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Influence of laser treatment on the corrosion properties of plasma-sprayed Ni-coated WC coatings

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Abstract

The electrochemical corrosion of plasma spray Ni-coated WC cermet coatings, after laser treatment, has been studied in 3.5% NaCl solution through immersion test. The main corrosion mechanism for as-sprayed coating is the galvanic corrosion between coating and substrate, resulting in the detachment of coating from substrate, while the homogeneous corrosion occurs for the laser treatment coating. However, the corrosion trace for the as-sprayed pure coating could not be found. It is found that the electrochemical corrosion has been found heavily depending on the galvanic corrosion between the coating and the substrate. The defects, such as pores and laminar structures in the coating, could act as the infiltration paths of the electrolyte.

Keywords: Immersion test; Plasma spraying; WC; Corrosion mechanism

1. Introduction

Cemented tungsten carbide cermets (typically with a cobalt or nickel binder phase) are widely used in applications where very high resistance to abrasive or erosive wear is required. They can be applied as coatings by thermal-spraying processes such as plasma-spraying, high-velocity oxy-fuel spraying and detonation gun methods [1]. The properties and performances of tungsten–carbide–binder coatings lead to a complex function of carbide size, shape and distribution, matrix hardness and toughness, and solution of carbon in the binder matrix. Therefore, a coating should retain to be in a large volume fraction of finely distributed tungsten monocarbide (WC) to achieve the optimal wear properties. This largely depends on the minimization of the decarburization of WC which potentially occurs at high temperature associated with the thermal spray process [2]. Furthermore, the two main differences between cobalt and nickel binder phases are (i) nickel is considerably more corrosion resistant than cobalt and (ii) it is a stable f.c.c. structure and hence does not undergo a phase transformation [3].

Plasma-sprayed ceramic coatings are used in many engineering applications to improve wear and corrosion resistance. 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]. To improve such properties, a heat treatment may be necessary 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 to enhance the coating strength, the chemical homogeneity and the other performances [6–9].

The aim of this study is to analyze the influence of laser treatment on the microstructure and electrochemical corrosion behavior of Ni-coated WC cermet coatings prepared using

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plasma spray. Here the nickel metal has two roles: the first is that it can reduce the decarburization of WC during plasma spray process. The second is that it contributes to a binder phase between the WC ceramic powders.

2. Experimental

A GB 45 steel (China) with the nominal composition of 0.43 wt.% C, 0.52 wt.% Mn, 0.22 wt.% Si, 0.01 wt.% P, 0.02 wt.% S and a balance of Fe was used as the substrate. Prior to spraying, one face of the steel substrate was cleaned in acetone solution and then sandblasted using corundum powder. Commercial Ni-coated WC powders (PPPC, yiyang, hunan, China) were used as the raw materials for plasma spray. The chemical composition of the powder in weight was 12% Ni, impurity smaller than 1.5% and the rest WC, with nominal hardness of HRC 45–55. The projection was carried out with a GTV equipment, of F4/F6 torches, using Ar and H_2 as fuel gases. The more detailed description can be found in our previous investigation [10]. The coating has an approximate thickness of 600 μm.

Once the Ni-coated WC had been deposited, the heat treatment was carried out using a CO_2 laser (PRC—2000, operating in a continuous way). The laser remelting parameters used are spot diameter = 2.5 mm; power = 800 W; scanning speed = 1.2 m/min; overlapping = 40%.

Some substrate-holding coatings were surface grounded with papers from 200 to 1000 grit SiC and were polished using 5 μm diamond paste. Resin was used to cover the edges and uncoated faces of the specimens. The specimens were then immersed in the solution of 3.5% NaCl that was acidified with acetic acid to achieve a pH of 3. Immersion was maintained for 60 days at the room temperature. Afterward the specimens were removed, ultrasonic cleaned and dried.

The pure coating detached from the substrate through mechanical method was also immersed in electrolyte at the same time with the as-sprayed and remelting coatings in order to detect the corrosion properties of the pure coating.

For comparison purpose, all the detected coatings were selected from the same base coating.

Microstructure of the coatings was observed using an OM (XJG—05) and a SEM (JEOL JSM and HITACHI 3000). Energy dispersive spectroscopy (EDS, HORRIBA 250) was used to determine the composition distribution.

3. Results and discussion

Fig. 1(a) shows the morphology of the PPPC feedstock powder. The powder can be seen being composed solely of irregularly shaped tungsten carbide grains with Ni coating. The grain sizes are estimated from 35 to 110 μm. However, from Fig. 2(b), it can be easily seen that there are some white spot on the WC grains. From EDS the white spot has large W content (19.06 at % W element and 8.29 at % Ni element at spectrum 1 in Fig. 1(b)). This shows that the Ni cannot be coated over all the WC grains.

Fig. 2 shows the microstructure of a Ni-coated WC plasma-sprayed coating, both before and after laser treatment. From Fig. 2(a and b), the existence of the abundant porosity can be appreciated in the as-sprayed coating. However, it is observed that the laser treatment has eliminated the pores, provided a more homogeneous and compact microstructure, especially for a fully dense top layer in the laser remelting coating, see Fig. 2(c). It should be noted that holes of small size appeared

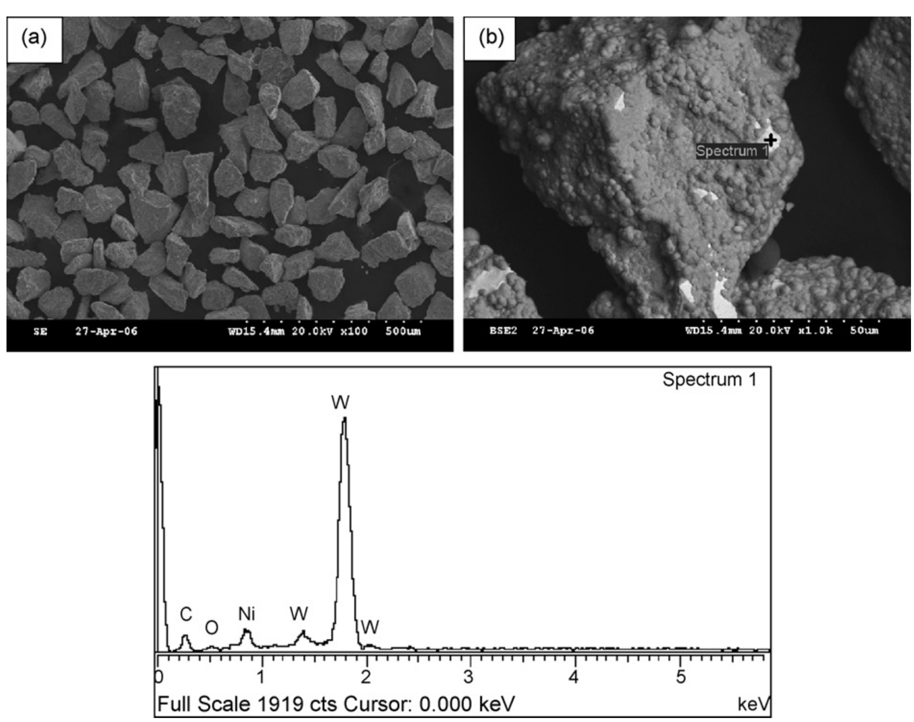

Fig. 1. Morphology of the PPPC feedstock powder (a) SE image; (b) BSE image.