Ni-5Al - CLADDING BY THERMAL ARC SPRAYING

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Abstract: Thermal spraying is the process of applying coatings of high performance materials, such as metals, alloys, ceramics, onto more easily worked and cheaper base materials. Electric arc spray tehnique is a thermal spray process that uses a direct current electric arc.
This work focuses on the microstructural and hardness properties of Ni-5Al claddings deposited on steel, iron and duralumin alloy substrates by using the Electric Arc Thermal Spraying method.
The microhardness of the Ni-5Al coatings and of the three substrate materials was measured with a Vickers indenter tester. For microstructural characterization Nikon Eclipse MA100 inverted metallurgical microscope was used. All the Ni-5Al cladding results are compared with Ni-2Al cladding experiments made by the same research team [11]. The main results obtained by Ni-5Al coatings were obtained with good bond capacity on all substrates, with uniform porosity distribution in all cases.
Keywords: Ni-2Al cladding, Electric Arc Thermal Spray, microstructure, adherence, microhardness.

1. INTRODUCTION

Thermal spraying is the process of applying coatings of high performance materials, such as metals, alloys, ceramics, cermets, and carbides, onto more easily worked and cheaper base materials [1, 10].
Thermal spraying can provide thick coatings, over a large area at high deposition rate as compared to other coating processes such as electroplating, physical and chemical vapor deposition, etc. Wire Flame and Electric Wire Arc are two of the most common thermal spray techniques they also are cost effective and productive methods [6].
Electric arc spray processes, unlike the other thermal spray processes use a direct-current electric arc. Because the wires are melted directly by the arc, the thermal efficiency of the electric arc spray process is considerably higher than that of any other thermal spray process [3, 6]. Traditionally it is used as a cost-effective method for providing corrosion resistance to large steel structures or wear resistance to smaller metal components [2].
Wire arc spraying is a technique in which tow consumable wire electrodes are fed from a continuous reel to an arc-spraying pistol located within 80 – 150 mm from the substrate. At the nozzle of the pistol the wires are placed at approximately 4 mm apart. The wires are connected to a high-current direct-current power source which creates an arc that melts the wires. The molten particles are then atomized and propelled by a compressed gas toward the substrate [3, 8].
Upon contact, the particles flatten onto the surface and mechanically bond first onto the roughened substrate and then onto each other as the coating thickness is increased. The quality of thermal sprayed coatings is directly related to the properties of the molten particles such as size, temperature, and velocity [8,12].
Ni-5Al coatings are recommended for use in the following applications: bond coatings, salvage and build-up of machinable carbon steels and corrosion resistant steels, conditions that require fret resistance, oxidation resistance up to 650^{o}C.

2. EXPERIMENTAL PROCEDURE

2.1 Development of coatings

Three types of substrate materials were used for coating deposition: steel, iron and duralumin alloy. These materials were cut to form samples. The samples were polished, degreased and blasted before electric wire arc spraying. Metco Smart Arc equipment with a hi-velocity air cap was used for coatings deposition using the spray conditions:

- air pressure=2.2bar;
- voltage=30V;
- amperage=200 A;
- spray distance = (100–120) mm;
- deposit effinciency = 80 (%);

We obtained Ni-5Al coatings by using Sulzer Metco 8400 wire. Sulzer Metco 8400 is a nickel-aluminum pre-alloyed wire which has been specifically designed for electric arc spraying [5].
The chemical composition of Ni-5Al wire used in the present study is: 0.48%Mn, 0.002%Fe, 0.005%C, 5.15%Al, Rest%Ni. This alloy has exceptionally high bond strengths due to its exothermic nature.
Ni-5Al coatings have also a high degree of structural integrity, are extremely dense and can tolerate oxidizing atmospheres at temperature up to 650^o C.

