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Study on surface diffusion of an effective powder-pack boronizing

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ABSTRACT – Boronizing is a surface treatment which is currently well developed in the industry to produce a super hard and good wear resistant surface layer on the metallic substrate. In this study, 10 mm diameter 316 stainless-steel ball bearings will be used as the specimens. Boronizing treatments will be done for 2, 4 and 6 hours in furnace at temperature 850, 900 and 950 °C using Ekabor 1. Powder conditions and powder pack surrounding will be studied in these experiments in order to analyze the effective powder usage for the treatment. The boronized surface will be characterized using optical microscope, SEM analysis, and hardness Rockwell indenter. The kinetic diffusion of boron will be determined from activation energy analysis using Arrhenius equation.

1. INTRODUCTION

Boronizing is one of a thermochemical surface hardening process. It is a thermochemical treatment that diffuses boron atoms through the surface of metallic substrates. The boronized steels exhibit high hardness, high wear resistance and high corrosion resistance. There are many types of boronizing processes that have been developed, such as pack boriding, paste boriding, electrolytic boriding and others. Powder-pack boronizing is the most cost-effective compare to other processes besides its simplicity [1]. The objectives of this research is to study the surface diffusion of boronized 316 stainless-steel using powder-pack procedure.

2. METHODOLOGY

2.1 Boronizing of Stainless Steel

10 mm stainless steel ball bearings will be borided and the variables for boronizing process are selected using Taguchi method in order to determine an effective powder pack boronizing conditions. The parameters are boronizing temperature, boronizing time, powder condition, and powder-pack surrounding. All these parameters are shown in Table 1. The different variables will be used to determine the effects of the combinations on the borided layer thickness, kinetic diffusion of boron, as well as surface hardness.

Table 1 The parameters for boronizing 10 mm stainless - steel ball bearing

No.of experiment	Boronizing Temperature (°C)	Boronizing Time (hours)	Powder Condition (%)	Powder Pack Surrounding
1	850	2	100	5mm
2	900	2	60	10mm
3	950	2	30	15mm
4	850	4	60	15mm
5	900	4	30	5mm
6	950	4	100	10mm
7	850	6	30	10mm
8	900	6	100	15mm
9	950	6	60	5mm

2.2 Powder-Pack Boronizing Procedure

The boronizing treatments will be carried out in a solid medium using powder-pack method. For this purpose, the specimen will be buried with boronizing powder in a stainless-steel container with lid as shown in Figure 1. The containers are in different diameters and heights in such a way the samples will be surrounded with different powder thickness.

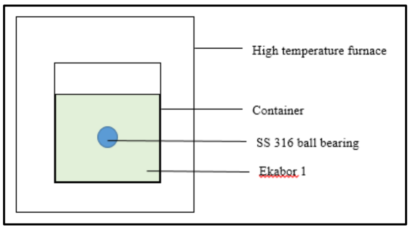

Figure 1 Schematic diagram of powder-pack boronizing in high temperature furnace

3. RESULTS AND DISCUSSION

3.1 Surface Appearance and Cross-Section

Figure 2 shows the outer surface appearance of boronized and unboronized 316 stainless-steel ball bearings. The cross-section of unboronized sample is shown in Figure 3 using optical microscope. It is reported that the cross-sectional surface of borided layer of boronizing stainless steel contains layer rich with iron [2]. The cross-section for boronized 316 stainless-steel ball bearings are shown in Figure 4 and Figure 5 with different parameters.

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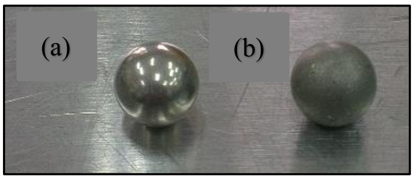

Figure 2 (a) Outer surface unboronized 316 stainless-steel ball bearing (b) Outer surface boronized 316 stainless-steel ball bearing

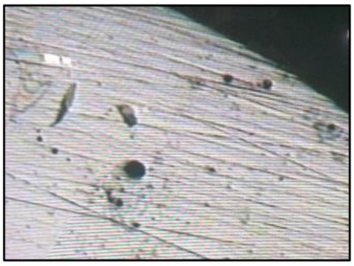

Figure 3 Cross-section of unboronized 316 stainless-steel ball bearing, near the outer surface.

Figure 4 Cross-section of boronized 316 stainless-steel ball bearing with parameters 850 ^{0}C, 2 hours, 10 mm powder surrounding and 100 % powder concentration.

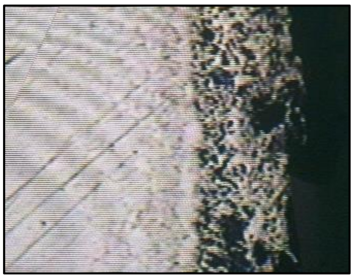

Figure 5 Cross-section of boronized 316 stainless-steel ball bearing with parameters 950 ^{0}C, 2 hours, 10 mm powder surrounding and 100 % powder concentration.

3.2 Hardness values

The initial hardness values for boronized and unboronized is measured using Rockwell hardness tester with load 981 N for each sample. The hardness results are in Table 2. From this initial few samples, it can be seen that the hardness value for boronized 316 stainless-steel ball bearing is greater than the unboronized sample.

Table 2 The hardness values for boronized and unboronized samples

Sample	Temperature	Hardness values
Unboronized	-	56.6 HRD
Boronized	850 ^{0}C	59.9 HRD
Boronized	950 ^{0}C	63.3 HRD

The greater surface hardening effect and the thick diffusion layer are the main cause of this higher hardness. It is possible to claim that the higher boronizing temperature is the cause of the hardness value [1].

3.3 Kinetics of Atoms at Surface Using Arrhenius Equation

The kinetics of layer growth is controlled by perpendicular boron diffusion into the Fe_2B layer. According to Fick's law [3], the squared thickness of the boride layer as a function of boronizing time is described as:

$$X^2 = Kt, \quad (1)$$

where X is the depth of boride layer (cm), t is the process time (s), while K is the diffusion coefficient (cm^2/s) depending on boronizing temperature and is calculated from the slopes of the X^2 versus treatment time graphs. The relationship between diffusion coefficient D, temperature T, and activation energy Q, can be expressed using an Arrhenius equation as follows:

$$K = K_o \exp (-Q / RT), \quad (2)$$

where K is the diffusion coefficient, K_o is called the pre-exponential constant, Q is activation energy (J/mol) required to make the reaction occur, T is the absolute temperature (Kelvin), and R is the universal gas constant (J/mol/K) [3]. The kinetics of atoms is not reported in this paper.

4. CONCLUSIONS

In this present study, with all the parameters combined, it is expected that the kinetics of atoms for boronizing process on stainless-steel material can be analyzed using Arrhenius equation together with the determination of an effective powder-pack procedure. It is also expected the boronization of 316 stainless-steel ball bearing can contribute to a new knowledge in the engineering field especially in the automotive industry.

5. REFERENCES

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