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Effects of CeO_2 on friction and wear characteristics of Fe–Ni–Cr alloy coatings

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Abstract

The effects of rare earth oxide CeO_2 on the microstructure and wear resistance of thermal sprayed Fe–Ni–Cr alloy coatings were investigated. The powders of Fe–Ni–Cr alloy with the addition of CeO_2 were flame sprayed on to a 1045 carbon steel substrate. The coatings were examined and tested for microstructure feature, compositions, and phase structure. Tribological properties of coatings were tested under reciprocating sliding test. The results were compared with those for coatings of the alloy without CeO_2. The comparison indicated that the addition of rare earth oxide CeO_2 could refine and purify the microstructure of coatings, and increase the microhardness of the coatings. As a result, by CeO_2 addition, the friction coefficient of the coatings was decreased slightly and the wear resistance of the coatings was enhanced significantly.

Keywords: Flame sprayed; Rare earth elements; Bond strength; Wear resistance

1. Introduction

Cerium and rare earth oxide, have been applied successfully in many fields, such as metallurgy, electronics, and chemical engineering [1]. With strong chemical activities and rather large atomic radius, RE can react easily with many elements such as H, O, N, S, Si etc., and then play a favorable role in steels and their production [2]. Nowadays, the applications of RE in the field of surface engineering are principally focused in surface chemical heat treatment and electroplating [3]. In recent years, RE was successfully applied to modify the surface properties of thermal spray coatings, thermal spray welding coatings and the laser-alloyed coatings, and studied the influence of rare earth elements on the microstructure, wear and corrosion resistance of modified layers [4]. In many current studies on surface modification technologies, there is an increasing interest in understanding the rapid solidification, particles remelting and precipitation, interface transformation, interface moving effect, counter flow pattern, alloying reaction and in the relationship between microstructures and properties of surface modified layers [5,6].

These works were mainly focused on nickel-based alloy coatings. Furthermore, there is very little published information on the application of CeO_2 in Fe–Ni–Cr alloy coatings. In this paper, the effects of rare earth CeO_2 on the microstructure and wear resistance of thermally sprayed Fe–Ni–Cr-RE alloy coatings is studied, and provide an experimental basis so as to enlarge applications of rare earth oxide.

2. Experimental details

2.1. Specimen preparation

The powders of Fe–Ni–Cr alloy was produced by gas atomization in an argon atmosphere, containing 0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt% mixed with CeO_2, and the average particle size of powders is 65 μm. The commercial carbon

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steel substrate was first degreased and blasted with coarse sand, the Fe–Ni–Cr alloy samples were prepared by oxygen-acetylene flame spraying process on one end of substrate bars, then the specimens were machined into $\phi 8\,mm \times 30\,mm$ pins with 0.8 mm thick layer on the commercial carbon steel. The composition of Fe–Ni–Cr alloy is C 2.0–3.0, B 3.0–4.0, Si 2.5–3.5, Cr 16–18, Ni 18–20 wt%, the rest is Fe.

2.2. Experimental procedure

Wear resistance was evaluated with an RFT-III Reciprocating Friction and Wear Tester at room temperature without lubrication. The bars of white corundum with the dimension $70\,mm \times 13.7\,mm \times 10\,mm$ was used as counterparts, and the surface roughness of the specimens ranges from 0.8 μm to 0.4 μm. The test was performed under loads 80–160 N, and at room temperature 18 °C and relative humidity 25% for 10 min. Wear distance of each reciprocation was 60 mm, sliding speed was 150 r/min, and times of reciprocation were 1500. Three replicate tests were performed for each condition and the average data of three replicate test results were given in the paper. The test deviation was no more than 10%. The wear weight loss was measured by Electronic Analytical Balance.

Microstructure and worn surface were observed by an optical microscope and a scanning electron microscope with a Kevex energy dispersive X-ray (JSM-5600LV SEM/EDS). Their compositions were analyzed by X-ray diffraction (X'Pert PRO) and energy dispersive spectroscopy analyses. The surface hardness of cross section of specimens was measured by a Vickers microhardness tester (MH-5-VM) with a 500 g load.

3. Results

3. Microstructure

Fig. 1 shows SEM observation of the Fe–Ni–Cr alloy powders. The powders with CeO_2 are fine and spheroidal. While the powders without CeO_2 have more irregular and not well distributed shape. Adding CeO_2 can accelerate the dissolution of particles and make their shape spheroidal [5].

Fig. 2 shows the microstructure photographs of Fe–Ni–Cr-RE (with 0.4 wt% CeO_2) alloy and Fe–Ni–Cr alloy coating. It can be observed that the microstructure becomes finer with the addition of CeO_2 and the number of cell grains increased, XRD reveals the existence of Fe_3Ni, γ-(Fe, Ni), Ni_3Si, CrB, $Cr_{23}C_6$, $(Fe,Ni)_{23}C_6$, Ni_4B_3. An energy dispersive X-ray spectrometry (EDS) analysis

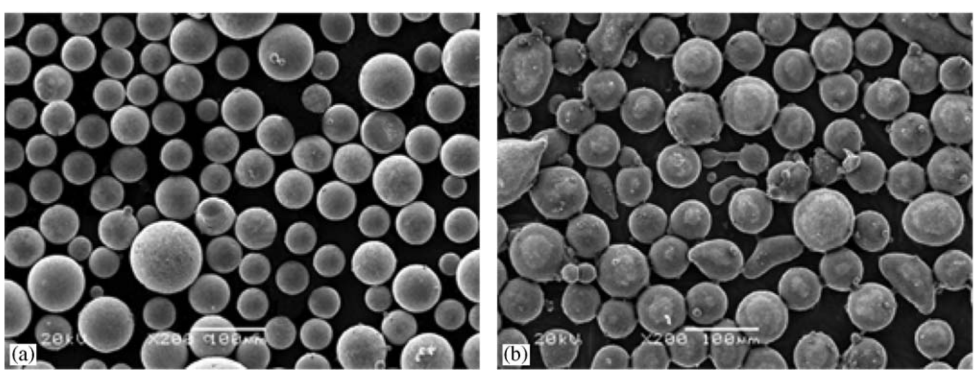

Fig. 1. Powder morphology obtained by gas atomization in an argon atmosphere (a) with CeO_2, and (b) without CeO_2.

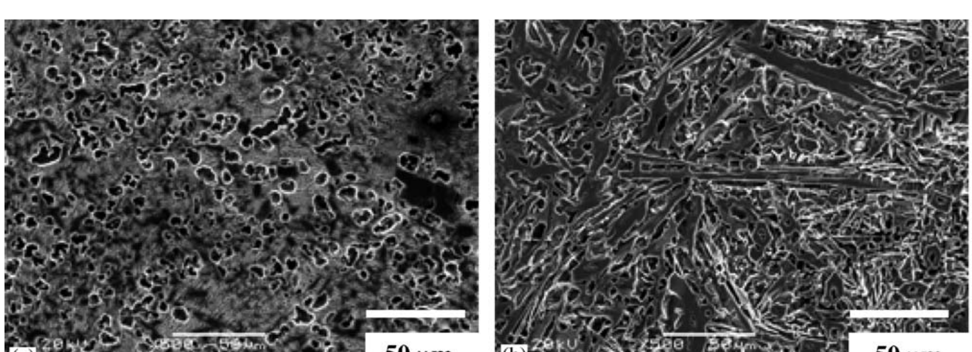

Fig. 2. Microstructure of Fe–Ni–Cr alloy (a) with 0.4 wt% CeO_2, and (b) without CeO_2.