

AN INVESTIGATION ON THE INFLUENCE OF DOUBLE HEAT TREATMENT
PROCESS ON ROUND STAINLESS STEEL BAR

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This report is submitted In Partially Fulfillment of Requirement for the Bachelor Degree
of Mechanical Engineering (Structure and Material)

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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).”


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DECLARATION

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

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ACKNOWLEDGEMENT

First of all I am grateful to ALLAH S.W.T for blessing me in finishing my final year project with success in achieving my objectives to complete this project.

Greatest gratitude to my supervisor, En. Nazri Huzaimi Bin Zakaria for guiding and supervising my final year project throughout this two semesters. He have been very helpful to me and I appreciate every advice that he gave in order to complete this project with successful. He never give up on me but give me moral support when there is a problem when doing this project.

Special thanks to my family for giving me their support and encouragement throughout four years of my studies here in Universiti Teknikal MalaysiaMelaka . I really appreciate for all what they have done for me and I take it as an inspiration for me to success.

Last but not least, I want to thank to all of my friends who shared and giving me their ideas and advice in completing this project. Thank you very much and may ALLAH bless you.

ABSTRACT

This research covered mainly the effect of double heat treatment on stainless steel bar. Three types of heat treatment are normalizing, quenching, and tempering. The specimen that used in this study consisted of round shape stainless steel bar with 25mm x 250 mm (length=250mm, diameter=25mm). During heat treatment process, specimen is heated up to 960°C for one hour before taken out from the furnace. Two of the specimens are quench 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 of two level heating process and temperature will be considered. After the first stage of the heat treatment process is complete, three types of test will be conducted which are hardness test, microstructure and tensile test 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 this research is that the hardness and strength of the specimen will increase according to the three type of heat treatment that has been conduct in the research.

ABSTRAK

Kajian ini meliputi kesan rawatan haba dua kali pada bar bulat keluli tahan karat. Tiga jenis rawatan haba yang digunakan adalah seperti penormalan, pelindapkejutan dan pembajaan. Spesimen yang digunakan dalam kajian ini adalah bar bulat keluli tahan karat dengan dimensi 25mm x 250 mm (panjang 250mm dan 25mm diameter). Semasaproses rawatan haba, spesimen akan dipanaskan sehingga 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 menyejuk pada suhu bilik untuk proses penormalan. Salah satu daripada spesimen akan mengalami proses pelindapkejutan serta diteruskan dengan proses pembajaan, proses pembajaan terdiri dua tahap proses pemanasan dan suhunya akan dipertimbangkan. Tiga jenis ujian akan dijalankan iaitu ujian kekerasan, analisis mikrostruktur dan ujian tegangan pada spesimen. Selepas itu, spesimen lain akan menjalani proses rawatan haba yang sama untuk kali kedua. Spesimen juga akan diuji dengan tiga jenis ujian dan hasil rawatan haba kali pertama dan rawatan kali kedua akan dibandingkan. Hasil jangkaan untuk kajian ini menentukan samaada kekerasan dan kekuatan spesimen akan meningkat mengikut jenis tiga rawatan haba yang telah dilakukan dalam penyelidikan ini.

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CHAPTER 1

INTRODUCTION

1.1 STAINLESS STEEL

Stainless steel are iron-base alloys that contain a minimum of about 12% Cr, the amount needed to prevent the formation of rust in unpolluted atmospheres (hence the designation stainless). Few stainless steels contain more than 30% Cr or less than 50% iron. They achieve their stainless characteristics through the formation of an invisible and adherent chromium- rich oxide film. This oxide forms and heals itself in the presence of oxygen. Other elements added to improve particular characteristics include nickel, manganese, molybdenum, copper, titanium, silicon, niobium, aluminum, sulfur, and selenium. Carbon is normally present in amounts ranging from less than 0.03% to over 1.0% in certain grades. Figure 1.1 provides a useful summary of some of the compositional and property linkages in the stainless steel family. [1]

