Pertanika J. Sci. & Technol. 25 (S): 11 - 18 (2017)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Effect of Boronizing Medium on Boron Diffusion of Surface Modified 304 Stainless Steel

Mohd Noor Halmy[1], Siti Khadijah Alias[1]*, Radzi Abdul Rasih[1], Mohd Ghazali Mohd Hamami[1], Norhisyam Jenal[1] and Siti Aishah Taib[2]

[1]*Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM) Johor, 81750, Masai, Johor, Malaysia*
[2]*Academy of Language Studies, Universiti Teknologi MARA (UiTM) Johor, 81750 Masai, Johor, Malaysia*

ABSTRACT

This study focuses on the effect of boronizing medium on the boride layer thickness of pack boronized 304 stainless steel after surface modification. Pack boronizing treatment was conducted in temperature of 900oC for a duration of eight hours. The treatment was performed using two different boronizing mediums which are powder and paste inside a tight box in an induction furnace. The characteristics of the samples were then observed using optical microscopy and XRD analyser. The thickness of boride layer was then measured using MPS digital image analysis software. The results showed that boronizing medium significantly affected the thickness of boride layer as paste boronized samples exhibited thicker boride layer thickness. The enhancement was mainly due to the size of boron particle in the paste medium which was smaller than powder medium that enabled better diffusion. It is expected that the enhancement of the boride layer thickness would result in further improvement of the mechanical and wear properties of this material.

Keywords: 304 stainless steel, boron diffusion, boronizing, boride layer thickness

ARTICLE INFO

Article history:
Received: 19 February 2017
Accepted: 17 July 2017

E-mail addresses:
halmy@johor.uitm.edu.my (Mohd Noor Halmy),
khadijah_alias@johor.uitm.edu.my (Siti Khadijah Alias),
radzi_rasih@johor.uitm.edu.my (Radzi Abdul Rasih),
ghazali.hamami@johor.uitm.edu.my (Mohd Ghazali Mohd Hamami),
hisyam0324@johor.uitm.edu.my (Norhisyam Jenal),
aishah711@johor.uitm.edu.my (Siti Aishah Taib)
*Corresponding Author

ISSN: 0128-7680

INTRODUCTION

In boronizing, which combines both thermal and chemical reactions, boron atoms are diffused on the surface of steel and iron with the purpose of improving the properties such as hardness and wear resistance. The diffusion process will create boronized layers containing iron boride of FeB and Fe_2B phase (Jacuinde, Guerra, Rainforth, & Maldonado, 2015). The enhancement of hardness and wear properties are dependent on the thickness of the boride layer formed on the surface of metal and alloy. Thicker boride layer will result in better surface protection, thus forming a material with superior hardness and wear resistance (Jacuinde et al., 2015). The formation of the boride layer is dependent on the boronizing medium (gas, liquid or solid), temperature and also time (Béjar & Henríquez, 2009; Kul, Oskay, Temizkan, Karaca, Kumruoğlu, & Topçu, 2016; Mao, X. Wang, W. Wang, & Wei, 2012).

Pack boronizing is the most common type of boronizing method as it offers advantages such as low cost and simple operation. This process is conducted by immersing the sample in a box filled with either powder or paste medium. The medium consists of boron compound, activator and diluents at a temperature of 750°C to 1100ºC for a duration of two to 10 hours (Alias, Abdullah, Latip, Roselina, Roseley, Jenal, & Kasolang, 2013a; Basir, Abdullah, & Alias, 2014). The variations of the medium result in different mechanical and wear properties of low alloyed steel and cast iron (Alias et al., 2013b; Dybkov, 2015). Generally, paste medium provides better boron diffusion thickness, thus acquiring better wear properties.

Other than pack boronizing, the treatment could also be conducted in liquid and gas states (Gunes, Ulker, & Taktak, 2011). A mixture of crystallised boraks and boric acid is often used in liquid boronizing while an inert gas such as argon is often used as carrier gas in gas boronizing. Using these methods, the improvement of wear resistance and mechanical properties could be achieved at a lower temperature and shorter time as compared to pack boronizing method. It is because more chemical reactions are activated during the treatment (Sahin, 2009). However, the restriction of this method is the requirement of removing the salt layers formed on the sample surface, which can be more complicated and expensive (Zepon, Nascimento, Kasama, Nogueira, Kiminami, & Botta, 2015). As the characteristic of boride layer thickness depends largely on the boronizing medium, this study focused on the effect of boronizing medium on the boron diffusion characteristic of 304 stainless steel.

