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ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN : 0974-4290
Vol.6, No.3, pp 1948-1951, May-June 2014

ICMCT-2014 [10th – 12th March 2014]
International Conference on Materials and Characterization Techniques

Microstructure and Characterization of Thermal sprayed Ni-Cr/Al_2O_3 coating

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Abstract: Thermal spray coating techniques are being extensively used for coating various materials for different applications. To combat the wear and to enhance the life, the coating should have the desirable properties like hardness, toughness, lower defects, homogeneous microstructure, and good adhesion to the substrate. The wide spectrum of properties can be achieved with composite coatings which consist of a hard reinforcing phase embedded in a tougher matrix material.

In this work, Ni-Cr/Al_2O_3 composite coating with an approximate thickness of 150 µm was produced by atmospheric plasma thermal spraying on SS 304 substrate. The main objective of this work was to characterize the Ni-Cr/Al_2O_3 coating. The microstructure and composition of powder and coatings were studied by Scanning Electron Microscopy (SEM), Optical Microscope and X-ray diffraction (XRD). The coating characteristics such as porosity, micro-hardness and surface roughness were evaluated.
Key words: Plasma Spray Coating, Nickel, Alumina, Porosity, Micro-hardness.

1. Introduction

In the wide variety of industry application, machinery parts in boilers, pipelines, and transfer of fluids area has to work under the severe conditions where they suffer from corrosion and wear. Hence, surface modification technology, especially coating technology provides an efficient way of protecting the components against various types of material degradation [1]. This can be achieved by thermal spray coatings which are often considered for its potential alternative to its traditional coating [2]. Atmospheric plasma spraying is the most versatile thermal spray technique. This technique uses either a ceramic or a composite material which can not only provide corrosion and erosion resistance but also thermal insulation.

Ni is a transition metal which hard and ductile. In addition, it has a high bonding strength, better corrosion behaviour, and excellent resistance to abrasion and erosion wear [3]. Alumina is a ceramic material which retain up to 90% of their strength even at 1100^{0}C. Alumina coatings developed by plasma spray technique, exhibit very high hardness, excellent wear resistance, and high temperature stability, which are essential for tribological and high temperature erosion applications [4].

Considering all these aspects, in this work a 60% wt NiCr-40% wt Al_2O_3 composite coating was developed on SS304 substrate using the atmospheric plasma spraying technique. The microstructure analysis, Phase composition evaluation and Microhardness tests were performed.

2. Experimental Details

2.1 Substrate Material and Coating Development

In this study, SS304 material with a chemical composition of 0.08C, 2Mn, 1Si, 18-20 Cr, 8-12Ni, 0.045P, and 0.03S was used [5]. The specimens, each measuring 25 mm × 25 mm × 6 mm, were polished with SiC papers down to 180 grit. Subsequently the specimens were grit blasted at a pressure of 3 kg/cm^2 at the standoff distance of 120-150mm with alumina grit having grit size of 60 to provide better adhesion between the coating and substrate. The average surface roughness of the substrate were found to be in the range of 4-5 µm. The samples were cleaned with acetone in an ultrasonic unit (Make: Lark, India).

The composite coating powder of 60% wt Ni-Cr/ 40% wt Al_2O_3 was used to spray to deposit coating using the Atmospheric Plasma Spraying unit (M/s Spraymet Surface Technologies Pvt Ltd, Bangalore, India). The particle size of Ni-Cr was -53+20 µm and that of Al_2O_3 was -45+22 µm. The fig. 1 shows the morphology of the coating powders.

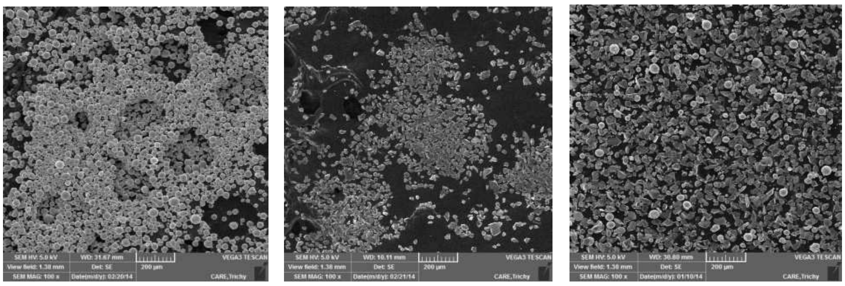

Fig. 1. a) Morphology of Ni-Cr b) Morphology of Al_2O_3 c) Morphology of Ni-Cr/Al_2O_3

Argon was used as the primary gas amalgamate hydrogen (fuel gas) as secondary gas. The coating parameters used are arc current of 490A, arc voltage of 70V, argon flow rate of 80 lpm, hydrogen flow rate of 25 lpm, carrier gas flow rate of 39 lpm and spraying distance of 127 mm.

2.2 Characterization of the coatings

The particle sizes of the raw materials used for coating were characterized using a Laser particle size analyser (Make: Malvern Instruments). The phase composition of coating powder and the as sprayed coatings were evaluated using the X-ray diffraction (XRD) apparatus (Rigaku D/Max ULTIMA III under CuK_{α} radiation (λ = 1.5406 Å) in the scanning angle range of 10° to 90°. The surface morphology and structure were analysed using the scanning electron microscope (Make: JEOL Model: 6701F). For the cross sectional examination, the samples were cut using the abrasive wheel cutter and mounted in resin by using a hot mounting press. The Porosity in % area was determined from micrographs using an image analyzer (Make: Getner, and Model: Inverto plan). The micro-hardness measurement was made using a micro hardness tester (Make: LEITZ MINILOAD 2 Model: LEITZ WETZLAR) at a magnification of 500X. The surface roughness of as- spayed sample was determined using the stylus type surface roughness tester (Make: Mitutoyo, Model: SJ 201).