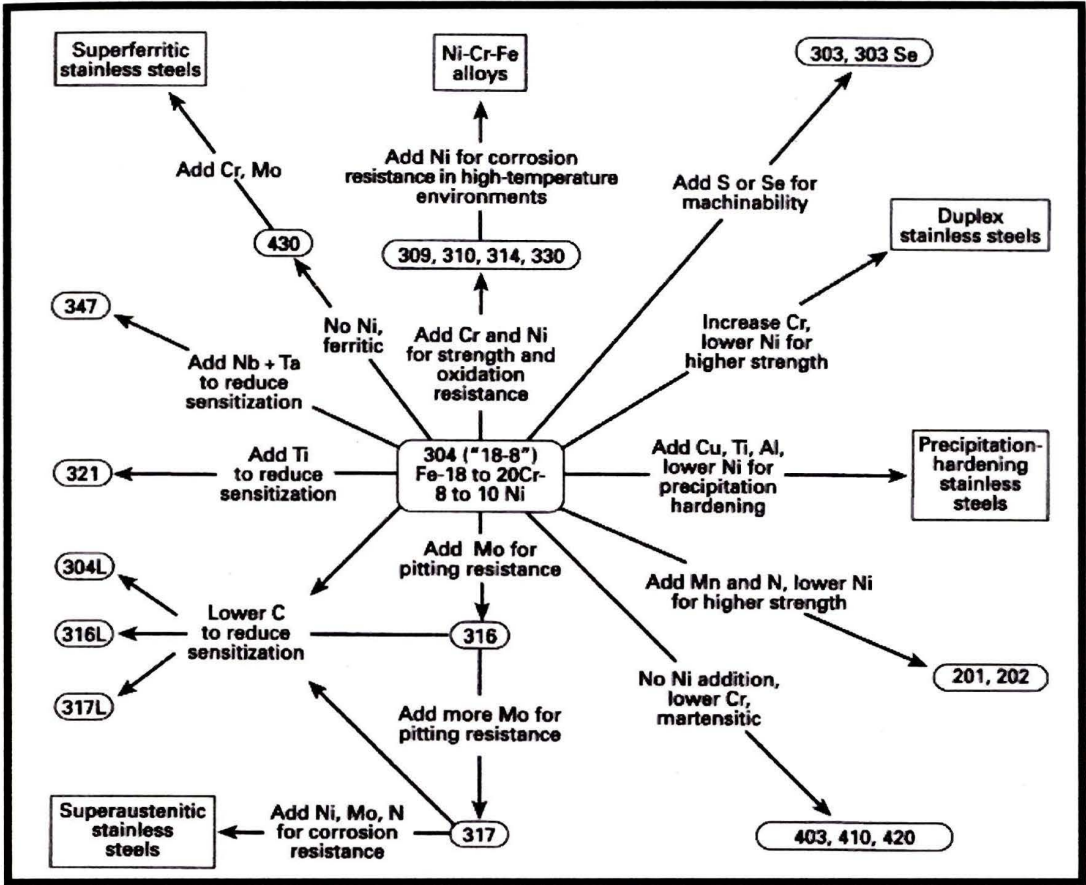


Figure 1.1 Composition and property linkages in the stainless steel family of alloys [1]

1.2 Heat Treatment

Heat Treatment may be defined as heating and cooling operations applied to metals and alloys in solid state so as to obtain the desired properties. Heat treatment is sometimes done inadvertently due to manufacturing processes that either heat or cool the metal such as welding or forming. In this research we will mostly consider the heat treatment of steel. Steels can be categorized as low, medium or high carbon steels.

