CORROSION PROPERTIES OF CERMET COATINGS SPRAYED BY HIGH-VELOCITY OXYGEN-FUEL

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Abstract
High velocity oxygen fuel (HVOF) is one of the most promising coatings deposition method used in many industrial applications as: aerospace, automation, transportation and power generation system.
The paper presents the experimental results regarding the corrosion behavior of different sprayed cermet powders WC CoCr and WC CrC Ni deposited on disc-like C45 steel specimens tested in a NaCl aqueous solution.
The powders and coatings morphology were analyzed by scanning electron microscopy (SEM), the phase's identification was performed by X-Ray diffraction technique (XRD). In order to evaluate the quality of the HVOF obtained coatings the porosity of the specimens was determined.
The polarization curves were obtained using the potentiodynamic polarization testing method and a three electrode open cell. The results showed that the both coatings had a good corrosion behavior. However, the overall corrosion resistance of the WC–CrC–Ni coating was inferior to that of the WC–Co–Cr coating.

Keywords: cermet coating, HVOF spraying method, corrosion behavior

1. INTRODUCTION

In the process industry, hydroelectric power plants, in offshore piping the materials are very often exposed to environments that are corrosive which can affect the lifetime of the components and produce high maintenance costs [1].

It is already known that the practice of applying thermal sprayed coatings onto the surface of components which operate in aggressive media can prevent their surface degradation by corrosion, erosion or combined erosion-corrosion. The ability of these coatings to protect the base metal against corrosion is given by their composition, morphology and structure. Microstructural features which enhance the corrosion resistance include high density, low porosity, small grain size, absence of the cracks [2].
The high velocity oxygen fuel (HVOF) spraying process is one the most promising deposition method in order to obtain excellent quality coatings with low porosity, good bond strength and high density.
Generally, this technique of thermal spraying can be used as a hard-chrome alternative as well as for new applications where thermal spraying was not put into account due to cost and technical reasons [3].
The present paper studies the corrosion behavior in 1M NaCl aqueous solution of thermally sprayed cermet powders WC CoCr and WC CrC Ni deposited on disc-like C45 steel specimens.

2. EXPERIMENTAL PROCEDURE

The materials used for investigations were two different fine sinterized powders: WC-Co-Cr with the nominal composition 86%WC-10%Co-4%Cr and WC-CrC-Ni having the composition 77%WC-20%CrC-7%Ni, the powder particle size being in range -10+2 µm.
Both powders were HVOF sprayed, using an ID Cool Flow gun from Thermico firm, Germany, on disc-like C45 carbon steel substrates which were previously degreased with acetone and gritblasted with corundum at
6 bars at a blasting distance of 230 mm. The spraying process was optimized to achieve a low porosity level of the coating and a high coating efficiency [4].

The morphology of the powder and the microstructure of HVOF sprayed samples have been characterized by scanning electron microscopy SEM (Philips XL-30 scanning electron microscope equipped with EDAX analyzer). The phase identification of the coatings has been performed by X-ray diffraction analysis with Cu Kα radiation (1.5406 Å) using a 0.020 step size and 0.2 s step time. X-ray diffraction was performed at a tube voltage of 40 kV and a tube current of 30 mA. The X-ray intensity was measured over a 2θ diffraction angle from 100 to 1000. Image analysis software (Image Tool Version 3.00) was used to quantify the coatings porosity. The quoted values are an average of seven areas measured at the same magnification for each coating.

The corrosion behavior of the coatings was measured by cyclic voltammetry using a standard three-electrode cell, comprising a platinum auxiliary electrode and a saturated calomel reference electrode. Polarization curves were recorded in the positive direction starting at the free corrosion potential at room temperature in a 1M NaCl solution.

3. RESULTS AND DISCUSSIONS

3.1 Powder and coatings characterization

Figures 1 and 2 presents the SEM images, at different magnitudes of the used cermets powders.

![Fig. 1 SEM micrographs of WC CoCr powder](image1)

![Fig. 2 SEM micrographs of WC CrC Ni powder](image2)
In Figure 1 one can observe that the WC CoCr powder presents polyhedral particles that are densely bounded by the metallic matrix. By the WC CrC Ni powder (Figure 2) the reinforcement particles are aggregated by an abundant binder.

