Vacuum 83 (2009) 185–189

Contents lists available at ScienceDirect

Vacuum

journal homepage: www.elsevier.com/locate/vacuum

Some properties of boronized layers on steels with direct diode laser

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Keywords:
Direct diode laser
Boronizing
Wear resistant
Fe–B powder
Hardness

A B S T R A C T

Boronized layer on steel is known to be formed by thermal diffusion of boron into the surface of steel improving corrosion–erosion resistant properties. Boronizing is carried out at temperatures ranging from 800 °C to 1050 °C and takes from one to several hours. There is one problem in this process, however, that the structure and properties of the base material are influenced considerably by the high temperature and long time of treatment. In order to avoid the aforementioned drawbacks of pack boronizing and laser-assisted boronizing, a better way is to activate the pack boronizing media and the workpiece with a high density power. The laser boronizing processes do not change the properties of the base material. In this study, the effect of laser characteristics was examined on the laser boronizing of carbon steel. After laser boronizing, the microstructure of the boride layer was analysed with an optical microscope and X-ray diffractometer (XRD). The mechanical properties of borided layer are evaluated using Vickers hardness tester and sand erosion tester. Results showed that the boride layer was composed of FeB and Fe_2B with thickness ranging 200–300 μm. The laser boronizing process did not change the properties of the base material.

1. Introduction

Boronizing (or boriding) is a reliable and functional technique among a wide variety of thermo-chemical surface-hardening processes known today [1–3]. It is known that boronizing results in enhanced hardness and increased wear, fatigue and corrosion resistance as compared to nitriding and carburising. Boronizing is a thermo-chemical surface treatment in which boron atoms are diffused into the surface of a workpiece to form borides with the base material. Boronizing is carried out at temperatures ranging from 800 °C to 1050 °C and takes from one to several hours. There is one problem in this process, however, that the structure and properties of the base materials are influenced considerably by the high temperature and long time of treatment. In order to decrease the boronizing temperature, ion implantation boriding [4] and plasma-assisted boriding [5] have been studied over the past 20 years. Ion implantation can only form a boride layer less than 1 μm thick, which is not applicable for heavily loaded parts. In order to avoid the aforementioned drawbacks of pack boronizing and laser-assisted boronizing, a better way is to activate the pack boronizing media and the workpiece with a high density power. This work carried out by laser boronizing has resulted in a new application, and promises a technological leap forward in boronizing for the future. In this study, a direct diode laser was utilized to melt inject Fe–B alloy powders on the surfaces of carbon steel. After laser boronizing, the microstructure of the boride layer was analysed with an optical microscope and X-ray diffractometer (XRD). The mechanical properties of boronized layer are evaluated using Vickers hardness tester and sand erosion tester. Results showed that the boride layer was composed of FeB and Fe_2B with thickness ranging 200–300 μm. At laser boronized steel, the pattern is dominated by FeB and Fe_2B peaks of low intensity; ferrite peak of high intensity can be observed. The laser boronized steel had significantly better erosion resistance than the carbon steel.

2. Experimental procedures

2.1. Materials

Block-shaped carbon steel plates of the dimensions 50 mm length × 40 mm width × 3 mm thickness were used as substrate in the boronizing process. The carbon steel (S45C) samples contained 0.45 mass% C, 0.18 mass% Si, 0.7 mass% Mn, 0.003 mass% P, 0.035 mass% S and balance Fe. These steel samples were boronized

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0042-207X/$ – see front matter © 2008 Published by Elsevier Ltd.
doi:10.1016/j.vacuum.2008.03.102

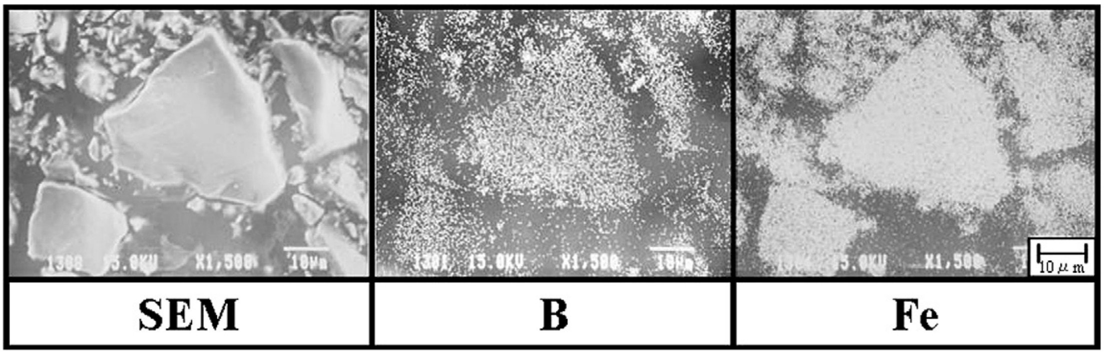

Fig. 1. EPMA analysis of Fe–B alloy powder.

by means of a diode laser boronizing process. The boriding materials used in experiments were iron based powder of about 50 μm average particle diameter (Fig. 1) and a 20 mass% ratio boron. In this process, a mixture of 20–50% boron trioxide (B_2O_3) powder and Fe–B powder was mechanically mixed with different content. Composite powder was paved on the surface of some carbon steel plates to form 0.3–0.6 mm thick layers, which were dried afterward by an infrared heater.

