

NiAl Behavior at Plasma Spray Deposition

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Abstract

Behavior of stoichiometric and near-stoichiometric NiAl at plasma spray deposition, without and with a bond coat, for coating layers realization on a low alloyed steel substrate, has been investigated. In all variants, NiAl particle melting and subsequent welding at the impact with substrate were observed, forming a relatively compact and adherent coating layer with the NiAl stability maintaining - all assuring the coating layer oxidation and corrosion resistance. Good results from these points of view, also validated through corrosion tests, were obtained for 45:55 Ni:Al composition without a bond coat but adopting an Ar protective surrounding of plasma jet.

Keywords : Plasma spray deposition, oxidation/ corrosion resistant coatings, NiAl coatings

1. Introduction

Owing to its outstanding properties of oxidation and corrosion resistance at both ambient and elevated temperatures, as determined by the ability to form compact, very adherent, Al-rich oxide scales, NiAl is going to be widely applied to the high oxidation and corrosion resistant coatings realization [1]. It has too other merits such as high melting point, low density, high elastic modulus-density ratio, high thermal conductivity [2]. These recommend it too for the high temperature structural applications. Despite of numerous investigations focused on overcoming the NiAl known limitations in using as structural material, the obtained results are not yet satisfactory. Thus, intensive researches are focused on its application to coatings [3].

In this connection, the present paper is focused on the establishing of NiAl behavior at plasma spray deposition, which seems to encounter problems due to the mentioned Al₂O₃ scale of high melting point and low diffusivity.

2. Experimental and Results

Two NiAl compositions were adopted for coatings realization: a stoichiometric NiAl (50:50 at.%) and a NiAl-Al solid solution (45:55 at.%). Both were elaborated by SHS in thermo-explosion mode and certified from the phase and composition points of view by XRD and EDS analyses. The as obtained bulk NiAl was then ball milled to -100 [μm], to get the necessary powder for plasma spraying.

The plasma spray depositions were realized using a METCO type apparatus and the processing parameters

recommended by its constructor [4]. A mixture of H₂ and N₂ was adopted as plasma forming gas, while technical N₂ was used as carrier gas. Argon was injected around the plasma jet in some tests to prevent oxidation. The substrate used was a low alloyed steel plate, prepared by sand blasting. AMDRY 995C bond coat was too applied in some tests [4]. The coating layers obtained were characterized by optical, SEM and EDS analyses, performed at a cross section. The coatings corrosion behavior was investigated by the cyclic voltammetry and by exposing to saline vapors.

NiAl behaviour at plasma spray deposition without a bond layer. From Figure 1, showing the SEM cross section images of the microstructure in the coating layers realised from the two considered compositions, without a bond layer and without the plasma jet protection, results that the 45:55 NiAl coating is more uniform and compact and its interface

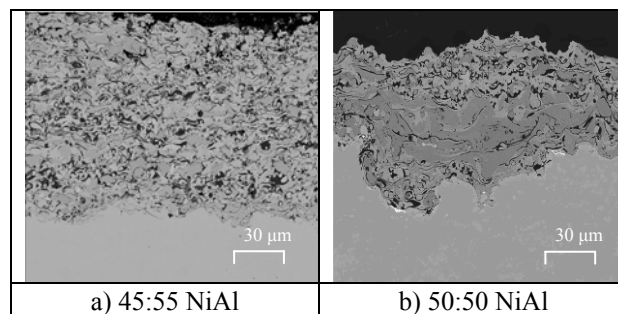


Fig. 1. SEM images of coatings realized without a bond coat and plasma jet protection.

with the substrate is more coherent than of 50:50 NiAl. This

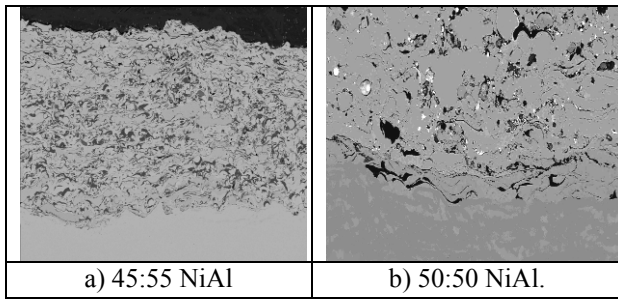


Fig. 2. SEM images of coatings realized without a bond coat and with plasma jet protection.

may be attributed to its aluminum excess that facilitates both particles melting and their more advanced flatening and welding at impact with the substrate. The higher porosity of 50:50 NiAl coating is probably due to the lower plasticity of its particles owing to them being covered by a thin Al_2O_3 layer during spraying. The oxygen presence inside the layer was confirmed by EDS analysis (not given). This situation would radically change if argon is injected.

