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STRUCTURAL STUDIES OF THE PLASMA-SPRAYED LAYERS DEPOSITED ON THE STEAM TURBINE BLADES

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Abstract: *The method of plasma spraying for obtaining superficial layers with special properties has begun to be increasingly used in industry. In this paper are described and presented a series of layers experimentally obtained, using powders of WC-Co type on different substrates (steel and Ni alloy) in order to observe the influence of the substrate on the interface and the characteristics of the deposited layer. The attention was paid to the layers that must meet the hardening requirements of the steam inlet borders in the rotor blades network of the low-pressure body of the steam turbines. The analyzed samples were obtained by thermal spraying, using an atmospheric plasma spray installation type SPRAYWIZARD - 9MCE. To highlight the results were performed analyses of scanning electron microscopy (electron microscope type QUANTA 200 3D DUAL BEAM) and X-Ray diffraction (diffractometer X'PERT PRO MRD) for determining the phases and constituents from the deposited layer.*

Key words: *SEM, XRD, WC-Co.*

1. Introduction

The thermal engine is a type of machine which converts thermal energy into mechanical energy. The thermal engine was two major categories: the internal combustion piston engine and installations with steam or gas turbines, also called turbomachines,[1].

The steam turbomachine consists of a number of complex aggregates, in which classic or nuclear fuel is burned to obtain thermal energy and the part in which the thermal energy is converted in mechanical energy is the steam turbine.

The hardening of the attack board of the blades which work in wet conditions is needed to create a hard surface where water drops which hit this zone are causing wear to the steam turbine blades due to erosion. To decrease the effect of erosion, the edge of the blade has to be very hard, this can be achieved with a coating of satellite or metallization with a hard metal.

The plasma jet spraying method is carried out in normal atmosphere at high speeds and high temperatures of the gas. In this process particles from the filler material are heated up to a "plasticized" state and accelerated to a extremely high

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speed, so that their kinetic energy is high enough to deform at impact, producing an dense, overlaying coating.

This paper deals with the problem of hardening the attack boards of the low pressure steam turbine blades, using plasma spray deposition in normal atmosphere using WC-Co powder.

2. The opportunity of the attack border hardening of turbine blades

To decrease the effect of erosion on the rotor blades, caused by the water droplets condensed from the steam, and to minimize moisture losses, in the last stages of the steam turbine, devices called droplets traps are used to retain the moisture (Figure 1.).

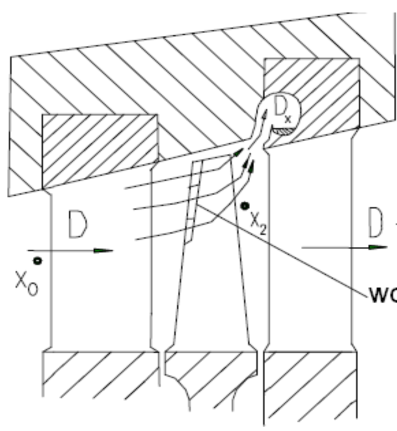

Fig. 1. *Example of a constructive solution to protect the turbine*

Because of the gas relaxation, when the vapor starts to condense and moisture is produced, on the suction side of the stator blade a thin layer of water is deposited which is driven by the steam, in the shape of shape droplets and projected unto the rotor blades. The absolute speed of the water droplets c_{1a}, will be much smaller than that of the vapor c_1, this happens because the droplets are driven by the steam (Figure 2), [1].

Therefore the relative speed of the water droplets w_{1a} has an inclination $\beta_{1a} >> \beta_{1g}$, so hitting the suction side of the blade. The angle β_{1a} and the speed w_{1a} increase the ratio u/c_1, so are bigger to the blades with reaction. Droplets of water bomb the input edge of the blade on the suction side, with maximum intensity in the point M where speed w_{1a} is normal on the profile. The curve with dashed line in Figure 1 represents the variation of impact energy.

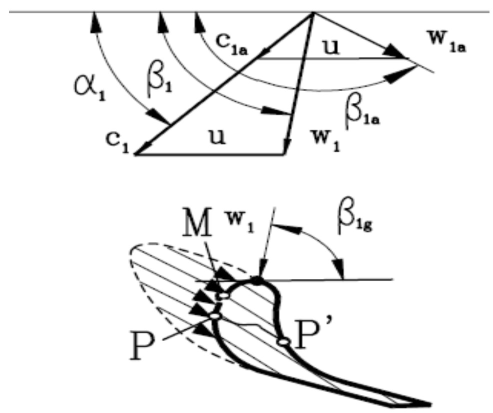

Fig. 2. *Velocity triangle for vapor and water droplets*

When the impact energy exceeds the admissible value for the material from which the blade edge is made, erosion occurs beginning in point M and develops rapidly, leading to the removal of material from the input edge to a plan PP' parallel w_{1a}.