2.2. Microstructural characterization

The microstructure of a material can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high / low temperature behavior, wear resistance, and so on [7].
Important thermal spray coatings features, which combine to determine the properties of a coating, include the lamellar or layered splat structure, entrapped unmelted or resolidified particles, pores, oxide inclusions, grains, phases, cracks and bond interface [3].
The samples were successively polished and analyzed using Nikon Eclipse MA100 inverted metallurgical microscope. Metallographic samples were examined using different degrees of magnification. Our main goal was to observe the coating-substrate interface and determining the coatings adhesion. We also wanted to see the coatings porosity, uniformity and thickness.

2.3. Microhardness analysis

The microhardness of coatings and of substrate was measured with a Vickers indenter tester (FM 700 hardness tester). The Vickers hardness test method consists of penetrating the test material with a diamond indenter, in the form of a right pyramid [4].
Usually microhardness test is made with loads not exceeding 1 kgf. We used a load of 0.1 kgf. The microhardness was taken along the cross section, spanning part of the substrate and the full thickness of the coatings.

3. EXPERIMETAL RESULTS

3.1. Microstructural characterization

Electric wire arc thermal spray technique was used for Ni-5Al coatings deposition on three different substrates. Cross-sections of Ni-5Al coatings are shown in figures 1-3. From these micrographs we can say that at the coating-substrate interface the porosity has a low level. This shows a very good adhesion of the coatings. Another observation that can be made is that the interface has a wavy shape. This may by caused be the droplet temperature at the impact with the substrate, but also by the substrate hardness. The wavy shape of the interface can be seen especially at duralumin alloy substrate (figure 3).

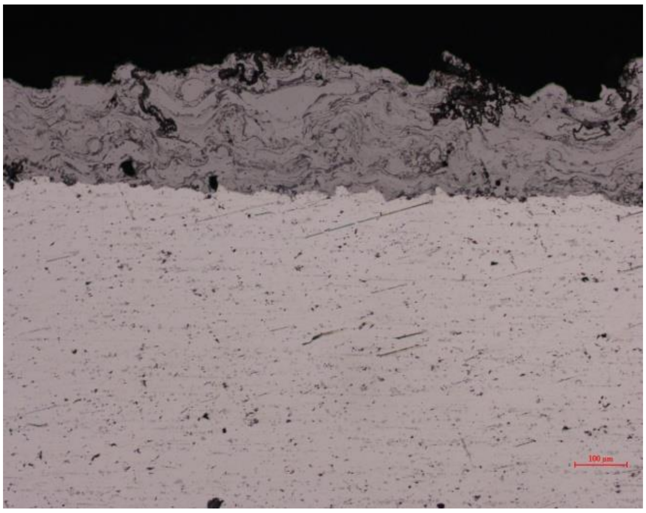


Fig. 1. Microstructure of cross-section of Ni-5Al cladding deposited on steel substrate

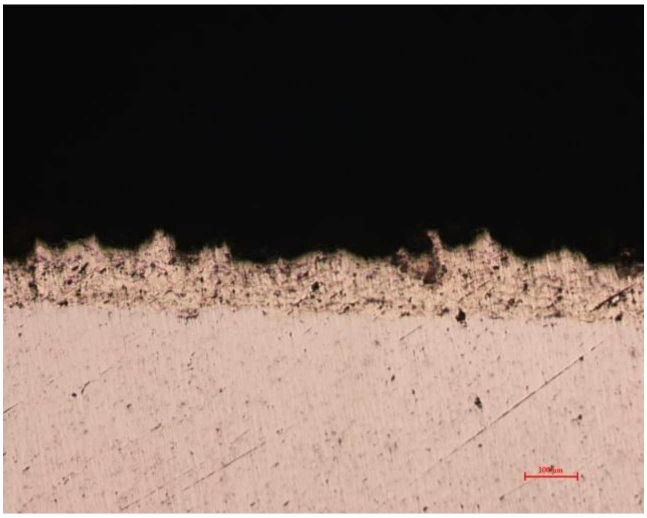


Fig. 2. Microstructure of cross-section of Ni-5Al cladding deposited on iron substrate

