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EFFECT OF HEAT TREATMENT PROCESS OF STAINLESS STEEL FOR WATCH MANUFACTURING APPLICATION

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"I hereby the author, declare this report entitled " EFFECT OF HEAT TREATMENT PROCESS ON STAINLESS STEEL FOR WATCH MANUFACTURING APPLICATION" is my own work except for quotation and summaries which have been state the source"

Signature : __________________________

Author : Mohd Fahmi bin Abdullah Sani

Date : 9 October 2008

To my dearest parent

Mr Abdullah Sani bin Salam and Mr Nafsiah binti Mat Wali

My sibling,

Masni binti Abdullah Sani

Mazlan bin Abdullah Sani

Mohd Najmi bin Abdullah Sani

Thanks for all the support

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ABSTRAK

Kajian ini mementingkan dan meliputi perkara berkaitan dengan kesan-kesan rawatan haba terhadap besi tahan karat yang digunakan bagi tujuan pembuatan jam. Proses rawatan haba yang sesuai bagi besi tahan karat adalah proses menyepuh lindap dan melindap menggunakan air. Menyepuh lindap adalah proses di mana bahan didedahkan kepada suhu piawai bahan yang digunakan dan didedahkan dalam masa yang panjang. Tujuan melindap pula adalah untuk menurunkan suhu besi tahan karat tersebut untuk tujuan ujian mekanikal. Besi tahan karat perlu dilindap di dalam air secara pantas supaya tiada tindak balas kimia akan berlaku dan menyebabkan kesan sampingan kepada ciri-ciri fizikal besi tahan karat tersebut. Suhu yang digunakan untuk proses menyepuh lindap besi tahan karat adalah dalam linkungan 1010ºC dan 1121ºC dan didedahkan kepada haba didalam relau pembakaran selama 1 jam dan 30 minit. Kajian dalam projek ini juga adalah bertujuan untuk mengetahui ciri-ciri besi tahan karat selepas proses rawatan haba. Ujian mekanikal dan analisis yang sesuai digunakan untuk kegunaan jam telah dipilih. Ujian dan analisis tersebut ialah Ujian Hentaman Charpy, Ujian Kekerasan Rockwell dan menggunakan Mikroskop Optik untuk menganalisis struktur mikro bagi besi tahan karat selepas dan sebelum proses rawatan haba. Projek ini bermula dengan tinjauan terhadap maklumat literatur sehingga mengendali kerja-kerja makmal terhadap bahan dengan melakukan proses menyepuh lindap yang berbeza suhu dan masa. Hasil daripada kajian ini adalah analisis statistik meggunakan Ujian F dan Ujian T berdasarkan parameter yang digunakan di dalam proses rawatan haba. Akhir sekali, pemerhatian terhadap struktur mikro akan dilakukan untuk mengetahui hubungannya terhadap proses rawatan haba.

ABSTRACT

This research concerned on the effect of heat treatment of stainless steel for watch manufacturing application which are annealing and water quenching. Annealing is the process that material is exposing to the standard material temperature in a long period of time. The purpose of the cooling process is to ensure the material get higher hardness and to low the temperature of material for use in mechanical testing. Stainless steel needs rapid cooling in water so that no chemical reaction get involve and affect the physical properties of stainless steel. The temperature range that use for annealing process is 1010ºC to 1121ºC and exposed in furnace about 1 hour and 30 minutes. This research also done to investigated the behaviour of stainless steel after heat treatment process. The suitable mechanical testing and analysis have been chosen. They are Charpy Impact Test, Rockwell Hardness Test and using Optical Microscope to study the microstructure of stainless steel before and after heat treatment. This project begins with literature review on subject topic and following by laboratory work on the material with different annealing temperature and annealing time. Statistically analysis using F-Test and T-test will be done according to the experiment parameter on heat treatment process. Finally microstructure observation will be done to predict the relationship with the heat treatment process.

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CHAPTER 1

INTRODUCTION

1.1 Background

Stainless steel is use in a wide range of application including plane, mechanical equipment, and railway application. These examples are synonyms with stainless steel which are the main material for their structure. Stainless steel is only uses in major industry, but also uses in non major industry such as watch manufacturing that consist of micro size of elements. With wide range of application, these prove that stainless steel is a good material that can be use for variety type of industry.

