

## SINGLE AND DOUBLE SHOT BLASTING TREATMENT OF 304 STAINLESS STEEL

M. Khairulmaini<sup>a\*</sup>, S. K. Alias<sup>a</sup>, B. Abdullah<sup>b</sup>, J. M. Said<sup>a</sup>, N. Sulong<sup>a</sup>, M. Mazni<sup>a</sup>, N. Jenal<sup>a</sup>

<sup>a</sup>Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM) Cawangan Johor, 81750 Masai, Johor Darul Takzim, Malaysia

<sup>b</sup>Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

### Article history

Received

15 February 2015

Received in revised form

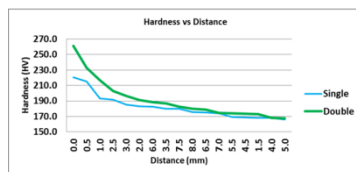
30 April 2015

Accepted

31 May 2015

\*Corresponding author  
miqdad@johor.uitm.edu.my

### Graphical abstract



### Abstract

Properties enhancement through surface modification has been established as a method to improve the dispersion quality of case hardening treatment. Improvement of dispersion thickness layers resulted in properties enhancement of metallic material. This study investigates the effect of shot blasting parameters which are single (SB) and double (DB) sand blasting on boronizing dispersion layer of 304 stainless steel. Boronizing treatment is conducted using paste boron at temperature of 900°C for 6 hours holding time. The dispersion layer measurement and phase identification were evaluated through optical microscope and XRD analysis. Vickers hardness test and surface roughness analysis were also conducted. The result shows that noticeable enhancement of dispersion layer thickness was observed after conducting double sand blasting as compared to single sand blasting. Thicker dispersion layer leads to the increment of hardness value and also enhancement in surface roughness properties.

Keywords: 304 stainless steel, shot blasting dispersion layer, boronizing

© 2015 Penerbit UTM Press. All rights reserved

## 1.0 INTRODUCTION

304 stainless steel is the most versatile amongst all types of stainless steel as it offers substantial welding characteristics, corrosion resistance and forming ability. The applications include compartment and casing for food processing equipments, heat exchangers, refrigeration equipments, kitchen sink and sanitary fittings. Thus it is essential for this stainless steel to possess excellent properties such as high hardness and high surface quality [1]. In low alloy steels, the establishment of boronizing method has been extensively applied as successful surface improvement method [2-4]. This method is popular due to the advantages its offer such as improving the hardness, wear and corrosion resistances and also oxidation properties. Unlike coating, boronizing is a surface diffusion method which offers excellent benefits in application where

dimensional accuracy is the main requirement. In opposition to that, high alloy steel such as stainless steels suffer insignificant effects as high content of alloying elements hinder the formation of boriding layers [5].

Previously, surface modification methods were implemented on the surface of the substance before conducting case hardening process such as carburizing, nitriding and boronizing with the purpose of allowing thicker diffusion layer [6-7]. Past study evaluated the effect of shot peening as surface modification treatment on nitrided 316 stainless steel. The results show significant improvement on both wear resistance and hardness properties as compared to untreated samples [8]. It was also found that the properties of plasma-sprayed AISI 316L stainless steel coating could be improved by roughening the substance by blasting it with alumina grit [9].

Although improvement of stainless steel properties had been proven through surface modification in previous studies, the effect of double shot blasting treatment has not been investigated. Thus this study concentrates on the effect of single and double shot blasting treatment on the properties of boronized 304 stainless steel.

