Study of Hardness and Wear Properties of Boronized Aisi 4340 Steel

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Abstract

In this study the hardness and wear properties of boronized AISI 4340 steels have been studied.The boronizing treatment increased the hardness of AISI 4340 steels and also significantly improved its wear behaviour. From obtained results it can be concluded that boronizing is very effective surface hardening method for improving the wear properties of AISI 4340 Steels.

I. Introduction

There are variety of coatings developed and used to improve surface material properties. There are several kinds of coating methods; chemical vapour deposition (CVD), physical vapour deposition(PVD), thermochemical treatment, oxidation, and plasma spraying. A new combination of two and three layers have been obtained by forming first boron diffusion coating followed by CVD.

Thermochemical treatment techniques have been well investigated and used widely in the industry. This is a method by which metals or non- metals are penetrated by thermodiffusion followed by chemical reaction into the surface. As a result of thermochemical treatment , the surface layer changes its composition, structure and properties. Carburizing, nitriding, aluminizing, chromizing and carbonitriding are the most popular methods for industrial applications. Boronizing is a thermchemical process which is used to produce hard and wear resistant surfaces.

Boronizing or boriding is a thermochemical treatment that diffuses boron through the surface of metallic substrates. As boron is an element of relatively small size it diffuses into a variety of metals; including ferrous, nickel and cobalt alloys. Normally boronizing is carried out in the temperature range of 1113-1323K by using solid, liquid, gaseous boron rich atmospheres.

Boronizing has been found to be an effective method for increasing the surface hardness and the wear resistance of metals. On the surface of boronized ferrous alloys, generally a boron compound layer is developed. This boride layer is normally composed of two sublayers; the outermost and innermost are rich in FeB and Fe2B respectively. Underneath the compound layer the diffusion zone hardly exits because the solubility of boron in Fe is very small. Since the FeB phase is more brittle and harder, and has a higher coefficient of thermal expansion than Fe2B one, the cracking of the double phase boride layer is often observed.

Boronized steel consistently outperforms nitride and carburized steels, essentially because the iron boride formed exhibits substantially higher hardness (HV=1600-2000) as compared to carburized or nitride steels(HV=650-900). In addition to the excellent resistance to wear, the resistance of boronized steel to attack by nonoxidising dilute acids, alkalis, and molten metals is also outstanding.

In this study we focus on the study of some mechanical properties of boronized AISI 4340 steels.

II. Experimental method

AISI 4340 steels are commercially produced as gear materials with compositions shown in Table 1. The test pieces used in tests are cut to 16mm diameter and 230mm length and normalized at 840ºC for 8 h to remove potential residual stresses before machining the specimens. The samples were then treated by a thermochemical treatment method: boronizing. The boronizing of the steels was achieved in a solid medium using the powder pack method.

TABLE 1
Chemical composition (wt%) of AISI 4340.

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al
0.374	0.600	0.0230	0.0230	0.226	0.0960	1.39	0.990	0.279	0.0180

This method involves a boronizing medium which is formed by throughly mixing together 94% w/w B4C(boron carbide), 5% w/w Al2O3(aluminium oxide powder) and 1% w/w KBF4(potassium tetrafluroborate) .KBF4 and Al2O3 were first mixed in the mortar to break the powder cluster and followed by gradually adding a small quantiy of B4C into the gradients. After all the substances were mixed in the mortar, the boronizing powder mixture was mixed again in the blender to be confident that the component was well homogenous. The test samples were packed with the boronizing medium and heated in an electrical resistance furnace for 4 h at 850ºC under the atmospheric pressure. During this process, boron was diffused into the material and thus , a boron diffused zone was formed at the surface region. After the treatment the boronized steels were removed from the furnace , cooled in air , sectioned from one side and fine ground with 1200- grit SiC abrasive papers. The hardness tests and wear resistance tests were conducted and the results are studied. Hardness of the steel was studied using Vickers hardness test. Wear tests of the materials were also performed. The weight loses of the borided and untreated AISI 4340 were determined as a function of time.

III. Results and discussion

Thermochemical heat treatments such as carbonitriding , carburizing and boronizing are widely used to improve surface properties of ferrous material for increasing their wear, corrosion and fatigue performance. Depending on the boronizing source , time, temperature, and chemical composition of the substrate the boride layer forms on the substrate and its depth changes with these parameters. In the present study, it is observed that the boride layer of AISI 4340 steels have a denticulate morphology. The thickness of the boride layer is in the range of 57-58 µm (Fig. 1).