Stainless steel is an iron-containing alloy, a substance made up of two or more chemical elements. Rasmussen K.J.R said “Stainless steel is characterized by having chromium content greater than 12 %”.Generally stainless steel is an alloy that distributed into four different groups. The group is Austenitic, Ferritic, Duplex and Martensitic. This 4 group have their own properties and these properties will be discussed in Chapter 2. In treatment of stainless steel, heat is used as an option to give better structure and strength of its physical properties. Usually types of heat treatment process depend on the type of alloy and the reason of the treatment.

Rasmussen (2006) said the tonnage price of stainless steel is typically 6-7 times than that of carbon steel, depending on the type of alloy. Hence stainless steel is likely to be used in specialized construction to take advantage of its superior material properties, reduce maintenance cost and/or provide aesthetically pleasing appearances

This treatment 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 structure able to withstand high stresses or abrasion in service. Heat treatment is often performed in controlled atmosphere to prevent surface scaling, or less commonly carburization or decarburization

In this project, there are several experiments that will be carried out to get the data on effect of heat treatment process to stainless steel. The data is needed in such a way that to make comparison between stainless steel with and without heat treatment. Hence the analysis consists of statistical analysis that contains of parameter such as temperature and time obtained from the data. For the first phase of the experiment, stainless steel will go through annealing process using standard material temperature and followed by quenching process. After heat treatment process the entire stainless steel specimen will be test on hardness test, impact test and microstructure verifying. The tests are chosen due to the need in watch manufacturing process. Every test that performs is important to ensure the quality of the watch. Hardness and impact test is applied to the stainless steel to know how much strength the stainless steel have after heat treatment process. Microstructure’s characteristic of stainless steel is important to know to ensure the material did not get other further defect in machining process.

1.2 Objective

The objective of this research is to study the effect of heat treatment process to stainless steel. This research also involved statistical analysis which is important in making comparison between heat treatment and without heat treatment of stainless steel.

1.3 Scopes

The scopes of the research are:

1) Literature study on stainless steel and heat treatment process
2) To obtain data from heat treatment process.
3) To apply hardness and impact test.
4) To compare the result of experiment using statistical analysis
5) To discuss about microstructure of stainless steel.

1.4 Problem Statement

In watch manufacturing application, several type of material are being used to produce the external and internal watch component. As an example stainless steel is one of the material that widely uses as a watch component such as crown, bracelet and body. Stainless steel is use in watch manufacturing application because of its stainless characteristic. This material is containing element that prevent it from corrosion. Some mechanical test and analysis is needed to perform so that the physical properties of stainless steel can revealed. To reveal the properties, heat treatment is the suitable method that can be applied. The effect of heat treatment process on stainless steel is needed to analyze so that we can know the differences of physical properties with and without heat treatment process.

CHAPTER 2

LITERATURE REVIEW

A literature review is a body of text that aims to review the critical points of current knowledge on a particular topic. In this chapter we will review the topic using some references from book and internet references so that we will get a better understanding about the whole project objective.

2.1 Watch History

Paul Morillo (2008) said, before watches, there were clocks. Before clocks, there was simply mechanism to tell and measure time. Sundials told time by shadows. Hourglasses measured time by predictable rates of sand moving through a narrow channel.

The earliest accurate clocks were built by monks in Italy to simply tell people what time to pray. Theses clocks told time audibly with bells and had no hand indicators. Located in Tudor, England, pocket watch was invented in 16th century. This watch is very popular among the upper class society. “It is rumored that in the famous painting of

Henry VIII, it was not a medallion around his neck, but a pocket watch he owned”(Lussori Inc, 2008).

Wristwatch that many people wear today is firstly create by Patek Philippe by 19th century. This type of watch is popular among woman rather than men that prefered pocket watch. “In the midst of war, some armies soon realized that it was much easier to glance at your wrist to check the time, than it was to fumble around in your jacket to find your pocket watch” (Lussori Inc, 2008). Starting at that time, both women and men wearing the wristwatch and year by year many watch was create and new technology like digital watch had been invented.

2.2 Watch Industry

The World Watch industry was at a crucial stage in the 1970’s when there was a possible phase of transition from one way of watch making technology to another, the example is from mechanical to electronic watches. The mechanical watches had been ruling the watch market for quite some time while the electronic watches were deemed to be the next big thing. Through this industry there have three most important watch producing nations. They are Swiss, Japan and United States whose competed with each other to maintain their market share as well as their profitability. The largest and the most important market for watches was the United States, hence all the three countries were targeting the United States market to succeed and in this process they had adopted various different strategies.

The Swiss watch industry had always been the dominant market in the world watch market, there had been several reasons to that and they are:

1) Swiss had built watch making into a strong brand.

