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Sliding wear behavior of different HVOF sprayed cermet coatings

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The current study is focused on cermet based WC hard coatings, materials that are extensively used in applications requiring wear resistance. Two different powders WC-20%CrC-7%Ni and WC-10%Co-4%Cr were thermally sprayed on low-carbon steel substrates using the high-velocity oxygen-fuel (HVOF) process. The used powders were spheroidized having the grain sizes in the range of -10+2µm. Both coatings were characterized by scanning electron microscopy (SEM) and X-ray diffraction (XRD) in order to study their morphology and phases. The sliding wear resistance was determined using the pin-on-disk method. Comparative results showed that the WC-CoCr coating has better wear properties than the WC-CrC-Ni coating.

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1. Introduction

Cermet coatings have been successfully applied on the surface of different industrial components where wear and corrosion resistance is required. Thermal spraying is a less sensitive technique which allows the deposition of cermet materials onto gritblasted surfaces providing a flexible choice of coating thickness [1]. WC based coatings are one of the most resistant coatings available nowadays on the market, able to resist at various wear conditions such as abrasion, erosion or sliding [2]. The WC-10Co-4Cr powder is one of the most widely used for thermal spray applications because this material combines high hardness with a satisfactory toughness and good corrosion resistance [3]. The Co-Cr metallic matrix provides a good bond to the hard WC grains. In comparison with the above mentioned material, WC-20CrC-7Ni is a complex powder, containing tungsten carbides, chromium carbides and a Ni metallic phase. The amount of primary carbides is smaller than in WC-CoCr powder. Very little information regarding the deposition of WC-20CrC-7Ni powder with reduced powder grains is presented in literature. The powders were deposited by HVOF (High Velocity Oxy-Fuel) thermal spraying process. During the spraying process the powder particles projected on the substrate posses high velocities and are in a semi-molten state [4]. The deposition efficiency is related to the particle velocity [5]. A feature of the HVOF deposited coatings is the lamellar grain structure resulting from the rapid solidification of small semi-molten particles flattened from striking a cold surface at high velocity [6]. During the thermal spraying process the decarburization by oxidation of the tungsten carbide leads to the formation of W_2C and W in the coating [7]. This happens when the binder phase reaches the melting point, solubility reaction start to dissolve the WC crystals, which has as a consequence an increased amount of tungsten and carbon into the binder phase [8]. However the HVOF process is able to provide coating with low porosity with a low oxidation rate and reduced carbides decomposition. An important parameter in mechanical properties as well as wear performances of carbide coatings which shows a gain in wear performances is the reduced carbide grain size [9]. With decreasing grain sizes is difficult to spray quality coatings because the small particles are facing the risk of overheating which might cause oxidation and decarburization effects [10]. In order to make suitable coatings using as feedstock fine grain sized powders is it necessary to choose proper process parameters [11].

The objective of this research paper was to deposit cermet coatings using as feedstock WC/20mass % Cr3C2/7mass% Ni and WC/ 10 mass% Co/4 mass% Cr powders and to analyze their sliding wear behavior. The depositions were performed by optimizing the spraying process in order to achieve a low porosity level of the coating and a high coating efficiency.

2. Materials and experimental procedure

The materials used for investigations were two different sinterized powders: WC CrC Ni with the nominal composition 77%WC-20%CrC-7%Ni and WC CoCr having the composition 86%WC-10%Co-4%Cr. Both powders have the powder particle size range -10+2 µm.

To avoid different behaviours during flight in the spraying process, the selected powders had the same porous morphology. They were sprayed using the HVOF method (ID Cool Flow gun from Thermico firm, Germany) onto the surface of a low carbon steel (40 × 40 × 5 mm).

The substrates were previously degreased with acetone and gritblasted with corundum at 6 bars using a blasting distance of 230 mm.

The deposition was made using a combustion mixture composed from oxygen, hydrogen and kerosene. The specimens were constantly cooled with compressed air at 2.7 bar and the guns were cooled with water during the thermal spraying.

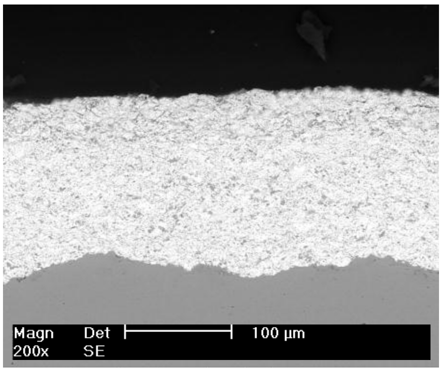
The morphology and the structure of the HVOF sprayed samples has been characterized by scanning electron microscopy (SEM; Philips XL 30 ESEM) and X-ray diffraction technique (XRD-Philips X'Pert) using a Cu-Kα radiation.

The sliding wear behaviour was determined by the pin-on-disk method using a tribometer from CJS Instruments Company. Coated samples surfaces were polished with diamond grinding, so that their surface roughness Ra would be the same. The wear rates were calculated using the measured values of the wear track depth as a result of the normal load applied to the ball (WC-Co with a 6 mm diameter). The operation conditions were: normal load 15 N, the relative velocity between the ball and surface v=20 cm/s, and the testing distance 1000 m (the trajectory was a circle with a radius of 5.4 mm).