Erosion is greater at the top of the blade because the water droplets are diverted due to the centrifugal force. To decrease the effect of erosion the input edge of the blade must be very tough in the third part from the top, which can be achieved by coating the blade with stellit, by steeling or by plasma jet spraying.

3. Experimental procedure

In the present paper were performed the spraying coatings deposited in the atmospheric plasma spray installation type SPRAYWIZARD - 9MCE , using tungsten carbide powder in the system with nominal composition of WC-Co.

The characterization of samples submitted to surface treatments by plasma spray deposition was performed morphologically (determination of surface roughness, determination of the layer thickness, determination porosity, adherence and absorption of the layer) and compositionally (determining the chemical composition of the layer).

To highlight the results, analysis was performed using electron microscopy with the QUANTA 200 3D DUAL BEAM electron microscope. The X-ray diffraction analysis was performed with X'Pert PRO MRD.

Deposition parameters for atmospheric plasma spray (APS) are presented in Table 1.

Technical parameters for the deposition
Table.1

Powder used	**WC-Co**
Cooling water debit	8,7 bar
Velocity of rotation	55 rot/min
Electrode voltage (U)	60 V
The intensity of the gas Plasma (A)	600 A
Composition of plasma	46,1%Ar/13,51%H_2
Spraying distance	120

4. Experimental results

4.1. Atmospheric plasma spraying method (APS)

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.

The particularity of this process is its 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.

Figure 3 shows how the layer is formed; a large number of particles are deposited over 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 lamellar structure of the grains, obtained after a quickly solidification of the powder particles after the impact with the substrate, which has a smaller temperature.

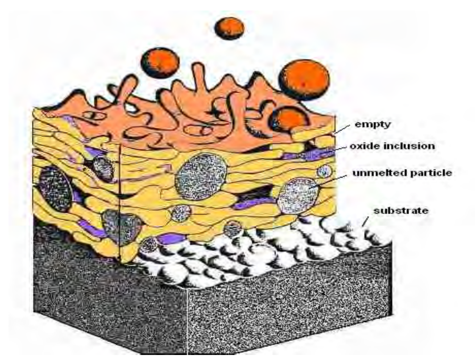

Fig. 3. *Schematic representation of deposition layer resulted after plasma spraying process*

4.2. Particle size distribution

Particle size is an important variable that influences coverage characteristics. To ensure the powder's melting in the plasma spraying, for a given set of parameters, the spraying powder's size should be checked. If powders are not produced to size necessary for the spraying parameters, the quality of the coating starts to deteriorate.

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. In Figure 4. can be observed morphology of WC-Co powders.

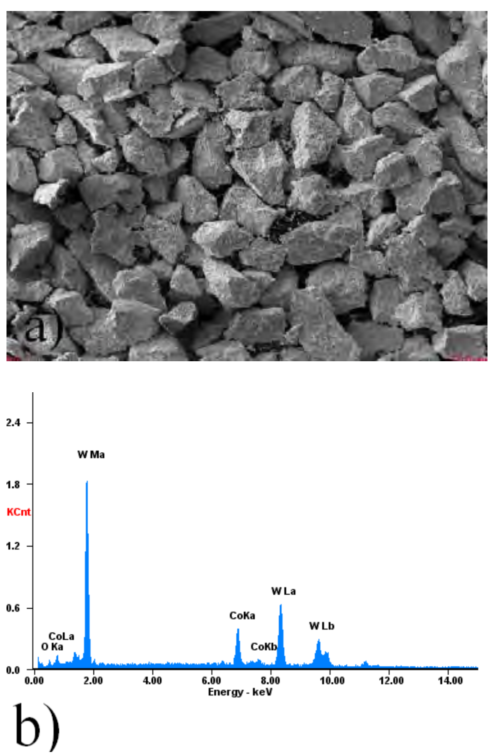

Fig. 4. *Powder WC-Co: a) SEM image of the powder used and b) the EDS chemical analysis.*

4.3. Micro structural characteristics

In Figures 5, 6, 7 there are presented the performed microscopy analyses using the electron microscope Quanta 200 3D type. The microscope has worked in High Vacuum (pressure of the order of 10-4 Pa), the sample was attached on the support with bands using a special carbon, and the EDS analysis was performed using EDAX –AMETEK, attached on the same scanning electron microscope.

For more clearly images of the structure, the metal pad was attacked with a HF 1% solution, for the newly formed layer solution was used for special attack, namely HF, HNO3, glycerin. [3]

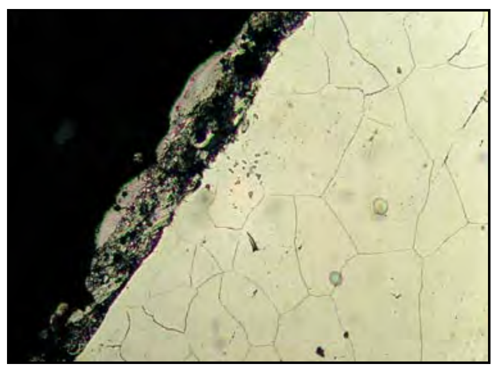

Fig. 5. *Deposition of tungsten carbide powder on metallic support 1000x*

In Figure 6, lenticular splats are observed with a small and polygonal geometry this is the evidence of a good cohesion between splats so that the obtained layer has superior properties, especially resistance to mechanical stress.