Figures 3 and 4 show polished cross sections of the WC CoCr and WC CrC Ni coatings, respectively. In both cases the thickness of the deposited coatings seems to be around 220 µm. The SEM micrographs of the coatings at low magnification (the left side from Fig 3 and 4) revealed a good bonding of the coating to the steel substrate. At higher magnification (the right side from Fig.3 and 4) one can observe a certain degree of porosity respectively of internal oxidation.

3.2 X-ray analysis

Figures 5 and 6 presents the XRD diffractograms recorded on WC CoCr and WC CrC Ni coatings. Before measuring, the samples were ground and polished in order to obtain a smooth surface.

The X-Ray diffraction of the WC CoCr coating (Fig. 4) evidences the presence of WC and W$_2$C phases. It can be observed that a decarburization of the WC in W$_2$C appeared. In case of the WC CrC Ni coatings (Fig. 5) the identified phases were WC and (W, Cr)$_2$C. The spraying process produced also in this case a decarburizing of the WC in (W, Cr)$_2$C.
3.3 Corrosion behavior of the coated specimens

It is well known that thermal sprayed coatings are often porous depending on the method of deposition and spraying parameters. Therefore, the electrochemical corrosion resistance of a metal coated by a thermal spraying technique is not only limited by the intrinsic corrosion resistance of the deposit, but also by the porosity of the coating [5].

In order to evaluate this characteristic and using the software Image Tool it has been quantified the porosity of the deposited coatings. It has been found a porosity of about 1% in both cases namely 1.05% ± 0.15% for
WC CoCr coating and 0.94 % ± 0.15%. for WC CrC Ni coating. The pores have been scattered randomly using seven cross-sectional micrographs at 1000X magnification for each coating. The corrosion behavior of the coatings was measured by electrochemical method. Fig. 5 shows the polarization curves recorded on C45 steel samples coated by HVOF spraying method using the WC CoCr and WC CrC Ni cermet powders. Analyzing the curves and the corrosion parameters \( U_{\text{corr}} \), \( i_{\text{corr}} \) presented in Tab. 1 it can be noticed a better corrosion behavior of WC CoCr coating in comparison with WC CrC Ni coating. As can be seen the corrosion current values were shifted to lower values from 24.78 \([\mu A/cm^2]\) to 5.61 \([\mu A/cm^2]\). A lower value for \( i_{\text{corr}} \) means an improvement in the corrosion behavior. Moreover, the corrosion rate decreases from 289 \([\mu m/year]\) to 65.53 \([\mu m/year]\) in case of WC CoCr coating.

![Polarization curves of the deposited WC CoCr and WC CrC Ni coatings](image)

**Fig. 7** Polarization curves of the deposited WC CoCr and WC CrC Ni coatings

<table>
<thead>
<tr>
<th>Coating</th>
<th>Corrosion potential ( U_{\text{corr}} ) [mV]</th>
<th>Current density ( i_{\text{corr}} ) [( \mu A/cm^2 )]</th>
<th>Corrosion rate [( \mu m/year )]</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC CoCr</td>
<td>-682.3</td>
<td>5.61</td>
<td>65.53</td>
</tr>
<tr>
<td>WC CrC Ni</td>
<td>-840.3</td>
<td>24.78</td>
<td>289.8</td>
</tr>
</tbody>
</table>

The coatings polarization curves reflect the passive behavior of the metallic matrix. Analyzing the chemical compositions of the coatings it can be seen that the metallic matrix proportions are different: 10 % Co + 4 % Cr in case of WC CoCr coatings and 7 % Ni in case of WC CrC Ni coatings. Therefore the specimens had different corrosion behavior.

4. **CONCLUSIONS**

The HVOF spraying process was used to deposit cermet coatings WC CoCr and WC Cr Ni with good corrosion properties. Structural investigations and properties evaluation showed that both coatings are dense (porosity about 1 %), compact and without defects as cracks.
The corrosion resistance of the WC CoCr coating in a 1M NaCl was higher than of the WC CrCr Ni coating. This better corrosion behavior can be influenced by the chemical composition differences of the metallic matrix.

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REFERENCES


