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Corrosion behavior of borided AISI H13 hot work steel

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Abstract

The corrosion behavior of borided hot work steel H13 (AISI) in specific acid solutions (HCl 5 vol.%, H_2SO_4 5 vol.%, H_3PO_4 30 vol.%) was studied. Boriding was done by pack cementation. The corrosion behavior was evaluated by potentiodynamic polarization experiments and immersion corrosion tests. The borided steel showed a better corrosion behavior in H_2SO_4 and H_3PO_4 environments for short exposure periods, up to about 100 h, when compared to H13 steel. On the contrary H13 steel presented a better corrosion resistance in HCl acid environment in comparison to the borided H13 steel. The main corrosion mechanisms in order of appearance were crevice corrosion observed in the coating, galvanic corrosion between coating and H13 steel substrate and pitting corrosion of the substrate.

Keywords: Boriding; Pitting; Crevice corrosion; Galvanic coupling

1. Introduction

Coatings are normally used to improve the corrosion and wear properties of metals. There are many methods, e.g. galvanizing, electrodeposition, electroless plating, metal spraying, physical and chemical vapour deposition (PVD, CVD), etc., that provide coatings which protect metals in aggressive environments. The thermochemical surface treatment of boriding leads to the formation of hard iron borides, due to boron diffusion occurring at high temperatures (850–1100 °C) on steel surfaces. Two borides, FeB (in the outer surface zone) and Fe_2B (in the inner surface zone), are formed and due to their high hardness values they increase the strength and life time of steels under friction and wear environments. It has been reported that these hard borides also influence the corrosion behavior of steels [1–3].

In the past, few studies examined the corrosion behavior of borided low and high alloy steels. Borided Ck 45 steel showed improved corrosion resistance properties in comparison to the non-borided steel when they were exposed to HCl 20 vol.%, H_2SO_4 10 vol.%, and H_3PO_4 30 vol.% acid solutions. High alloy steel X10CrNiTi18 9 is normally attacked by HCl 20 vol.% and its corrosion was greatly reduced when this steel was borided. This alloy is very resistant to H_2SO_4 10 vol.% and further improvement was also observed when borided [1,4,5].

In the present study the corrosion resistance behavior of borided H13 steel in several acid solutions is examined. The purpose was to find out whether iron boride diffusion coatings could protect steels against aggressive corrosion environments. Electrochemical potentiodynamic polarization tests and immersion experiments were used in order to evaluate corrosion behavior. A combination of corrosion mechanisms was found to take place (pitting, crevice corrosion, galvanic coupling) as it might be anticipated in cases like this [6,7].

2. Experimental procedure

2.1. Materials

The material used was heat treated H13 alloy. More specifically specimens from the above material were heated to 1050 °C for 1 h and air-cooled , then tempered at 590 °C for 1 h and air-cooled again. The pack cementation process at 950 °C for 6 h led to the formation of borides FeB (brittle phase in the outer zone of the surface) and Fe_2B (ductile phase in the inner zone of the surface). Rectangular specimens of dimensions 20×12×5 mm were used in corrosion immersion tests while cylindrical specimens with a diameter of 5 mm and length of 10 mm were used in potentiodynamic corrosion tests.

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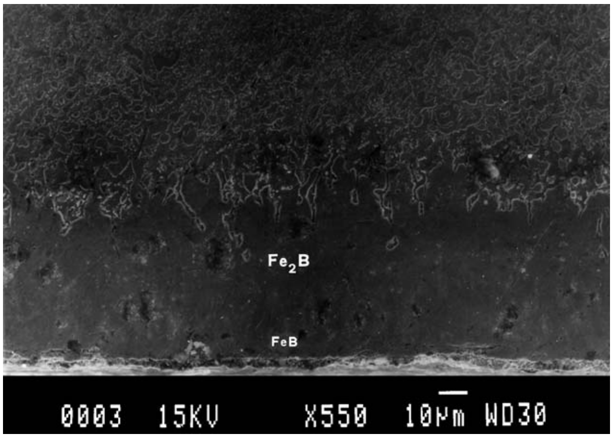

Fig. 1. Borided H13 steel after heat treatment in argon atmosphere and tempering. Boride layer thickness was 60 μm.