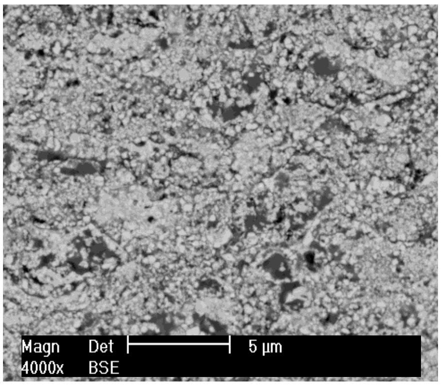
3. Results and discussions

3.1 Coatings morphology

The SEM cross-sectional images (at different magnifications 200x and 4000 x) of the as-sprayed coatings using the cermet powders are presented in Figs. 1 and 2.



(a)

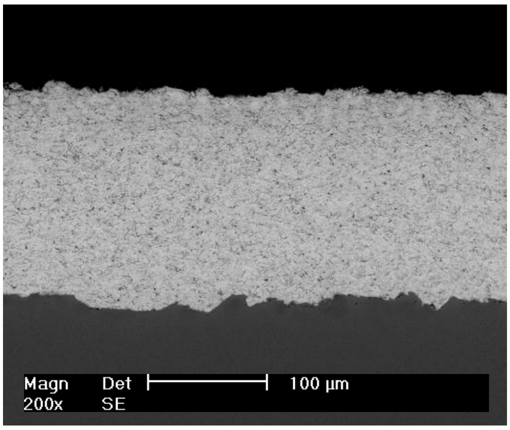


(b)

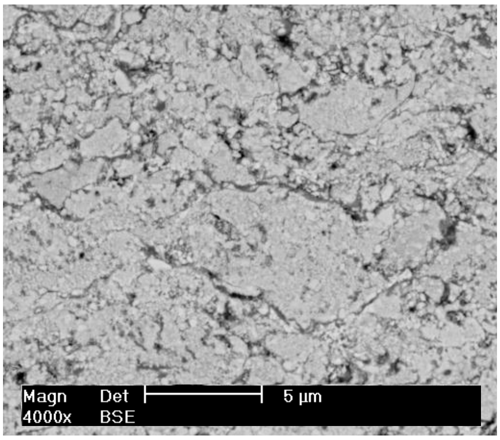
Fig. 1. SEM micrographs of the WC CrC Ni coatings (a) x 200, (b) x 4000.

In both cases one may observe a certain degree of porosity respectively of internal oxidation. The thickness of the deposited coatings seems to be around 200 µm.

Also it can be observed an excellent interface bonding between the coating and the roughened steel surface.



(a)



(b)

Fig. 2. SEM micrographs of the WC CoCr coatings: (a) x 200, (b) x 4000.

3.2 Phases analysis

The XRD patterns of the WC CrC Ni and WC CoCr coatings are presented in Fig. 3 and 4. Before measuring, the samples were ground and polished in order to obtain a smooth surface.

The measurements showed that the identified phases in case of WC CrC Ni coatings were: WC, W_2C, C_6Cr_{23}, $Cr_{0.8}Ni_{0.2}$. In case of WC CoCr coatings it was found WC, W_2C, Co and Cr. Comparing the XRD patterns, one can observed that in both cases a decarburization of the WC in W_2C appeared.

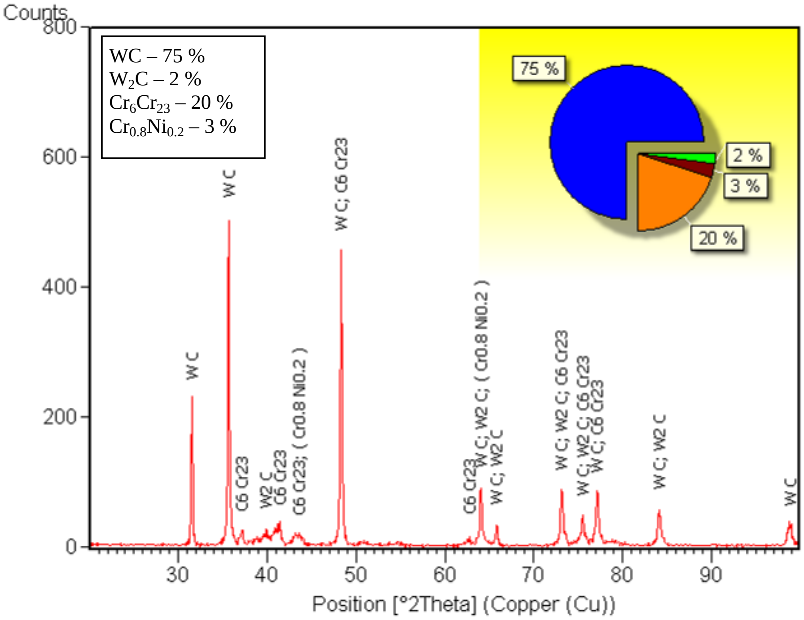


Fig. 3. XRD pattern of the WC CrC Ni coating.

