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Analysis on Microstructure, Hardness and Surface Roughness of Shot Blasted-Paste Boronized 316 Austenitic Stainless Steel

Muhamad Hafizuddin Mohamad Basir[a*], Bulan Abdullah[a], Siti Khadijah Alias[b], Muhammad Hafizuddin Jumadin[a], Muhammad Hussain Ismail[a]

[a]Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[b]Faculty of Mechanical Engineering, Universiti Teknologi MARA, 81750 Masai, Johor, Malaysia

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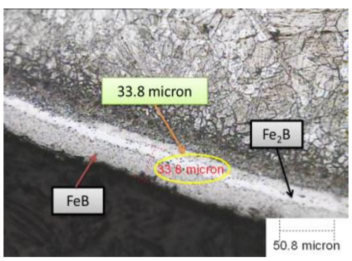
*Corresponding author
firedon89@gmail.com

Graphical abstract



Abstract

In this research, analysis on microstructure, hardness and surface roughness of 316 austenitic stainless steel were conducted before and after boronizing process. Boronizing treatment was conducted using a paste medium at a temperature of 850°C, with and without shot blasting. Microstructures of the specimens were observed under Olympus BX60 Optical Microscope. Vickers Micro Hardness Tester was used to determine the hardness of the specimens while Optical 3D Surface Metrology Sys was used to measure the surface roughness of the specimens. The process of boronizing diffuses boron into the surface of steel which resulted in the formation of the boride layers that consist of FeB and Fe_2B. Shot blasting process increased the boron diffusion which resulted in increment of the boride layer thickness and hardness value while the surface roughness was fluctuated. Increment in the hardness value of 316 stainless steel causes the steel to be able to withstand a heavy load.

Keywords: Stainless steel, boronizing, shot blasting, hardness, surface roughness

1.0 INTRODUCTION

Stainless steel is a type of steel that has high corrosion resistance and it is divided into three classes which are martensitic, ferritic and austenitic [1]. 316 stainless steel is an austenitic stainless steel which has been used widely in many applications including the industrial processes such as chemical industry, pulp and paper industry and food industry [2]. Austenitic stainless steel is famous on its excellent corrosion resistance but it has its own limitation which is poor tribological characteristic [3].

Boronizing treatment is one of the surface treatments that diffused boron on to the surface to form boride layers [4]. Powder pack method is a method of boronizing that is commonly used as the process is simple and low cost but it needs long processing time and high processing temperature to obtain the desired boride layers thickness [5,6]. Paste boronizing process is a recent method of boronizing in the pack method in which the boronizing process is conducted using paste medium. A surface treatment which is shot blasting was introduced to create surface deformation that will increase the thickness of boride layers. The objective of this research is to analyze the microstructure, hardness and surface roughness of 316 stainless steel after it had been subjected to the surface treatments.

2.0 EXPERIMENTAL DETAILS

2.1 Sample Preparation

The raw material of cylindrical 316 stainless steel (ø = 10 mm) was cut into specimens with 10 mm length for microstructure observation and hardness test and specimens with 5 mm length for surface roughness test using Specimen Cut-Off Machine. The specimens for all experimental testing were labeled as A (untreated), B (shot blasted), C (unshot blasted and paste boronized) and D (shot blasted and paste boronized). Before conducting the process of hot mounting, grinding and polishing, surface treatment was conducted first on the specimens for microstructure observation and hardness test while surface treatment were carried out on the specimens for surface roughness test after conducting grinding process.

2.2 Surface Treatment

The whole surfaces of the specimens were shot by shot blasting process using Finimac Shot Blasting Machine using ceramic shots. Boronizing process using paste medium was conducted on the unshot blasted and shot blasted specimens at 8 hours of holding time and temperature of 850^0C of each sample using Carbolite High Temperature Furnace.

