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Morphology and phase modification of HVOF-sprayed MCrAlY-coatings remelted by electron beam irradiation

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Abstract

The electron beam remelting process is one of the most convenient processes to reduce the disadvantages of thermal-spray coatings. The effect of high-energy electron beam irradiation on surface remelting and microstructural modification in MCrAlY coatings are investigated in this study. This surface treatment is made to modify the morphology and the phases of the coated layer in order to improve the corrosion resistance. The specimens were remelted by using a high-energy electron beam accelerator. The microstructure, corrosion resistance and phase modification were examined. Scanning Electron Microscopy, light microscopy and X-Ray Diffraction were performed to characterize the phase modification and morphology before and after the treatment.

Keywords: Thermal spraying; Corrosion; MCrAlY; Remelting; Electron beam

1. Introduction

For the protection of surfaces novel coating methods are increasingly used. Thermal spray processing has become an important technique, and new developments are resulting in more novel material synthesis routes and processing of unique material combinations. Thermal coatings can be deposited by a variety of methods, depending on the material and application of interest.

The present study is motivated by the need to optimise an electron beam remelting (EB—remelting) process of MCrAlY-coatings sprayed on copper substrate with the area size of approximately $100 \times 100\,mm^2$ [1].

The coatings show lamellar or flattened grains appearing to flow parallel to the surface. Chemical interaction occurs during spraying, notably oxidation, metallic particles oxidise over their surface forming an oxide shell. This is evident in the

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coating microstructures where the oxide inclusion outlines the grain or particle boundaries. Also the coatings contain some porosity caused by low impact energy (unmelted particles), shadowing effects (unmelted particles/spray angle), shrinkage and stress effects. These all constitute drawbacks when the thermally sprayed coatings are used to prevent corrosion.

The most efficient and reliable technique involves remelting of the sprayed coating by using an electron beam [2,3].

The goal of this paper has been to investigate the influence of the parameters used in electron beam remelting on the MCrAlY coatings in order to reduce the amount of porosity of the coating and roughness of the surface. The phase modification and the improvement in corrosion resistance [4] of the coatings has been studied.

2. Experimental procedures

CoNiCrAlY coatings (0.7–1 mm) with 8 wt% Al content were sprayed onto a copper substrate (5 mm thick) using the HVOF (High Velocity Oxygen-Fuel)-spraying technique. The chemical composition of CoNiCrAlY powder is shown in Table 1.

The electron beam system used was ESW 700/3-60 apparatus. Maximum beam input power was 3 kW. An incident electron beam was absorbed by the coating surface, and then the sprayed coating was remelted from its surface. The detailed EB-remelting conditions are shown in Table 2.

The CoNiCrAlY coatings have been subjected before and after electron beam remelting to phase analysis by X-ray diffraction (XRD). A Philips X'Pert PW 3020 diffractometer was used. The corrosion tests were carried out in 0.001 M sulphuric acid solution, using an electrochemical corrosion cell and a potentiostat/galvanostat PGP201 from Radiometer. The morphology of the samples has been characterized using scanning electron microscopy (SEM; XL 30 ESEM) and energy dispersive X-ray analysis (SEM/EDS) from Philips, and light microscopy (Leica-DM RME).

Table 1
Powder composition

Material	Co (%)	Ni (%)	Cr (%)	Al (%)	Y (%)
CoNiCrAlY	37.5	32	22	8	0.5

3. Results and discussion

3.1. Surface morphology

After the electron beam treatment, the MCrAlY coating presents a rapidly solidified surface. Fig. 1 shows SEM micrographs of the cross section of the MCrAlY-coatings before and after the treatment by electron beam. In Fig. 1(a) the presence of pores and oxides and also a highly rough surface can be observed. After the remelting, Fig. 1(b), the number of pores is reduced significantly and the structure is refined. Also, a smooth surface is achieved.

The remelted zone presents two distinct areas (Fig. 2). The upper region is free from oxides and pores showing that the structure was refined. In the lower region a higher quantity of oxides is present (the dark phase).

Analysing the EB remelting parameters it can be seen that the homogeneity of the structure varies especially with the current intensity. In Figs. 2 and

Table 2
Experimental conditions for EB remelting

Input power, *P*	0.5–1.5 kW	Oscillation (deflection)	
Voltage, *U*	30 kV	Width, *l*	12 (mm)
Current, *I*	10–40 mA	Frequency, *f*	1000 Hz
Speed, *v*	3–17 mm/s	Wave shape	Triangle, sin
Work distance, *L*	240 mm	Direction	*X* only, *X*+ *Y*