## 2.0 SAMPLE PREPARATION

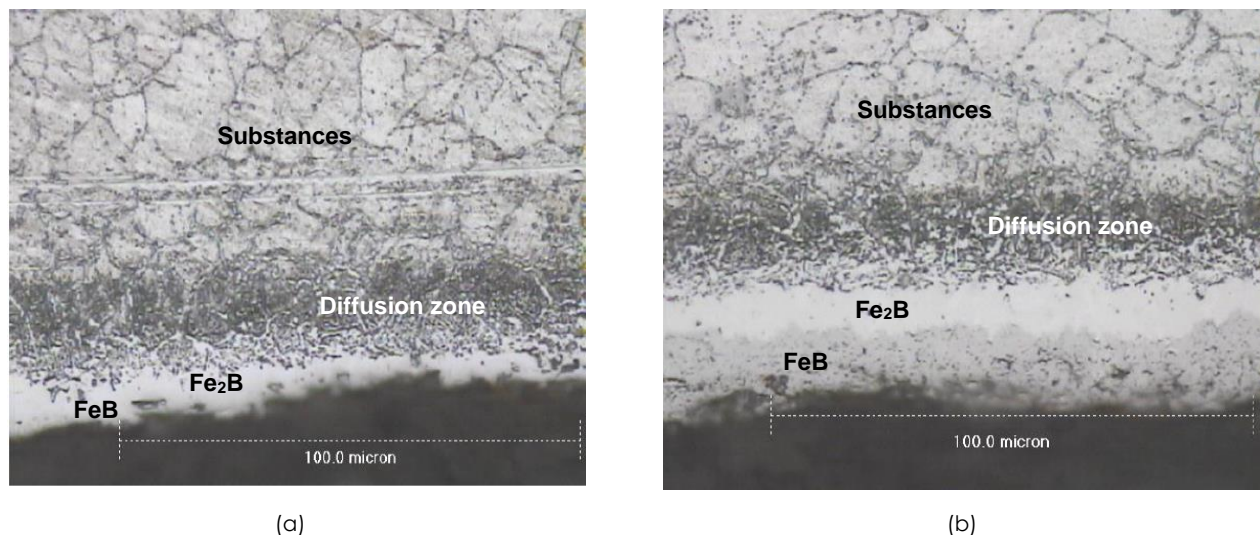
The samples used for this study is 304 stainless steel with carbon content of 0.07 wt%, chromium content of 18.5% and nickel content of 8.0 wt%. Samples with dimension of 10 mm diameter and 30mm in length were prepared by cutting, grinding and polishing the surfaces according to the standard sample preparation method. Single shot blasting surface treatment was conducted using alumina composite having mesh sizes of 50-100  $\mu\text{m}$  with a velocity of 65 m/s for 15 minutes. For double shot blasted samples, the method was repeated with the same parameter after the samples was once blasted. Both samples were then undergoing boronizing and the required testing.

## 3.0 BORONIZING TREATMENT

Boronizing treatment was conducted using Borax paste medium at temperature of 900°C for 8 hours holding time. The samples were coated with the boronizing paste and placed inside the container. Samples were then heated inside the Carbolite electric muffle furnace and let cooled inside the furnace.

## 4.0 EXPERIMENTAL TESTING

The thickness of the dispersion layer of the sand blasted samples after boronizing was measured using Olympus BX41M System metallurgical microscope. The samples were hot mounted and grinded with sand papers with roughness of 240  $\mu\text{m}$  to 1200  $\mu\text{m}$  before being polished using 1  $\mu\text{m}$  to 9.5  $\mu\text{m}$  rotating polisher. Kalingo no 2 was used for etching process. Hardness values of single sand blast sample and double sand blast samples were measured using Vicker Hardness Testing Machine. Every sample was indented with 1kg load at 17 spots with a gap of 0.5 mm. Surface roughness analysis was conducted using Alicona 3D surface roughness machine.



**Figure 1** Micrograph of boron dispersion layer of (a) SB and (b) DB boronized samples

## 5.0 RESULT AND DISCUSSION

Figure 1 (a) and (b) shows the micrograph of single (SB) and double (DB) shot blasted boronized stainless steel samples. In both samples, the boride layer formed contained a narrow saw tooth structure of FeB and Fe<sub>2</sub>B phases, similar to past literatures. The formation of these phases will act as protective layer to the substance. For SB sample, the dispersion layer measurement is approximately 53.5 microns and for DB sample, the measurement is 87.2 microns, which is an improvement of more than 60%. Boron dispersion rate is higher in DB

