Deposition of coatings containing Si and B on steels in a CVD fluidised bed reactor

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Abstract

Diffusion coatings are frequently used to protect materials in various aggressive environments and in order to improve their surface properties. Fluidized bed technology (FBT) has been successfully used for the deposition of different types of diffusion coatings by a C.V.D. process, e.g. aluminizing, chromizing, nitriding, carburizing. On the other hand, very little information exists on boronizing or siliconizing using FBT, although the method is simple, efficient and environmentally friendly and the boride coatings have been reported to have an excellent combination of properties, e.g. high fatigue strength and wear resistance and the silicide coatings are well known for their excellent corrosion resistance. In this paper the results of a process of boronizing and siliconizing of steels via C.V.D. in a fluidised bed reactor are presented. Coatings of different thicknesses were obtained at temperatures below 1000°C. The coatings were analysed by means of optical microscopy, as well as by x-ray diffraction (XRD) and Vickers microhardness, in terms of the coating’s composition, morphology, thickness, hardness and phase formation. The boride coatings showed significantly improved tribological properties under dry wear conditions.

Keywords: C.V.D., diffusion coatings, siliconizing, boronizing, fluidised bed technology.
1 Introduction

Diffusion coatings are frequently used to protect materials in various aggressive environments and in order to improve their surface properties. FBT has been successfully used for the deposition of different types of diffusion coatings by CVD [1-3]. The coatings produced with this technique have good uniformity and are characterized by a random distribution of grains. This is due to good mass and heat transfer conditions established in the reactor.

Briefly, fluidisation is a process in which a bed of particles, e.g. Al₂O₃, behave like a liquid, when a carrier gas is fed through the bed. There are several types of fluidised beds and their main advantages are the high rates of mass and heat transfer. This leads to uniformity of temperature throughout the volume of the reactor and flash mixing of all the compounds in it, which results in improved quality of coatings. Some further advantages of this process are the capability of immediate adjustment of the furnace atmosphere for specific requirements, the relatively low capital and operation cost, and the fact that it is environmentally friendly. The parameters that affect the quality of fluidisation in a fluidised bed reactor are the properties of the solids and fluids used, the bed geometry, the gas flow rate, the type of gas distributor and the reactor design.

The present paper is concerned with the boronisation and siliconisation process carried out on St37, low carbon steel substrate material, by the fluidised bed process. The prepared coatings were characterized by optical microscopy and X-Rays diffraction. Finally, the microhardness and tribological properties of selected coatings under dry wear conditions were evaluated.

2 Experimental procedure

The fluidised bed system used consists of the fluidised bed reactor, the gas preheating and reactants feeding system, a furnace for heating the reactor, the control panel and the measurement instruments for the temperature monitoring and the trapping of hazardous by-product unit, fig. 1. Argon was used as the fluidising gas, while the fluidising media was composed of Al₂O₃, B₄C, Fe-Si and halogen containing compounds. The temperature of the process was 990°C.

The tribological properties of selected coatings were evaluated using a pin on disk type equipment under dry wear conditions.

3 Results and discussion

3.1 Siliconizing

The as-produced coatings were uniform with average thickness of 50 µm, fig. 2. No cracks appeared in them. X-Rays diffraction patterns, fig. 3, indicated that they were consisted from four different phases: a) Fe₃Si, b) solid solution a-FeSi, c) Al₂O₃ and d)Fe-Si crystals. The presence of Al₂O₃ in the coating could be attributed to the temperature of the process. It has been reported that at temperatures greater than 1300°C, alumina does not stay inert. From our own
previous experience this temperatures could be as low as 1000°C. Further more some filler Al₂O₃ particles may have adhered to the substrate.

Figure 1: Schematically representation of the fluidised bed reaction system.

Figure 2: Typical morphology of Si coating produced at 990°C.
3.2 Boronizing

In figure 4 a typical morphology of boride coating obtained on St37 steel after 1.5 hours of treatment is shown. This coating had average thickness of 80 µm and Vickers microhardness values of 1800-2000 Hv, fig. 5. It is characterized by very good adherence due to its tooth-shape morphology and is consisted of only...
one uniform compound, which was found to belong to Fe$_2$B phase. In the tribological tests under dry wear conditions (pressure 15 kp, SiC paper 220 grit, testing time 2 min, velocity 30 rev./min) the Fe$_2$B layer showed an up to 50% increased resistance to wear compared to the untreated steel. When the layer was removed (after approximately 2 minutes of testing) the wear performance was similar to that of the uncoated steels, fig. 6.

Figure 5: Measurement of the microhardness of boride coating obtained on St37 steel.

Figure 6: Tribological properties of uncoated and borided St37 steel.

4 Conclusions

A simple, environmental friendly, fast siliconizing and boronizing process was carried out in a C.V.D. fluidized bed reactor. Iron-silicide and iron-boride
coatings with good quality were produced. Fe$_2$B was the boride phase formed during boronizing and it showed improved tribological properties under dry wear conditions.

References

