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Short Communication

Plasma paste boronizing of AISI 8620, 52100 and 440C steels

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ABSTRACT

In the present study, AISI 8620, 52100 and 440C steels were plasma paste boronized (PPB) by using 100% borax paste. PPB process was carried out in a dc plasma system at temperature of 700 and 800 °C for 3 and 5 h in a gas mixture of 70%H_2–30%Ar under a constant pressure of 4 mbar. The properties of boride layer were evaluated by optical microscopy, X-ray diffraction and Vickers micro-hardness tester. X-ray diffraction analysis of boride layers on the surface of the steels revealed FeB and Fe_2B phases for 52100 and 8620 steels and FeB, Fe_2B, CrB and Cr_2B borides for 440C steel. PPB process showed that since the plasma activated the chemical reaction more, a thicker boride layer was formed than conventional boronizing methods at similar temperatures. It was possible to establish boride layer with the same thickness at lower temperatures in plasma environment by using borax paste.

1. Introduction

Boronizing is a thermo-chemical diffusion process in which boron is diffused into the steel at high temperatures. Surfaces of boronized irons and steels have high hardness, excellent wear resistance, good corrosion resistance and strong chemical stability. Boronizing process can be applied in solid, liquid and gaseous environment [1–7]. The above three boronizing methods have certain disadvantages. In gaseous boronizing, boron sources such as BCl_3, TMB (trimethyl borate), TEB (triethyl boron) and BF_3 along with H_2 and Ar gases are used [8–10]. Traditional gaseous boronizing agents are very sensitive to even the slightest traces of moisture, very poisonous, more costly and subject to explosion. In the case of liquid boronizing, the sample is dipped into a melted salt bath which consists of borax, boric acid and ferro silica and held at that temperature for the required amount of time. But formation a firmly adhered salt layer on the workpieces constitutes its advantages and this can be quite costly to remove after boronizing has been completed. Pack boronizing is generally performed with patent protected agents that consist of approximately 5%B_4C, 5%KBF_4 and 90%SiC (commercial Ekabor®). In this method the powder mixture is filled into a leak proof box in which the sample is placed. The box is heated up to the required temperature. It is kept at this temperature as necessary and then cooled [11]. Although pack boronizing is used commonly for commercial purposes among these methods, higher treatment temperatures and longer periods of time constitutes its drawbacks [12,13].

Studies have been carried out in order to reduce the boronizing temperature and time for the last 40 years. The studies have demonstrated that ion implantation boronizing [14,15], and plasma enhanced boronizing processes [13,16–19] are effective for the reduction of the boronizing temperature and time. Lately, studies carried out on plasma boronizing (PB) have been increasing gradually [19–23]. PB process has a superior advantage when compared to conventional boronizing processes. For example, thanks to the high energy generated in PB process it is possible to operate at lower temperatures and distortion (deterioration of shape) can be minimized. In addition to this, in PB process it is possible to reduce FeB amount or establish a single layer Fe_2B layer by changing gas mixture ratios [11,19,20]. However, the gases (B_2H_6, BCl_3) used in plasma boronizing, which are expensive, poisonous and explosive characteristics, is a disadvantage. Moreover, in plasma boronizing process carried out in BCl_3 environment, the boride layer having pores poses a tremendous problem [8,21,22].

The disadvantages in PB process can be eliminated through PPB surface process. The paste used having environmentally friendly boron raw materials and gases generally being hydrogen, argon and nitrogen which have inert characteristics make this process advantageous. Yoon et al. [9] have boronized AISI 304 steel by plasma paste which consists of borax ($Na_2B_4O_7$) and amorphous boron, at different temperatures in Ar/H_2 gases and have examined the diffusion kinetics and morphology of the layer. They reported that using plasma paste process caused lower activation energy for the formation of the boride layer than that for the conventional boronizing processes.

The characterization of boronized steels by using various boronizing processes has been evaluated by a number of investigator

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