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ABRASION AND EROSION WEAR PROPERTIES OF SURFACE DEFORMED STAINLESS STEEL

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ABSTRACT

Boronized stainless steel often contained insufficient thickness layer because the existences of high alloying element hinder the diffusion process that resulted into low hardness and wear properties. Thus, in this study, improvement of dispersion layer was performed by inducing surface deformation onto the surface of the material. The main objectives of this study is to investigate the effect single and double sand blasting on the abrasion and erosion wear properties of 304 stainless steel. Pin on disk tester was used in order to obtain the value of coefficient of friction that indicated the wear resistances and slurry erosion test rig was used to obtain the erosion wear properties. Surface deformation was conducted through single and double shot blasting process before boronizing was performed. The results indicated that by performing double shot blasting process, enhancement of dispersion layer was achieved, thus lead to enhancement of both abrasion and erosion wear behaviour.

Keywords: 304 stainless steel, shot blasting, boronizing, wear resistance.

INTRODUCTION

Occurrence of wear in steel is definitely unavoidable as these materials are commonly used in applications that are constantly exposed to loading and frictions. Wear could significantly deteriorate the surface and properties of steel, thus reducing their performance and lifetime, leading to increment of maintenance and replacement cost. Boronizing of stainless steel has been tedious and almost impossible method requiring long boronizing time with only 5-10 µm boride layer thickness produced [1]. In low alloy steel, boronizing resulted in fully diffuse saw tooth Fe2B and FeB layer with minimum thickness of 50µm, indicating better protection to wear and other resistances [2-3]. Due to variation of carbon and other alloy in metallic material, boron diffusion may take longer to form as carbon and alloy will usually congregated at the boron diffusion zone [4].

The presence of certain alloys in steel such as chromium may also prevent the boron layer from diffusing on the surface. It is important that modifications of surfaces through atom dislocation could be performed before boronizing process, thus resulted in reduction of boronizing temperature and time. Decreasing the boronizing temperature and time are essential for cost effective reasons without compromising the thickness of boron dispersion layer. Paste boronizing will be implemented as boron in paste form offer better dispersion quality compared to powder form.

Past researches had evaluated surface deformation such as shot blasting, sand blasting, shot peening and Surface Mechanical Attrition Treatment (SMAT) has played an important part in enhancing the efficiency of case hardening method such as carburizing, nitriding and also boronizing [5-7]. Application of surface deformation had resulted in formation of interstitial vacancy in which allowing the boron to disperse onto the surface at faster rate resulting in improvement of the required properties such as hardness, strength, corrosion and wear resistance. Thus, in this study, shot blasting was implemented as surface deformation method in order to evaluate the effectiveness on the abrasion and erosion properties of boronized 304 stainless steel.

EXPERIMENTAL DETAILS

The sample used in this study is 304 stainless steel having carbon contained of 0.07 wt%, 18.5% chromium and 8.0 wt% nickel. Shot blasting was implemented as the surface modifications process in order to facilitate boron diffusion on the steels samples using FinimacShot blasting machine. The variation of surface deformation in term of single and double shot blasting was chosen as the main parameter for this study. Boronizing heat treatment as conducted using paste boronizing medium which is the mixture of Boron carbide, flux and binder before applying to the surfaces by brushing over the portion of the parts to be boronized. Boronizing treatment was performed at boronizing temperature of 800°C at boronizing time of 6 hours.

Samples were then taken out and let cooled at room temperature. The abrasion and erosion wear behavior of the samples was evaluated through pin on disktest and slurry erosion test rig respectively. The erosion test was conducted inside slurry medium at 4, 8 and 12 hours holding times. The micrograph of all samples was observed using optical microscope at 100X magnification. All testing was conducted at room temperature.

RESULTS AND DISCUSSIONS

The micrographs of single and double shot blasted stainless steel after boronized at 800˚C are shown in Figure-1. Both samples show presence of boride layer containing FeB and Fe2B phases as well as diffusion zone at different thickness layer of 63.5µm and 87.2µm. It

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could be seen that by blasting the sample two times, the enhancement of boride layer thickness was observed. This was associated with more atom dislocation and interstitial vacancies which enable boron to disperse deeper onto the surface during boronizing [6].

The existence of FeB phase were confirmed through XRD analysis at 2Θ angle of 45˚, 57 ˚ and 62 ˚ while 2Θ angle of 44˚, 65˚ and 80˚ validated the existence of Fe2B phases.

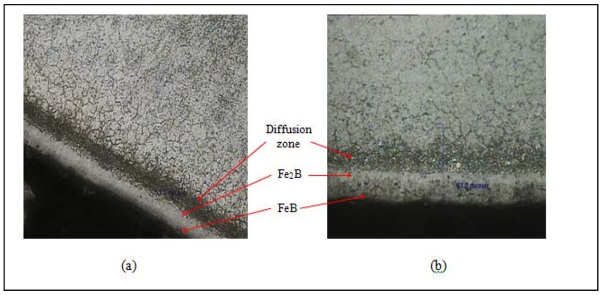

Figure-1. The micrograph of (a) single and (b) double shot blasted boronized stainless steel at 800 ˚C.