samples as compared to SB samples, proven by the increment of the boronizing dispersion thickness layer. It was stated that for 304 stainless steel samples, the dispersion layer could not exceed 50 microns due to the presence of alloying elements that have hindered the formation of FeB and Fe<sub>2</sub>B phase[5]. By implementing surface deformation through shot blasting, the thickness of dispersion layer obtained in this study had achieved more than 50 microns, which is the minimum thickness layer that could provide substantial protection to the surfaces as compared to other case hardening method. Further increment in thickness layer was achieved by

conducting double shot blasting process. Double sand blasting creates more surface deformation on the surface, allowing higher penetration of boron dispersion

layer. The existences of Boron Iron ( $Fe_2B$ ) phase and Iron Boride ( $FeB$ ) phases were verified through XRD analysis at  $2\theta$  angle of  $30^\circ$  to  $120^\circ$ , shown in Figure 2.

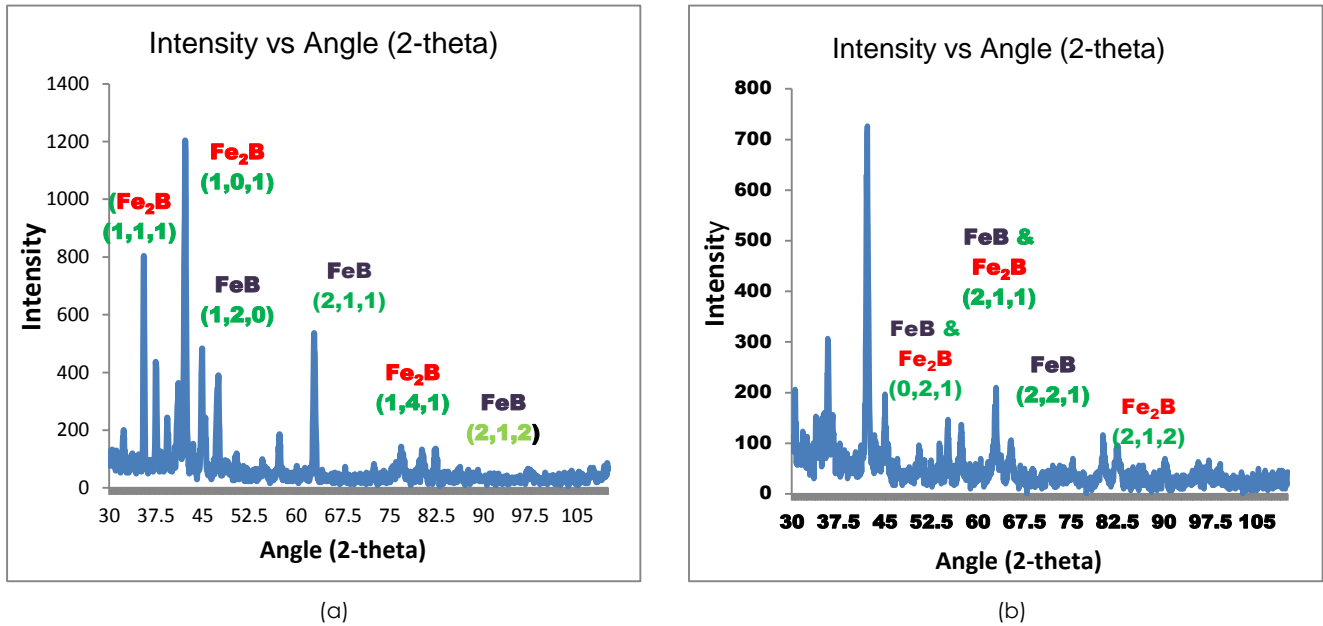


Figure 2 XRD analysis of (a) SB and (b) DB boronized 304 samples

Figure 3 shows the hardness of SB and DB samples applied on 5.0 mm measured distance on the sample cross-section. It can be observed that the hardness decreased from the distance of 0.0 mm which is from the outer surfaces of the samples, up to 5.0 mm, moving inwards the material substances.  $FeB$  layer produced the highest hardness value as compared to

$Fe_2B$  which produced the lowest hardness value. However, the hardness value of DB sample is higher than SB sample as the formation of boride layer is thicker in the samples. Boron addition to metallic material has proven to improve the hardness value [10-11].

