasan. Ukuran yang berbeza diperlukan untuk ujian regangan dan ujian kekerasan selepas martensit pembajaan. Spesimen dipanaskan pada suhu 900°C and pelindapkejutan daripada suhu austenit dalam medium minyak. Spesimen dipanaskan semula pada suhu 450°C pada masa yang berbeza. Kemudian, ujian regangan dan ujian kekerasan dilakukan. Ujian regangan adalah untuk menentukan kekuatan regangan dan kekuatan alah. Manakala ujian kekerasan adalah untuk mengukur kedalaman penembusan takuk dibawah daya yang besar berbanding kedalaman penembusan oleh daya yang kecil. Teknik metalografi digunakan untuk penyediaan contoh keluli dalam ujian mikrostruktur. Keputusan eksperimen yang dijalankan dicatatkan dan dibincangkan disamping kesimpulan dibuat mengenai martensit pembajaan.

ABSTRACT

The purpose of heat treating E8M-04 plain carbon steel is to change the mechanical properties of steel, usually ductility, hardness, yield strength, and others. As carbon content rises the metal becomes harder and stronger but less ductile. Higher carbon content lowers steel's melting point and its temperature resistance in general. Martempering process is use to overcome the restrictions of conventional quenching and tempering. Martempering or marquenching permits the transformation of austenite to martensite to take place at the same time throughout the structure of the metal part. This is achieved by interrupting the quench cycle; the cooling is stopped at a point above the martensite transformation region to allow sufficient time for the centre to cool to the same temperature as the surface. Then cooling is continued through the martensite region, followed by the usual tempering. The different dimensions of specimens are needed for the tensile test and hardness test after the martempering process. These specimens are heating until 900°C and then quenching from the austenitizing temperature into the oil medium. Then the specimens are heated again at temperature 450°C at the different temperature. Then, the tests are doing in the specimens like tensile test and hardness test. Tensile tests are used to characterize the tensile strength and yield strength. While the hardness test is to determine the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. Lastly, the metallographic technique is doing for samples preparation in microstructure test. The result based on the experiment is discussed and the conclusion is stated whether satisfy objectives of the martempering process.

CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Ms	=	The temperature at which the austenite in a steel finishes transforming to martensite
M_f	=	the temperature at which the austenite in a steel starts to transform to martensite
UTS	=	ultimate tensile strength
ASTM	=	American Society for Testing and Materials
L_0	=	Initial length
L_f	=	final length
e_f	=	total elongation
D_0	=	intial diameter
A_0	=	intial area
UTeM	=	Universiti Teknikal Malaysia Melaka
CNC	=	Computer numerical control

LIST OF APPENDIXES

CHAPTER I

INTRODUCTION

1.1 Background

Plain carbon steel is the main alloying that constituent of carbon and other elements. The other elements that also in carbon steel are Manganese with maximum 1.65%, silicon with maximum 0.60%, and copper with maximum 0.60%. As carbon content rises the metal becomes harder and stronger but less ductile and more difficult to weld. Higher carbon content lowers steel's melting point and its temperature resistance in general. Martempering or marqueching is the heat treatment process for plain carbon steel.

This is a method of hardening steel by quenching from the austenitizing temperature into some heat extracting medium, usually salt, which is maintained at some constant temperature level above the point at which martensite starts to form (usually about 450 F.), holding the steel in this medium until the temperature is uniform throughout, cooling in air for the formation of martensite and tempering by the conventional method. The advantages of this method of interrupted quenching are a minimum of distortion and residual strains. The size of the part can be considerably larger than for austempering.

It differs from austempering in that the work piece remains at temperature only long enough for the temperature to be equalized throughout the work piece. When the temperature has attained equilibrium but before transformation begins, the work piece is removed from the salt bath and air cooled to room temperature. Oils are used successfully for martempering, but molten salt is usually preferred because of its better heat-transfer properties. Cooling from the martempering bath to room temperature is usually conducted in still air. Deeper hardening steels are susceptible to cracking while martensite forms if the cooling rate is too rapid. Martempering does not remove the necessity for subsequent tempering. The structure of the metal is essentially the same as that formed during direct quenching.