Fig. 6. *Surface observations for WC–Co coatings 1000x*

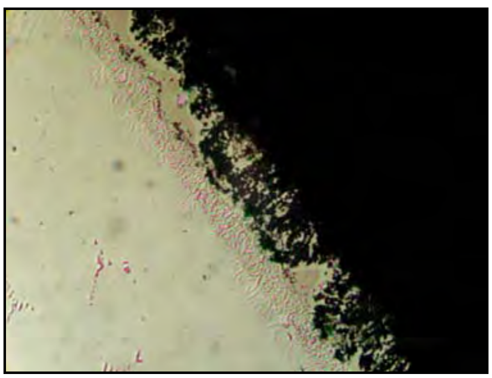

Fig. 7. *Surface observations for WC–Co coatings 500x*

From the SEM analysis a good compactness of the deposited layers can be seen (*Fig. 5*) and a very good support adherence to the filler material. Structural attack revealed that in all the samples, a diffusion zone appears in the layer-covered interface with the substrates, (very well be highlighted in *Fig.6, 7).*

4.4. X-ray diffraction

Using XRD analysis, phases and constituents, obtained by plasma spraying, present in the coating have been observed and compared with the powder used. These phase transformations may help to understand the comportment of the layers at different types of testing. The configuration of operating for X'PERT PRO MRD diffractometer, which analyzes were performed are: Copper anode with λ = 1.54 Å, supporting samples open eulerian cradle, the samples were run at 2θ from 20° to 90º. [2]

In Figure 8, is presented the diffractometry performed on WC-Co powder (a) and the layer obtained by plasma spraying (b). Diffractometry performed on powder shows the existence of two stable carbides WC and W_2C (both with hexagonal structure) powder characteristics of pseudo binary system WC-Co, [5] majority is carbide WC. Also present phase's α-Co and β-Co, which highlight the existence of connection metallic matrix consisting of the Co.

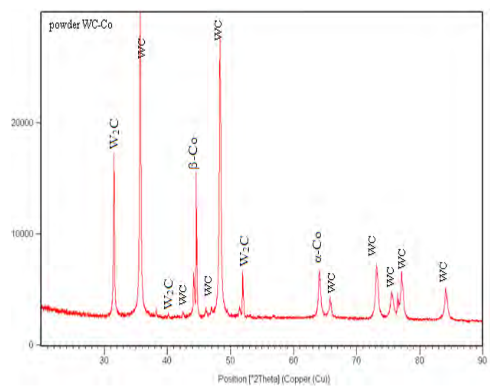

Fig. 8.a. *XRD spectrum of the powder (WC-Co)*

In the spectrum performed on the layer it can be observed that the proportion modification of the phases existing in the powder but also the presence of a ternary complex carbides – W_3Co_3C – which appears in the case of a decarburization process in the moment when spraying the samples, known as η the type of $M_{12}C$. [4]

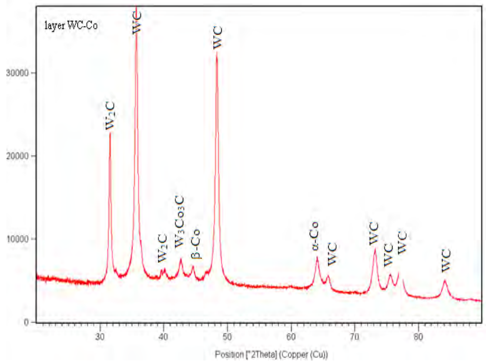

Fig. 8.b *XRD spectrum of the APS-sprayed coating (WC-Co layer)*

5. Conclusions

Atmospheric plasma spraying method is a complex process, which develops very high temperatures, enabling deposit of a large range of powders.

The characteristics of layers obtained by deposition of WC-Co could be varied by changing process parameters (their injection angle in plasma jet, spray distance, the working atmosphere, powder flow of injection, the substrate temperature, speed of the gun toward the surface on which spraying is performed etc).

Was been observed a good tightness of the layer and a good adhesion to the substrate of filler material.

Have been highlighted different characteristics peaks following phases: a) two stable carbides WC and W_2C (both with hexagonal structure) majority is carbide WC and phases α-Co and β-Co, which highlight the existence of connection matrix metallic form of Co and b) in addition to the powder diffractometry appeared ternary complex carbides – W_3Co_3C, whose presence influences behavior of different of layers to request and give the value characteristic physic - chemical phenomena produced during spraying.

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