AN INVESTIGATION ON THE INFLUENCE OF DOUBLE HEAT TREATMENT PROCESS ON MILD STEEL PLATE

RAHFIZAN BIN KHAIRUZZAMAN

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Faculty of Mechanical Engineering

Universiti Teknikal Malaysia Melaka

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DECLARATION

"I hereby declare that this report entitled "AN INVETIGATION ON THE INFLUENCE OF DOUBLE HEAT TREATMENT PROCESS ON MILD STEEL PLATE" is the result of my own research except as cited in the reference."

Signature: ....

Author: Rahfizan Bin Khairuzzaman

Date: 25 June 2013

SUPERVISOR DECLARATION

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

Signature: ....

Supervisor: En. Nazri Huzaimi Bin Zakaria

Date: 25 June 2013

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ABSTRACT

This research covered mainly the effect of double heat treatment on mild steel plate. Three types of heat treatment are quenching, tempering and normalizing were used in this study. The specimen that used in this study is consisted of square shape mild steel plate with 250mm x 40 mm x 4 mm dimension. During heat treatment process, specimen is heated up to 960°C for one hour before taken out from the furnace. Two of the specimens then are quenched in water at room temperature. For other specimen, it will cool at room temperature due the normalizing process. One of the specimens from quenching process will be continued with tempering process, tempering process consist two level of heating process and temperature will be considered. After the first stage of the heat treatment process, three types of test will be conducted which are hardness test, microstructure and tensile testing the specimen. After that, another specimen will undergo the same heat treatment process for second time. The specimen also will be tested with three types of testing and the result of single and double heat treatment will be compared. The expected result for hardness and strength for tempering, quenching and normalizing is the specimen becomes more increase.

ABSTRAK

Kajian ini meliputi kesan rawatan haba dua kali terhadap plat keluli lembut. Tiga jenis rawatan haba yang akan digunakan didalam kajian ini adalah pelindapkejutan, pembajaan dan penormalan. Dimensi spesimen yang digunakan adalah terdiri daripada plat keluli berbentuk segiempat dengan ukuran 250mm x 40mm x 4mm. Semasa proses rawatan haba, spesimen dipanaskan pada suhu 960°C selama satu jam sebelum dibawa keluar dari relau. Dua daripada spesimen akan disejukkan di dalam air pada suhu bilik. Bagi spesimen lain, ia akan dibiarkan menyejuk pada suhu bilik untuk proses penormalan. Salah satu daripada spesimen daripada proses pelindapkejutan akan diteruskan dengan proses pembajaan, proses pembajaan terdiri dua tahap proses pemanasan dan suhu akan dipertimbangkan. Selepas peringkat pertama proses rawatan haba telah selesai, tiga jenis ujian yang akan dijalankan pada specimen adalah ujian kekerasan, mikrostruktur dan ujian tegangan. Selepas itu, spesimen lain akan menjalani proses rawatan haba yang sama untuk kali kedua. Spesimen tersebut juga akan diuji dengan tiga jenis ujian dan hasil rawatan haba pertama dan kedua akan dibandingkan. Hasil yang dijangkakan untuk kekerasan dan kekuatan untuk pelindap kejutan pembajaan, dan menormalkan adalah spesimen menjadi lebih kuat.

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CHAPTER 1

INTRODUCTION

1.1 HEAT TREATMENT

Heat treatment is defined as an operation or combination of operation, involving heating and cooling of a metal, for this case involving the mild steel in its solid state with the object of changing the characteristic of the material. For this project, the mild steel plate will be run with double heat treatment process that is normalizing, quenching and tempering to investigate the influence of the process to the material. The characteristic changing can be explored through the microstructure test with applying the microscope test that was form various characteristics as pearlite, martensite, tempermartensite and so on. S275JR mild steel plate will we used in this research, this steel contain the carbon percentage of 0.22%. [1]

Heat treatment is generally employed for following purpose such as to improve mach inabilility, to change or refine grain size, to improve mechanical properties like tensile strength and Rockwell hardness test and microstructure test to obtain various collection data before it can be evaluated to determine the result compare with the standard data of mild steel as a comparison. [2]

1.2 OBJECTIVE

a. To investigate the influence of double heat treatment process on mild steel.
b. To observe the change of microstructure and strength of mild steel plate after subjected to normalizing, tempering and quenching process.

1.3 SCOPE

The scope of this research is:

a. Analyze the strength, hardness and change of microstructure between one and double heat treatment process on mild steel plate.
b. Specimen preparation for make double heat treatment process.