Martempering is a heat treatment for steel involving austenitisation followed by step quenching, at a rate fast enough to avoid the formation of ferrite, pearlite or bainite to a temperature slightly above the Ms point(Figure 1.1). Soaking must be long enough to avoid the formation of bainite. The advantage of martempering is the reduction of thermal stresses compared to normal quenching. This prevents cracking and minimises distortion. (Wikipedia, 2008)

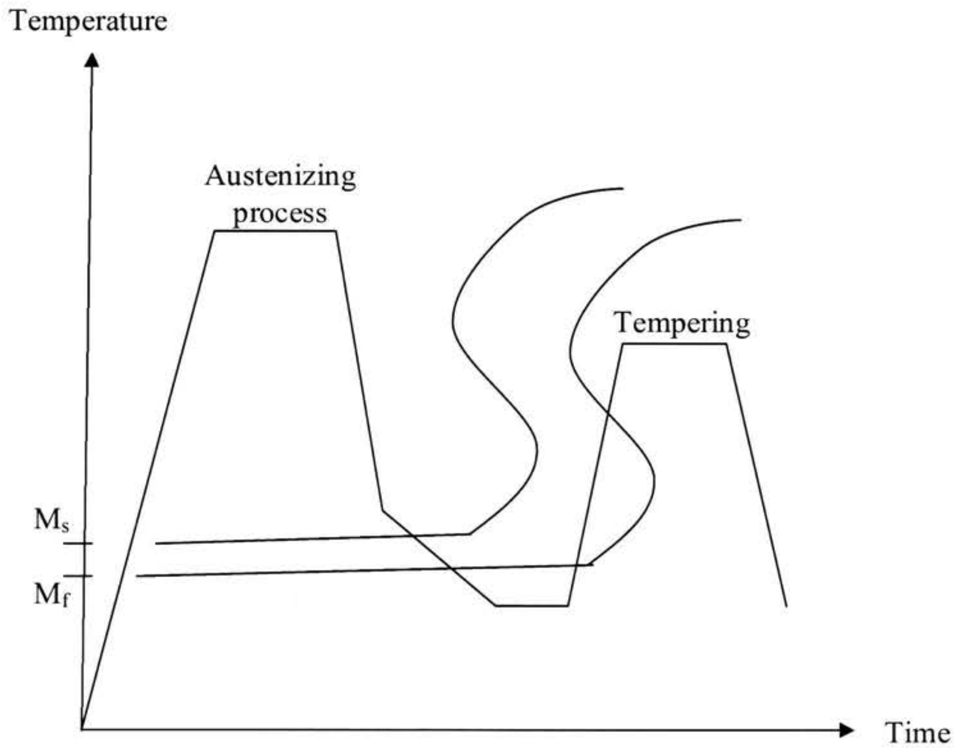

Figure 1.1 Martempering Cooling Curve

1.2 Application of Martempering Process

Alloy steels generally are more adaptable than carbon steels to martempering. In general, any steel that is normally quenched in oil can be martempered. Some carbon steels that are normally water quenched can be martempered at 205 °C (100 F) in sections thinner than 5 mm using vigorous agitation of the martempering medium. In addition, thousands of flay cast iron parts are martempered on a routine basis. Occasionally, higher-alloy steels such as type 44O stainless are martempered, but this is not a common practice. (ASM 1995).

1.3 Problem Statement

Martempering process is one of the most important and interest process to study. These microstructures exist when the material is quenching rapidly in the oil. Microstructure development and mechanical properties of the plain carbon steel that involve in martempering process are depend on time and tempering temperature. These parameters need to be properly controlled to produce proper microstructure and mechanical properties. So, it is necessary to create experiment of this martempering process to study of its microstructure and the mechanical properties of the existence microstructure at the different tempering time and tempering temperature.

1.4 Objectives

The objectives of this paper are to describe the concept of martempering process. The martempering consist of austenization of the steel, quenching it in the hot oil at a temperature just slightly above the Ms temperature, holding the steel in the quenching medium until the temperature is uniform throughout and stopping this isothermal before the austenite to bainite transformation begin and cooling at a moderate rate to room temperature to prevent large temperature differences.

The second objective of this experiment is to explain the effect of time and temperature of martempering process on the microstructure and mechanical properties of the plain carbon steel. Other than that, the objective of the martempering is to clarify the effect of time and temperature of martempering process on the mechanical properties of the plain carbon steel.

1.5 Scope

The focuses of this report are identifying the significance sample of steel that depends on the temperature parameters, time parameters and heat parameters of the martempering process, and elaborate the metallographic technique in sample preparation and doing the microstructure test to identify the types of microstructures, size of microstructure. The tensile test for stress and strain curve and Rockwell hardness test are the focuses in this project, but most of the priority in this project is about to analyze the mechanical properties, martempering time and martempering temperature and microstructure of the plain carbon steel.

CHAPTER II

LITERATURE REVIEW

2.1 Quenching and tempering processes

The structural of the steel are different when the martempering process is doing on it. Steels can be heat treated to high hardness and strength levels. The reasons for doing this are obvious. As-quenched hardened steels are so brittle that even slight impacts may cause fracture.

The hardness of the steels will reduce and it will become ductile and also fracture because of the austempering process. Tempering is a heat treatment that reduces the brittleness of steel without significantly lowering its hardness and strength. All hardened steels must be tempered before use.