2) Availability of highly skilled employee, knowledge about watch making had passed down through generations, hence Swiss had a position of competitive advantage.

3) They had much more experience and knowledge about the world watch market compared to their competitors.

4) They viewed watches as more of a luxury item. Hence the fashion trends they created into their watch making was difficult to challenge.

Watch industry is an industry that can be growing and blooming time by time. There are many factor that can support the fact that this industry can stand for the very long period. The major factor that can affect the future of watch industry are:

1) Technology Factors

a) The Japanese focused their efforts on producing strategies, advanced mechanical and automatic process to helped them achieved market needs.

b) The United State companies focused on research and development and hence they could come up with newer technologies in the field of watch manufacturing.

2) Regulator Factors

a) The watch cartel in Switzerland was disbanded in 1966 giving the Swiss manufacturers freedom to expand their operations.

b) The United State government did well to encourage research and development which helped them strengthen their technology base.

c) The Japanese government provided protection to its industry by limiting the exports operation. This is to ensured that the local market did not get eroded.

3) Lifestyle Factors

One of the main differences that has been noticed is that watches were now considered more of a utility item than a luxury piece. Swiss watch is the popular among the fashion trends compare to other competitor watch manufacturer.

4) Social Factors

The introduction of electronic watches was predicted to have an adverse effect on the job market. Many employee has loss their job result from electronic watch invention. As a result the Swiss and United State watch industry might subsidize the industry and bring watch prices down.

2.3 Steel

Steel is common name for a large family of iron alloys which are easily malleable after the molten stage. Limestone, iron ore and coal is the material that produce steels. These three raw materials are put into the blast furnace and then the material is resulting as a “pig iron” which has a composition of iron, carbon, manganese, sulfur, phosphorus and silicon. This pig iron is hard and brittle in its physical properties. So the “pig iron” must be refine by purifying it and then adding other elements to strengthen the material. The steel is next going through deoxidized process which is the steel is deoxidized by a carbon and oxygen reaction. The steel that strongly deoxidized is called killed, and a less deoxidized steels are called semi killed, capped and rimmed.

George E. Totten (2006) said that steel can be classified by different system depending on:

1) Compositions, such as carbon (or non alloy), low-alloy and alloy steels.

2) Manufacturing methods such as converter, electric furnace or electroslag remelting methods.

3) Application such as tool, structural, gadget and accessory.

4) Finishing methods such as cold and hot rolling.

5) Product shape such as bar, plate, strip, tubing or structural shape.

6) Required strength level as specified in the American Society for Testing and Materials (ASTM) standards.

7) Heat treatment such as annealing, quenching, tempering, air cooling (normalization and thermo mechanical processing.

8) Microstructure such as ferrictic, pearlitic, martensitic and austenitic.

9) Oxidation practice employed such as rimmed, killed, semikilled and capped steels.

10) Quality descriptors and classifications such as forging quality and commercial quality.

2.4 Stainless Steel

The stainless steels are branch of the family of ferrous alloys designed for extremely high levels of corrosion resistance. This effect is achieved by alloying primarily with chromium but may also enhanced by the addition of elements such as molybdenum and nickel. Moreover, these alloy elements may significantly alter the phase relationships in the steel and procedure a wide spectrum of possible microstructures. The range of microstructures serves to qualify some stainless steels for special types of service beyond their use in corrosion service (Daniel H, Alan W. P. (2002). “Structures and Properties of Engineering Material”. 5th Edition. New York. Thomas Casson. Page 248). 12wt% of chromium concentration give the stainless character to the steel. To ensure a robust material, the higher chromium concentration and other solute such as molybdenum, nickel and nitrogen is needed.