2.3 Experimental Testing

The microstructures of the specimens were observed under Olympus BX60 Optical Microscope after the specimens were etched with Kalling's No 2. MITUTOYO MVK-H1 Vickers Micro Hardness Tester was used to determine the hardness of the specimens. The Vickers method measures the depth of indentation produced by load on an indenter. The unit that was used in this test is HV with 100 g of indentation load. Three times of indentations were taken in this test. The surface roughness of the specimens was obtained by using ALICONA (INFINITE FOCUS) Optical 3D Surface Metrology Sys at 5x of objective lens.

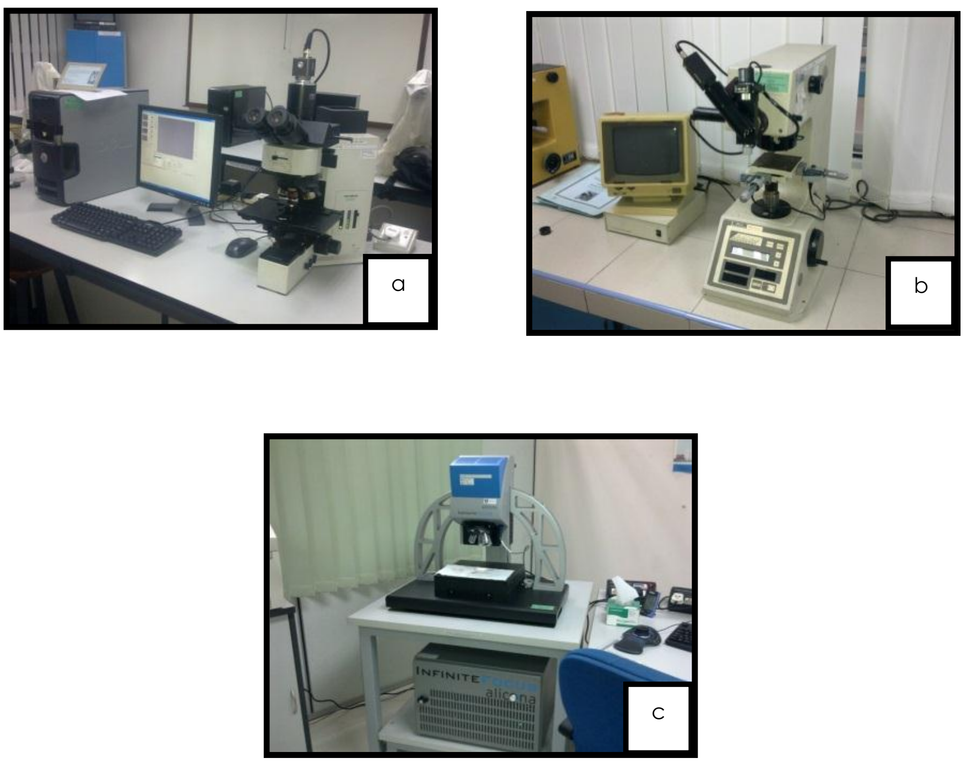


Figure 1 Equipments for experimental testings (a) Optical Microscope (b) Vickers Micro Hardness Tester (c) Optical 3D Surface Metrology Sys

3.0 RESULTS AND DISCUSSION

3.1 Microstructure Observation

316 stainless steel is an austenitic stainless steel due to its face centered cubic crystallographic structure and this austenitic structure can be seen as in Figure 2(a). After shot blasting process had been implemented on the 316 stainless steel, the surface of the steel had been deformed into white thick layer as shown in Figure 2(b). Boronizing process creates boride layers at the surface of 316 stainless steel that

consists of FeB and Fe_2B. The outermost layer shows the presence of FeB and the inner layer in which the colour is lighter than the outermost layer represents Fe_2B. This phenomenon can be seen at the cross-section view of the microstructure as in Figure 2(c) and 2(d).

