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Effect of laser remelting on corrosion behavior of plasma-sprayed Ni-coated WC coatings

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Abstract

The corrosion properties of plasma-sprayed (PS) Ni-coated WC coatings are studied for both before and after laser remelting of the coatings. Optic microscope (OM), scanning electron microscope (SEM) and X-ray diffraction (XRD) are applied to investigate the microstructure and phase composition of PS Ni-coated WC coatings. The results indicate that coatings with laser remelting could improve their microstructure, such as lower porosity rate, weaker lamellar structure and more uniform distribution of phases. XRD shows that the W_2C phase is not identified both in as-sprayed and coatings with laser remelting, which means that the decarburization of WC has not happened because of Ni-coated WC grain. However, the Ni compounds were observed both in the plasma spray and the laser-remelting coatings. The salt spray corrosion (SSC) shows that the laser remelting coating has better corrosion resistance, which is mainly due to its fully dense top layer, low number of defects and uniform distribution of the phase and composition.

Keywords: Plasma spray; WC; Decarburization; Laser remelting

1. Introduction

Plasma spraying is a well established and versatile technique for producing coatings of both metals and ceramics. By means of a plasma the coating material is heated to a molten or plastic state and rapidly propelled in the form of droplets or soft particles towards the substrate where they spread out and solidify to produce a covering protective coating [1]. It is a technique that fits better with the properties of these materials due to the high temperature reached by the plasma (above 18000 °C) [2]. Also, minor risk of distortion of the substrate exists since its temperature does not rise above 300 °C [3]. However, there are two major problems with plasma spraying. The primary problem is the poor bonding strength between the coating and the substrate, which causes the sprayed material to peel off under high bending stress or heavy load. The second problem is the high porosity in the as-sprayed coatings, which reduces the wear and corrosion performance [4].

Due to the aforemetioned, post-spray treatments, such as an appropriate heat treatment, need to be applied to plasma-sprayed coatings to improve their mechanical and metallurgical properties for most practical applications. For this purpose, a heat treatment may be necessary in order to reduce the porosity and to improve the mechanical properties of coatings. Among the known heat treatment processes, heat treatment using a furnace in vacuum is usually applied [5,6]. Other methods, such as laser treatment, have also been used to densify coatings to eliminate porosity and enhance the coating strength, chemical homogeneity and other performance [6–9].

Tungsten carbide (WC) alloys are used as protective coatings [10]. Tungsten carbide coatings have several interesting properties [11], e.g. high hardness, corrosion resistance, excellent adhesion, high elasticity, chemical inertness, low friction in combination with high wear resistance, which make them a good candidate for many engineering applications [12].

Decarburization of WC is a common phenomenon during PS deposition, resulting in a large amount of W_2C and other carbon-deficient phases in the coating. Consequently, the properties and performance of the coating may be inadequate and unreliable [13].

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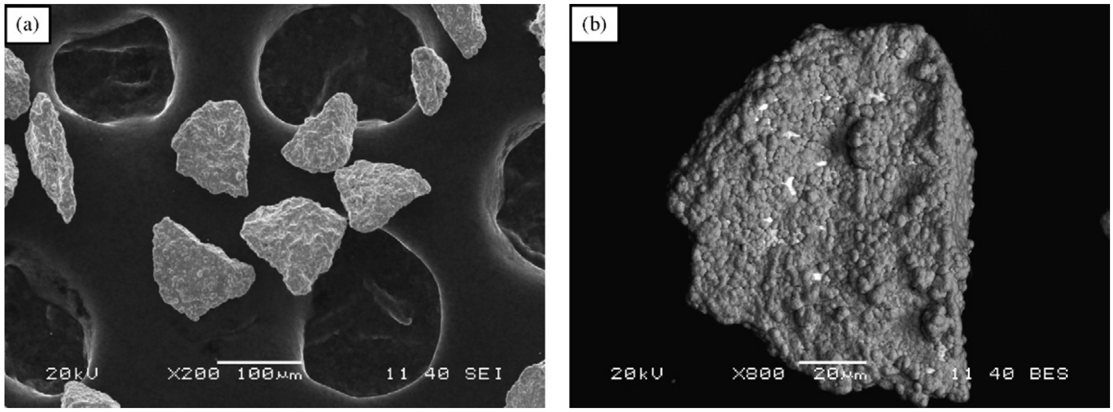

Fig. 1. Morphology of the PPPC feedstock powder: (a) SE image and (b) BSE image.