3. Results and Discussion

3.1 Coating structure and Properties:

Porosity of the 60 Ni-Cr/40 Al2O3 coating was found to be around 5.08%. The measured values of porosity were found to be in good agreement with the finding of H. S. Grewal [6]

The microhardness value for the substrate SS304 was found to around 120-150 HV. The hardness value increased to 338-400 HV for the coated specimen. The surface roughness (Ra) values of the as sprayed coatings were found to be around 6.95 µm.

XRD analysis of the coating and powder are shown in the fig 2. In our work the percentage of Ni will be more hence the image shows the Ni peak high when compared with Al_2O_3. In the image the presence of NiO is the weak intensity of the coating combined with the Ni as the main phase. The presence of the NiO indicates that some oxidation of the Ni powder has taken place during the deposition process. In addition, comparing both figures it was found out that the **γ** phase of Al_2O_3 got dissolved during coating process, which might be due to transformation from **γ** to **α** phase.

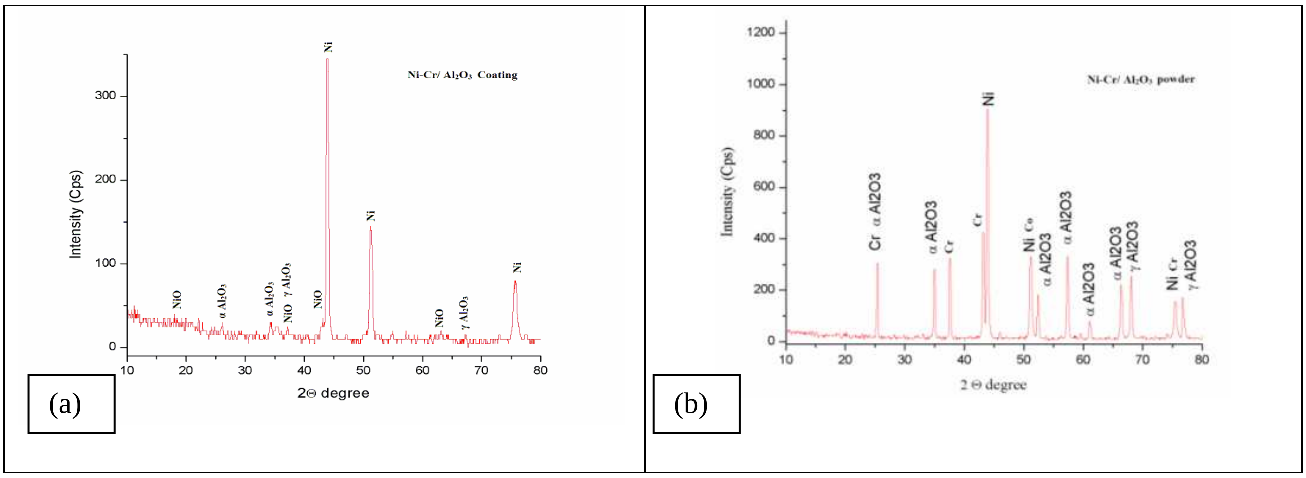

Fig. 2 : X-ray diffraction patterns for a) Ni-Cr-Al_2O_3 coating b) Ni-Cr-Al_2O_3 powder

The SEM morphology for the plasma sprayed Ni-Cr/Al_2O_3 coating on is shown in the fig. 3 revealed that the coating was uniform. It is also observed that the coating contains splats, irregular mere pores typical of a plasma spray process. The dark contour shows the presence of nickel. The globules near the splat boundary indicates any unmelted particles present in the coating.

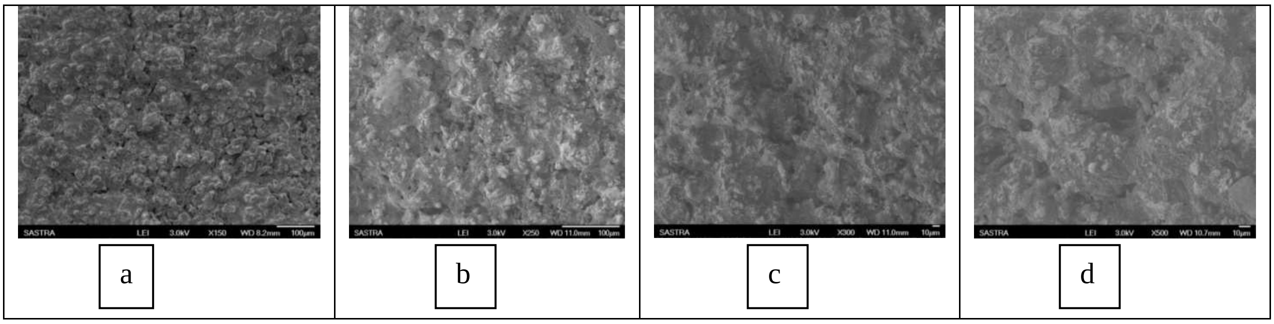

Fig 3 Surface SEM microscope image of coating at different magnification

4. Conclusions:

60Ni-Cr/40 Al_2O_3 composite coating was carried out on the SS304 substrate using the atmospheric plasma spraying technique. The coating was found to pose porous and tiny cracks with an average porosity of 5.08%. The coatings also exhibited a maximum micro hardness value of 400 HV. Hence, these coatings are suitable for surface protection because of their exclusive properties.

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