Boronizing Effect on the Corrosion Behaviour of Chilled Cast Iron and AISI 1050 Steel

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ABSTRACT

Corrosion behaviour of boronized and unboronized AISI 1050 steel and chilled cast iron were investigated by the weight loss method. Corrosion studies were performed with 10 % H_2SO_4 solution as a corrosive medium at temperatures 298, 333 and 353 K and 2 h immersion periods. The weight loss of AISI 1050 steel and chilled cast iron treated in the corrosive medium increased with increasing temperature. While the weight loss of the AISI 1050 steel increased exponentially with increasing temperature, the chilled cast iron showed continuously decreasing values. Very low weight losses were observed in boronized samples compared with unboronized samples. The boronizinig process significantly decreased the weight loss of both materials and improved the corrosion behaviour.

INTRODUCTION

Chilled cast iron belongs to a group of metals possessing high strength, hardness, toughness and damping capacity /1,2/. For many years, chilled cast irons and steels have been used as structural members in bridges, buildings, pipelines, heavy vehicles and numerous other applications /3,4/. These structural materials are subjected to the effect of not only loads and temperature but also to different corrosive media. In many cases, these factors act together in the most unfavorable combinations, thus greatly reducing the load-carrying capacity and shortening the service life of structures /5/. Considering the corrosion behaviour of materials, a number of research studies on corrosion properties of steels have been reported /3,6-11/. However, these studies were mostly centered around the influence of alloying element concentrations, microstructure and phases /3,10,11/. In these studies, it has been shown that alloying additions affect the microstructure, which in turn affects the corrosion properties. Moreover, several attempts have been made to establish a quantitative correlation between corrosion rate and acid concentration /6,8,9/. A literature survey /6/ has shown that the corrosion rate of steels generally increases in concentrated acids such as HCl and H_3PO_4, but in H_2SO_4, the increase of acidity is accompanied by passivity.

Corrosion is a prevailing destructive phenomenon in science and technology. Also, considerable economic loss occurs due to corrosion in mechanical parts of machinery and equipment during service /12/. In order to reduce this loss, surface properties must be improved. One of the methods used to improve the surface quality is boronizing /12,13/. In the literature /14-16/, it has been shown that industrial boronizing processes can be applied to most ferrous materials such as structural steels, cast steels, ductile cast and sintered irons. In these studies, in particular, it has been shown that boronizing increases the resistance of low alloy steel to acids such as H_2SO_4, H_3PO_4 and HCl acids.

Steels are differentiated from cast iron in part by the level of carbon. Cast iron has typically 1.7 to 4.5 mass % carbon while steels have only 0.05 to 1.7 mass % carbon /17/. In the present study, comparison of the boronizing effect on the corrosion behaviour of AISI 1050 steels and chilled cast iron have been studied as a function of temperature.

Table 1
Chemical compositions of AISI 1050 steel and chilled cast iron (mass %)

Material	C	Si	Mn	P	S	Cr	Ni	Mo	V	Fe
AISI 1050	0.486	0.238	0.611	0.016	0.004	0.178	0.123	0.001	0.004	98.14
Chilled Cast Iron	3.250	2.030	1.040	0.063	0.012	0.759	0.102	0.592	0.031	92.00

EXPERIMENTAL METHOD

The substrates used for this study are chilled cast iron and AISI 1050 medium carbon steels. Chemical compositions of the test materials are listed in Table1. The boronizing of the materials was achieved in a solid medium using the powder pack method. In this method, commercial Ekabor-II boron source and activator (ferro-silicon) were thoroughly mixed to form the boriding medium. The pack was heated in an electrical resistance furnace for 4 h at 1210 K under atmospheric pressure. After the process, the boronized samples were removed from the furnace, cooled in air, sectioned from one side, prepared metallographically up to 1200-grid emery paper, and polished using 3 μm alumina pastes. The polished samples were etched with 4% Nital before the test. The morphology and the thickness of the boride layers were observed by using an optical microscope. The presence of borides on the surface of the boronized steels was also determined by using an X-ray diffractometer (Rigaku D-MAX 2200) with a CuKα radiation of 0.15418 nm wavelength. The corrodant used was a 10 % H_2SO_4 solution. The corrosion tests were conducted for boronized and unboronized chilled cast iron and AISI 1050 steels at temperatures 298, 333 and 353 K. The weight losses were measured at 2 h immersion intervals. After each corrosion test, the specimens were immersed in ethanol, dried thoroughly, and weighed again. Further experimental details are described in Ref. 18.