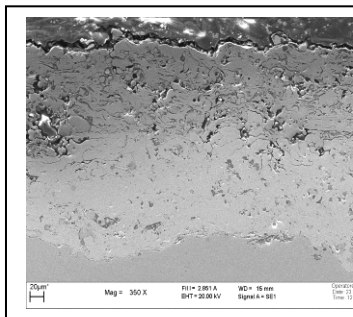


Fig. 3. The 45:55 NiAl coating layer with AMDRY

Really, in Figure 2, showing the coating layers realized with Ar injection, one can see a notable difference of density, uniformity and interface aspect of these coatings comparing to those realised without Ar. Even in this case, the 45:55 NiAl showed a better behavior than 50:50 one.

NiAl behavior at plasma spray deposition with a bond coat. Based on the above findings, the use of a bond coat was limited to the 45:55 NiAl composition and using Ar protection. Figure 3 shows the obtained microstructure. Certainly, it is more uniform and dense in the bond coat, while in the NiAl layer it seems to be

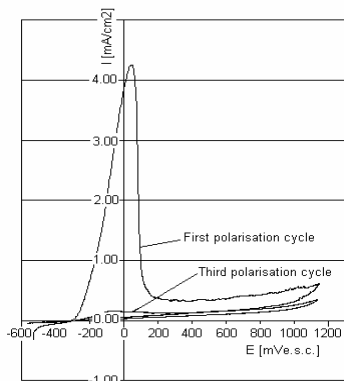


Fig. 4. Voltammograms of the first and third polarization cycles. Electrolyte: 1N H_2SO_4 .

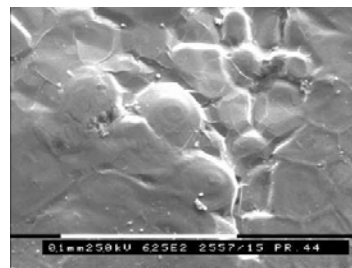


Fig. 5. The sample surface after three polarization cycles.

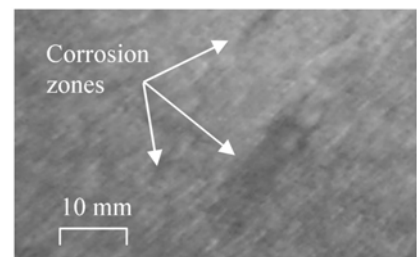


Fig. 6. 45:55 NiAl coating surface after 340 h in saline vapours at 80 °C.

even less uniform and dense than that realized without the bond coat, probably due to the bond coat melting at the NiAl deposition. So, the best results appear to be obtained by 45:55 NiAl without a bond coat.

SEM and EDS analyses performed on such a layer (not included) confirmed this conclusion. On them, 45:55 NiAl shows a compact microstructure and the determined Al/Ni contents very close to the initial ones.

Corrosion behavior of 45:55 NiAl coatings. Figure 4 presents the direct anodic curves after the first and the third complete polarization cycles for the 45:55 NiAl coating without a substrate. As can be seen, the characteristics of behavior to passivation – critical current density and passivation current – dropped drastically from the first to the third polarization cycle, indicating an irreversible anodic oxidation process. Really, the sample surface showed a compact oxide film (Fig. 5), proving its good passivation. A similar behavior was obtained for coatings that were exposed to saline vapors. Figure 6 presents the surface of such a coating after 340 h of exposure at 80 °C. Only the beginning of the corrosion process is observed, showing good corrosion resistance.

3. Summary

NiAl can be successfully used in oxidation and corrosion resistant coatings realization by plasma spray deposition. The best behavior in terms of density, uniformity and adherence has been obtained for a near-stoichiometric Al-rich composition, with Ar injection as protective gas around the plasma jet and without bond coat.

4. References

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