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INNOVATIVE CHARACTER OF PLASMA SPRAY DEPOSITION METHOD

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Abstract: Atmospheric plasma spraying method (APS), is one of most utilised methods for deposition of layers with different thickness on surfaces with different degrees of complexity. In this paper is shown the innovative character of this method, given by the wide range of powders that can be used, both pure and in various combinations, experimental determined (ex: Al alloys and oxides, Si or W carbides, Ni-Cr-Ti alloys which can compose carbides or nitrides, intermetallic compounds, ceramic materials with B or Si oxides or nitrides, borides or carbides). There are presented the substrates and chemical composition of the powders used for turbine blades highly stressed of wear and corrosion. The samples studied in this paper were obtained by thermal spray using an atmospheric plasma spray installation SPRAYWIZARD - 9MCE. To highlight results were performed some optical microscopy analyses using the inversed metallographic microscope LEICA DMI5000 M and SEM (Scanning Electron Microscopy) analyses using a Quanta 200 3D Microscope Dual Beam. ***Key words:*** *plasma spray, deposition method*

1. INTRODUCTION

Thermal spraying is a pack of processes for the deposition of these layers, where, fine metallic or non metallic powders are deposited in molted or almost molted state to create a deposition [1].
The particularity of this process is it's capacity for deposition of metallic, ceramic – metallic (named "cermets"), ceramic and polymeric layers with a thickness from 100 µm to 1 mm, for a various industrial applications. Using this process, almost any kind of material can be deposited, in case it can be melted or plasticized during the deposition process [2]. The layer is totally created when a big number of powder particles are covering each other. These particles are related to substrate mainly with mechanical links. A common characteristic for all types of layers obtained with this process is given by the lenticulare or lamelare structure of the grains, obtained after a quickly solidification of the powder particles after the impact with the substrate, which has a smaller temperature.

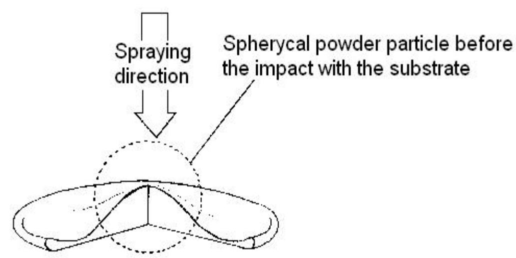

Figure 1. Schematic representation of a spherical particle sprayed onto a plate substrate

The mechanisms for creating links between thermal spray coating and the interface created by the substrate, and forming the layer of particles deposited by thermal spray are topics still opened to speculations.
Generally, it is enough to consider that the deposited layer should not merge with the substrate or to form a solid solution to create the contact. This is an important feature of the thermal spray process in comparison with many other deposition processes, in particular electric arc welding, laser soldering and coating.

There are opinions who say that the formation of bonds mechanisms between coating and substrate are several types [3]:

- mechanical fixing and locking
- diffusion links or metallurgical connections;
- other type of adhesion mechanisms, chemical or physical mechanisms – oxide films, Van der Waals links etc.

Factors that may affect the creation of links between sprayed particles, the substrate and deposited layer, and even the entire implementation process of the deposited layer are: cleaning the substrate surface; substrate surface roughness, its profile, size of the covered surface, temperature (thermal energy), time (reaction time, cooling time, etc.), speed (kinetic energy), physical and chemical properties, physical and chemical reactions

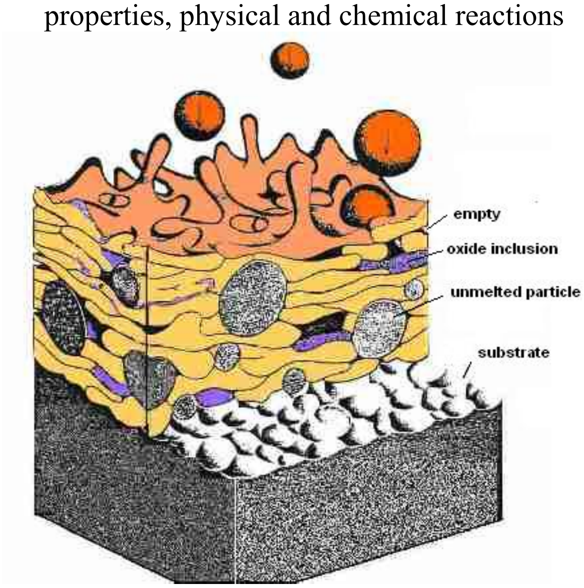

Figure 2. Schematic representation of deposition layer resulted after plasma spraying process

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Because each individual particle hits work piece surface and are flattening due to strong shock, the result is a local contraction of each particle is offset somewhat by creep or creep of the material surface interaction.