According to Habarakada (2007), "to overcome the restrictions of conventional quenching and tempering, Martempering process can be used. Martempering or marquenching permits the transformation of Austenite to Martensite to take place at the same time throughout the structure of the metal part. (Refer Figure 2.1). By using interrupted quench, the cooling is stopped at a point above the martensite transformation region to allow sufficient time for the center to cool to the same temperature as the surface. Then cooling is continued through the martensite region, followed by the usual tempering."

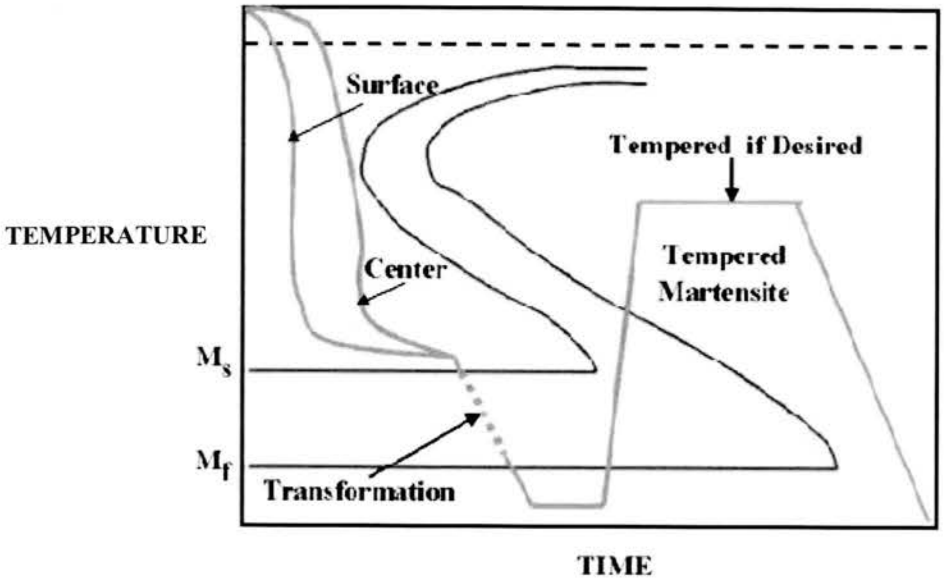

Figure 2.1 Martempering Process
(Source: Habarakada (2007))

Martempering is not actually a tempering procedure, hence the term "Marquenching." It is a form of isothermal heat treatment applied after an initial quench of typically in an oil or brine solution at a temperature right above the "martensite start temperature". At this temperature, residual stresses within the material are relieved and some bainite may be formed from the retained ferrite which did not have time to transform into anything else. In industry, this is a process used to control the ductility and hardness of a material. With longer marquenching time, the ductility increases with a minimal loss in strength; the steel is held in this solution until the center and surface temperatures equalize. Then the steel is cooled at a moderate speed to keep the temperature gradient minimal. Not only does this process reduce internal stresses and stress cracks, but it also increases the impact resistance. (McGraw Hills 2006)

Martempering of steel consists of quenching into a hot fluid medium (salt, oil, water) from the austenizing temperature that usually above the martensite range. The steels are holding in the quenching medium until the temperature throughout the steel is substantially uniform and the steels are cooling (usually in air) at a moderate rate to prevent large differences in temperature between the outside and the center of the section. Plain-carbon steel with at least 0.4 wt% C is heated to normalizing temperatures and then rapidly cooled (quenched) in water, brine, or oil to the critical temperature.

The critical temperature is dependent on the carbon content, but as a general rule is lower as the carbon content increases. This will results in a martensitic structure; a form of steel that possesses a super-saturated carbon content in a deformed Body Centered Cubic (BCC) crystalline structure, properly termed Body Centered Tetragonal (BCT). This crystalline structure has a very high amount of internal stress. Due to these internal stress quenched steel is extremely hard but brittle, usually too brittle for practical purposes. These internal stresses cause stress cracks on the surface. Quenched steel is approximately three (lower carbon content) to four (high carbon content) times harder than normalized steel. (Smith& Hashemi, 2006)

If the steel is quenched to below the Ms, martensite will be the predominate structure, however if the steel is quenched to a point slightly above the Ms point. This is called marquenching and is commonly used because it is less stressful particularly in difficult cross sections. When the steel is removed from the quench it is still above the Ms point and has very unusual properties. It can be easily bent or straightened and is still quite soft.

As it cools however, it begins to setup martensite and will harden at room temperature. These steels benefit from sub zero quenching because the colder temperatures are necessary to complete the austenite transformation and to reach the martensite finish. Care must be taken that the blade is not chilled by placing on a cold surface or even by being placed in a breeze or draft. The safest method is to allow it to cool in still air. The steel should be tempered after it has cooled to the point where it can be handled with bare hands.

