A COMPREHENSIVE STUDY ON MICROSTRUCTURE OF APS CR-NI-RE COATING AFTER ELECTRON BEAM REMELTING

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Introduction

Thermal spray processes, such as APS (Atmospheric Plasma Spraying) represent an important and rapidly growing group of surface modification technologies, using a very wide range of solid feedstock materials, mostly in the form of particles or wires. For coating formation, plastic deformation of the feedstock particles at the moment of impact is a precondition after acceleration inside or outside of the spray gun. In most of the thermal spray processes, it is achieved by full or partial melting of the feedstock material, while the substrate remains unmelted, i.e. the coating is primarily mechanically bonded to the substrate. Hardmetals are one of the most important group of materials processed by thermal spray processes into coatings. Thermal spray is a technology that allows the development of large parts, which cannot be produced by the powder metallurgy for technical and economical reasons, with hardmetal characteristics via the application of hardmetal coatings. Coating properties depend both on the feedstock material and the spray process. APS technology allows formation of coatings with a desired chemical composition and thickness. However, it should be noted, that the thermal sprayed coatings are characterized by numerous defects associated with the process of depositing the powder on the previously prepared surface of the substrate material. In order to improve properties and eliminate material defects, choosing the right parameters of the process and optimisation of technology can be carried out. Moreover, the remelting process of sprayed coatings can be applied. Until now, the most commonly used technologies are gas flame, induction, laser beam and electron beam remelting.

In the present paper, the microstructural evaluation of plasma sprayed layers before and after electron beam remelting was presented. The microstructural analysis by means of light microscopy, scanning electron microscopy, chemical microanalysis by energy dispersive spectroscopy (EDS) analysis were carried out.

Experimental procedure

Ni 20% Cr + 30% Re coatings were prepared in three steps. Firstly, the plasma sprayed materials in the form of powder were produced at the Łukasiewicz - Institute of Non-Ferrous Metals from commercial NiCr powders by the modification of them with rhenium (Figs. 1 and 2). The technique of powder modification with rhenium has been already elaborated at the Łukasiewicz - Institute of Non-Ferrous Metals. The process is based on an application of thermo-chemical treatment for producing metallic rhenium from a raw material in the form of ammonium perhenate directly on the surface of modified powders.

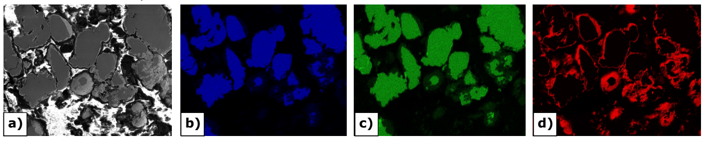

Figure 1. EDS analysis, Ni 20% Cr + Re powder for plasma spraying, a) general view, b) Ni, c) Cr, d) Re

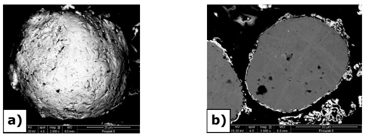

Figure 2. NiCr + Re powder for plasma spraying, a) general view, b) cross section

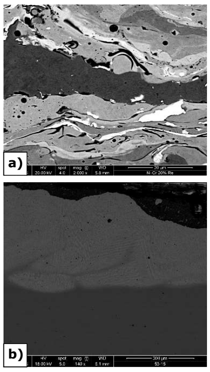

Figure 3. The cross-section SEM images of, a) APS coating, b) EB remelted coating

Secondly, manufactured alloy powders were sprayed on a stainless steel (316Ti) substrate by an APS facility (AP-50 Plasma Spray System). The plasma spraying parameters: current 530 A, arc voltage 690 V, shielding gas flow rate (Ar) 54 l/min, plasma gas flow rate (H_2) 9 l/min, transport gas flow rate (Ar): 5 l/min, spray distance 140 mm, travelling speed 0.4 m/s. Before plasma spraying the surface of the substrate was decreased and oxide layers were removed. Abrasive blasting using corundum abrasive F36 (500 -600 µm grain size) and F40 (425-500 µm grain size) were applied. After plasma spraying, a coating ~380 µm in thickness was achieved. The average roughness of the APS surface was 21.34 µm. Finely, electron remelting was carried out. XW150:30/756 (Cambridge Vacuum Engineering) machine was used. The following parameters were applied: U=60 kV, I=28 mA, v=0.5 m/min. EB remelting in vacuum was carried out.

The resultant plasma sprayed and electron remelting coated samples (cross-section) were cut, polished and etched chemically (NH_4F+HNO_3). The microstructures of the etched samples were investigated by light and scanning electron microscopy (SEM; FEI Nova NanoSEM 450) with energy dispersive spectroscopy (EDS).

