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EFFECT OF BORONIZING MEDIUM ON DISPERSION LAYER OF AUSTENITIC STAINLESS STEEL

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ABSTRACT
This paper presents the phase transformation of boronized 304 grade stainless steel under different heat treatment temperature. The coatings were produced by thermo-chemical treatment with powder and paste mixtures at high temperature. The microstructure of obtained coatings was investigated and the micro hardness was measured. Micro hardness of the obtained boron coatings was measured. Optical microscopy was used to investigate the microstructure and measure the thickness of the diffusion boron coatings. The heat treatment was conducted at 850 °C, 950 °C and 1050 °C for 4 hours for paste and 8 hours for powder specimens. Samples were characterized for spectrometer test, microstructure analysis, density test and hardness properties. The results revealed that paste boronized sample provide deeper boron layer than powder boronized.

Keywords: heat treatment, stainless steel, boronizing.

INTRODUCTION
Heat treatment of stainless steel depends to a great extent on the type (wrought or cast) and grade of stainless steel. It is often to ensure that the properties altered during fabrication are restored for example corrosion resistance, ductility or and hardness. So that, the stainless steel component can performs in its intended service environment. The recognizing of the stainless steel is as the low carbon steel whereby it contains chromium at 10% or more by weight. The unique addition of stainless steel is containing of chromium element which can reduce corrosion. It (chromium element) allows the formation of a rough, adherent, invisible, corrosion-resisting chromium oxide film on the steel surface. By increased the chromium content and the addition of other elements like molybdenum, nickel and nitrogen, the corrosion resistance can be improved. There are more than 60 grades of stainless steel. The grades can be divided into five main groups [1]. The commonly type of stainless steel is austenitic grades. Extensively, the type of the 304 which is austenitic stainless steels is used in biomedical implants and nuclear reactors [2, 3]. It is also use for chemical and food industries. The main problem with type 304 stainless steels and considering the science of material is that it has poor wear resistance yield strength, fracture and impact toughness [4]. Recently, there are high numbers of studies on the improvement of mechanical properties of this type of stainless steel have been carried out. Consequences to this, the wear strength increased, the friction coefficient decreased and improved corrosion resistance by using surface treatment [5-8]. Therefore, the possibility for material characteristic use of surface coatings gives the specific properties that are located where they are most needed. This austenitic stainless steel can be applied to industrial boriding of most ferrous steels. Achieving deeper boron diffusion layer is essential as it indicates significant improvement in the properties of stainless steel. But then, it requires long dispersion time and would increase the manufacturing cost. It would beneficial if deeper boron dispersion layer could be achieved, thus expanding the application of stainless steel.

This study investigated two form of boronizing which were powder and paste that helped to improve the thickness of dispersion on boron layer. Normally, heat treatment process of stainless steel concentrates more on the mechanical properties. Not much work focused on the understanding of phase transformation in after the heat treatment. Thus, this study was conducted in order to investigate the effect of phase transformation of boronizing medium in stainless steel under different heat treatment temperature.

EXPERIMENTAL SETUP

Sample Preparation
Samples used in this study were rounded stainless steel of grade 304. The samples were cut into 20 x 20 x 20 mm dimensions by rotary diamond abrasive cutter and were ground using 600 grit abrasive papers. Samples were tested using Spectrometer Test Machine for chemical compositions, as shown in Table-1. Samples with size of 20 x 20 x 10 mm (height) were also prepared for powder and paste boronizing heat treatment in order to study effect of these boronizing on its hardness and transformation of microstructure phases of this stainless steel type.

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Table-1. Chemical compositions of 304 stainless steel.

Element	wt [%]
C	0.049
Si	0.42
Mn	1.7
P	0.08
S	0.0045
Cr	18.08
Ni	8.03
Cu	0.56
V	0.058
Fe	70.3

Boronizing Treatment

Powder samples and paste samples were placed in different containers for different temperatures in the furnace. Three different temperatures of heat treatment test were conducted, 850 ^oC, 950 ^oC and 1050 ^oC for each sample types. All powder samples were heated at 8 hours while paste samples were heated about 4 hours. After the required temperature and time achieved, the furnace was cooled down to 300 ^oC under the argon atmosphere and the furnace was switched off. When the furnace was cooled down to room temperature, all samples were removed from the container and were cleaned for further testing.