A specific residual tension remains in the heat plasticized particles when forming a new layer of each particle. There are accumulated tensions achieving a systematic voltage. Such tensions can be eliminated by preheating the substrate before thermal spraying process so that by contraction, this tension is released [4].

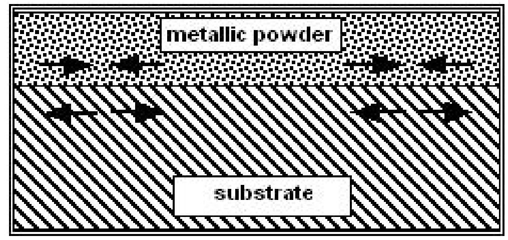


Figure 3. Metal-free intermediate layer. The shear tension between layer based interface and the metallic layer

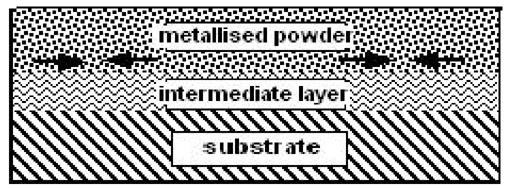


Figure 4. Metallisation with a intermediate layer. Shear stresses at the interface between basic layer and the metallic layer disappears.

To enhance adhesion between the intermediate layers, sometimes it must be used an intermediate layer, the so-called stores layer, formed by spraying, too.

These tensions can be avoided or even removed through application of the intermediate layer and a substrate preheating before spraying the powder, these operations being performed the ease of the material, and the cracks propagation can be avoided.

2. CASE STUDY - hardening borders steam inlet rotor blades in a network of low pressure associated with the body of steam turbines

2.1. Working conditions

The amount of water particles from the steam-water emulsion is different from one turbine to another and more precisely one can say that even for the same type of turbine, steam differ in value because of the quality turbine operation. In this context we can say that the same type of blade turbines operating in the same conditions of erosion may differ when it is applied the same process of hardening the blade board, but the operation of these turbines is different.

Erosion Board palette: the action of bombing range by the board surface water particles drive at excavations at the metal surface, creating craters in board paddles. These are sources of priming craters and cracks and, on a case by case basis, causing damage to turbine blades resulting break and high costs for implementation of new rows of blades were damaged including the installation of turbine blades and repair damaged body.

The causes of broken blades in craters area of damage by fatigue phenomenon is caused by vibrations on that row of blades. In some cases these craters have depths greater than one millimeter crossing the hard plate, getting into the base metal of the blades

Blades vibrations: each type of blade, when is projected, is defined for an area of operations, depending on the demands created by the sources of dangerous vibration that can be subjected [5].

Because in a turbine there are several types of blades, the designer prescribes restrictive technical conditions of the operations at different excitation frequencies, other than nominal frequency.

These technical conditions are required in order to avoid increasing the bending stresses that develop in blades in normal conditions without the existence of other tensions concentrators created by the craters appeared on the edges of the blades.

2.2. Need for hardening

The borders hardening, which works in wet conditions, is necessary to create a hard surface on the blade surface, where it is hitting the water droplets and is degraded (see Figure 3).

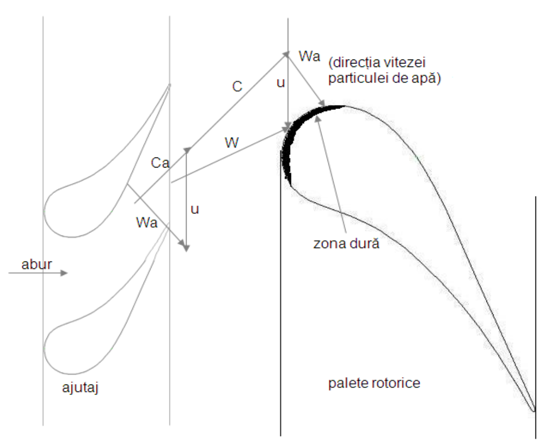


Figure 5. The area hardened on the blade surface

The turbine rotors have specific operations cycles and there are subject to stringent checks during operation. it was proved that restored components using plasma spraying metallization passed the toughest tests.