As quenched, martensite is brittle with significant internal stresses. The ductility and toughness of martensite enhanced by tempering (heating to temperature below eutectoid for a specified time). Martensite produces extremely small, uniformly dispersed cementite in uniform ferrite (similar to spheroidite, but much smaller). Nearly as strong as martensite, with much better ductility and toughness. Increased cementite particle size results in softer more ductile material (larger particles produced at higher tempering temperature).

The tensile properties of annealed and normalized steels are controlled by flow and fracture characteristics of the ferrite (strength ~alloying elements, grain size), amount of ferrite, shape of ferrite and distribution and amount of cementite (C content). Figure 2.2 shows the microstructure exists when the martempering process is doing. The shape occurs are martensite. While Figure 2.3 shows the continous cooling transformation (CCT) diagram for eutectoid iron carbon alloy.

Figure 2.2 Martensite microstructure that the needle shaped grain are the martensite grain and the white are the austenite that failed to transform during the rapid quench.

(Source: William (1985))

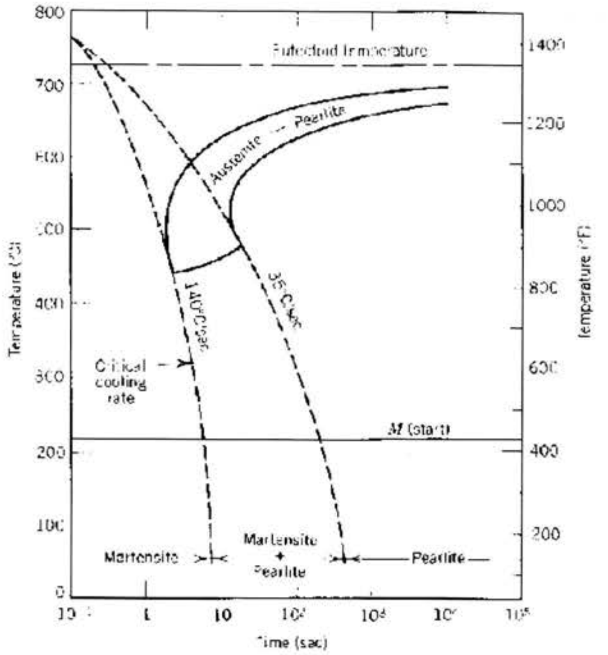

Figure 2.3 The continuous cooling transformation (CCT) diagram for eutectoid iron-carbon alloy, and superimposed cooling curves, demonstrating the decency of the final microstructure on the transformations that occur during cooling.

(Source: William (1985))

2.2 Martempering Medium

Water is a common quench especially in steels with low hardenability. It is fast and clean, but it is also severe especially with odd cross sectioned pieces. If look at what happens when steel is quenched in water it will give us an idea of how this process works. As the hot steel enters the water, the water immediately takes heat until it reaches boiling temperature. As the water boils, it forms a vapor jacket around the steel and unless it is circulated or flushed rapidly from the surface, this jacket will inhibit cooling. In thin cross sections this is not as much of a problem as it would be in thicker sections, but if not taken into consideration results can be spotty.

Oil quenches are slower than water based quenches, but in thin cross section will harden most steels. Quenching oils can divided into several categories depending on operational requirements. These include quenching speed operating temperature and ease removal. It is not as drastic a quench as water or brine and lessens the chance for cracking. It is fast, has high flash point and is reliable. Oil also can be used at lower temperatures and easier to handle at room temperature.

2.3 Advantages of Martempering Process

The advantage of martempering lies in the reduced thermal gradient between surface and center as the part is quenched to the isothermal temperature and then is air cooled to room temperature. Residual stresses developed during martempering are lower than those developed during conventional quenching because the greatest thermal variations occur while the steel is in the relatively plastic austenitic condition and because final transformation and thermal changes occur throughout the part at approximately the same time.

Martempering also reduces or eliminates susceptibility to cracking. Another advantage of martempering in molten salt is the control of surface carburizing or decarburizing. When the austenitizing bath is neutral salt and is controlled by the addition of methane gas or proprietary rectifiers to maintain its neutrality, parts are protected with a residual coating of neutral salt until immersed in the marquench bath.

Although martempering is used primarily to minimize distortion, eliminate cracking, and minimize residual stresses, it also greatly reduces the problems of pollution and fire hazard as long as nitrate-nitrite salts are used rather than martempering oils. This is especially true where nitrate-nitrite salts are recovered from wash waters with systems that provide essentially no discharge of salts into drains. Any steel part or grade of steel responding to oil quenching can be martempered to provide similar