2.4.1 Stainless Steel Phase Diagrams

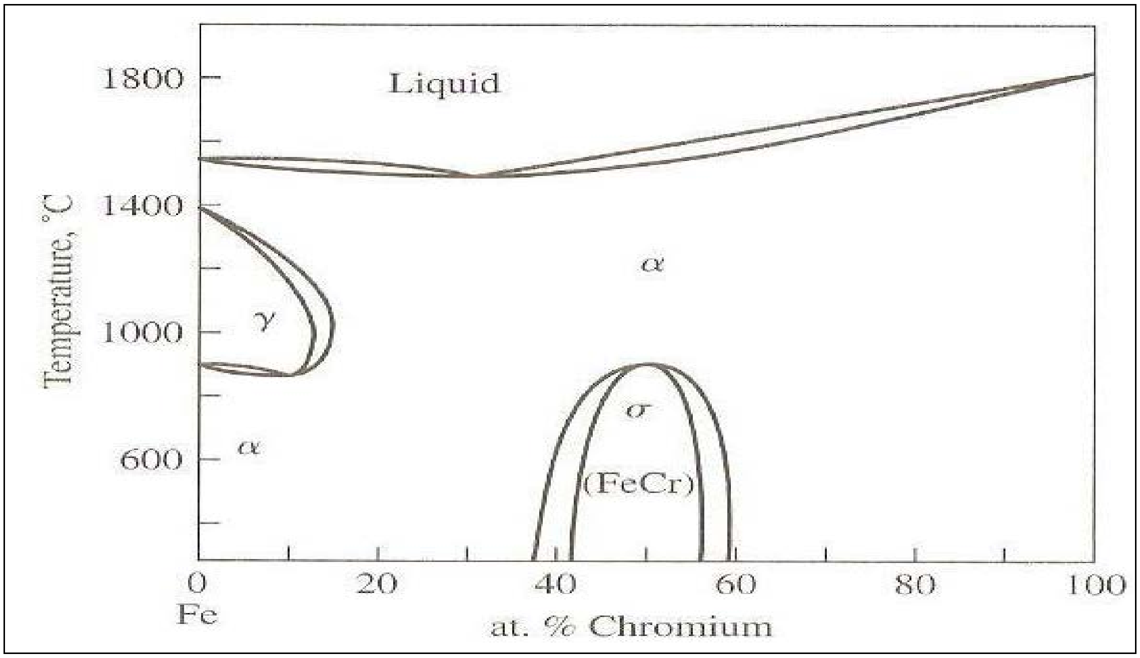

Figure 2.1: Binary Fe-Cr Phase Diagram (Source: Daniel H, Alan W.P, 2002)

Chromium is an element that contain in stainless steel. The material also have the mixture of chromium and nickel or manganese element. Figure 2.1 show that closed γ lopp as body centered chromium and body centered iron form ferrite solid solutions. The sigma phase centered at the 50/50 composition is an ordered structure of the CsCl type. Closed γ loop is form by high temperature merge counterpart of δ. Body centered cubic (bcc) chromium tends to stabilized the bcc α-iron. There are no austenite found in 16% of chromium in binary alloys which conclude that they resemble most non-ferrous solid solution alloys. Thus, binary Fe-Cr alloys, free of carbon and are not properly called steels but stainless irons.

2.4.2 Classification of Stainless Steel

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

1) 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

This material is good in ductility because of the face centered cubic(fcc) of austenitic steel that provides more plane for the flow of dislocations, combined with the low level of intersitial elements. This result conclude that this material doesn't have clear defined yield point. Austenitic steels also have excellent toughness down to 273°C of temperature, with no steep ductile to brittle transition.

2) Ferritic Stainless Steel

Ferritic stainless steels are highly corrosion-resistant, but less durable than austenitic grades. They contain between 10.5% and 27% chromium and very little nickel, if any, but some types can contain lead. Most compositions include molybdenum; some, aluminium or titanium (Wikimedia Foundation Inc (2008).

Ferritic stainless steel contains more chromium but less carbon than the martensitic stainless steel. This type of stainless steels cannot be hardened using heat treatment method. This is because the material changes act towards stabilization of ferrite against austenite so that ferrite is stable at all temperatures.

They have their own physical properties which is they are ferromagnetic material. They also have good ductility, formability and their toughness is limited at low temperature and heavy section.

3) Martensitic Stainless Steel

Martensitic stainless steels are not as corrosion-resistant as the other two classes but are extremely strong and tough, as well as highly machineable, and can be hardened by heat treatment. (Wikimedia Foundation (2008)).

This type of stainless steel is typically contains of chromium and carbon that possess the martensitic crystal structure in hardened condition. This material is a ferromagnetic steel that use for some apllication such as knife or blade. Its contains chromium about 14%, molybdenum about 1%, nickel not higher than 2% and carbon on range 0.1% to 1%. This composition making its physical properties more hardness and bit more brittle.Martensitic stainless steel are suitable for application that related to wear and corrosion. As an example this material is use in hydroelectric turbines. They are specified when the application also required good tensile strength, creep and fatigue strength properties.

4) Duplex Stainless Steel

Duplex stainless steels have a mixed microstructure of austenite and ferrite, the aim being to produce a 50/50 mix, although in commercial alloys, the mix may be 40/60 respectively. Duplex steels have improved strength over austenitic stainless steels and