The aim is to achieve the following goals about the technical and technological conditions:

- deposition layer will not break;
- deposition layer will not tear due to the effect of centrifugal force
- do not create cracks in the base metal that may propagate over time causing the blade fracture;
- do not create thermal stress in the hardened profile that can lead to distortion or modification of its range
- hardened area to be achieved at more than 500 HB;
- hardened layer thickness is between 1.5 mm and 2 mm;
- hardened area do not change the mass of the blade and to influence the value of its own frequency.

3. RESULTS AND DISCUSSIONS

Present paper describes a series of experiments, using different recipes submitted layers powders, to meet the needs of hardening of turbine blades described above. To highlight the results, were performed tests using optical microscopy with optical microscope type Leica M DMI5000, and scanning electron microscopy (SEM) Quanta 200 3D dual beam type.

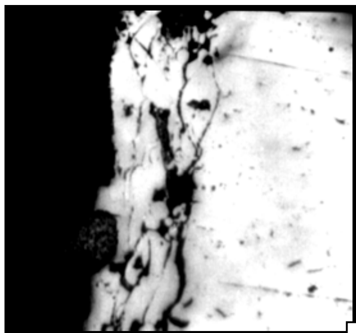
The quality of the sprayed coatings is characterized by the structure of the covering layer, the size and distribution of phases, pores, oxides, inclusions of different materials, segregations, cracks.

3.1. Aspect of deposited layers for Fe-Cr-V-B-C-Si-Mn-Nb system powders

The powder from Fe-Cr-VBC-Si-Mn-Nb system powders was deposited on a steel substrate. Technical parameters for the deposition are described in Table 1:

Table 1. Technical parameters for the deposition

Mettalisation distance	100 mm
Gas debit	12,5 l/min
PAC	1,035 bar
Pressure of O_2	1,725 bar
Composition of plasma	80% Ar + 20% H_2


a)

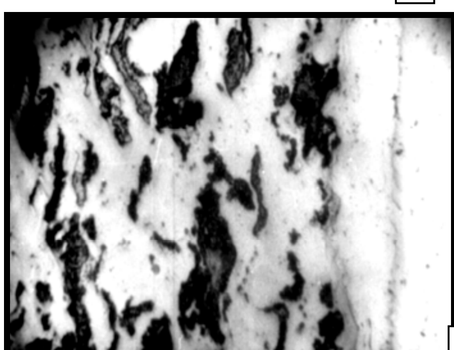

b)

Figure 6. SEM image for the layer obtained with plasma spraying of a Fe-Cr V-B-C-Si-Mn- Nb powder onto a OL 37 steel (a - 125x); (b – 600x)

Figure 6a, b show two images at different magnification, taken by Scanning Electron Microscopy for the powder coating, deposited using powders from the Fe-Cr-VBC-Si-Mn-Nb system.

From the image above it can be observed that the deposition layer has a good compactness and adhesion to the substrate. Also, it can be seen how the powder's particles was deformed at the impact with the substrate; limit between particles disappeared because the temperature reached during the process was very high. An area of diffusion is present between deposited layer and substrate (Figure 6 b).

Plasma spraying process induced a very high thermal gradient during the layer formation and TBC (Thermal Barrier Coating) creating. Nature of residual stress might influence the fatigue behavior of the samples covered by TBC.

3.2. Appearance of layers obtained by WC-Co coatings

Fine particles of tungsten carbide can be used when wishing smooth surfaces and improved impact resistance. Larger particles of tungsten carbide produced a rough surface, improved abrasion resistance but lower toughness which can lead to cracking and subsequent loss of carbides[2].

There are presented two cases of WC-Co deposition on different substrates (steel and nickel alloy), made such a desire to see the influence of substrate on the interface and characteristics of the deposited layer. Analysis was made with metallographic microscopy.