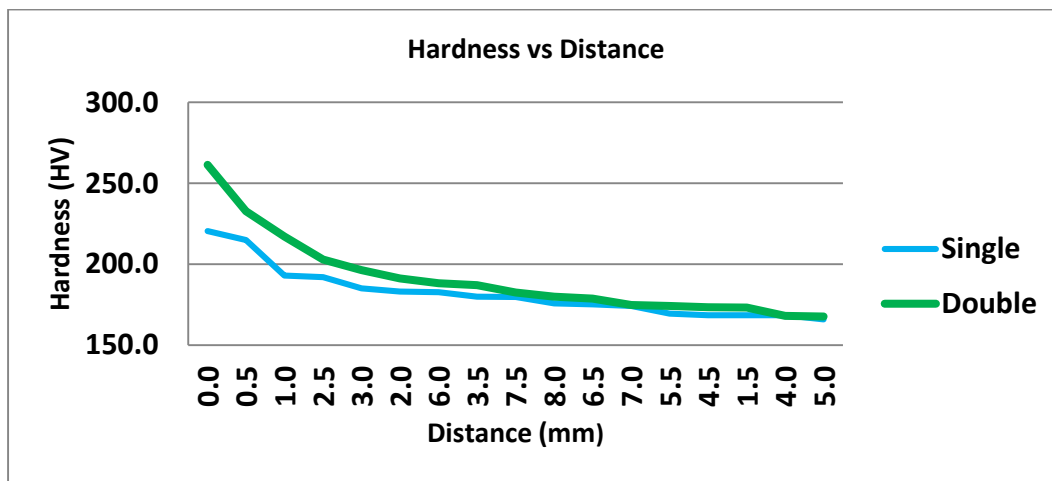


Figure 3 Hardness values of all types of samples

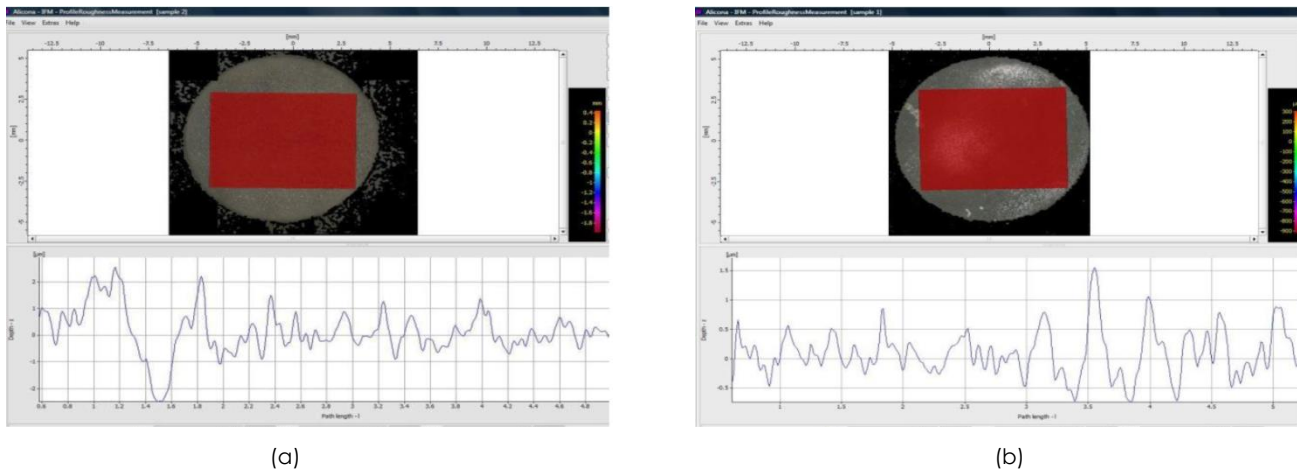


Figure 4 Surface roughness morphology of (a) SB and (b) DB boronized samples

Figure 4 shows the surface roughness morphology for SB and DB samples. DB sample produce a lower Ra value which is  $0.293 \mu\text{m}$  while SB sample produce a higher Ra value which is  $0.595 \mu\text{m}$ . The particles shots impact on the 304 stainless steel creates imperfection on the sample surface, thus resulting in the formation of a rough surface. However, a longer treatment initiates more impacts exerted on the material and thus yields more nanocrystallites onto the surface. The presence of more nanocrystallites therefore decreases surface roughness [7]. Previous research has also shown that double shot peening on nitrogen austenitic stainless steel has increased the surface roughness approximately up to 0.4 microns [9].

## 6.0 CONCLUSION

A study to investigate the effect of shot blasting parameters which were single (SB) and double (DB) sand blasting on boronizing dispersion layer of 304 stainless steel was conducted. The results obtained showed that using DB blasting resulted in an improvement of 40% for dispersion layer thickness, and an increase in surface hardness value when compared to SB due to the thicker layer formed. Surface roughness of DB blasting samples also decreased indicating smoother surface as compared to SB samples.

## Acknowledgement

This research is funded by the Ministry of Education (MOE), Malaysia and Faculty of Mechanical Engineering, Universiti Teknologi MARA, Malaysia, mainly via grant no. 600-RMI/RAGS 5/3 (50/2013).

## References

- [1] David M. Nielsen. 2005. *Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring*. Florida: CRC Press.
- [2] Kuper, A., Qiao, X., Stock, H.R. & Mayr, P. 2000. A Novel Approach to Gas Boronizing. *Surface and Coatings Technology*. 130(1): 87-94.