Heat treatment is often associated with increasing the strength of material, but it can also be used to refine the grain size, relieve internal stress, to improve machinability and formability and to restore ductility after a cold working process. Some of the objectives of heat treatment are summarized as follows:

- Improvement in ductility
- Relieving internal stresses
- Refinement of grain size
- Increasing hardness or tensile strength
- Improvement in machinability
- Alteration in magnetic properties
- Modification of electrical conductivity
- Improvement in toughness

1.2.1 Heat Treatment Processes

Heat treatment is an important at industry. A heated workpiece in a heat-treating furnace will undergo a given thermal schedule, typically, a heating-soaking-cooling cycle. In this research the cooling process is studied. The main types of heat treatment applied in practice are

- 1) Normalising
- 2) Quenching
- 3) Tempering

1.2.2 Normalising

The process of normalizing consist of heating the metal to a temperature of 30 to 50 c above the upper critical temperature for hypo-eutectoid steels and by the same temperature above the lower critical temperature for hyper-eutectoid steel. It is held at this temperature for a considerable time and then quenched in suitable cooling medium. The purpose of normalizing is to refine grain structure, improve

machinability and improve tensile strength, to remove strain and to remove dislocation.[2,3]

1.2.3 Quenching

This process is used to provide hard steels. The steel heated to above critical temperature and held for sufficient time to change the structure. It is then quench in oil or water such as not to change the microstructure of the steel. The rate of cooling is important to establish desired properties and can be affected by the alloy content. The resulting hardened steel can be very brittle. Hardened metals are difficult to cut and shape. They are very difficult if not impossible to bend. As a rule they are heated and cooled very quickly by quenching in oil or clean, cold water.

1.2.3 Tempering

This process consists of reheating the hardened steel to some temperature below the lower critical temperature, followed by any desired rate of cooling. The purpose is to relieve internal stress, to reduce brittleness and to make steel tough to resist shock and fatigue.

1.3 PROBLEM STATEMENT

There are several studies that concentrated on the double heat treatment process for stainless steel to prove that the hardness of stainless steel after double heat treatment is larger than before one heat treatment process. In this research, round stainless steel bar type 304 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. The effect of heat treatment process on stainless steel need to be analyzed so that the differences of physical properties between one heat treated and with double heat treatment process. Double heat treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objective such as to improve formability, restore ductility after a cold working operation.

1.4 Objective

To study the effects of double heat treatment on the microstructure and mechanical properties of round stainless steels bar.

1.5 Scope

- 1) Study the literature review on stainless steel and heat treatment process
- 2) To select the type of the stainless steel that can be used
- 3) To prepare the sample for the experimental process
- 4) To perform the experimental analysis of stainless steel after undergoing a double heat treatment

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This literature review shows the investigation for the background of this experiment process and the studies for mechanical properties, heat treatment and process included in this studies. This literature review will help and give some information for experiment or process included in these studies.

2.2 Stainless Steels Grade 304

Stainless steels are often heat treated; the nature of this treatment depends on the type of stainless steel and the reason for the treatment. These treatments, which include annealing, hardening and stress relieving, restore desirable properties such as corrosion resistance and ductility to metal altered by prior fabrication operations or produce hard structures able to withstand high stresses or abrasion in service. Heat treatment is often performed in controlled atmospheres to prevent surface scaling, or less commonly carburisation or decarburisation.[4]

304 stainless steels are fully austenitic and they are a ternary alloy (Fe-Cr-Ni). They have a high corrosion resistance for preventing rusty. Due to they are unstable in austenitic phase, quenching is an important process at high temperature.

It can compose their micro-structure at high temperature. However, the precipitation is a disadvantage for this alloy after a fire. It not only reduces their strength, but also reduces their corrosion resistance in Cr-deplete zone.[4]

Grade 304 is the standard "18/8" stainless; it is the most versatile and most widely used stainless steel, available in a wider range of products, forms and finishes than any other. It has excellent forming and welding characteristics. The balanced austenitic structure of Grade 304 enables it to be severely deep drawn without intermediate annealing, which has made this grade dominant in the manufacture of drawn stainless parts such as sinks, hollow-ware and saucepans. For these applications it is common to use special "304DDQ" (Deep Drawing Quality) variants. Grade 304 is readily brake or roll formed into a variety of components for applications in the industrial, architectural, and transportation fields. Grade 304 also has outstanding welding characteristics. Post-weld annealing is not required when welding thin sections.[5]

Grade 304L, the low carbon version of 304, does not require post-weld annealing and so is extensively used in heavy gauge components (over about 6mm). Grade 304H with its higher carbon content finds application at elevated temperatures. [5]The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.