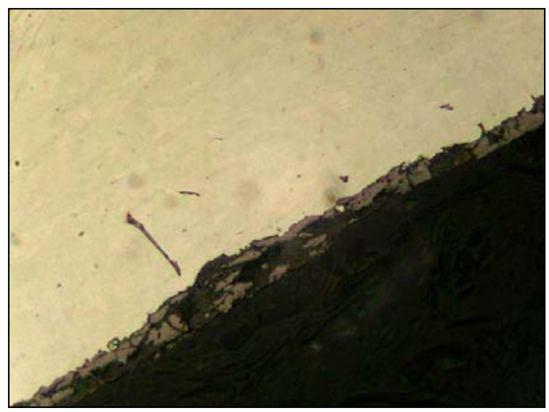


Figure 7. WC –Co powders prayed onto steel plate

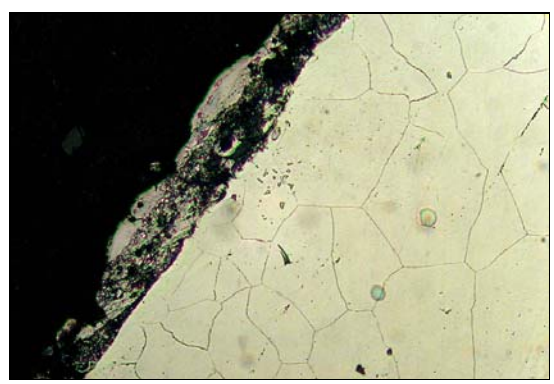


Figure 8. WC – Co powders sprayed onto Ni alloy substrate

In figure 7 it can be seen backing layer made of steel, characterized by good adhesion and a uniform aspect and it can be observed in the deposited layer angular carbide grains attached to in the Co matrix.

In figure 8 is presented the deposition layer onto the nickel alloy substrate. This substrate was metallographic attacked (with a solution of concentrated HNO_3 + CH_3-COOH). The polygonal crystallization occurred as a result of heat treatment applied to the alloy. The layer deposited, as in the previous case, is characterized by good adhesion, a uniform appearance and the presence of small angular WC grains attached to in the matrix Co.

3.3. The appearance of deposited layers of Zr_2O_3 powder

Another kind of deposited layer by plasma spraying is based on Zr_2O_3. The substrate used in this case, Ni-based alloy, whose chemical composition (2.6% Ti, 19.4% Cr, 1 % Fe, 16% Co, 61% Ni) was evidenced by EDS analysis type (Figure 9).

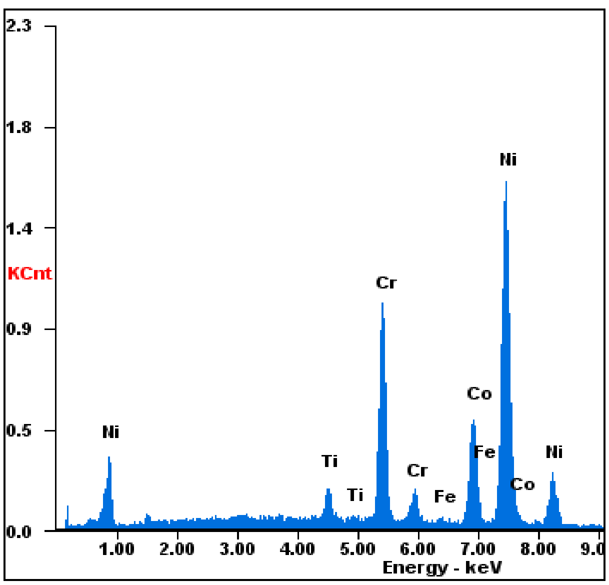


Figure 9. EDS analyse of the used substrate.

Depending on the elements of stabilization, there are several types of powders based Zr_2O_3, of which we mention YSZ (Yttria Stabilised Zirconia - Zr_2O_3 - Y_2O_3) and CeSZ (Cerium Stabilised Zirconia - CeO_2 - Zr_2O_3) used for plasma spray deposition process.

3.3.1. The appearance of YSZ deposited layers

Zirconium oxide yttrium-stabilized ceramic layer ensure getting a very good thermal isolation properties. Also provides very good resistance to thermal shock and particle erosion at high temperatures.

In Figure 10 a, b are shown images of a YSZ deposited layer on Ni alloy substrate, taken with scanning electron microscope at different magnification.