1.4 PROBLEM STATEMENT

Mild Steel is most common form of steel because its price is low, malleable and acceptable for many applications. However, the most common problem we are encountered by mild steel is that it has a relatively low tensile strength. Usage properties, as well improper heat treatment processes contributes to this problem. In this research, low carbon steel S275JR has been selected as the material for double heat treatment process. The hardness and strength of the carbon steel can be analyzed through Rockwell tester and ultimate tensile testing and the internal structure can be analyzed by using microscope image analyzer. This research is also to proof that the hardness and strength of mild steel with double heat treatment is larger compared to the single heat treatment. [3]

CHAPTER 2

LITERATURE RIVEW

2.1 INTRODUCTION

The purpose of literature review is to find out all the necessary information and unknown knowledge in the research of the effect of double heat treatment towards mild steel plate strength, hardness and microstructure. The objective of literature review is to use the source found out to support the research. The sources include books, journals, articles and internet sources.

2.2 CARBON STEEL

Carbon steel is steel that contain carbon as main alloying element. It also has up to 1.5% carbon and other alloying elements like copper, manganese and silicon. As we can see, nowadays most of the steel produced is plain carbon steel.

Steel with low carbon content has properties similar to iron. As the carbon content increases the metal becomes harder and stronger but less ductile and more difficult to weld. Higher carbon content lowers the melting point and its temperature resistance carbon content cannot alter yield strength of material.

2.2.1 Low carbon steel

Low carbon steel or mild steel has carbon content of 1.5% to 4.5%. Low carbon steel is the most common type of steel as its price is relatively low while its provides material properties that are acceptable for many applications. It is neither externally brittle nor ductile due to its low carbon content. It has lower tensile strength and malleable.

2.2.2 S275JR steel plate

The S275JR steel plate has reliable mechanical properties, good formability and excellent welding performance; it's also used widely in various industries such as architecture, bridge construction, marine craft, railway locomotive heavy machine and other structure parts. Table 2.1 show the properties S275JR mild steel plate.

Table 2.1: Properties S275JR mild steel plate

Source : www.steelnumber.com/en/steel_composition_eu.php?name_id=3

<table>
<tr><td colspan="3">S275JR STEEL</td></tr>
<tr><td rowspan="7">Minimum Properties</td><td>Tensile Strength (1 - 100mm thickness)</td><td>410Mpa - 560Mpa</td></tr>
<tr><td>Minimum Yield Strength (to 16mm thickness)</td><td>275Mpa</td></tr>
<tr><td>Minimum Elongation (3 – 40mm thickness)</td><td>23%</td></tr>
<tr><td>Carbon (C)</td><td>0.22%</td></tr>
<tr><td>Manganese (Mn)</td><td>1.5%</td></tr>
<tr><td>Phosphorus (P)</td><td>0.04%</td></tr>
<tr><td>Sulfur (S)</td><td>0.04%</td></tr>
</table>

2.3 THE BACKGROUND OF MILD STEEL

Mild steel is least expensive of all steel and most common steel used. It is used in most of product created from steel, mild steel is easy to weld, very hard and very durable. Mild steel contain less than 2% carbon and it is able to be magnetized. Most of the object today that are created of steel are made using mild steel, for example, automobile chassis, motorcycle frame and most cookware are made using mild steel. Due to the poor corrosion-resistance of mild steel, it must be painted or otherwise protected and sealed in order to prevent rust from damaging it. The properties of the steel allow the electrical current to travel through the steel without distorting the makeup of the material.

Mild steel is one of the least expensive steels used and it's the most common of all metal. It is to be found in almost every product created from metal in industry. It is relatively hard, weldable, easy annealed and very durable.Steel is an alloy of iron containing a small but definite percentage of Carbon ranges from 0.15-1.5% [4]. Mild Steel are those containing 0.1-0.25% carbon, they are soft, malleable and ductile [5]. It has less than 2% carbon and it will magnetize well and being relatively inexpensive, any project that requiring a lot of steel can used mild steel.