The graph for coefficient of friction of all types of samples is shown in Figure-2. Coefficient of sliding friction values was obtained through the equation of:

$$m=f/N \quad (1)$$

where m is the coefficient of sliding friction, f is the force of friction, and N is the normal force.

The value of coefficient of friction of single blasted samples was averaged at 0.63 µm while the value for double shot blasted samples was averaged at 0.45 µm. higher coefficient of friction values indicated low resistance to wear and vice versa.

The improvement of wear resistance was achieved in the double shot blasted samples due to the enhancement of boronizing layer thickness in the sample with reasons mention above. Dandan Mao *et al*, 2012 in his study found out that formation of single Fe2B phase are more efficient in enhancing the abrasion resistance of DC53 steel [8].

The weight loss values also compliance with the coefficient of friction value. The weight loss values of single shot blasted samples was approximately 0.034 g while the value of double shot blasted was at only at about 0.0082 g after pin on disk test. As the protective layer increased, the weight loss value decreased, in which the trend also divulged in past studies by [9-10].

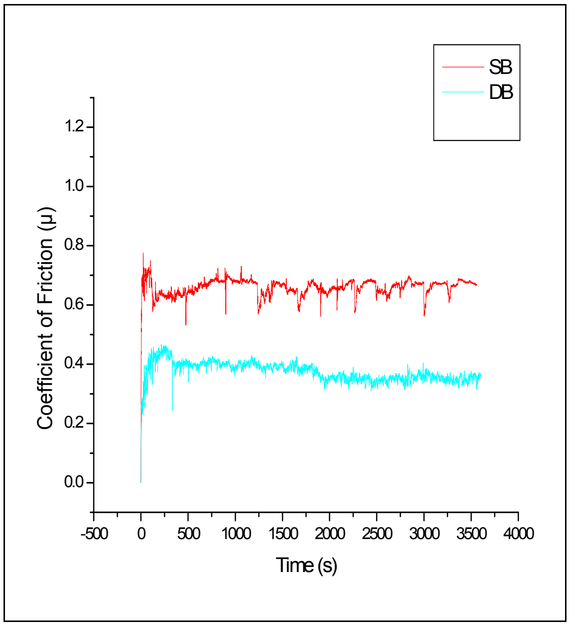

Figure-2. The coefficient of friction of SB (single shot blasted) and DB (double shot blasted) samples.

The result of erosion testing in term of weight loss values was depicted in Figure-3. The weight loss values decreased with respect to the erosion time for both samples. The weight loss value of SB samples was averaged at 0.63 g at 4 hours and the values significantly increased to 0.98g and 1.51g for 8 hours and 12 hours holding time. Longer exposure to the slurry caused higher weight loss values as the act of the slurry beads caused impaction of the exposed surface thus deteriorated the protected surface.

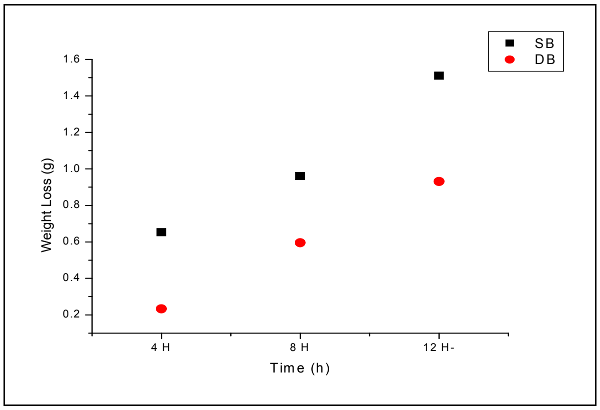

Figure-3. Erosion testing in term of weight loss values.

The weight loss values of double shot blasted samples however was much lower than single shot blasted surfaces. The values were averaged at 0.23 g, 0.57 g and 0.85g for 4, 8 and 12 hours holding times respectively. Thicker boronized layer was formed on the surface of the samples, thus allowing better protection layer than increased the erosion wear resistances. Past studies also

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indicated that erosion slurry medium also play important roles in mass or weight loss decrement other than erosion holding time [11].

Density

Table-1. Density of single sand blast boronized and double sand blast boronized samples.

Samples	**Density** (g/cm^3)
Single Sand Blast	7.7796
Double Sand Blast	7.7801

Table-1 shows the density of single sand blast and double sand blast samples after boronizing was calculated. Single sand blast sample possess density value of 7.7796 g/cm^3 and double sand blast sample possess density value of 7.7801 g/cm^3. From analysis, we can observe that the density of double sand blast sample is higher compared to single sand blast sample. According to AISI standard for 304 stainless steel, the standard density for 304 stainless steel is 8.00 g/cm^3. This shows that the density of these samples is still in 304 stainless steel range even after it has undergone sand blasting and boronizing.