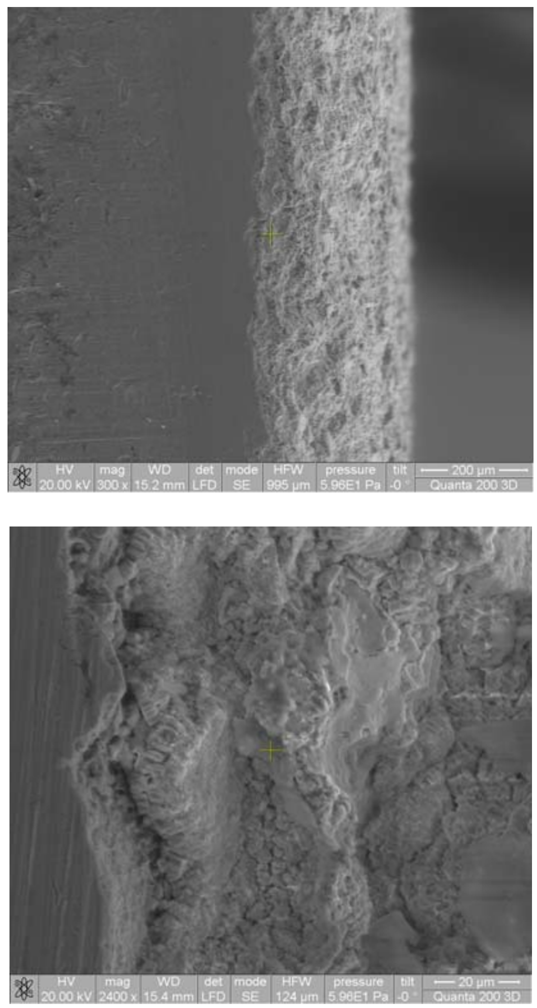


Figure 10. Deposition layer after plasma spraying deposition of YSZ powder (a - 300x); (b – 2400x)

The deposited layer has a good adhesion and compactness (Figure 10 a), and is evidenced the lenticular shape of the the powder granules because the impact with the substrate. The lenticular shape is favorable to a good compactness of the adhesions layer, although in some areas are present almost melted granules. Figure 11 is presenting the result of EDS analysis performed on the deposited layer to highlight its chemical composition. Note powder elements: Zr, Y, A, and the presence of elements from the substrate, which have migrated during sample preparation (by grinding): Ni, Cr, Co.

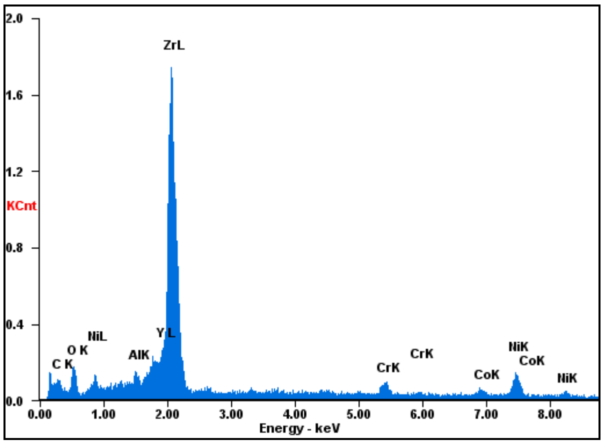


Figure 11. EDS analyse of YSZ layer.

3.3.2. The appearance of plasma sprayed CeSZ layers.

Using CeSZ powder type, resulted layers have excellent resistance properties operating in high temperature environments, in thermal shock conditions and to abrasion process.
Figure 12 a, b show SEM images of a deposited layer on the CeSZ Ni alloy substrate described above.
The general appearance of CeSZ deposited layer thickness of about 200 µm, the characteristic method of plasma spray deposition is shown in figure 12 a, and figure 12 b describes the deposited layer - substrate interface who shows a good adhesion to substrate the deposited layer appearance - compact, porous, lenticular looking less significant than in previous case (of YSZ powder).