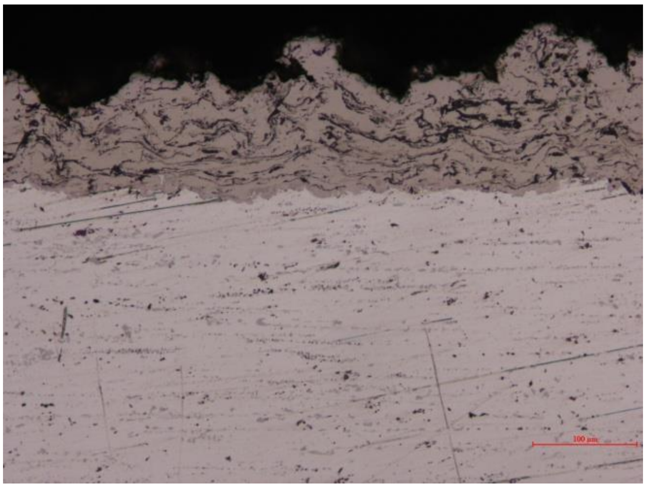


Fig. 3. Microstructure of cross-section of Ni-5Al cladding deposited on duralumin alloy substrate

Coatings are uniformly deposited on each specimen. Ni-5Al coating deposited on iron substrat has a thickness of about (150–180)µm, on steel of about 200 µm and deposited on duralumin alloy of about (210-240)µm.
Porosity is another important property of thermal spray coatings. In this case we can observe that coating deposited on duralumin alloy has a low porosity compared with Ni-5Al deposited on iron.

3.2. Scratch Test

Scratch Testers are dedicated instruments for characterizing the surface mechanical properties of thin films and coatings, e.g. adhesion, fracture and deformation. The scratch tester's ability to characterize the film-substrate system and to quantify parameters such as friction and adhesive strength, using a variety of complementary methods, makes it an invaluable tool for research, development and quality control. This technique involves generating a controlled scratch with a sharp tip on a selected area. The tip material - commonly diamond or hard metal (WC) is drawn across the coated surface under constant, incremental or progressive load. At a certain critical load the coating will start to fail. The critical load data is used to quantify the adhesive properties of different film-substrate combinations. In addition to acoustic emission, the Scratch Testers measure the applied normal force, the tangential (friction) force and the penetration depth. These parameters, provide the mechanical signature of the coating system. In our case, some data are given in micrografs presented in figure 4.

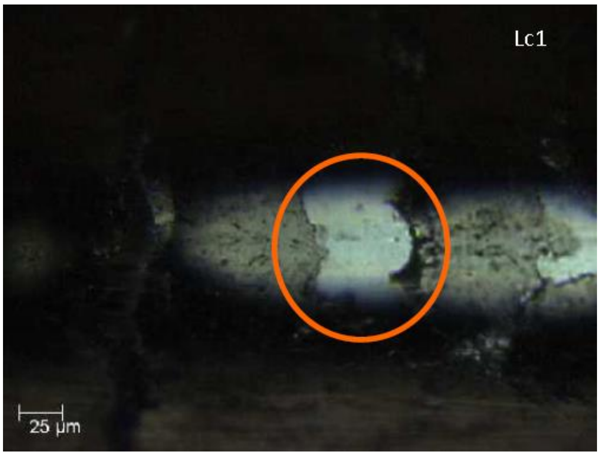
3.3. Microhardness analysis

Microhardness values measured for Ni-5Al coatings for steel, iron and duralumin alloy are reported in table 1.

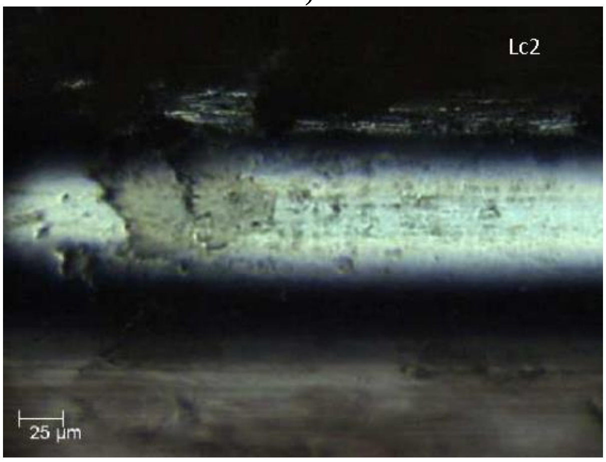
Table 1. Microhardness values

Coating	Microhardness [HV_{01}]
Ni-5Al	110 -150
Substrate	
Steel	180 – 230
Iron	200 – 240
Duralumin alloy	130 - 150