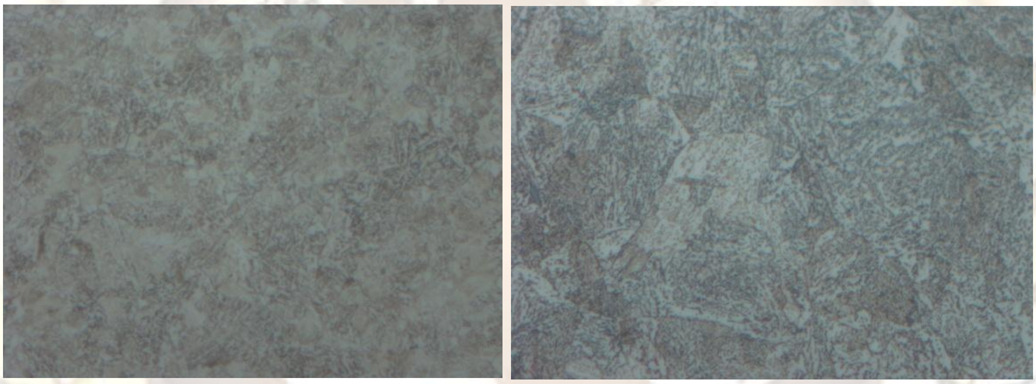

Fig 1. Optical micrograph of cross section of AISI 4340 Steels (a) normalized, (b) boronized.

Now let us consider the relation between hardness and wear properties of the AISI 4340 steels. It is well known that the wear in any component depends upon a number of factors such as applied load , testing machine charecteristics , sliding speed , sliding distance, environmental and material properties. In the present study, a special wear testing machine with load of 90 N was used to measure wear behaviour of the AISI 4340 steels(Fig.2). The figure shows the weight loss of the AISI 4340 steels found through the wear tests performed after surface hardening and also the untreated steels. As can be seen from the figure the weight loss of both the steels increases with testing time. The weight loss of the boronized AISI 4340 steel is lower than the untreated steel. There is apparently a linear relationship between the wear behaviour and hardness of the steels. It is therefore claimed that the boronized AISI 4340 steels show improved wear performance because of their superior hardness properties.

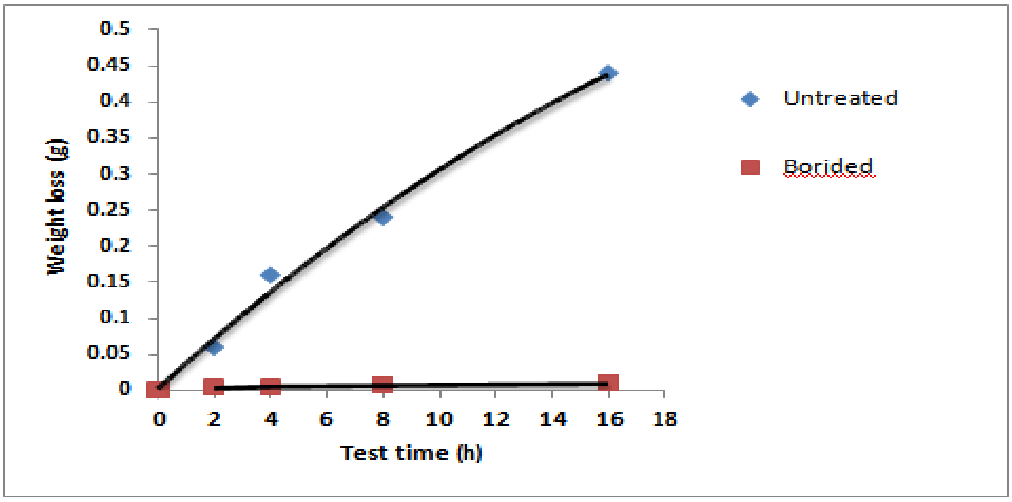

Fig. 2. Weight loss vs. test time curves measured for untreated and boronized AISI 4340 steels

The thickness of the diffusion layer also contributes to the higher wear properties of the boronized AISI 4340 steel. It is mainly because of the hard boride layer consisting of the Fe2B and α- SiC phases. In other words compared to untreated AISI 4340 steels boronized AISI 4340 steels have a better wear charecteristics because of the greater surface hardening effect and relatively thick diffusion layer.

IV. Conclusions

1. The diffusion layer formed on the surface of boronized AISI 4340 steel has a denticulate morphology. The thickness of diffusion layer was measured 57-58µm.
2. The hardness of diffusion layer was found to be much higher for the borided sample than that of the untreated samples.
3. The weight loss increases with the increasing test time. There is a linear relationship between hardness and wear charecteristics of AISI 4340 steels.
4. The hardness of borided AISI 4340 steel was found to be around 1800-2200 HV.

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