2.2. A 500 W class direct diode laser system

Fig. 2 shows the configuration and size of a 500 W class direct diode laser system. This diode laser system consists of a very small diode laser head, a power supply and a water cooling unit. The size of the laser head was 100 mm × 85 mm × 290 mm and weighted 5.5 kg. A maximum output power was 443 W and the wavelength was 807 nm. As shown in Fig. 2, the specimen was directly irradiated without optical fiber. The beam profile was examined by using a UFF100 beam profiler. The focal point was 42.5 mm length. The laser beam size was 230 μm × 1820 μm.

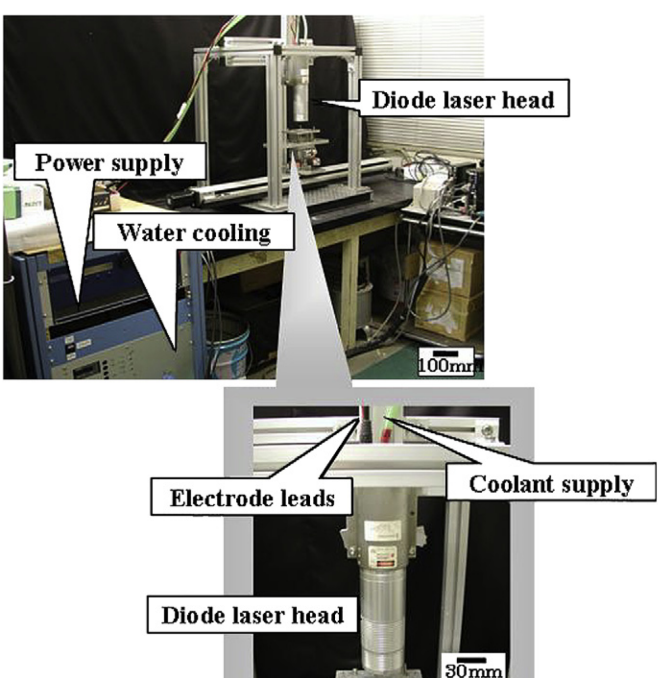

Fig. 2. A 500 W class direct laser system.

2.3. Laser boronizing method

A flow chart of fabrication method and outline of construction by diode laser system is shown in Fig. 3. The surface of carbon steel (S45C) was degreased and Al_2O_3 grit blasted. Composited powder was paved on the surface of some carbon steel plates to form 0.3–0.6 mm thick layers, which were dried afterward by an infrared heater. After laser boronizing, the samples were degreased with acetone. The specimens were then etched in a 3% Nital solution and were examined in the optical microscope. A XRD system was used for phase characterization and crystallinity analysis of the samples. Subsequently, the sample was sectioned, mounted and polished for microscopic examination and Vickers hardness testing. The Vickers

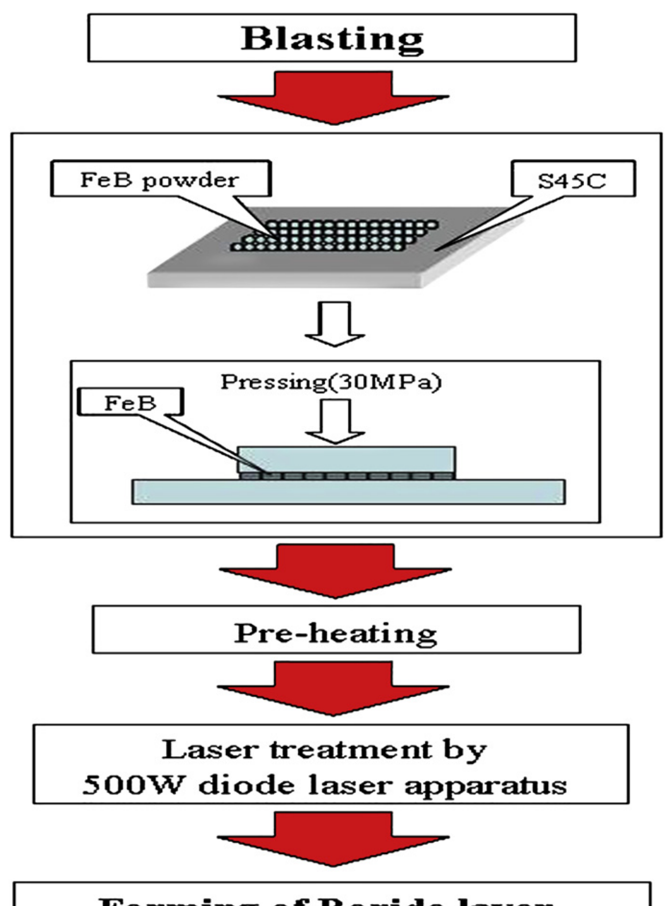

Fig. 3. Flow diagram of laser boronizing process.