MATERIALS AND METHOD

The characteristics of the samples were observed using Olympus B X 41 M microscopes. The thickness of boride layer was then measured using MPS digital image analysis software. The microstructures were prepared by mounting, cross-sectioning, and polishing according to ASTM E3 standard and etching according to ASTM E407 standard. 2% Nital was used as the chemical etchant. The phase structures were then confirmed through Rigaku X-Ray Diffraction (XRD) diffractometer by means of CuKα radiation with the 2θ angle between 30 to 120. Table 1 shows the chemical composition of 304 stainless steel.

Table 1
Chemical composition of 304 stainless steel

Chemical composition	Weight percentage (%)
Carbon (C)	0.08
Silicon (Si)	0.8
Manganese (Mn)	1.8
Phosphorus (P)	0.045
Sulfur (S)	0.035
Nickel (Ni)	8.00
Chromium (Cr)	18.00

The surface modification process which was shot blasting was conducted on the surface of stainless steel in order to initiate boron diffusion using the Finimac shot blasting machine. The ceramic silicon carbide (SiC) ball with velocity between 150 to 200 m/s and a diameter of 2 mm was used as the steel shot. Figure 1 shows the surface modification process and the parameter implemented. The surface modification process helps initiate dislocation and vacancy, which allows better boron diffusion onto the surface of boronized stainless steel as the presence of alloying elements in high amount often restricted the boride layer formation.

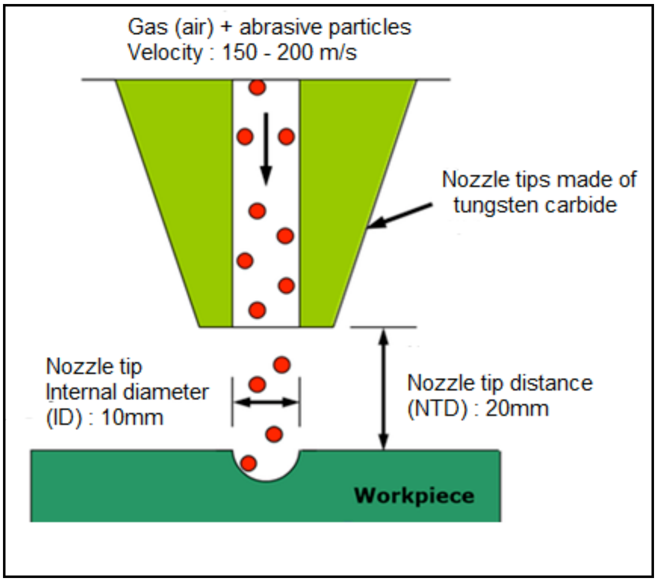
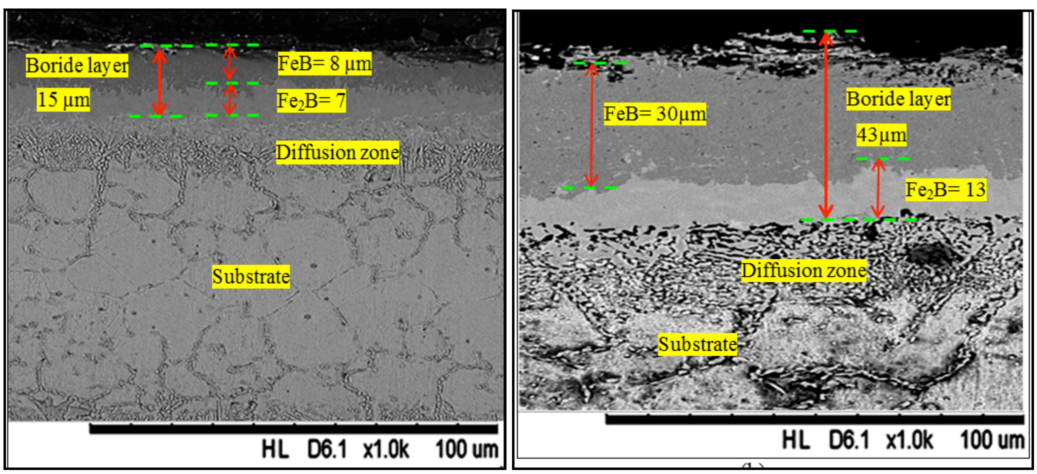


