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The performances of TiB_2-contained iron-based coatings at high temperature

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Abstract

The TiB_2-contained composite Fe–B–C coatings are deposited by the plasma transferred-arc (PTA) powder surfacing process. The coating's thermal ability, arc ablation resistance and wear resistance at high temperature were analyzed. It is concluded that TiB_2-contained composite Fe–B–C coating having excellent wear resistance at 600 °C and tempering resistance at 900 °C. Furthermore, this coating can effectively resist the arc ablation (120 A arc currents) within 7 s.

Keywords: TiB_2; Fe–B–C coating; Thermal ability; Arc ablation resistance; High temperature

1. Introduction

The research of the materials for elevated temperature purpose can always attract many attentions in the material research field since the demand for improvement on materials' high temperature performance has gotten more intensive with the modern industry progress [1,2]. However, most of the high temperature alloys such as Ni-based alloy and Co-based alloy are rather costly. By preparing a special coating with high temperature resistance on it, the much cheaper Fe-based alloy is promise to be used for some elevated temperature purposes.

There is a wide interest in using high power heat source for surface alloying and cladding on the steel substrates in order to enhance hardness, wear and corrosion resistance at elevated temperature [3,4]. The Co-based WC alloy is an often-used commercial coating material for this purpose. However, during the preparation of Co-based WC alloy coating, the WC particles are easy to be accumulated or sedimented in the bottom of the coating due to its much bigger mass density than the base metals while the laser cladding or plasma transferred-arc powder surfacing are employed. TiB_2 shows a series of attractive features just like hardness, strength and electric conductivity at elevated temperature and has been considered to be one of the most promising coating materials for high temperature purpose [5]. The TiB_2-contained composite Fe–B–C coating that contains a lot of in situ synthesized TiB_2 whiskers was prepared by laser cladding or plasma transferred-arc (PTA) powder surfacing process on the mild steel substrates [6,7]. These TiB_2 particles and whiskers are known to possess a good distribution, excellent wettability and favorable interface characteristics for reinforcement in Fe-base metal matrix. The microstructures, hardness and cracking resistance of such a TiB_2 whiskers reinforced PTA powder surfacing composite Fe–Ti–B coatings were investigated in the previous work [8]. The thermal stability (anti-tempering resistance), wear resistance, and arc ablation resistance of this coating are investigated in this paper.

2. Experimental procedures

2.1. Materials

The mild steel (composition: 0.18 wt.% C, 1.32 wt.% Mn, 0.53 wt.% Si, and Fe balance) was used as substrate. Specimens were cut to the dimensions $200 \times 50 \times 10$ mm^3, polished with 200-grit SiC abrasive paper and degreased in acetone prior to

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Table 1
The nominal compositions and characteristics of the used powders

Powders	Composition (wt.%)						Melting point (°C)	Density (g cm^{-3})	Size (μm)
	Ti	C	B	Al	Si	Fe			
Fe–Ti alloy	21.07	3.80	–	2.50	3.10	Balance	1085	6.15	≤150
B_4C	B≥76% , dissociated C≤2.0%						2450	2.52	≤50

coating. The powder used in this investigation was a mixture of commercial Fe–Ti alloy powder (manufactured by Jinzhou Alloy Factory, China) and B_4C powder (produced by Mudanjiang Boron Carbides Factory, China). The nominal compositions and characteristics of these powders are given in Table 1, according to manufacturers.

2.2. PTA powder surfacing processing

A PTA powder surfacing equipment made in China was used in the coatings treatment. Ensuring a good interface fusion, a smooth coating surface and a minimum dilution, the PTA depositing parameters were optimized in Table 2. The powders were weighed in desired proportions and mixed in a ball mill for 20 min without any addition. Subsequently, the powder mixture was painted on the sample substrate using a water glass to about 5 mm thick before processing. Argon was blown coaxial to protect the processing area. All of the test coatings for the microstructural examinations were deposited with a 22 min^{-1} torch swing frequency and 30 mm track width (swing width).