In order to overcome this disadvantage, the Ni-coated WC powders are selected as the feedstock powder. Ni serves both as paste and as protection of WC. The main focus is to determine the microstructure and salt spray corrosion (SSC) behavior of Ni-coated WC cermet coatings before and after laser remelting.

2. Experimental

Commercial Ni-coated WC powders (PPPC, Yiyang, Hunan, China) were used as raw material for plasma spray. The chemical composition of the powder was 12 wt.% Ni, impurity smaller than 1.5 wt.% and the rest WC with nominal hardness of HRC 45–55. Fig. 1 shows the morphology of the PPPC feedstock powder. Fig. 1a shows the SE image of the PPPC feedstock powder. The powder can be seen to be composed solely of irregular shape tungsten carbide particles with Ni-coated. The particle sizes are estimated from 35 to 110 μm. However, from the white spots in Fig. 1b, BSE image, it can be easily seen that there are some white spot on the WC particles. From EDS the white spot has large W content. This shows that the Ni cannot be coated overall WC grains.

The XRD patterns for the feedstock powder are shown in Fig. 2. It can be seen that the XRD patterns are composed of diffraction peaks for WC, Ni, NiC and NiC_x phase. The carbide of Ni was observed may be related to the process of preparation of Ni-coated WC powder. However, the diffraction peaks of WC are relatively weaker, which is due to the fact that Ni was incompletely coated, according well to Fig. 1b.

Coatings were plasma-sprayed onto a low-carbon steel substrate. The layer had an approximate thickness of 700 μm. The plasma spray was carried out with a GTV equipment, with F4/F6 torches, using Ar and H_2 as fuel gases. Substrates pretreatment consisted of grit blasting using 35 mesh Al_2O_3, followed by ultrasonic cleaning and degreasing in acetone solution. The best spray parameters in terms of lower porosity and lower amount of cold particles, which is recommend by equipment manufacturer as following: used gases, argon 50 L/min and hydrogen 8 L/min; powder gas, argon 5 L/min; spray distance, 110 mm.

Once the Ni-coated WC was deposited, the melting was carried out using a CO_2 laser (PRC–2000, operating in a continuous way) by the spray of argon as protection. The parameter of laser remelting was selected with an appropriate optimize. The laser remelting parameters are: spot diameter, 2.5 mm; power, 800 W; scanning speed, 1.2 m/min; overlapping, 40%.

Microstructure of the coatings was observed using an OM (XJG–05) and a SEM (JEOL JSM). Energy dispersive spectroscopy (EDS) and X-ray diffraction (Cu Kα radiation, i.e. 1.54 Å wavelength) were used. Microhardness measurements were performed on mounted samples using a conventional Vickers microhardness tester (HXD-1000TC) with a 200 g load. The value presented is the average of 10 or 15 measurements after the highest and lowest values were discarded. The China GB/T 10125-1997 Salt spray test was used to evaluate the corrosion performance of the coatings. The salt spray test is an accelerated corrosion test by which samples exposed to the same condition can be compared, therefore, one could rank the relative corrosion resistance. In the corrosion test, the samples were exposed to a salt fog generated from a 5% NaCl solution with a pH level between 6.5 and 7.2. The temperature in the chamber was held at 35 °C. The uncoated edge areas for samples were protected with epoxy resin. All coating/substrate combination placed in the salt fog chamber could not be taken out until the corrosion blister or stripe appeared at one interval. The maximum exposure time was 400 h no matter whether corrosion product came out or not.

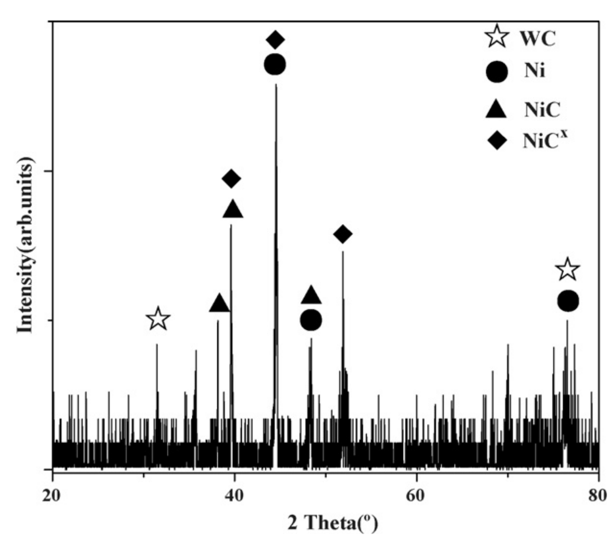

Fig. 2. XRD pattern of the Ni-coated WC feedstock powder.