EFFECTS OF BORONIZING ON GROOVED METAL SURFACE

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DECLARATION

I declare that this report entitle “The effect of boronizing on grooved metal surface” is the result of my own research except as cited in the references.

Signature : ....

Name of Student : ……………………………..

Date : ……………………………..

SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the 2nd examiner.

Signature	: …………………………
Name of Supervisor	: …………………………
Date	: ………………………....

DEDICATION

To my beloved father and mother

ABSTRACT

The main purpose of this project was to study the effects of temperature and time on the boride layer thickness of grooved surface. Boronizing is a thermo-chemical surface hardening process that allow the boron atoms diffuse into the metal surface. Different geometry groove surface is expected to affect the boronizing thickness and diffusion rate. The boronizing thickness and effectiveness of diffusion rate on different grooved geometry surfaces were studied. There were nine fabricated specimens in this project. Each of the specimen has four different grooved surfaces which are U-shaped (rectangular), 2mm C-shaped (circular), 4mm C-shaped (circular) and V-shaped (triangular). The specimens were placed in furnace for heating process. The boronizing time were 2 hours, 4 hours and 6 hours wheareas the boronizing temprature were 1123K, 1173K and 1223K. The specimens were cooled down in room temperature. Specimens were grinded and polished. The specimens were characterized for boride layer thickness measurement by using Scanning Electron Microscope and Inverted Optical Microscope. The activation energy of each grooved surface was calculated and analysed. The result and analysis showed that the boronizing thickness of different geometry surfaces were increased with temperature but inconsistent with time.

ABSTRAK

Tujuan utama projek ini dijalankan adalah untuk mengkaji bagaimana suhu dan masa mempengaruhi ketebalan lapisan borida pada permukaan beralur. Penyusukanboronan adalah satu proses pengerasan permukaan termo-kimia yang membolehkan atom boron meresap ke dalam permukaan logam. Perbezaan permukaan geometri alur dijangka memberi kesan kepada ketebalan dan kadar resapan penyusukboronan. Ketebalan penyusukboronan dan keberkesanan kadar resapan pada permukaan geometri beralur yang berbeza telah dikaji. Sembilan spesimen telah disediakan dalam projek ini. Setiap spesimen mempunyai empat permukaan beralur yang berbeza bentuk iaitu; bentuk-U (segi empat), bentuk-C bersaiz 2mm (bulat), bentuk-C bersaiz 4mm (bulat) dan bentuk-V (segi tiga). Semua spesimen telah diletakkan ke dalam dandang untuk proses pemanasan. Masa proses pemanasan adalah 2 jam, 4 jam dan 6 jam. Suhu proses pemanasan pula adalah 1123K, 1173K dan 1123K. Setiap spesimen telah disejukkan dalam suhu bilik. Pencirian spesimen telah dilakukan untuk pengukuran ketebalan lapisan borida dengan menggunakan alat Mikroskop Imbasan Electron dan Mikroskop Optik. Tenaga pengaktifan untuk setiap permukaan beralur telah dikira dan dianalisis. Keputusan dan analisis menunjukkan bahawa ketebalan penyusukboronan pada permukaan geometri yang berbeza telah meningkat dengan suhu tetapi tidak konsisten dengan masa.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBEREVATIONS

CVD-5B	-	Chemical Vapor Diffusion process
CNC	-	Computer Numerical Control

LIST OF SYMBOLS

x	-	Thickness
K	-	growth rate constant
t	-	Time
Q	-	Activation energy
T	-	Temperature
x	-	Horizontal displacement
y	-	Vertical displacement
µm	-	Micrometer
UTeM	-	Universiti Teknikal Malaysia Melaka
HV	-	Hardness Vickey