2.3. Thermal stability test (temper resistance test)

The temper resistance tests were carried in order to evaluate the coating's thermal stability in this paper. The deposited specimens were cut to be a dimension of 20×20×10 mm^3, polished for metallographic examination and then measure its average HV hardness (under 98N load) on the coating's upper surface and cross section before temper test. The temper test was taken in the electric resistance-tempering furnace. While the furnace temperature reaches 900 °C, the test specimen was taken into the furnace and then kept there for 30 min under this temperature before the furnace electric current was cut off. The test specimen was kept in the furnace until it was cooling down to 100 °C (about 12 h) and then be taken out of the furnace to continue its cooling in the open air to ambient temperature. There is some ferric oxidation produced on the surface of tested specimen. All of the ferric oxidation must be cleaned off from the specimen and then polish it for microstructure and HV hardness examination. The HV hardness on the deposited coating surface and cross section of

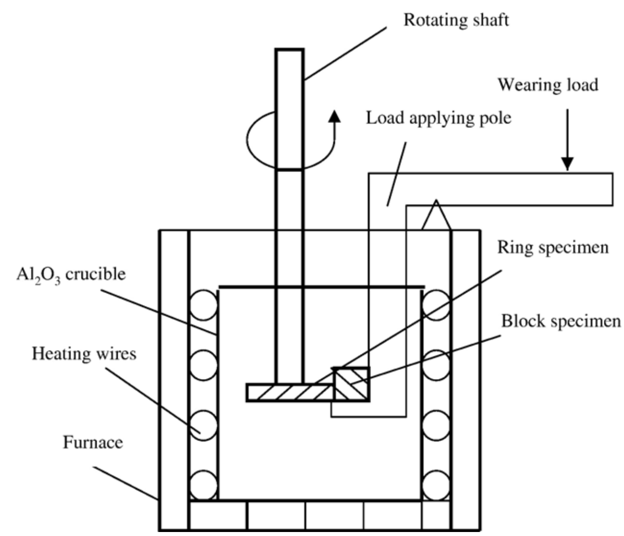

Fig. 1. The schematics of the specially-designed ring-against-block high temperature wearing test machine.

this tempered specimen were measured once more using the same equipment. As a reference material, the commercial iron-based hardfacing alloy deposited with powder Fe07 (0.45 C, 4.5 Cr and the Fe balance) that is made in Tianjin Hardfacing Materials Co. Ltd, P.R.China was the same tested.

2.4. Arc ablation resistance test

The arc ablation resistance is one of the most important performances for high temperature materials [9]. The arc ablation resistance test of the TiB_2-contained composite Fe–B–C coating is conducted using carbon arc attack method on the tested coating's surface. The tested sample was processed to be the dimensions 50×50×10 mm^3 and the test surface was polished with 400-grit SiC abrasive paper. The test sample was meet with the positive pole and the carbon stick meets the cathode at the D. C. welding power machine. As a reference material, the carbon steel with 0.45 wt.% carbon content was also tested. The distance between carbon stick tip and coating surface is fixed about 10 cm. The arc current used is 120 A and arc voltage is kept about 30 V when the arc was ignited by another carbon stick. In order to evaluate the size of the fusing zone simply, a series of circles with different diameters was draw on the surface of the tested sample under the carbon stick tip. Due to the surface of mild steel substrate will get very shiny from gray when it is melting under the arc space, the time (t_1) from the arc ignition to the moment that the tested face begin to be melting (from the arc ignition to the moment the tested surface gets great shining) can be easily recorded. The time (t_2) from the arc ignition to the

Table 2
The PTA powder surfacing parameters

Arc current (A)	Arc voltage (V)	Thickness of painted powder coating (mm)	Arc travel speed (mm min^{-1})	Torch swing frequency (min^{-1})	Torch swing width (mm)
150–250	28–32	5	20–50	22	30

Table 3
The high temperature wearing test conditions

Wear pressure, N	Wearing period, min	Temperature, °C	Rotation rate, r/min
100	60	600	90