Typical compositional ranges for grade 304 stainless steels are given in table 2.1

Table 2.1 Composition ranges for 304 grade stainless steel [6]

Grade		C	Mn	Si	P	S	Cr	Mo	Ni	N
304	min.	-	-	-	-	-	18.0	-	8.0	-
	max	0.08	2.0	0.75	0.045	0.030	20.0	-	10.5	0.10

Typical mechanical properties for grade 304 stainless steels are given in table 2.2

Table 2.2 Mechanical properties of 304 grade stainless steel.[6]

Grade	Tensile Strength (MPa) min	Yield Strength 0.2% Proof (MPa) min	Elongation (% in 50mm) min	Hardness	
				Rockwell B (HR B) max	Brinell (HRB) max
304	515	205	40	92	201

2.2.1 Stainless steel categories and grades

Stainless steels can thus be divided into six groups: martensitic, martensitic-austenitic, ferritic, ferritic-austenitic, austenitic and precipitation hardening steels. The names of the first five refer to the dominant components of the microstructure in the different steels. The name of the last group refers to the fact that these steels are hardened by a special mechanism involving the formation of precipitates within the microstructure. Table 2.3 gives a summary of the compositions within these different categories.[4]

Table 2.3 Composition ranges for different stainless steel categories.[4]

Steel category	Composition (wt%)					Hardenable	Ferro-magnetism
	C	Cr	Ni	Mo	Others		
Martensitic	>0.10	11-14	0-1	-	V	Hardenable	Magnetic
	>0.17	16-18	0-2	0-2			
Martensitic-austenitic	<0.10	12-18	4-6	1-2		Hardenable	Magnetic
Precipitation hardening		15-17	7-8	0-2	Al		
		12-17	4-8	0-2	Al,Cu,Ti,Nb	Not hardenable	Magnetic
Ferritic	<0.08	12-19	0-5	<5	Ti		
	<0.25	24-28	-	-		Not hardenable	Magnetic
Ferritic-austenitic (duplex)	<0.05	18-27	4-7	1-4	N, W		
Austenitic	<0.08	16-30	8-35	0-7	N,Cu,Ti,Nb	Not hardenable	Non-magnetic

The two first categories, martensitic and martensitic-austenitic stainless steels are hardenable, which means that it is possible to modify their properties via heat treatment in the same way as for hardenable carbon steels. The martensitic-austenitic steels are sometimes also referred to as ferritic-martensitic steels. The third category, the precipitation hardening steels, may also be hardened by heat treatment. The procedures used for these steels are special heat treatment or thermo-mechanical treatment sequences including a final precipitation hardening and ageing step. The precipitation hardening steels are sometimes also referred to as maraging steels. The last three steel categories, ferritic, ferritic-austenitic and austenitic are not hardenable, but are basically used in the as received condition. The ferritic-austenitic stainless steels are often referred to as duplex stainless steels. It may be noted that there is only one category of stainless steels that is non-magnetic: the austenitic steels. All the others are magnetic. [4, 7]

2.2.2 Classification of Stainless Steel Stainless

Stainless steel has different group that have their own properties. There have four type of stainless steel group which is:

Austenitic Stainless Steel

Compare to a carbon steel, an austenitic stainless steels have high ductility, low yield stress and relatively high ultimate tensile strength. Mixture of ferrite and cementite is transform from austenite in cooling stage of carbon steel. With austenitic stainless steel, the high chrome and nickel content suppress this transformation keeping the material fully austenite on cooling. Pre-heating is required to austenitic stainless steel because of its not easy influence by hydrogen cracking, and except to reduce the risk of shrinkage stresses in thick sections. Post weld heat treatment is required as this material has a high resistance to brittle fracture; occasionally stress relief is carried out to reduce the risk of stress corrosion cracking. [8, 9]