2.2. Corrosion

2.2.1. Immersion testing

The acid solutions used were HCl 5 vol.%, H_2SO_4 5 vol.% and H_3PO_4 30 vol.%. The already mentioned rectangular borided as well as non-borided specimens were weighted before immersion, with an accuracy of 0.1 mg. In specific time intervals the specimens were withdrawn from the solutions and weighted without any additional treatment. Thus, the weight loss in relation to the initially exposed surface was continuously recorded. The immersion tests were repeated 3 times and mean values were used for the acquisition of weight loss curves.

2.2.2. Potentiodynamic polarization testing

Potentiodynamic polarization tests were carried out in a standard apparatus by using the already mentioned acid solutions in atmospheric air at 25 °C. The cylindrical borided as well as non-borided specimens were used as working electrodes while two Pt electrodes were used as the counter electrodes. The potential was controlled by a Wenking PGS 81 potentiostat and measured through a Luggin capillary with reference to a saturated calomel electrode. Polarization started at the cathodic overpotential of −1000 mV and the scan rate was 10 mV/min. Typical potentiodynamic polarization curves were extracted for every material in every different corrosion environment.

2.3. Specimen examination

Morphological and microstructural features were observed by the use of stereo (Leica MS-5) and optical microscopy (Olympus BX-60). The chemical composition of critical phases was acquired in a JEOL 840A scanning electron microscope equipped with the EDS Oxford ISIS analytical system.

3. Results and discussions

After pack cementation, boride coating thickness was found to be about 60 μm. Its hardness varied from 1750 to 1200

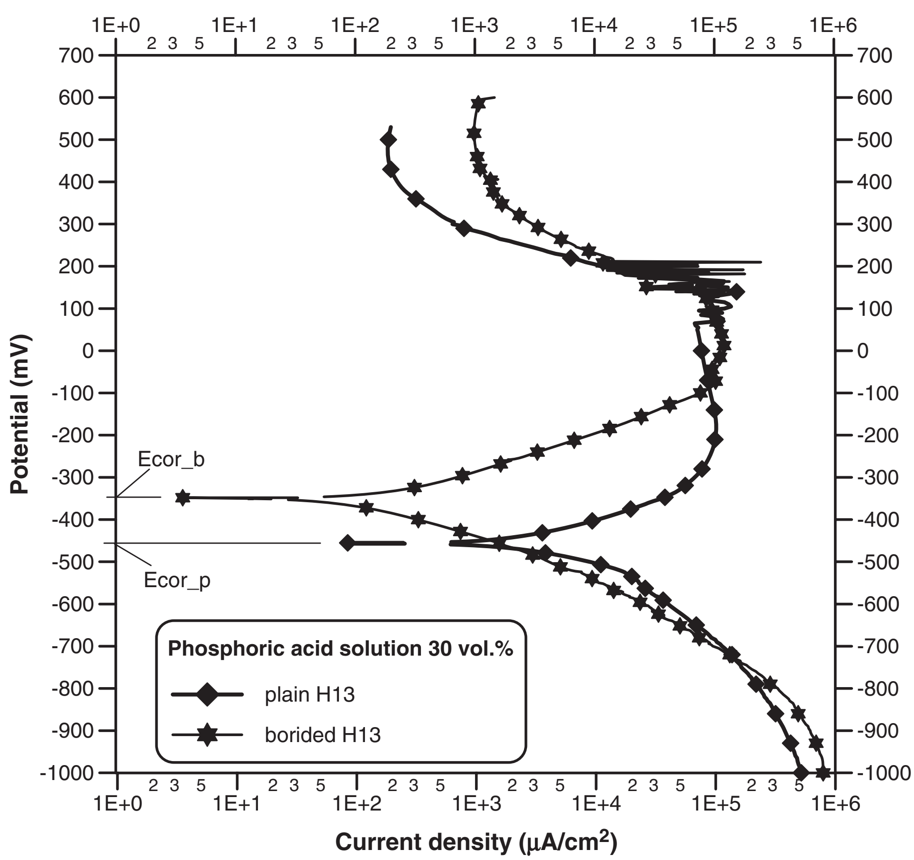

Fig. 2. Potentiodynamic polarization curves of the plain and borided H13 steel in H_3PO_4 30 vol.% solution.