CHEMICAL STRIPPING METHODS FOR THE REMOVAL OF NiCrAlY THERMAL SPRAY COATINGS

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The present paper is focused on the "stripping" of serviced blades and vanes for gas turbine, which need the removal of the coating in order to be repaired and refitted with a new coating. The stripping process requires, normally, the separate removal of the top coat (Yttria Partially Stabilized Zirconia, YPSZ) and of the bond coat (MCrAlY where M stays for Co, Ni or both). The present paper examines only chemical procedures able to remove the NiCrAlY bond coat. The blades and vanes surfaces after removal of NiCrAlY coatings were characterized from the point of view of surface morphology, metallurgical structure and chemical composition. The efficiency of the acid solution in NiCrAlY removal has been investigated and the behaviour of two Ni based alloys substrates in aggressive environment has been tested. The HCl based stripping solution shows good performances in Vacuum Plasma Sprayed NiCrAlY coatings removal from Ni superalloys. The tested stripping procedure is fast and safe because no damage to base materials has been noted.

Key words: coating, plasma spraying, nickel alloys

1. Introduction

Coating technologies are rapidly becoming a fundamental method in improving materials properties. In particular, thermal spray technologies are an effective and versatile method used to obtain coatings of different thickness with a good cost-quality ratio in the aerospace field as well as for gas turbines in the power generation sector. In these areas, the surface properties of the base materials can be improved by means of antioxidation materials, such as MCrAlY (where M means Ni, Co or a combination of both), and thermal barrier coating materials, such as Yttria Partially Stabilized Zirconia (YPSZ).

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MCrAlY coatings are used to improve the resistance of the component to aggressive media at high temperature (900–1000 ℃), while the low thermal conductivity of Zirconia coatings decreases the in-service temperature of the components [1]. The system MCrAlY/Zirconia is normally called Thermal Barrier Coating (TBC), where the MCrAlY layer acts as a bonding layer between the Zirconia coating and the substrate and is normally termed "bond coat". MCrAlY coatings are normally manufactured using thermal spray technologies such as Vacuum Plasma Spray, Air Plasma Spray, High Velocity Oxygen Fuel (HVOF) depending on the specified porosity and oxides content. Zirconia coatings are almost always produced by Air Plasma Spray [2, 3].

In the aerospace and power generation sectors, coating removal is an important part of the process cycle. The coating removal methods, called also "decoating" and "stripping", are used to recycle unsuccessfully coated parts or, more often, for reconditioning serviced parts after their functional service. Stripping is used to remove damaged "in service" coatings, the component can be then repaired and finally re-coated with a new coating.

The main characteristic of the stripping procedure is to guarantee the complete removal of the coating without damaging the substrate. Stripping must not cause corrosion or roughening of the substrate surface and it must ensure a minimum dimensional change of its geometrical characteristics. Stripping of ceramic and MCrAlY layers remains a delicate problem in industrial production, for which the perfect solution has not been found yet [4–6].

The present paper focuses on the removal of NiCrAlY coatings performed by chemical attack using a solution based on hydrochloric acid. The results obtained show that the method is safe and effective for stripping various base materials such as conventional casting MAR M247 and single crystal MK4.

2. Experimental

NiCrAlY alloy coatings of thickness in the range of 300–400 μm were deposited by Vacuum Plasma Spray on a conventional casting Ni based alloy containing also elements as Co, W and Mo. The coating material was commercial NiCrAlY powder with a nominal grain size distribution of 15–45 μm. After deposition, the samples underwent a diffusion treatment in vacuum at about 1100 ℃ for two hours.

Furthermore, in order to understand the effects of acid attack on the substrate surface, a test has been carried out by immersing different substrates materials in the acid solution: two Ni based super alloys have been chosen for the test: MAR M247 in form of conventional casting and MK4 in form of single crystal.

Stripping was performed in an HCl based solution to which a corrosion inhibitor was added (composition and concentration are proprietary data of Turbocoating S.p.A.). The treatment consisted in alternating immersion in the acid solution and sand blasting of the surface to be stripped, in order to reactivate the sample surface for a total of 7 cycles; for each cycle the immersion time was one hour.