Experimental Testing

Outer surface or layer of the samples were hot mounted before undergo metallographic preparation. All samples which were unboronized, powder samples and paste samples were observed and analyzed through Olympus BX 41M microscope. Samples were ground and polished using SiC sand papers with grade between 180 to 1200 μm and 6 μm and 3 μm diamond paste polisher respectively. Then, about 2% Nital was used as chemical etchant to reveal the microstructure of this 304 grade stainless steel. Hardness test was conducted using Rockwell hardness tester. All testing were carried out at room temperature with at least of 10 values were taken and its average value were recorded.

RESULTS AND DISCUSSIONS

Figure-1 shows cross sectional microstructures of all three sample types heated at 850, 950 and 1050 ^oC. The higher temperature resulted deeper and thicker boron layer observed under 200x magnifications. A thicker boron layer is essential as this layer phase acted as hard casing in order to protect the substrate or surfaces, which give significant improvement on its properties especially wear, corrosion and hardness [9, 10]. The paste form of boronizing used exhibit higher boron dispersion at all temperature applied as it's dispersed and penetrated more easily at surfaces and promoted atom dislocation that allowed for a deeper boron dispersion compared to powder (dry form). The thicker boron layer of paste form compared to powder form is shown in Figure-2. Both form of powder and paste exhibited the thickest layer at the highest temperature applied of 1050 ^oC. It can be seen that the most significant surface affected by this heat treatment was in the paste form.

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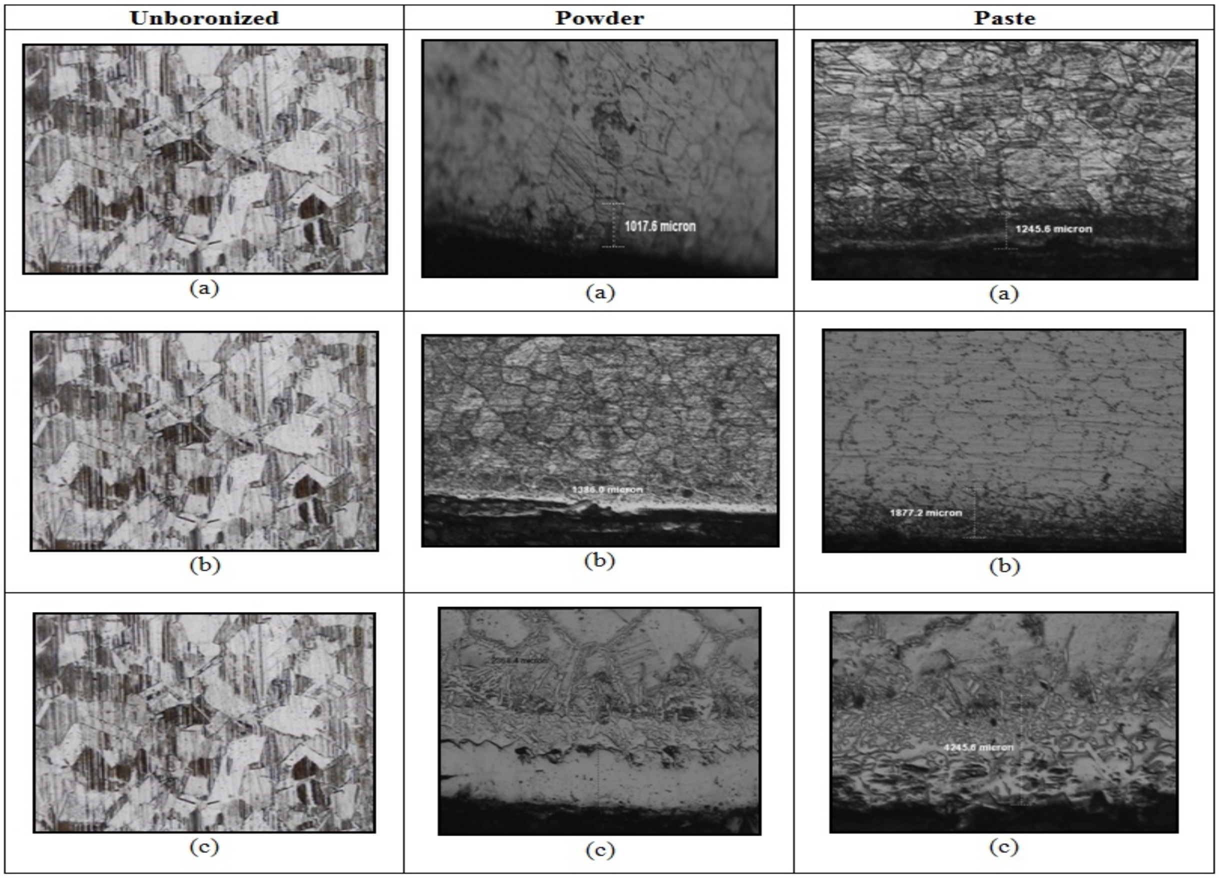