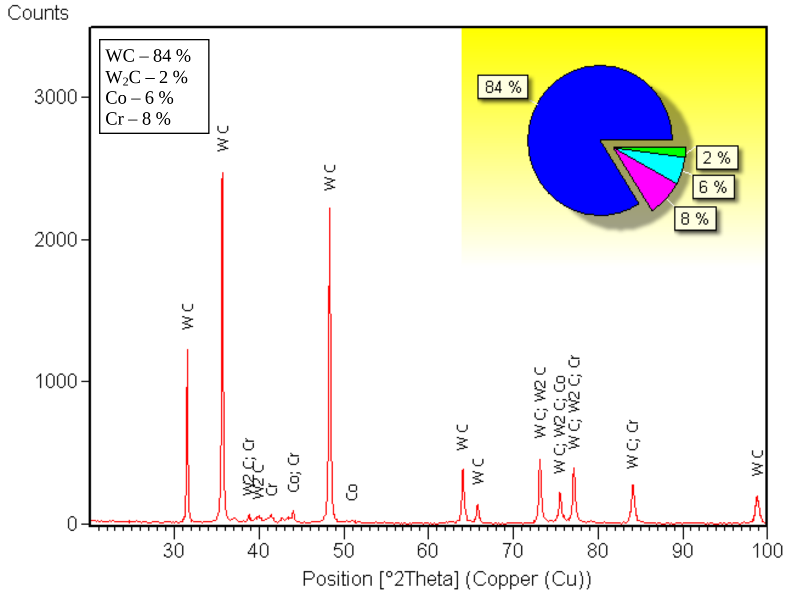


Fig. 4. XRD pattern of the WC CoCr coating.

3.3 Hardness measurements

It is well known that the hardness is an important parameter which can affects the sliding wear resistance of the coating. For this reason, microhardness Vickers measurements HV0.3 were performed. These were made in 10 differents points on the cross section of the coatings. The average microhardness values for the measured points were 1024 HV0.3 for the WC CrC Ni and 996 HV0.3 for the WC CoCr coatings. Comparing the results the micro hardeness looks to be almost similar for both samples.

3.4. Sliding wear resistance

The tribological characteristics of the cermet coatings depends on different properties such as coating composition, nature of phases and their distribution, microstructure, porosity, and residual stress.

The wear rates (the volumetric material losses) were obtained measuring the section of the wear track of the coating produced by the WC Co ball. During the tests the friction coefficient was also determined. In case of the WC CrC Ni this was 0.82, much higher in comparison with WC CoCr coating which has a friction coefficient of 0.37. By the WC CoCr on the wear track it has been noticed a thin film of free carbon (graphite) this was lead to decreasing of the friction coefficient. In case of the WC CrC Ni coating, the presence of Ni from the metallic matrix acts as a barrier for the carbon diffusion in order to form the graphitic traces on the samples surface

This is the reason why the wear rate of the WC CrC Ni coating (26.42 × 10^{-7} [mm^3/N/m]) was higher than of WC CoCr coating (12.72 × 10^{-7} [mm^3/N/m). A higher friction coefficient lead to a large amount of the material lost during the test. Also the width of the wear track was larger for the WC CrC Ni coating.

The results of the sliding wear rates are represented in the histograms from Fig. 5.

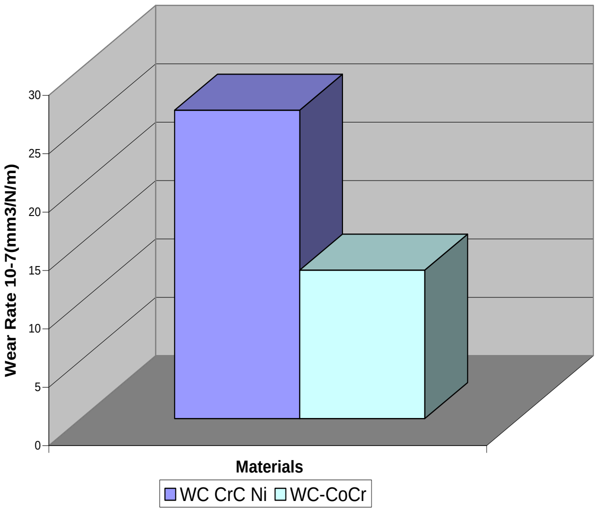


Fig. 5. Sliding wear rates of the tested coatings.

4. Conclusions

Two different cermet coating WC CrC Ni and WC CoCr have been deposited by HVOF spraying method in order to determine their sliding wear behaviour.

Analysing the obtained results it has been found that the WC CoCr had a better sliding wear resistance (lower rate) in comparison with the WC CrC Ni. The better sliding wear resistance of the WC CoCr is given by the graphitic traces formed during the test on the coating surface. By WC CrC Ni the friction coefficient was higher in comparison with the other coatings because the presence of Ni opposes to the carbon diffusion, resulting no carbon traces on the material surface.

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