EFFECTS OF BOROZINING ON SHARP CORNERED METAL SURFACE

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**This thesis is submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project report entitled "Effects of Boronizing on Sharp Cornered Metal Surface" is the result of my own work except as cited in the references

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Materials).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved mother, bah and family,

thank you for your understanding and endless support.

ABSTRACT

Boronizing is a thermochemical process usually used to harden the material. Based on published previous researches, boronizing process was studied but only focusing on the hardening of the material. This study is focusing on the boronizing process on the cornered of the metal surface. In this study, the sharp cornered surface will be studied in order to know which part of the geometries that shows the most effective boronizing process by using two parameters that are temperature and time. The parameters are 850^{o}C - 950^{o}C (1123K – 1223K) for 2, 4 and 6 hours. Besides that, this study is to analyse the effect of different cornered geometries by using the activation energy. There are four different geometries at each corner of the metal specimen that are 90^{o}, 1mm fillet, 5mm radius, and chamfer. The specimens need to be designed and fabricated with the dimension of 20mm X 20mm X 20 mm to suit into the existing container. After the boronizing process has been done, metallographic analyses were used to determine the boride layer thickness. From the boride layer thickness, the activation can be calculated and the geometry with lowest activation energy is the best shape and the boron is easy to diffuse. As the conclusion, the 90^{o} geometry has the lowest activation energy with value of 61.785 kJ/mol.

ABSTRAK

Boronizing adalah satu proses termokimia biasanya digunakan untuk mengeraskan bahan. Berdasarkan kajian sebelum diterbitkan, proses boronizing dikaji tetapi hanya memberi tumpuan kepada pengerasan bahan.Dalam kajian ini, proses penyusukboronan di penjuru permukaan logam akan diberi tumpuan. Dalam kajian ini, permukaan penjuru yang tajam akan dikaji untuk mengetahui bentuk geometri yang menunjukkan proses penyusukboronan yang paling berkesan dengan menggunakan dua parameter iaitu suhu dan masa. Parameternya adalah 850^{o}*C - 950*^{o}*C (1123K - 1223K) selama 2, 4 dan 6 jam. Selain itu, kajian ini adalah untuk menganalisis kesan geometri pada penjuru yang berbeza dengan menggunakan tenaga pengaktifan. Terdapat empat geometri yang berbeza pada setiap sudut spesimen logam iaitu 90*^{o}*, fillet 1mm, jejari 5mm, dan talang. Spesimen perlu direka terlebih dahulu dengan dimensi 20mm X 20mm X 20 mm untuk disesuaikan ke dalam bekas yang sedia ada. Selepas proses penyusukboronan itu telah dilakukan, analisis metallographic digunakan untuk menentukan ketebalan lapisan boron. Daripada ketebalan lapisan boron yang diperolehi, tenaga pengaktifan boleh dikira dan geometri yang mempunyai tenaga pengaktifan paling rendah adalah bentuk yang terbaik dan boron mudah untuk meresap. Sebagai kesimpulan, geometri 90*^{o}* mempunyai tenaga pengaktifan yang paling rendah dengan nilai 61,785 kJ / mol.*

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LIST OF ABBEREVATIONS

ANSI	American Iron and Steel Institution
ASTM	American Society for Testing and Materials
AISI	American Iron and Steel Institute
SEM	Scanning Electron Microscopy
2H	2 Hours
4H	4 Hours
6H	6 Hours

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k	Rate constant
E_a	Activation energy
R	Gas constant
T	Temperature in Kelvin
A	Arrhenius constant
d	The depth of boride layer

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CHAPTER 1

INTRODUCTION

1.1 Background

Boronizing is a broadly utilized thermochemical preparing system for surface adjustment. The surface adjustment such as surface hardening is where the boron is diffused into the material's surface at high temperature. This procedure has connected to an extensive variety of materials, for example, ferrous or non-ferrous composites, and cermet and the end goal is to enhance their solidness and mechanical execution (He et al., 2015). Boronizing can be produced by using blends of powders, salts, liquid oxides, and additionally gas mediums and glues (Campos et al., 2007). The temperature of this process is usually within the range of 700^{o}C to 1000^{o}C for 1 to 12 hours. The capacity of boronizing is to boost the wear execution, hardness and erosion for the material and segment in modern applications.