The hardness values of the coatings were found to be within the range of 110 – 240 $HV_{0.1}$. The hardness values of the substrate vary between 180 and 230 $HV_{0.1}$ for steel, 200 and 240 $HV_{0.1}$ for iron and between 130 and 150 $HV_{0.1}$ for duralumin alloy. Hardness depth profiles for the electric wire arc sprayed Ni-5Al coatings and the microhardness indentations along the cross section are shown in Fig. 5. There are aproximately the same results as there obtained by Ni-2Al cladding [11].



a)



b)


c)


d)

Fig. 4. Ni-5Al coating micrigraphs after adherence test: a)-area with first crack; b)-area were the exfoliation occurs; c)-panorama wiew with total exfoliation of the coating; d)-panorama wiew with partial exfoliation

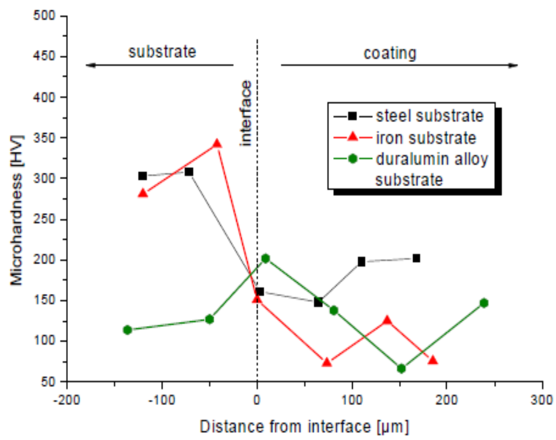


Fig. 5. Microhardness depth profiles for Ni-5Al electric wire arc sprayed coatings.

The difference between steel and iron microhardness and duraluminum alloy microhardness is also evident. At the interface of coating with the duralumin alloy substrate, microhardness is higher that at the interface of coating with steel and iron substrate.

4. CONCLUSIONS

Electric wire arc thermal spray tehnique was used for Ni-5Al coatings deposition. Coatings were deposited on three different substrate: steel, iron and duralumin alloy. For microstructural characterization we used a Nikon Eclipse MA100 inverted metallurgical microscope [11].

From the micrographs obtained it can be concluded that:

-Ni-5Al coatings have a good bond on all three substrate but especially on duralumin alloy substrate like Ni-2Al coatings [11];

-Also, the porosity of Ni-5Al coatings deposited on duralumin alloy substrate has a low level compared with coatings deposited on steel and iron substrate;

-The coatings are uniformly deposited on each sample with the difference that Ni-5Al deposited on steel substrate is thicker than Ni-5Al coating deposited on iron substrate and thinner than Ni-5Al deposited on duralumin alloy substrate.

Also was measured the microhardness of coatings and substrates with a Vickers indenter tester, by using a load of 0.1 kgf. The microhardness was taken along the cross section, spanning part of the substrate and the full thickness of the coatings. Like we expected, the difference between ferrous and non-ferrous metals, in terms of hardness, is evident.

The spray conditions are influenced in a good manner by air pressure and spray distance. A better air pressure gives a better compaction of the thin film with a better diffusion to the substrate and a reduced porosity. For example, by an air pressure of 3.5 bar, the porosity decreases with (15-20)%.

But approximately the same results it can be obtain then at the constant air pressure (2.2 bar), the spray distance will decrease with 30 cm.

For the other parameters used like voltage and amperage, it can be concluded that at 30V and 200A has been obtain the optimum results for a better efficiency of spraying conditions and energy saving. For increasing of these parameters, the risk is to burn the sprayied particles.

5. REFERENCES

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