The samples were examined using optical microscopy and microgeometrical evaluation of the surface morphology with determination of 3D roughness parameters.

3D microgeometrical measurement and analysis have been performed by means of a Three-Dimensional Digital Stylus Profilometer (3DSP). The 3D parameters obtainable by this method are based on three-dimensional extensions of 2D parameters defined in the ISO 4287 and DIN 4776 standards [7]. In the paper the considered parameter has been the arithmetic mean roughness (S_a).

For metallographic investigation a metallographic optical microscope (Zeiss Axiovert 100A) with an image analyzer based on gray contrast has been used.

X-ray Photoelectron Spectroscopy (XPS) analysis has been performed on sample surfaces in order to investigate its chemical composition after each hour of immersion in the acid. XPS measurements were performed using a standard UHV-XPS spectrometer equipped with an Mg source [8].

3. Results and discussion

The acid attack resulted in the removal of the coating at speeds of the order of 100–150 μm/hour (the results are reported in Table 1). We observed that the acid had the effect of creating a visually detectable dark layer on the sample surface. This layer was found to progressively inhibit the stripping reaction. We also observed that the stripping speed could be increased by reactivating the surface by sand blasting until the dark layer is not visible any more. XPS analysis has been performed on the dark layer in order to investigate its chemical composition. The quantitative XPS analysis confirms that this layer results from the accumulation of compounds of organic corrosion inhibitor as evidenced by the presence of large amounts of organic carbon.

Table 1. Coating thickness measurement before and after immersion in the acid for different time and coating removal rate

Immersion time	Thickness before stripping [μm]	Thickness after stripping [μm]	Stripping rate [μm/h]
1 h	330	170	160
2 h	400	60	170
3 h	350	15	112
4 h	400	0	100
5 h	380	0	–
6 h	300	0	
7 h	300	0	

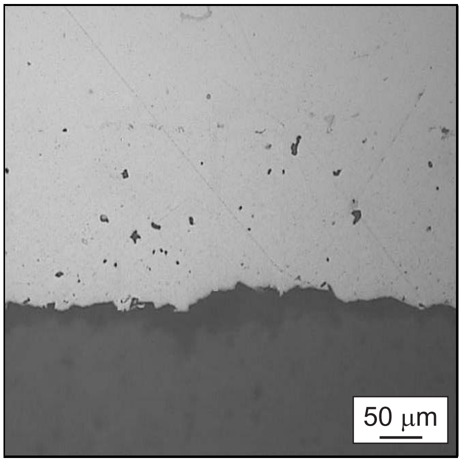

Fig. 1. Micrograph of the NiCrAlY coated sample after 1 hour of immersion in acid solution. The initial thickness was 330 μm, at this stage it was reduced to about 170 μm.

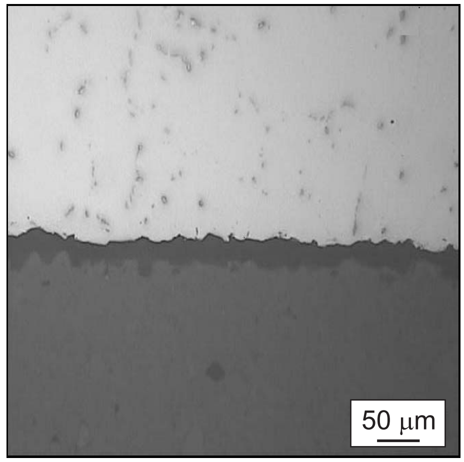

Fig. 2. Micrograph of the NiCrAlY coated sample after 4 hours of immersion in acid. The initial coating thickness was 400 μm. The coating was completely removed by the treatment.

We observed that, even using this reactivating procedure, the coating removal rate decreases with progressive stripping from about 150 μm/h to about 100 μm/h for periods up to 5 hours of treatment. This could be due to variation of acid concentration since the used acid is not replaced during the process.