The attributes of this boride layer rely on upon the physical condition of the boron source utilized, the boronizing temperature, the treatment time, and the concoction piece of the material to be borided (Chegroune et al., 2016). It is realized that boronizing performed at high temperature is a dissemination controlled process. It is vital to set up the procedure parameters that influence the boronizing energy with a specific end goal to choose prepare parameters to accomplish the sought thickness of boride layer and hardness (Genel et al., 2003).

Boride has a high melting point and high hardness at elevated temperatures and, consequently is the basic advantage of boriding. Based on the researches of the boriding in transition metals, it have accelerated particularly for the applications in the production of cutting tools and heavy gears, and in the automotive, casting, textile, food-processing, packaging and ceramic industries where huge friction-dependent energy losses and intensive corrosion and wear occur (Gunes, et al,. 2015).

A high temperature is essential for boronization because of two facts: 1) heat-induced formation of vacancies in the matrix and 2) activation of boron atoms to overcome the energy barrier for diffusion. Conventional boronizing processes for ferrous were conducted at temperatures around ~1000 °C (He et al., 2015).

This study, will focus on the effect of boronizing on the sharp cornered surface. There will be four geometries for each sharp cornered surface and the boronizing process will be held using two parameters. The parameter uses are temperature and time. The ranges of the temperature that will be used are 850^{o}C, 900^{o}C and 950^{o}C while the time is 2, 4 and 6 hours. The result after boronizing process will be used to evaluate the diffusion by the boride layer thickness and activation energy analysis.

1.2 Problem Statement

In engineering there are many things that are important such as designs, build, improve structures, machines, tools, components and materials. Boronizing is one of the processes that available in engineering field. Based on published previous researches, boronizing process was studied but only focusing on the hardening of the material. In this study, the sharp cornered surface will be studied in order to know which part of the geometries that shows the most effective boronizing process by analyzing the rate of diffusion.

1.3 Objectives

The objectives of this study are as follows:

1. To study the effect of boronizing in temperature and time on the sharp cornered surface using the metallographic analysis.
2. To analyse the effect of different cornered geometries on the boronizing diffusion using the activation energy analysis.

1.4 Scope of Project

The scope of this study including:

1. Design and fabricate a suitable dimension for the specimen to suit the container that available
2. Determine the thickness of the boride layer by using the metallographic analysis.
3. The activation energy will be analysed by using Arrhenius Eq.

CHAPTER 2

LITERATURE REVIEW

2.1 Background of Steel

Based on the World Steel Association, it have been recorded that the steel grades are more than 3,500 types, environmental properties, encircling unique physical and chemical (About steel, 2016). In quintessence, the steel is composed of iron and carbon. The properties of each steel grade can be determined by the amount of carbon and additional alloying element as well as the level of impurities. The amount of carbon contents in steel are in the range of 0.1-0.25% carbon. However, the carbon content of 0.1-0.25% usually used in steel that is widely used in the industry. In all grades of steel, there are any other elements such as manganese, phosphorus and also sulphur. The manganese offers beneficial effects while the phosphorous and sulfur is harmful for the strength and durability of steel (Bell, 2016).

There are different types of standard in the industries and one of it is the standard for steel. American Iron and Steel Institution (ANSI), American Society for Testing and Materials (ASTM) for steel standard are used for different types of steels to categorizing, properties of metallurgical, evaluation, specifying of material, chemical, and mechanical. The steel standard is useful for guiding in metallurgical laboratories and refineries, manufacturing the product, and for end-users of steel. In order to ensure the quality towards the safe of use, the modifications for the steel must be in proper process and application procedure (ASTM, 1998-2016).

Steel have been widely used in production industries such as automobile, shipbuilding, the construction, canned foods, electrical appliances, surgical instruments and many more (Bell, 2016).

2.1.1 Types of Steel

There are different types of steel produce based on the properties that are required for the application and several grading systems that are used to differentiate the steel based on the properties. Based on the American Iron and Steel Institute (AISI), there are four group of chemical composition that used to categorize the steel (Bell, 2016). The groups are as follows:

i) Carbon Steels
ii) Alloys Steels
iii) Stainless Steels
iv) Tools Steels

i) Carbon Steels

For Carbon steels, its contain traces amounts of alloying elements. According to the carbon content, the carbon steel can be further categorized into three groups as in Table 2.1.

Table 2.1: Carbon contain for three groups of Carbon Steel (Source: Bell, 2016)

Types of Steel	Carbon Contain
Low Carbon Steels/Mild Steels	up to 0.3%
Medium Carbon Steels	0.3 – 0.6%
High Carbon Steels	more than 0.6%