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

There are numerous surface hardening technologies at the present time. Thermal spray (Sampath, 2015), stellite (Kapoor, 2012) and hard chromium plating (Koorapati *et al*., 2013) are methods that often used in metal hardening. Boronizing or so called boriding can achieve reliable effect in metal hardening process. Boronizing is a chemical vapor diffusion process (CVD-5B) which allow the boron atoms diffuse into the metal surface of a wide variety of ferrous and non-ferrous materials to form complex boride such as Iron Boride (FeB) and Iron(II) Boride (FeB_2) (Buijnsters *et al*., 2003). This process are surrounded by a boron rich substance such as a fine powder or granulated medium before being taken to elevated temperature for a time during which the boron diffuses into the outer layer of the steel. Chemical vapor diffusion frames a hard layer that attains a hardness of close to Rockwell Hardness of around 84 HRC and strong wear-resistant metal mesh on the metal surface (Black and Kohser, 2008).

Practically all the ferrous material can be boronized including titanium (Ti), Nickel (Ni) and Cobalt alloy (Co). Nevertheless, the content of alloy element has direct influence to the diffusion rate. Higher content of alloy element might have longer the diffusion rate. The boride layer thickness is varied according to temperature, treatment duration and material. Boride layer thickness is around 10μm-200μm and it can attain a Vickers Hardness of between 1600HV to 2000HV (Arun *et al*., 2013). Boron yielding material can be heated to temperatures between 650 ºC to 1000 ºC (1200ºF-1830ºF) during the boronizing process (CVD-5B). Thus, metal that undergo boronizing is immensely wear resistant and last longer than conventional heat treatment such as Nitriding, Carburizing and Nitrocarburizing (Suwattananont, 2004).

Boronizing include ferrous metals, non-ferrous metal and alloys as shown in Table 1.1. Different material has different properties and outcome. Boronizing increases the hardness of ferrous material and temperature resistance by 1400HV-2000HV and 1830ºF respectively (Jurci and Hudakova, 2010). Most importantly the boride layer can reduce the coefficient of friction and the resistance of acid. In addition, heat treatment can be fully hardened after boronizing. Treatment can apply to irregular shape and it dimension of diffusion layer are adjustable.

Table 1.1 Material of boronizing (Adapted from Fichtl, 1981)

Ferrous Metal	Non-Ferrous Metal	Alloy
• Stainless steel • Carbon steel • Wrought Iron • Mild steel • Cast iron	• Aluminum • Copper • Silver • Lead	• Hastelloy • Nimonic 80A • Inconel 625

1.2 PROBLEM STATEMENT

Steel is an important material that comprises many residential and commercial structures. It ranks among the sturdiest construction material and multi shaped. Different geometry on groove surface is expected to affect the boronizing thickness and diffusion rate. In this project, the boronizing thickness and the effectiveness of diffusion rate on different grooved geometry surfaces are studied.

1.3 OBJECTIVES

1. To identify how the temperature and time affect the boronizing thickness on the grooved surface by using metallographic analysis.
2. To analyses the effect of different grooved geometries on the boronizing diffusion by using activation energy analysis.

1.4 SCOPE OF PROJECT

The scopes of this study focus on:

1. The boronizing apparatus design, preparation and process.
2. The analysis of diffusion for boride layer thickness by using microscopic observation.
3. The analysis of activation energy for boronizing on different grooved geometry surfaces.

CHAPTER 2

LITERATURE REVIEW

2.1 BORONIZING

Boronizing is a thermo-chemical surface hardening process that enables the boron atom diffuse into a pedestal metal to create a compact metallic boride layer on the surface. Boron atom disperse into the metallic lattice of the metal surface by heating in the temperature range of 1200°F- 1830°F during the boronizing process (Suwattananont, 2004). As a consequence, a single-phase boride or poly-phase boride appear and form an interstitial boron compound. The boron compound layer is usually about 20µm-300µm. Different substrates have different microhardness and constituent phases of the boride layer as shown in Table 2.1. Thermo-chemical surface treatments can strengthen the resistance to corrosion and abrasive wear, decreases coefficient of friction and increase the surface hardness. Boronizing can be applied to ferrous metals, non-ferrous metals and alloys. Magnesium alloy and aluminium alloys cannot be boronized because of its low melting point.