Hardness test

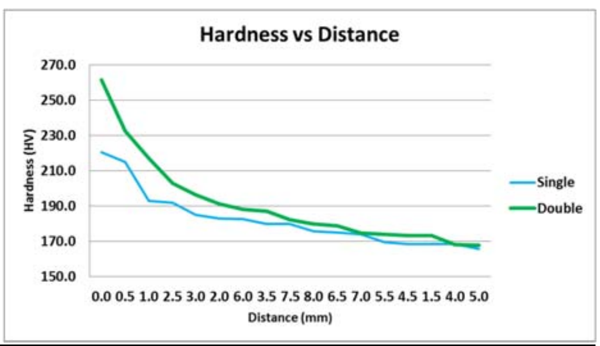

Figure-4. Hardness distribution of single sand blast and double sand blast across the samples.

The hardness values of the samples for both single sand blast and double sand blast on 8.0 mm distance across the sample cross-section was tested. The hardness test was carried out on polished and etched microsections after boronizing. Vickers hardness test is used as Brinell and Rockwell tests will deform the substrate and destruct the iron boride phase (W. Fichtl, 1981). For both samples, it can be observed that from the distance 0.0 mm till 5.0 mm, the hardness values are decreasing. This is due to the formation of hard layer consisting of FeB and Fe2B layer. However, the hardness value of double sand blast sample is higher than single blast sample. These could be summarised as the increment in dispersion layer has contributed on the increment of the hardness values. Increment in the thickness layer causes better protection of boronized surface (S.K Alias *et al,* 2013). This is also the reason why the hardness value decreases by the distance from the treated surface towards the centre of the cross sectional area for both samples.

CONCLUSIONS

By improving the shot blasting parameters, the enhancement of boride layer thickness were observed containing both strong FeB and Fe2B phases. In both types of wear tests which are abrasive and erosion test, double short basted samples outnumbered the single shot blasted samples due to the improvement of boride layer thickness.Thus, this study has proven that surface deformation through sand blasting process helps to facilitate boronizing process. By conducting sand blasting, the constraint related to the presence of alloying elements in 304 stainless steel can be eliminated as sand blasting causes the atoms on the surface to be dislocated and this allows better penetration of boron into the metal. Sand blasting is more effective to be conducted in double sand blasting manner as it has proven to provide further increment in boronizing dispersion layer. In future study, double sand blasting can be established as a compulsory pair to boronizing process.

REFERENCES

[1] Enver A., Umut Y. and Cevdet M. 2003. The effects of conventional heat treatment and boronizing on abrasive wear and corrosion of SAE 1010, SAE 1040, D2 and 304 steels. Journal of Tribology International. 36(3): 155-161.

[2] Xie F. and Sun L. 2013. A novel approach to achieve thick single phase Fe_2B coating by alternating current field enhanced pack boriding. Journal of Physics Procedia. 50: 88-93.

[3] Mustafa U., Osman N. C., Hakan G. and Umit E. 2010. Effect of different surface treatment methods on the friction wear behaviour of AISI 4140 steel. Journal of Material Science Technology. 26(3): 251-257.

[4] William F. S. 1993. Structure and properties of engineering alloys. 2nd Ed McGraw-Hill Higher Education Inc. (UK). pp. 127-140.

[5] Shinichiro A. and Nobuhiro U. 2013. Surface hardness improvement of plasma-sprayed AISI 316L stainless steel coating by low-temperature plasma carburizing. Journal of Advanced Powder Technology. 24(5): 818-823.

[6] Balusamy T., Narayanan T.S.N.S., Ravichandran K., Park I. S. and Lee M. H. 2013. Pack boronizing of AISI H11 tool steel: role of surface mechanical attrition treatment. Vacuum. 97: 36-43.

ARPN Journal of Engineering and Applied Sciences

[7] 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.

[8] Mao D., Wang X., Wang W. and Wei X. 2012. Effect of boronizing on the dry sliding wear behaviour of DC53/0.45 mass (%) carbon steel pairs. Journal of Surface & Coating Technology. 207: 190-195.

[9] H. Sert, A. Can, H. Arikan, B. Selcuk and H. Toprak. 2006. Wear behavior of different surface treated cam spindles. Journal of Wear. 260(9-10): 1013-1019

[10] M. Kulka, N. Makuch and A. Pertek. 2013. Microstructure and properties of laser-borided 41Cr4 steel. Journal of Optics and Laser Technology. 45: 308-318.

[11] Jiang S. L., Zheng Y. G. and Yao Z. M. 2006. Cavitation erosion behaviour of 20SiMn low alloy steel in Na_2SO_4 and $NaHCO_3$ solutions. Corrosion Science. 48(9): 2614-2632.