- [3] Tabur, M., Izciler, M., Gulb, F. & Karacanc, I. 2009. Abrasive Wear Behavior of Boronized AISI 8620 Steel. *Wear*. 266(11-12): 1106–1112.
- [4] Dandan Mao, Xin Wang, Wurong Wang & Xicheng Wei. 2012. Effect of Boronizing on the Dry Sliding Wear Behavior of DC53/0.45 Mass% C Steel Pairs. *Surface & Coatings Technology*. 207: 190-195.
- [5] Enver Atik, Umut Yunker & Cevdet Menc. 2003. The Effects of Conventional Heat Treatment and Boronizing on Abrasive Wear and Corrosion of SAE 1010, SAE 1040, D2 and 304 steels. *Tribology International*. 36: 155-161.
- [6] Mustafa Ulutan, Osman N. Celik, Hakan Gasan & Umit Er. 2010. Effect of Different Surface Treatment Methods on the Friction and Wear Behavior of AISI 4140 Steel. *Journal of Materials Science and Technology*. 26(3): 251-257.
- [7] Arifvianto, Suyitno & Mahardika, M. 2011. Effect of Sandblasting and Surface Mechanical Attrition Treatment on Surface Roughness, Wettability, and Microhardness Distribution of AISI 316L. *Key Engineering Materials*. 462-463: 738-743.
- [8] Hashemi, B. 2011. The Wear and Corrosion Resistance of Shot Peened-Nitrided 316L Austenitic Stainless Steel. *Materials and Design*. 32: 3287-3292.
- [9] Lakhwinder Singh, Khan, R. A. & Aggarwal, M. L. 2010. Effect of Shot Peening on Hardening and Surface Roughness of Nitrogen Austenitic Stainless Steel. *International Journal of Engineering Science and Technology*. 2(5): 818-826.
- [10] Ozkan Gulsoy, H., Kemal Bilici, M., Yahya Bozkurt & Serdar Salman. 2007. Enhancing the Wear Properties of Iron Based Powder Metallurgy Alloys by Boron Additions. *Materials and Design*. 28: 2255-2259.
- [11] Siti Khadijah Alias, Bulan Abdullah, Syazuan Abdul Latip, Nik Roselina Nik Roseley, Norhisyam Jenal & Salmiah Kasolang. 2013. Boron Dispersion Layer of Paste Boronized 304 Stainless Steel Before and After Shot Blasting. *Applied Mechanics and Materials*. 393: 217-221.