Table 2.1: Constituent phase and microhardness of different substrate
(Adapted from Suwattananont, 2004)

Substrate	Constituent phases in the boride layer	Microhardness of layer, HV
Fe	FeB Fe_2B	1900-2100 1800-2000
Co	CoB Co_2B	1850 1500-1600
Co-27.5 Cr	CoB Co_2B	2200 (100g) ~1550 (100g)
Ni	Ni_4B_3 Ni_2B Ni_3B	1600 1500 900
Inco 100	-	1700 (200g)
Mo	Mo_2B Mo_2B_5	1660 2400-2700
W	W_2B WB W_2B_5	~2700 (overall hardness)
Ti	TiB TiB_2	2500 3370
Ti-6Al-4V	TiB TiB_2	3000(100g)(overall hardness)
Nb	Nb_2B_2 NbB_4	2600-3000 (overall hardness)
Ta	Ta_2B TaB_2	3200-3500 2500
Zr	ZrB_2 Zr_2B	2300-2600 (overall hardness)
Re	ReB	2700-2900

2.1.1 Material of boronizing

Borides can be formed on ferrous metal, non-ferrous metal and alloys. There are two separate reactions during the process. The first reaction is a steady process between the boron merge with the base-metal surface and form a hard and thin boride layer. Second reaction is the boron atoms diffused further into the substrate at a faster rate and form a boron compound layer. (Keddam *et al.*, 2015)

Ferrous metal

Most of the ferrous metals can be boronized such as low-alloy steel, tool steel, stainless steel, carbon steel, and mild steel. The boron compound layer will be formed on the ferrous metal surface. The boron compound layer can be either in single phase formation or double phase formation with a certain composition. The single phase consists of Fe_2B layer whereas the double phase formation consists of FeB layer and Fe_2B layer as shown in Figure 2.1. (Yorulmaz, 2007)

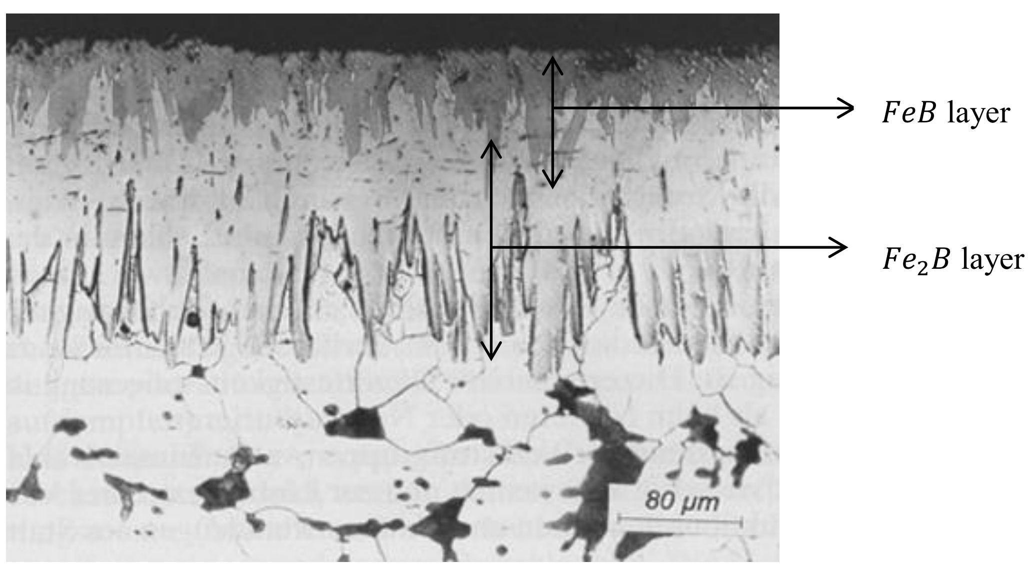

Figure 2.1: Boron compound layer consists of FeB layer (dark) and Fe_2B layer (light) (Krastev, 2012)