RESULTS AND DISCUSSION

The cross-section morphologies of the boronized chilled cast iron and the AISI 1050 steel are shown in **Figure 1**. As can be seen from this figure, three distinct regions have been identified on the surface of the borided AISI 1050 steel and chilled cast iron: i) the boride layer including borides, (ii) the transition zone, and (iii) the matrix that is not affected by boron. The morphology of the boride layer formed on the surface of AISI 1050 steel is denticular , while the boride layer in chilled cast iron is columnar due to chemical composition (**Figure 1a** and **b**). The effective thickness of the diffusion layer of the boronized AISI 1050 steel is about 115 μm . The transition zone shows signs of grain growth (**Figure 1a**). The thickness of the boride layer of the chilled cast iron is slightly less than that of the AISI 1050 steel (**Figure 1a** and **b**). Graphite platelets can also be observed in the borided layer of the chilled cast iron. Moreover, the transition zone of

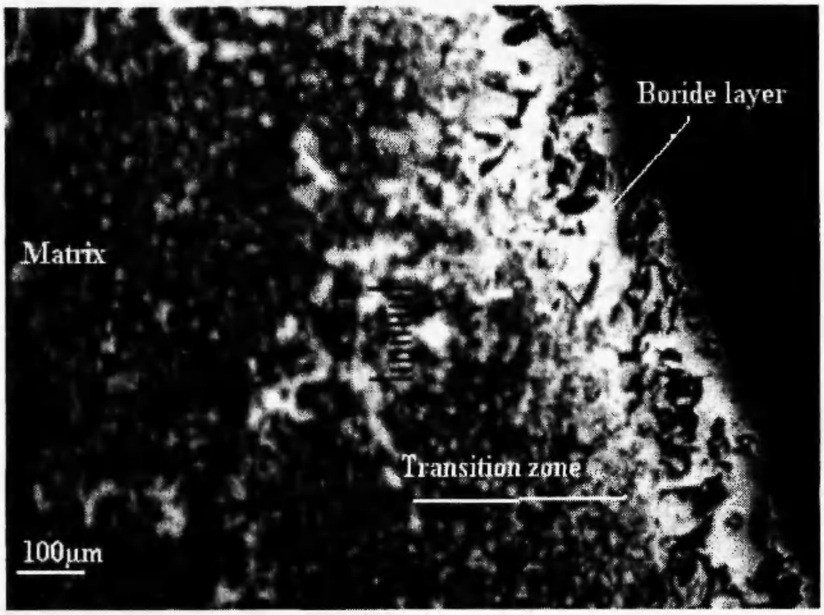

Fig. 1.a

Fig. 1.b

Fig. 1: Cross-sectional view of boronized materials with Ekabor-II at 1210 K for 4 h: (a) chilled cast iron and (b) AISI 1050 steel.

chilled cast iron has refined grain structure. This is because alloying elements Mo, Cr, C give low boride layer thickness while C, Si ve Mn introduce grain refinement /19,20/.

Figure 2a and **b** show the weight loss curves of the AISI 1050 steel and the chilled cast iron as a function of temperature. The curves of weight loss vs temperature of AISI 1050 steel and chilled cast iron are close to each other. There is a progressive increase in weight loss as the temperature is increased from room temperature to 353K. This observation is attributed to the general rule guiding the rate of chemical reaction, which dictates that chemical reaction increases with increasing temperature /9/. Also an increased temperature favors the formation of activated molecules, which may be doubled in number, with 10 K rise in temperature,