Figure 1. The schematic diagram of the mechanism for shot blasting process

RESULTS AND DISCUSSION

Microstructure Observation

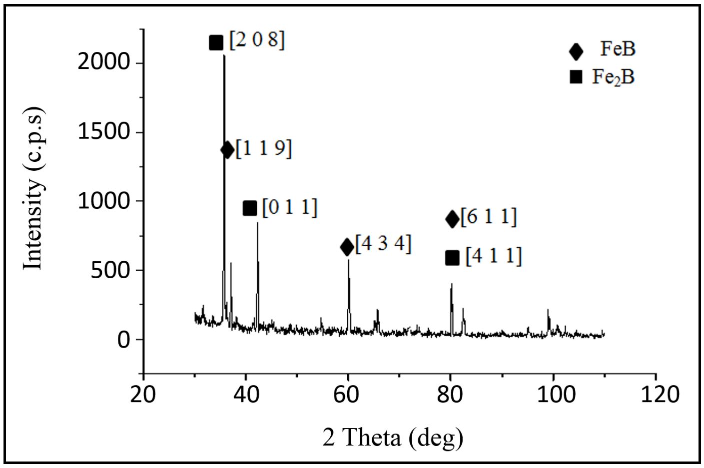
The result of microstructure observation is shown in Figure 1. Figure 1(a) shows the microstructure of powder boronized sample while Figure 1(b) shows the microstructure of paste boronized sample. Both samples depicted the austenitic structure with sizes of 70 to 90 µm. There was a formation of boride layer consisting of iron boride I (FeB) and iron boride II (Fe_2B) in both samples. Iron boride I (FeB) exhibited more brittle manner with boron percentage of 16.23 wt% when compared to iron boride II (Fe_2B) which contained only 88 wt% of boron. The combination of these two layers, however, provided good strength and hardness to the surface of the material. The diffusion zone,which was a boron enriched area,was under the boride layer, while the substrate of the material was in the diffusion zone. Similarly, it was found that pack boronizing usually produce inter metallic phase containing FeB and Fe_2B phases when heated at a temperature between 800°C to 900°C for six to eight hours holding time (Alias et al., 2013a; Basir, Abdullah, & Alias, 2014).



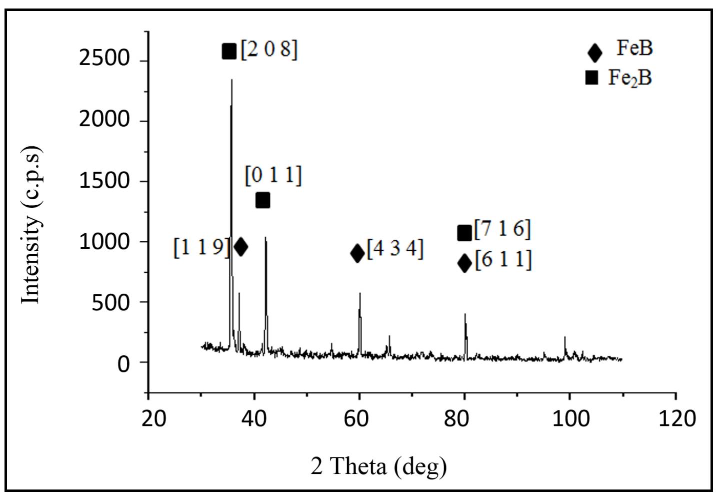
(a) (b)

Figure 2. Microstructure of: (a) powder; and (b) paste boronized 304 stainless steel

The validation of FeB and Fe_2B phases is depicted in Figure 3. The formation of FeB and Fe_2B phases were confirmed via XRD analysis at 2 Theta angles of 37°[1 1 9], 62°[4 3 4] and 80°[6 1 1] for FeB phase and 35°[2 0 8], 42°[0 1 1] and 82°[7 1 6] for Fe_2B phase.



(a)



(b)

Figure 3. XRD Pattern of: (a) powder and (b) paste boronized stainless steel

Boride Layer Thickness

The result of the boride layer thickness is shown in Figure 4. It was observed that the overall thickness layer of powder boronized sample was 15 µm with a similar thickness of FeB and Fe_2B. However, paste boronized sample had successfully enhanced the boride layer thickness three times the value of the powder bronzed samples with the value of 43 µm. The thickness of FeB layer was more than twice the value of the Fe_2B layer as the value of the boron percentage in FeB was higher than Fe_2B. In paste medium, the particle size of the medium was smaller than the powder, which resulted in higher activation energy that enabled better diffusion at high temperature. Similarly, it was found that the boride layer thickness of low alloyed steel was thicker when boronized using paste medium as compared to powder medium because more active boron ion, B^{+1} was diffused and reacted with Fe in the samples (Zepon et al., 2015).