But when it comes to load bearing, its structural strength is not usually sufficient to be used in structural beam and girders. Carbon is the main element in the formation of steel causing hardness and strength to be increased with increasing content. Increase in carbon also lowers the transformation temperature and increase Martensite (brittle structure). Higher carbon content tends to increase the risk of hydrogen induced cracking (H.I.C.) due to welding and reduce fracture toughness. Carbons increase strength and decrease ductility and weld ability. It both controls the maximum attainable hardness and contributes substantially to hardneability. Carbon has a moderate tendency to segregate. [6]

2.4 HEAT TREATMENT

Heat treatment is defined as a physical process which entails the controlled heating and cooling of material, such as metal or alloys to obtain desired properties. Heat treatment is an energy intensive process that is carried out in different furnace such as electric and gas. Shortening heat treatment cycle can provide great environment and financial benefits through energy saving. Many texture detail furnace equipment and its design but little to no literature can be found on furnace temperature methods. [7]

Heat treatment is an important operation in the manufacturing process of many machine parts and tools. Only by heat treatment it is possible to impart the high mechanical properties to steel required for the normal operation of modern machinery and tools. Heat treatment is usually classified into four typical groups. The first group comprises first-order or re-crystallization annealing which is employed to relieve internal stresses, reduce the hardness and to increase the ductility of strained-hardened metal. It is also known as stress-relieving. At first, upon an increase in the heating temperature, the elastic distortions of the crystal lattice are eliminated (recovery). At high temperature, new grains form and begin to grow (re-crystallization). Due to recovery and re-crystallization, the metals are softened and regain its high ductility. It is important to point out that the heating temperature for first order annealing is not associated with phase transformation temperature and only depends upon the recovery or re-crystallization temperature peculiar to each metal. The second group, second order of full annealing, which involves phase re-crystallization, consist in heating alloys above temperature required for phase transformation.

This is followed by sloe cooling. Full annealing substantially changes the physical and mechanical properties and may refine a coarse-grained structure. In the third group, hardening, alloys are heated above the phase transformation temperature and are then rapidly cooled (quenched) to retrain at room temperature, either a phase stable at high temperatures or various stages of decomposition or transformation of this phase. Thus, hardening cause the transformation of unstable (non-equilibrium) structures. The fourth group, tempering, involve the re-heating of a hardened alloy (steel) to a temperature below that required for phase transformation so as to bring it nearer to an equilibrium state. [1]

Heat treatment is a collection through many processes such as annealing, stress relief, quenching, tempering normalizing and ageing. All the different heat treatment processes consists the following three stages:

1) Heating of the material
2) Holding the temperature for a time.(soaking time)
3) Cooling, usually to room temperature. (normalizing)

However, the temperature and time for the various processes is dependent on the material mechanism controlling the water effect. For example, if the driving mechanism is diffusion the time must long enough to allow necessary transformation reaction. During heating and cooling, there is an existing temperature gradients between the outside and interior portion of the material; their magnitudes depends on the size and geometry of the workpiece. If the rate of temperature change in the surrounding in the surrounding is too high, large temperature gradients may develop in the component. This creates internal stresses that may lead to the plastic deformation and even to cracking. [8]

The Korea research institute chemical technology also investigated the effect of heat treatment on bioactivity and mechanical properties of a poly E-Caprlactore/Silica hybrid containing calcium. It was conclude from the research that the mechanical properties of PCL/Silica hybrid could be improved by heat treatment. It was conjectured to be coursed by the reduction of the low molecule weight PCL phase and the intensification of silica network by heat treatment. The mechanical properties of the specimens treated at $150^{o}C$showed comparable value to those of canceller's bone and it mean that its likely to be used for bio-active and degradable bone substitute. [9]Heat treatment tends to relive internal stresses and remove coarseness of grain and have significant influence on the properties of welded material. [6]

The hardness and strength properties (yield strength and ultimate tensile strength) gradually increase up in anexperiment; the experiment is to study the effect of cyclic heat treatment on microstructure and mechanical properties of 0.6% carbon steel. Graphical of the result is represent in Figure 2.1, hardness and strength properties initially increase due to the finer microstructure (finer pearlite and ferrite) originated from non-equilibrium forced air cooling in each heat treatment cycle. After 5 heat treatment cycle, the graph initially increase but after that the graph marginally decrease until the 8th cycle due to elimination of lamellar pearlite and generation of more commentate spheroids in the microstructure. However, the steel still possesses much higher strength than the as-received steel due to extremely fine grain size of ferrite in the microstructure. [10]