Results and discussion

The cross-section SEM images of plasma-sprayed Ni 20% Cr + Re coatings are shown in Fig. 3. The APS coating has a typical plasma sprayed lamellar-like structure and contains a lot of pores and cracks.

The micro-area chemical composition of the plasma-sprayed coating were analyzed. The high-magnification SEM of cross-section of coating and EDS of different micro-areas are shown in Figure 4. The analysis of the chemical composition of the Ni-Cr-Re coating, revealed that the ratio of nickel and chromium in different areas is not the same. It was found that the distribution of elements is uneven. There are areas consisting mainly of nickel (blue) and chromium (red), nickel and chromium with approx. 30% rhenium addition (green). The EDS analysis, shown in Figure 5, reveals a uniform distribution of chemical elements in the electron-remelted zone for coating. This is a particular change compared to the initial state (before remelting), where the chemical composition of the individual splats are differ.

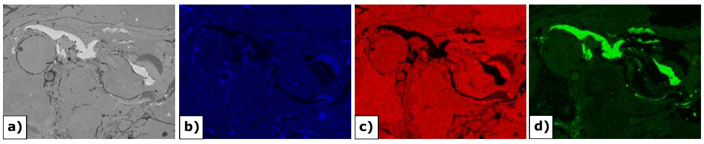

Figure 4 EDS analysis, Ni 20% Cr + 20% Re coating, a) general view, b) Ni, c) Cr, d) Re

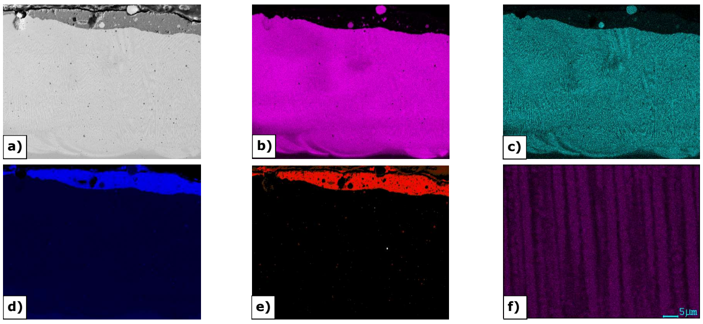

Figure 5. EDS analysis, Ni 20% Cr + 30% Re coating after EB remelting, a) general view, b) Ni, c) Re, d) Cr, e) O, f) Re at higher magnification, I=40 mA, v=1.0 m/min

Electron remelting can partially reduce the pores and microcracks of plasma sprayed coating, and coating became much denser. In addition, the lamellar defects of the plasma sprayed coating were erased and fine equiaxed grains with homogenous distribution were obtained (Fig. 5). So the compactness of the plasma sprayed coating was improved significantly using remelting. A dendritic microstructure can be observed in which boundaries of former particles/splats are no longer identifiable. However, it should be noted, that after remelting on the surface the thin layer reach in Cr (Fig. 5c) as well as oxygen (Fig. 5e) can be observed. Probably, the oxygen comes from the APS coatings. The high volume of oxygen in after thermal spraying can be detected. There are two stages of oxidation in thermal spray coatings: (i) in-flight and (ii) post-impact oxidation. In-flight oxidation encompasses two regions: (i) the jet core and (ii) beyond the jet core and before impact onto the substrate, where local atmosphere is entrained into the flame. Post-impact oxidation refers to the deposition, solidification, and cooling stages. Moreover, the higher content of Re in dendrited was observed (Fig. 5f). On the other hand in interdendritic spaces the content of Ni and Cr is higher.

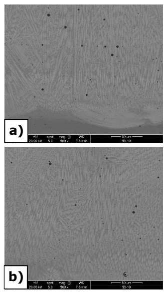

Figure 5. SEM images of the cross-sections of the coatings after electron-remelting treatment: 40 mA - 1.0 m/min

Conclusion

In this work, Ni 20% Cr + 30% Re coating fabricated by plasma spraying was remelted by electron beam, and the effect of remelting on microstructure of coatings was studied.

- The plasma sprayed coating shows a lamellar-like structure and has a lot of pores. The microcracks were also detected. Remelting can reduce the pores and microcracks and eliminate the lamellar defect. The microstructure of the coating becomes homogenous and compact.
- The Re content decreased after remelting, however the chemical composition became more uniform after remelting.
- The higher content of Re in dendrited was observed. On the other hand in interdendritic spaces the content of Ni and Cr is higher.
- After remelting the oxide layer CrO can be observed on the top.
- At higher power beam cracks after remelting process can be observed.

Acknowledgements

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