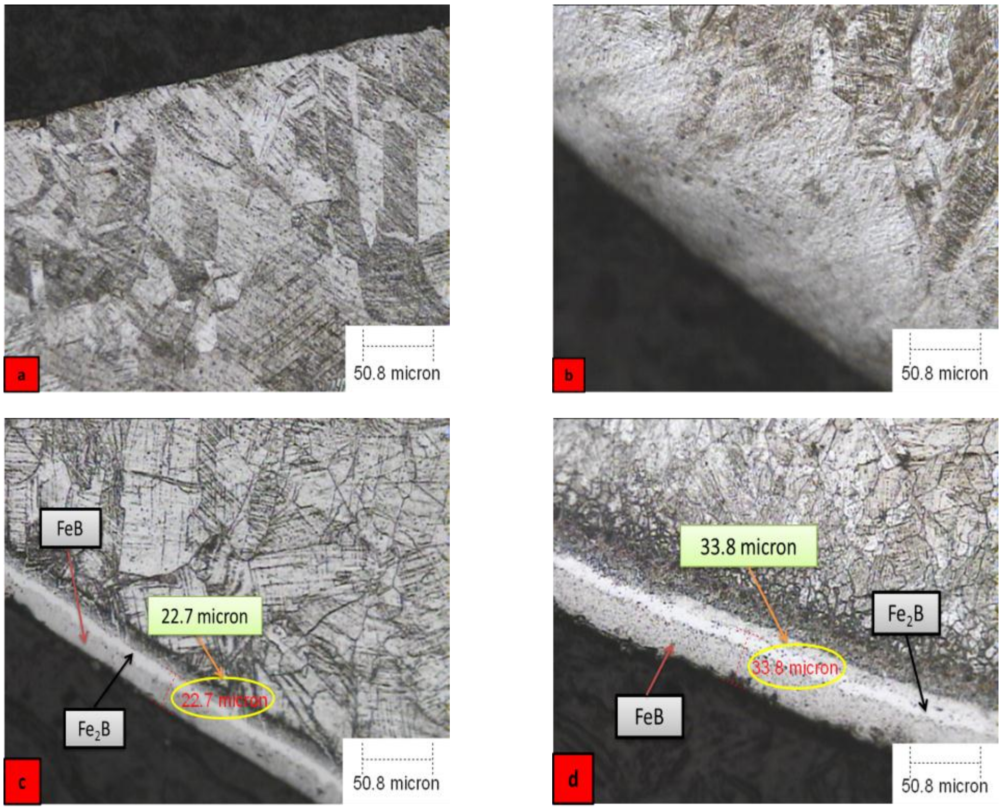


Figure 2 Microstructure of (a) untreated (b) shot blasted (c) unshot blasted and paste boronized (d) shot blasted and paste boronized 316 stainless steel

It is also reported on the presence of FeB and Fe_2B in the other researches on boronizing effect [7-9]. The thickness of the boride layers varies on the presence of shot blasting process. The steel that had been shot blasted before it had been boronized have higher boride layers thickness than the same steel that only had been boronized. This is due to the atom dislocation on the steel's surface created by applying shot blasting treatment that enhances the boron diffusion into the steel.

3.2 Hardness Measurement

Hardness is the amount of the resistance of a material to plastic deformation such as from scratch or indentation [10]. Figure 3 shows the hardness of all of the specimens. It can be seen that the hardness of the 316 stainless steel increased with the aid of shot blasting process and boronizing treatment.

The combination of shot blasting process and boronizing treatment provide better result in the hardness of the specimen compared to the single process. The process of shot blasting on the 316 stainless steel dislocates the atoms in it that enhances boron diffusion into the steel. Thus, it can be said that the effect of boronizing process together with shot blasting process raise the hardness of 316 stainless steel.