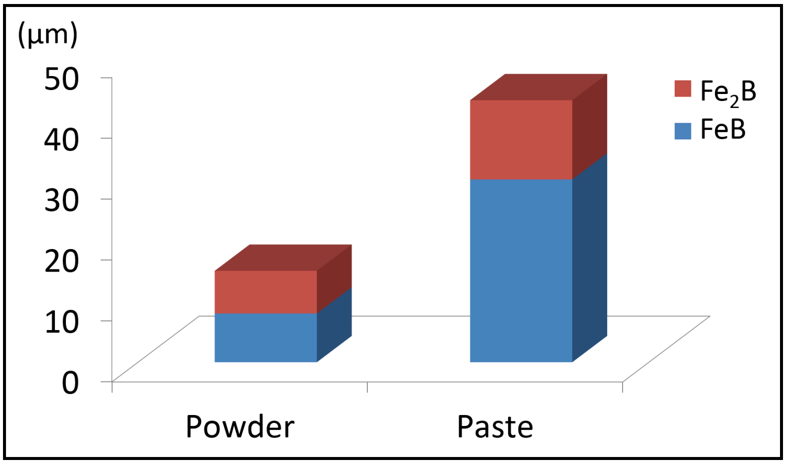


Figure 4. Boride layer thickness of power and paste boronized stainless steel

CONCLUSION

The main objective of this study which is to study the boronizing medium on boron diffusion of surface modified 304 stainless steel has been successfully achieved. It can be concluded that paste medium induced deeper boride layer with an improvement of almost three times as compared to powder medium due to smaller particle size that enabled higher citation energy during the boronizing process. This indicates that paste medium provides better protection to the surface of the material, thus leading to improvement of hardness and wear resistance of the material. It would be useful to study the kinetic energy of this method in the future to further improve this research.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Education and IRMI UiTM for awarding the Grant: 600-RMI/RAGS 5/3 (160/2014), Universiti Teknologi MARA Shah Alam and Universiti Teknologi MARA Johor Branch, Pasir Gudang Campus.

REFERENCES

Alias, S. K., Abdullah, B., Latip, S. A., Roselina, N., Roseley, N., Jenal, N., & Kasolang, S. (2013a). Effect of temperature variations on wear properties of boronized stainless steel. *Applied Mechanics and Material, 393*, 217-221.

Alias, S. K., Abdullah, B., Latip, S. A., Roselina, N., Roseley, N., Jenal, N., & Kasolang, S. (2013a). Boron dispersion layer of paste boronized 304 stainless steel before and after shot blasting process. *Applied Mechanics and Material, 393*, 217-221.

Basir, M. H., Abdullah, B., & Alias, S. K. (2014). Wear properties of paste boronized 316 stainless steel before and after shot blasting process. *Scientific Research Journal, 11*, 2.

Béjar, M. A., & Henríquez, R. (2009). Surface hardening of steel by plasma-electrolysis boronizing. *Materials and Design, 30*, 1726–1728.

Dybkov, I. (2015). Thermochemical Boriding of Iron-Chromium Alloys. *Chemistry Journal, 1*(3), 81-89.

Gunes, I., Ulker, S., & Taktak, S. (2011). Plasma paste boronizing of AISI 8620, 52100 and 440C steels. *Materials and Design, 32*, 2380–2386.

Jacuinde, A. B., Guerra, F. V., Rainforth, M. I., & Maldonado, C. (2015). Sliding wear behavior of austempered ductile iron microalloyed with boron. *Wear, 330-331*, 23–31.

Kul, M., Oskay, K. O., Temizkan, A., Karaca, B., Kumruoğlu, L. C., & Topçu, B. (2016). Effect of boronizing composition on boride layer of boronized GGG-60 ductile cast iron. *Vacuum, 126*, 80–83.

Mao, D., Wang, X., Wang, W., & Wei, X. (2012). Effect of boronizing on the dry sliding wear behavior of DC53/0.45 mass% C steel pairs. *Surface and Coatings Technology, 207*, 190–195.

Sahin, S. (2009) Effects of boronizing process on the surface roughness and dimensions of AISI1020, AISI 1040 and AISI 2714. *Journal of Materials Processing Technology.* 1736-1741.

Zepon, G., Nascimento, A. R. C., Kasama, A. H., Nogueira, R. P., Kiminami, C. S., & Botta, W. J. (2015). Design of wear resistant boron-modified supermartensitic stainless steel by sprayforming process. *Materials and Design, 83*, 214-223.