The results of the metallographic analysis on the treated samples show that the coating structure before stripping is homogeneous and the porosity is near to zero. The examination carried out every hour during the stripping procedure showed that coating structure remains the same also during progressive stripping. Figures 1 and 2 show the optical micrography of the samples after 1 h immersion and after 4 hour when the coating has been completely removed.

Regarding the analysis on the MAR M247 and MK4 substrates, the effect of complete stripping and possible damages due to corrosion on the substrate surface were investigated by visual inspection, metallographical analysis and determination of the 3D roughness parameters. No difference was detectable in the visual aspect of parts which had been stripped in comparison with never coated parts. The metallographic analysis (Figs. 3 and 4) shows that no damage to the surface is caused by the treatment. The quantitative roughness measurements are shown in Fig. 3 for the S_{a} parameter. The figure shows that there are no significant changes in the roughness due to the treatment.

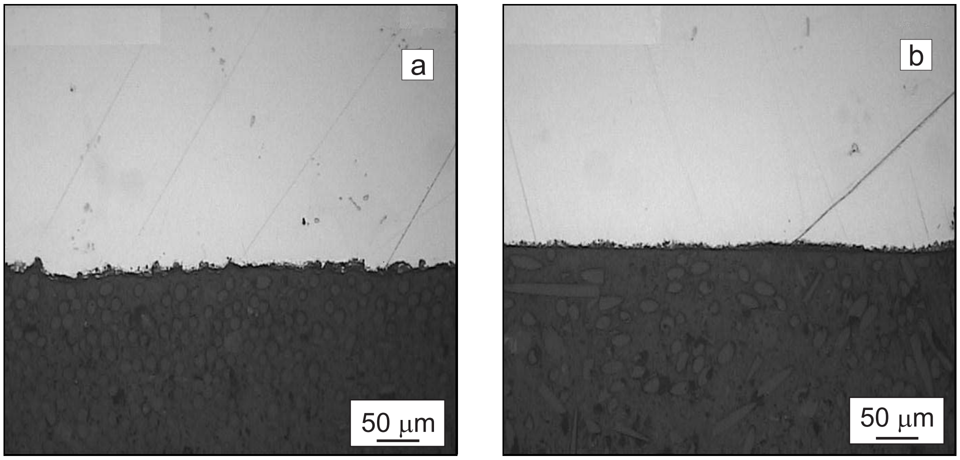

Fig. 3. Optical microscopy images of section of the MK4 single crystal sample. a) virgin substrate, b) substrate alloy after complete removal of the coating by 7 hours of treatment.

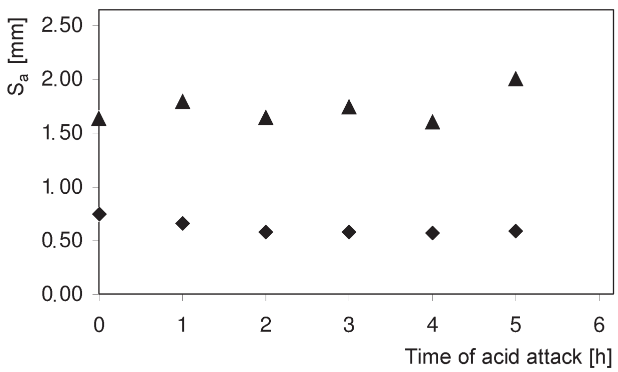

Fig. 4. Trend of the roughness parameter S_a in different time of treatment: the triangular shape is for MK4 substrate and the rhombus shape is for MAR-M247.

4. Conclusion

The method described in the present paper is an effective stripping method, which does not affect the characteristics of the tested Ni alloys substrates, namely conventional casting (MAR M247) and single crystal (MK4). The method is able to remove several hundreds of μm of NiCrAlY coating at rates of about 100÷150 μm/h. Since the usual NiCrAlY thickness for gas turbine parts is in the range of about 400–600 μm, the whole process can be performed in few hours without the need to protect uncoated parts.

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