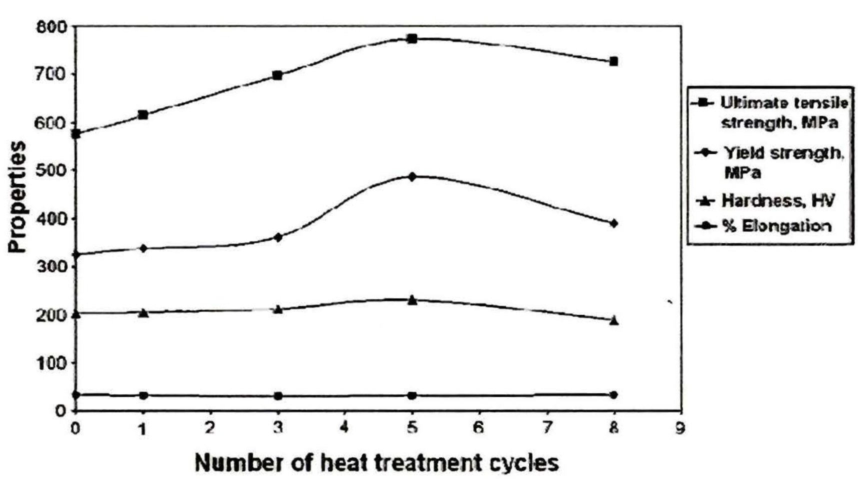

Figure 2.1: Variation of hardness and mechanical properties

with number of heat treatment cycles [10]

2.4.1 TEMPERING

Tempering is carried out after quenching to reduce the brittleness of steel. The steel is heated to below the critical temperature, held, then cooled slowly to provide the require properties. Tempering is carried out in oil, salt or lead bath and also in furnace controlled by fans circulating air. The combination of quenching and tempering can produce the best combination of strength and notch ductility. The purpose is to relive internal stress, to reduce brittleness and to make steel tough to resist shock and fatigue.

Variable associated with tempering that affect the microstructure and the mechanical properties of tempered steel include temperature; time at temperature; cooling rate from the tempering temperature; and composition of the steel; including carbon content, alloy content and residual elements. In steel, quenched to a microstructure consisting essentially of martensite, the iron lattice is strained by the carbon atom, producing the high hardness of quenched steels. On heating, the carbon atom diffuses and reacts in a series of distinct steps that eventually form Fe_3Cor alloy carbide in a ferrite matrix of gradually decreasing stress level. The properties of the tempered steel are determined primarily by the size, shape, composition and distribution of the carbide that form, with a relatively minor contribution from solid-solution hardening of the ferrite. These changes in microstructure usually decrease hardness, tensile strength and yield strength but increase ductility and toughness.

Under certain conditions, hardness may remain unaffected by tempering or may even be increased as a result of it. For example, tempering of a hardened steel at very low tempering temperature may cause no change in hardness but may achieve a desired increase in yield strength. Also, those alloy steels that contain one or more of the carbide-forming elements (chromium, molybdenum, vanadium and tungsten) and capable of 'secondary hardening'- that is, they may become somewhat harder as a result of tempering. The tempered hardness values for several quenched steel are presented. [1]

For heat treatment and subsequent hardness and tensile testing specimen were obtained from ½'' diameter bar of 0.20%C low carbon steel. Using muffle furnace, the specimen is heated at 960^oC for one hour for austenitizing and then quenched in cold water and oil. After quenching process is done, hardness and tensile properties were evaluated and then the specimens were continued with tempering heat treatment in the temperature range of$150 - 550^oC$. After tempering process is done, the hardness and tensile properties were again determined. The result from this experiment shown that 2% C low carbon steels that were heated using tempering method showed a reasonable increase in both hardness and strength during water and oil quenching. Tempering of both oil and water quench specimen resulted in a decrease in both hardness and strength in the entire range of tempering temperatures. Effect of tempering on ductility also was not very clear. [11] Table 2.2 and table 2.3 show the hardness testing result and tensile testing result respectively.

Table 2.2: Hardness testing result[11]

	ROCKWELL(HRA)	
As received	53.75	
	Oil	Water
As quenched	55.5	68.55
Tempering temperature °C		
150	49.35	56
250	47	49.5
350	46.4	49
450	46.2	47.4
550	44	45.4

Table 2.3: Tensile testing result [11]

TENSILE TESTING					
UTS(N/mm^2)			%Age elongation		
As received	853.89				
Oil			Water		
	UTS(N/mm^2)	%Age elongation		UTS(N/mm^2)	%Age elongation
As quenched	872.75	20.1	As quenched	1096.38	23.6
Tempering temperature		Tempering temperature			
150 °C	629.91	23.7	150 °C	732.83	23.6
350 °C	618.48	25.7	450 °C	656.44	25.5
550 °C	579.02	32.2	550 °C	636.51	28.4

The objectives during the Tempering process are:

i) Relieving of internal stress.

ii) Restoration of ductility and toughness

iii) Transformation of retained austenite.

iv) Tempering treatment also lowers hardness, strength and wear resistance of the hardened steel marginally.