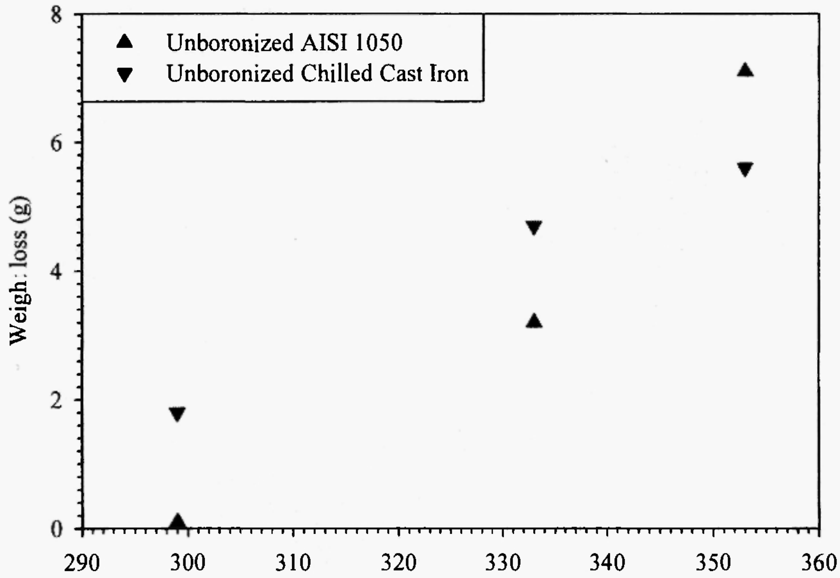

Fig. 2.a

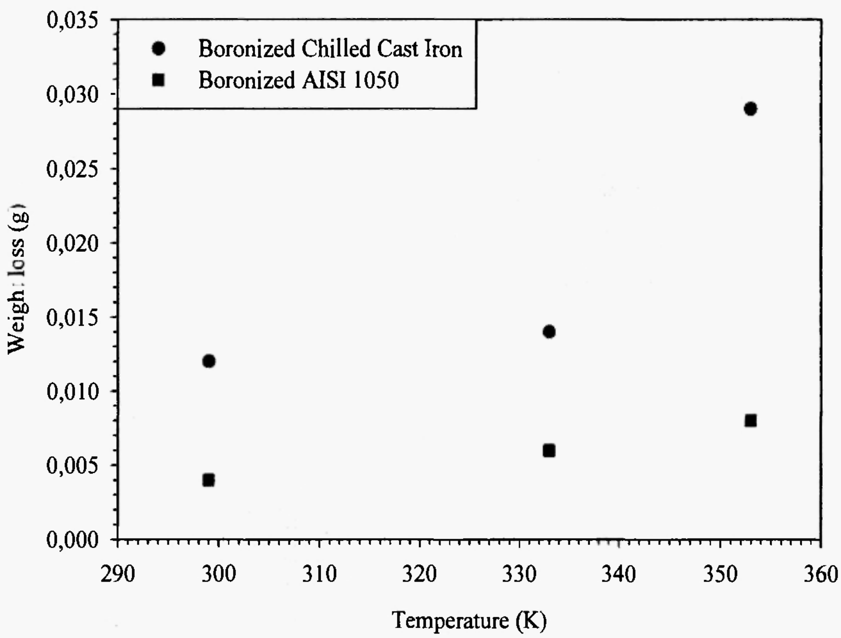

Fig. 2.b

Fig. 2: Weight loss of (a) unboronized and (b) boronized chilled cast iron and AISI 1050 steel at different temperatures.

thereby increasing the reaction rate. In addition, in the literatures /6,8/ it has been shown that the rate of chemical reaction increases with increasing time and concentration of solution. In the present study, at low temperatures, the weight loss of chilled cast iron is higher than that AISI 1050 steels both in the boronized and unboronized condition. On the other hand, at high temperatures, the corrosion behaviour of these materials was completely different to that seen at low temperatures (**Figure 2a**). With increasing temperature, weight loss of unboronized AISI 1050 steel increases rapidly compared to chilled cast iron. Thus we say that the corrosion resistance of chilled cast iron is enhanced with increasing temperature. This could be due to the formation of surface oxides. Corresponding to this, Kashani et al. /21/ showed that weight loss increases, passes through a maximum and then decreases with increasing temperature. The decrease in weight loss with increasing temperature has been explained with the oxidized or partially oxidized debris connected with oxide phase on the worn surface. Considering the boronizing effect on the corrosion behaviour of AISI 1050 steel and chilled cast iron, **Figure 2b** shows that the weight loss of boronized AISI 1050 steel and chilled cast iron also increases with increasing temperature. The increase in weight loss of boronized chilled cast iron becomes more drastic at high temperature. Moreover, the total weight loss of boronized AISI 1050 steel and chilled cast iron is decreased by a factor of 620% and 220%, respectively. This is because the boronizing process is characterized by increased surface hardness and increased wear resistance due to hard boride phases. The friction coefficient is very low, no extra heat treatment is required after boronizing. On the other hand it has been shown that the weight loss decreases with boride layer thickness depending on boronizing temperature and time, as well as the chemical composition of material. Rao et al. /22/ showed that corrosion rate of iron aluminides increases with carbon content. This increase was attributed to the preferential attack of the carbide phases. In contrast, the corrosion of mild steel in all the acidic media has been found to be higher than that of high carbon steels /6/. This result shows that the carbon content in itself has little if any effect on the general corrosion resistance of steels. In another study, Choi et al. /23/ showed that the increase in the corrosion rate of steels is attributed to the addition of small amounts of alloy elements such as Cu, Cr, Ni and also the microstructure.

By comparing experimental results, it is seen that the effect of boronizing on the corrosion behaviour of AISI 1050 steel is much more significant compared to its effect on the chilled cast iron. This result is explained by the fact that alloy elements and boride layer thickness. The AISI 1050 steel and chilled cast iron have large differences in alloying element additions such as C, Si, P, Cr, Mo, V. In the chilled cast iron, CrB was introduced into the boride layer due to the high Cr content as indicated in ref. 18. It is well known that CrB has a low corrosion resistance. The observations made so far agree with those of Hemanth /3/ who concluded that the corrosion rate of cast iron can be varied more significantly by altering the alloying elements than by any heat treatment method in austempered chilled cast iron.

CONCLUSIONS

In the present study, the AISI 1050 steels show considerably higher corrosion resistance with respect to the chilled cast iron in 10 % H_2SO_4 acidic media. The thickness and microstructure of the diffusion layer of boronized materials is the most characteristic acidic reaction effect on general corrosion resistance of materials. It is noticable that the boronizinig process decreases the weight loss of the steels and significantly improves its corrosion behaviour.

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