Figure-1. Microstructure of unboronized, powder and paste form of 304 stainless steel at 200x magnifications (a) heat at 850 ºC, (b) heat at 950 ºC, (c) heat at 1050 ºC.

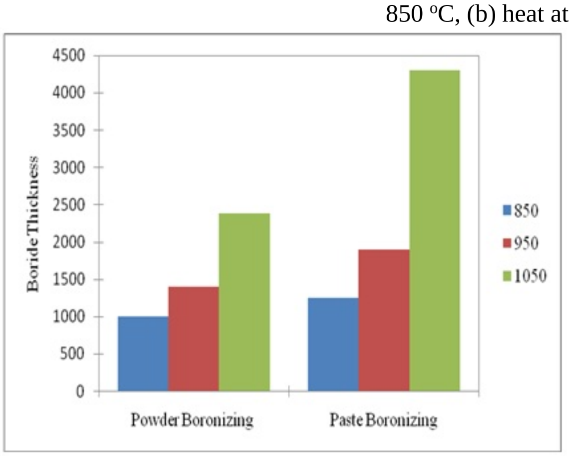

Figure-2. Thickness of powder and paste boronizing medium at three different temperatures.

Hardness of boride layer depends on the amount of boron atoms that diffused into the substrate. The hardness properties decreased as the depth from the surface increased. It can be seen in that the hardness is higher in the subsurface of boronized layer. And the hardness values of specimens boronized at different temperatures are in the range of 78.79-95.05 HRB (850 °C), 82.27-96.20 HRB (950 °C), and 83.11-102.61 HRB (1050 °C), respectively as shown in Table-2. Hardness values of the boronized layer related to the temperature which is in accordance with the tendency that the thickness of the layer increases with increasing temperature. Meanwhile, Table-3 shows density values and demonstates the boronized material is slightly dropped compared to the un-boronized material after the boronizing process. Basically, the weight of the boronized material will drop because of the heating process. However, as the boronizing process will be the source in improving number of boron content, this process will slightly reduce rate of dropping density for the boronized material. The higher number of heating temperature will give a lesser number in dropping density of boronized material. This situation indicates that heating process with unsuitable heating temperature (low temperature) in the boronizing process may cause more dropping number of density because lack of boron content added to the testing material.

Table-2. Hardness of powder and paste boronizing medium at three different temperatures.

Temperature	Hardness [HRB]	
	Powder boronizing	Paste boronizing
850 °C	78.79	92.70
950 °C	82.27	93.98
1050 °C	83.11	96.48

Table-3. Density of powder and paste boronizing medium at three different temperatures.

Temperature	Density [g/cm^3]	
	Powder boronizing	Paste boronizing
850 °C	7.7151	7.5655
950 °C	7.6834	7.3533
1050 °C	7.6603	7.2660

CONCLUSIONS

The medium of boronizing affected on the thickness layer of boron. Paste boronized sample provide deeper boron diffusion layer. This proves that boron diffusion layer could be achieved faster through paste boronizing compared to powder boronizing. The hardness properties of the boronized sample were related to the temperature applied, which is in accordance with the tendency that thickness of the layer increased with increasing temperature. Density of the boronized sample was slightly dropped due to the heating process.

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