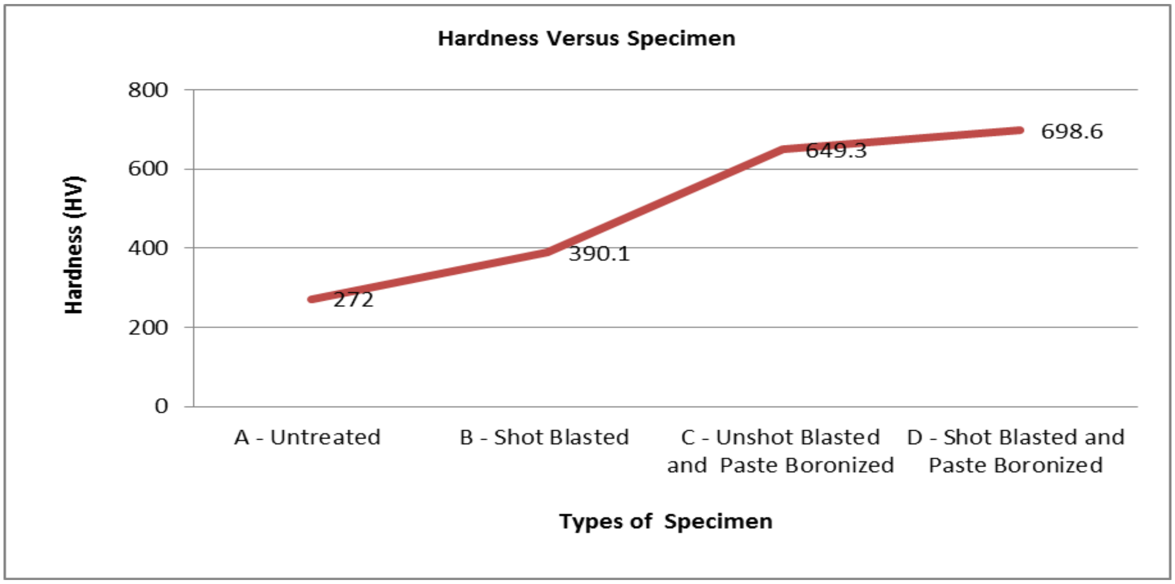


Figure 3 Hardness versus different types of specimen

3.3 Surface Texture Measurement

Surface roughness is a measure of the pattern of a surface and it is usually considered to be the high frequency, small wavelength part of a measured surface [11]. It can be seen that the values of surface roughness are fluctuating with respect to the specimens as shown in Figure 4. The values are due to the roughness of the surface of the specimens and not considering on the other aspects such as deeper boron diffusion, etc. High surface roughness of a specimen is not means that it has high hardness.

From the result of surface roughness as shown in Figure 4, it can be seen that untreated 316 stainless steel has rougher surface than the shot blasted 316 stainless steel so it can be said that shot blasting process produces smoother surface on the steel rather than the unshot blasted steel. If comparing with the unshot blasted and paste boronized and shot blasted and paste boronized specimens, the unshot blasted and paste boronized specimen has lower roughness than the shot blasted and paste boronized specimen due to the effect of shot blasting process that tending the boron to attach more on the surface of the shot blasted specimen.