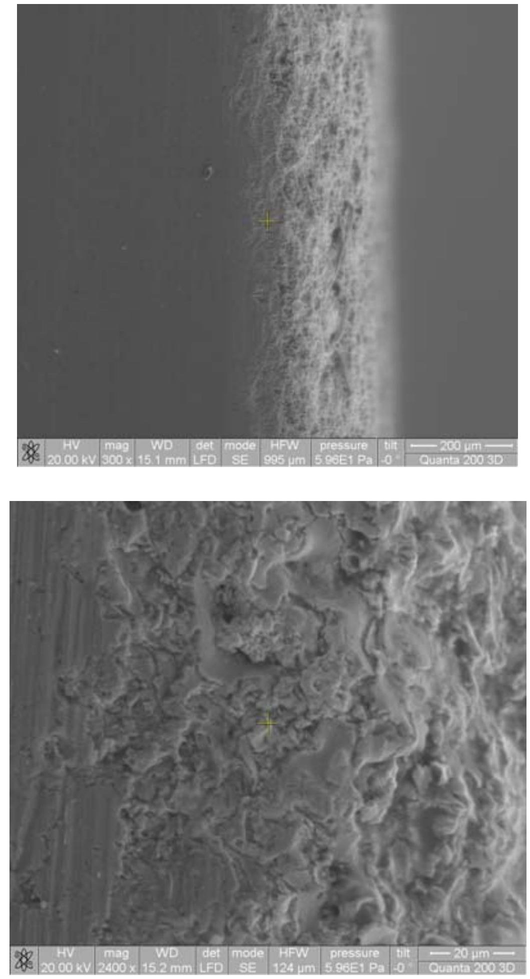


Figure 12. CeSZ plasma sprayed deposition layer. SEM images (a - 300x); (b – 2400x)

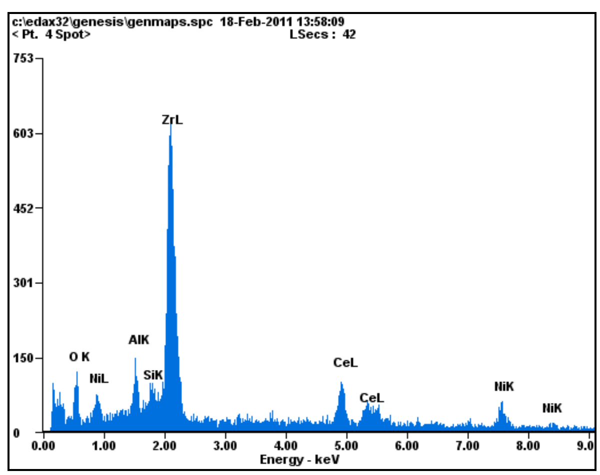


Figure 13. EDS analyse of YSZ deposition layer.

In figure 13 is presented the result of an elemental chemical analysis (EDS type) performed on the deposited layer to highlight its chemical composition. Can notice the powder elements: Zr, Ce, O but also the presence of elements from the substrate, which have migrated during sample preparation (by grinding): Ni, Cr, Co. This element Al is caused by abrasive polishing with Al_2O_3 suspension.

4. CONCLUSIONS

The applications presented in this paper is highlighted the versatility of this method of plasma spray deposition given by the variety of powders which can be used, depending on the characteristics required of the obtained layers (coated components are used on aerospace, electronics, energy, automotive, food, chemical and medicine).

It is clear that this innovative and has found fertile ground, because the possibilities of developing new recipes for various applications in powder mixtures (with different grain size and chemical composition) are endless.

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Caracterul inovativ al metodei de depunere în jet de plasmă

Rezumat: „Atmospheric plasma spraying method" (APS) este una dintre cele mai utilizate metode de acoperire a suprafețelor complexe cu straturi de diferite grosimi. Lucrarea prezintă caracterul inovativ al acestei metode, rezultat din gama variată de pulberi care pot fi folosite, atât pure cât şi în diferite combinații, determinate experimental (ex. aliaje de Al şi oxizi, carburi de Si şi W, aliaje Ni-Cr-Ti care pot forma carburi sau nitruri, compuşi intermetalici, materiale ceramice cu oxizi sau nitruri de B sau Si, boruri sau carburi). Sunt prezentate substraturile şi compoziția chimică a pulberilor folosite la acoperirea palelor de turbine utilizate în medii corozive. Eşantioanele studiate în această lucrare au fost obținute prin utilizând instalația SPRAYWIZARD - 9MCE. Pentru a evidenția rezultatele au fost realizate analize cu ajutorul microscopului optic LEICA DMI5000M şi analize SEM (microscop electronic de baleiaj) utilizând microscopul Quanta 200 3D Dual Beam.

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