EFFECTS OF HEAT TREATMENT ON THE MICROSTRUCTURES AND ELECTROCHEMICAL BEHAVIOR OF STAINLESS STEEL

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A thesis submitted in partial fulfillment of the
requirements for the award of degree of
Master of Engineering (Mechanical-Materials)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

JANUARY 2013

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my supervisor, Professor Dr Esah Hamzah for her constant guidance and advice comments throughout the completion of this work.

Thanks a lot to all the technicians of Material Science Lab in Faculty of Mechanical Engineering for their willingness to guide and help me to do my thesis experiments using all available facilities.

Very special thanks go to my mother Mrs. Ruslina Binti Dollah, my father Haslan Bin H.Abdullah and my husband Mohd Hafiz Bin Harun for their support and dedication.

Finally, I would like to thank all for their encouragement and constructive advice.

ABSTRACT

The objective of this project is to investigate the effects of heat treatment parameters on corrosion resistance and phase transformation in relation to the microstructures and electrochemical behaviors of austenitic 304 and martensitic 420 stainlesssteel. In this project, there are several heat treatment parameters under investigation namely annealing at temperature 900 °C and 1000°C and normalizing with difference soaking times. Other heat treatment process carried out on martensitic stainless steel only is quench and temper. Corrosion test was conducted on non-treated and heat treated samples according to British Standard (BS ISO 17475:2005) for electrochemical test (Tafel test). Hardness test was also carried out on the non-treated and heat treated samples using Vickers hardness test. Microstructure analysis was performed on the samples using characterization equipment such as Glow Discharge Spectroscope (GDS), Optical Microscope (OM), Scanning Electron Microscope (SEM), Energy Dispersive X-ray (EDX) and X-ray Diffraction (XRD). The results shows that heat treatment affect the microstructures and electrochemical behaviors of stainless steel. It was also found that higher temperature gives lower hardness. From the corrosion test results, it can be concluded that higher austenization temperatures and higher normalizing soaking times improved the corrosion resistance of stainless steel due to increase in grain size and less in formation of carbides. These carbides will contribute to the corrosion whereby it provides sites for anodic and cathodic reaction to occur between the carbide and the matrix phases.

ABSTRAK

Objektif projek ini adalah untuk mengkaji kesan parameter rawatan haba ke atas rintangan kakisan dan penjelmaan fasa dalam hubungan dengan mikrostruktur dan tingkah laku elektrokimia 304 austenit dan martensit 420 keluli tahan karat. Di dalam projek ini, terdapat dua parameter rawatan haba yang dikaji iaitu suhu austenit bersuhu 900°C dan 1000 °C dan menormalkan dengan perbezaan masa merendam. Lain-lain proses rawatan haba yang dijalankan pada keluli tahan karat martensit sahaja iaitu pelinkejutan dan pembajaan. Ujian kakisan telah dilakukan ke atas sampel-sampel yang belum dirawat dan telah dirawat haba berdasarkan Piawaian British (BS ISO 17475:2005) untuk ujian elektrokimia. Ujian kekerasan juga telah dilakukan ke atas sampel-sampel belum dirawat dan yang telah dirawat haba menggunakan ujian kekerasan Vickers. Analisis mikrostruktur telah dilakukan ke atas sampel-sampel menggunakan peralatan pencirian seperti Spektroskopi Nyahcas Bara (GDS),Mikroskop Optik (OM), Mikroskop Imbasan Elektron (SEM), Sinar-X Serakan Tenaga (EDX) dan Pembelauan Sinar-X (XRD). Keputusan kajian menunjukkan rawatan haba menjejaskan mikrostruktur dan tingkah laku elektrokimia keluli tahan karat. Ia juga didapati bahawa suhu yang lebih tinggi memberikan kekerasan yang lebih rendah. Daripada hasil ujian kakisan, dapat disimpulkan bahawa suhu austenit dan lebih tinggi masa rendaman penormalan meningkatkan rintangan kakisan keluli tahan karat disebabkan oleh peningkatan dalam saiz bijian dan pengurangan pembentukan karbida.. Karbida ini akan

menyumbang kepada kakisan di mana ia menyediakan laman untuk reaksi anodic dan katod berlaku antara karbida dan fasa matriks.

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CHAPTER 1

INTRODUCTION

1.1 Background

Stainless steels form part of the great section cut through history by the development of iron alloys, beginning about 1400 B.C. with the first man-made iron. The so-called industrial revolution was made possible only through Cort's improvement in iron making methods and his introduction of mills to produced rolled sections (J. Gordon Parr, 1971). As a class of materials, stainless steels stand apart and are considered the backbone of modern industry since they find wide applications in chemicals, petrochemicals, off-shore, power generation, allied industries (Maurer E. and Strauss B, 1920).

With the mass production of steel came a scientific interest in the material. Of course, there were brilliant examples of earlier research. But it is not until about 1890 that the constitution and properties of steels were methodically investigated. By 1920 metallurgist were applying methods of x-rays diffraction to the study of metallic properties (J. Gordon Parr, 1971).

Satisfactory and economical heat treatment plays and important role in the selection and development of engineering materials, and stainless steel are no exception. Such steels are normally favored for engineering applications requiring good strength at moderate temperatures and high corrosion resistance. Most grades of stainless steels are usually low in carbon (0.05 to 0.20%) but contain 4 to 18% chromium along with other alloying elements (M. I. Qureshi and M. Mujahid, 2000). In the industry, the component that used stainless steel will expose to the high temperature environment and at the long time exposure. That will result in changing mechanical properties or microstructures of the stainless steel due to the failure. Many researches had been conducted to investigate the effect of the heat treatment on the stainless steels.

Besides the favorable corrosion properties of stainless steels, the good mechanical properties make these materials very interesting for mechanical engineering applications. They are used in demanding applications as, for instance, in the processing and power industry (Henrik Sieurin, 2006).

Austenitic stainless steels of the AISI 304 and 316 types, amongst other hundred types of stainless steels available in the market, are the most frequently used ones worldwide. They are selected for numerous applications due to their favorable combination of characteristics such as low price, moderate to good corrosion resistance, excellent ductility and toughness along with good weldability (C.Herrera, 2007).

Martensitic stainless steels are commonly used to manufacturing components with excellent mechanical properties and moderate corrosion resistance, so that they can work under high and low temperatures. Unlike other stainless steel, their properties could be changed by heat treatments hence these steels usually are used for a wide range of applications such as steam generators, pressure vessels, cutting tools, and offshore platforms for oil extraction (J.-Y. Park and Y.-S. Park, 2006).

1.2 Objectives of The Research

The objectives of the research are as follows:

1. To characterize the microstructures of stainless steels after various heat treatments.
2. To determine the electrochemical behavior of heat treated stainless steels.

1.3 Statement of Research Problems

Microstructures of stainless steel can be varied by heat treatment. Variation in microstructures is expected to affect the mechanical properties and electrochemical behavior of the steels. The heat treatment may enhance the steel properties but it may also gives poor performance. Therefore, selection of correct heat treatment is paramount in order to have stainless steel with better mechanical and electrochemical properties.

1.4 Scopes of Study

The scopes of the study are as follows:

a) Initial investigation on as-received martensitic and austenitic stainless steels in terms of chemical composition, microstructures and properties
b) Selection of heat treatment methods that can vary the microstructures and properties: Annealing, normalizing, quench and temper.
c) Detail investigation on the heat treated samples by using optical microscope, SEM, EDX and XRD.
d) Electrochemical test (Tafel) on heat treated samples to relate between variation in microstructures due to heat treatment and the corrosion resistance of the steels.

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