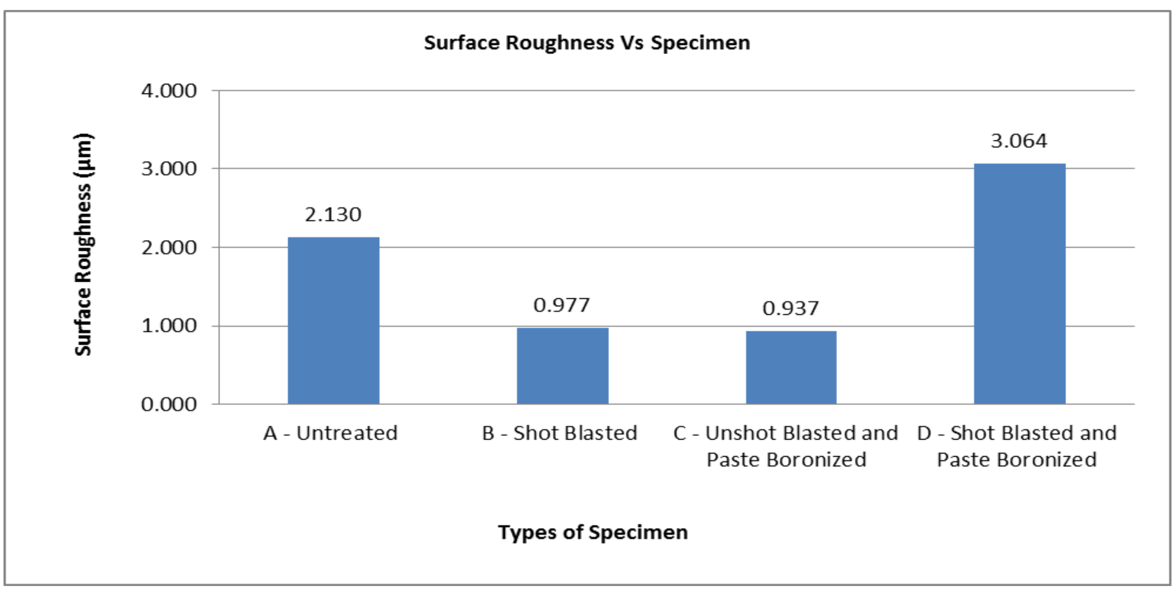


Figure 4 Surface roughness versus different types of specimen

4.0 CONCLUSION

From the microstructure observation, it was observed that the boronizing process creates boride layers at the surface of 316 stainless steel which consists of FeB and Fe_2B. The addition of another surface treatment which is shot blasting process gives impact on increasing the boride layer thickness.

The effect of boronizing process and shot blasting process also increases the hardness of the 316 stainless steel. From the surface roughness result, it could be observed that the roughness of the 316 stainless steel was fluctuated for the specimens before and after they had been boronized and shot blasted. This shows that the surface roughness does not effect the hardness of the 316 stainless steel.

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References

[1] Callister, W. D. 2007. *Materials Science And Engineering: An Introduction*. John Wiley & Sons (Asia) Pte Ltd.

[2] Grayeli-Korpi, A. R. and Savaloni, H. 2012. Effect of Nitrogen Ion Implantation on Corrosion Inhibition of Nickel Coated 316 Stainless Steel and Correlation with Nano-Structure. *Applied Surface Science*. 258: 9982-9988.

[3] Abedi, H. R., Salehi, M., Yazdkhasti, M. and Hemmasian-E, A. 2010. Effect of High Temperature Post-Oxidizing on Tribological and Corrosion Behavior of Plasma Nitrided AISI 316 Austenitic Stainless Steel. *Vacuum*. 85: 443-447.

[4] Yoon, J. H., Jee Y. K. and Lee, S. Y. 1999. Plasma Paste Boronizing Treatment of the Stainless Steel AISI 304. *Surface and Coatings Technology*. 112: 71-75.

[5] Jauhari, I. Yusof, H. A. M. and Saidan, R. 2011. Superplastic Boronizing of Duplex Stainless Steel Under Dual Compression Method. *Materials Science and Engineering A*. 528: 8106-8110.

[6] Yang, H., Wu, X., Yang, Z., Pu S. and Wang, H. 2014. Enhanced Boronizing Kinetics of Alloy Steel Assisted by Surface Mechanical Attrition Treatment. *Journal of Alloys and Compounds*. 590: 388-395.

[7] Meric, C., Sahin, S., Backir B. and Koksal, N. S. 2006. Investigation of the Boronizing Effect on the Abrasive Wear Behavior in Cast Irons. *Materials & Design*. 27: 751-757.

[8] Akkurt, I., Calik, A. and Akyıldırım, H. 2011. The Boronizing Effect on the Radiation Shielding and Magnetization Properties of AISI 316L Austenitic Stainless Steel. *Nuclear Engineering and Design*. 241: 55-58.

[9] Alias, S. K., Abdullah, B., Latip, S. A., Roseley, N. R. N., Jenal, N. and Kasolang, S. 2013. Boron Dispersion Layer of Paste Boronized 304 Stainless Steel Before and After Shot Blasting Process. *Applied Mechanics and Materials*. 393: 217-221.

[10] Smith, W. F. and Hashemi, J. 2006. *Foundations of Materials Science and Engineering*. The McGraw-Hill Companies.

[11] Parthasarathi, N. L., Borah, U. and Albert, S. K. 2013. Effect of Temperature on Sliding Wear of AISI 316 L(N) Stainless Steel – Analysis of Measured Wear and Surface Roughness of Wear Tracks. *Materials and Design*. 51: 676-682.