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STRUCTURAL, MORPHOLOGICAL AND ADHERENCE ASSESSMENT OF A 40Cr130 COATING DEPOSITED IN ELECTRIC ARC

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Abstract: *Electric arc thermal deposition, unlike other methods (D-gun, plasma spraying, flame spraying, laser surfaces alloying), induce reduced structural changes in the base material due to lower temperatures in the deposition process. The samples analyzed in this paper were obtained by electric arc deposition with the Smart Arc 350 installation from Sulzer Metco. This paper presents structural and morphological analyzes of the obtained coatings and also analyses the adherence of the coating to a 18MnCr11 steel alloy base material. For highlighting the results electron microscopy analyses were made with the QUANTA 200 3D DUAL BEAM electron microscope. The XRD analyses helped to establish the phases and constituents of the electric arc deposited coating. The adherence of the layer was assessed using the scratch method with the UMTR 2M-CTR micro tribometer.*

Keywords: *40Cr130, scratch, SEM*

1. INTRODUCTION

The quality of electric arc deposited coatings can be assessed by: adherence, roughness, thickness and deposition efficiency etc., aspects which can be influenced by the technological parameters specific to the deposition method. [1]

One of the most important characteristic of a deposited coating is its adherence to the base material to which it was deposited. [2]

Adhesion is a molecular or atomic interaction phenomenon acting on the contact area between two solid state material surfaces. [3]

This process is obvious when one of the two solid layers in contact is thin or has a small size. Also the adherence between surfaces is very strong when no lubricant, grease or oxides are present between the contact surfaces. When the contact area of the surfaces is large, the real contact points will represent only a small part of the total area; therefore the specific adhesion of these points will be weak, related to the entire surface of the bodies. [3]

The materials plasticity has an important influence on adherence. With the increase of plasticity, the adhesion between the layers will be stronger [4] The thermal state of the contact materials is another crucial factor to obtain a strong adhesion between layers. A high temperature regime for two sliding surfaces can led to the scuffing phenomenon. [1]

2. MATERIALS, METHODS AND INSTRUMENTATION

In this paper is presented a method to enhance the contact behavior of sliding surfaces. This method consists of an electric arc coating deposition. The material used for the coating is a 40Cr130 wire steel alloy deposited using the Smart Arc 350 installation from Sulzer Metco on an 18MnCr11 base material. This layer has the purpose to enhance the fatigue, adhesive and abrasive wear resistance.

The 18MnCr11 samples, on which the deposition was performed, are of disc shape with a diameter of 49 mm and the thickness of 5 mm.

In table 1 are presented the deposition parameters used for the electric arc deposition using the Smart Arc 350 installation.

Table 1: Technical parameters

Smart Arc 350	40Cr130
U	28V
I	252A
Air pressure	60PSI

The Quanta 200 3D electron microscope was used to perform secondary electron images and EDS analysis, working in the High Vacuum module at a pressure of $1,65x10^{-3}$ Pa and using the ETD detector (Fig.1).

Fig. 1. Quanta 200 3D electron microscope

In order to perform a more complete analysis in terms of structural changes due to the deposition process, the metallic layer was analyzed using X-ray diffraction with the X'Pert PRO MRD installation presented in Fig.2.

Fig. 2. X'Pert PRO MRD X-ray diffraction installation

The scratch test conducted on the UMTR 2M-CTR type tribometer uses three methods to detect the coatings failure (Fig. 3). Firstly, a load cell is used to measure the change of the friction force value, secondly the acoustic emission made by the cracks are detected and thirdly, after the test is complete, the scratch channel can be viewed using an optical or an electron microscope, to see how the crack has propagated.

The intensity of the acoustic emissions is dependent on the type of failure suffered by the coating during the adhesion test: cracking, chipping or delaminating. [5]

For this reason is important to view how the coating had failed after the adhesion test and to confirm the critical load by analyzing the failure with a microscope.

Fig. 3. CETR UMT-2 tribometer

The method used to assess the analyzed layer in this paper is the progressive loading method (PLST - Progressive Load Scratch Test) and consists of applying a force gradually (from 0 - 19N) over the indentation for a defined period of one minute. The speed of the indentation is 10 mm/min. The indenter used is a DFH-20 Dual Friction/Load Sensor, which has been mounted with a micro blade with a peak radius of 0.4 mm.

3. EXPERIMENTAL RESULTS

3.1. Structural analyses using SEM

In Fig. 4 and 5 are presented SEM images of the coatings surface which shows pores, micro cracks and its roughness. The cracks presented on the surfaces are produced by the stresses which occur during the cooling process of the coating. The stresses are generated by the different rates of cooling between the coating material and the base material from which the sample is made of.

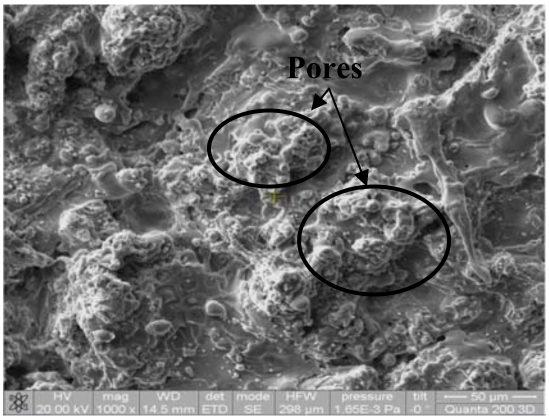

Fig.4. SEM image of the coatings surface at a magnification of 1000X

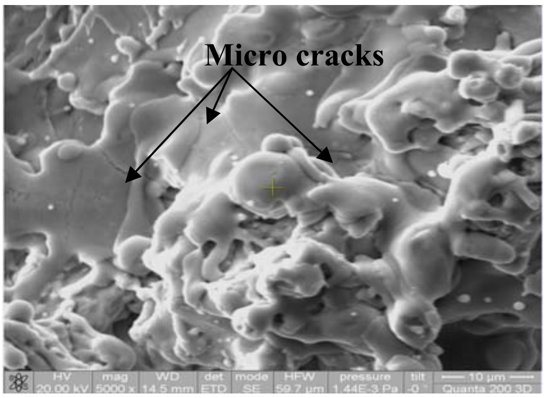

Fig.5. SEM image of the coatings surface at a magnification of 5000X

Fig. 6 shows the topography of the surface presented in Fig. 4.

In Fig. 7 is presented the elementary chemical analyses of the coating. From the analyze results that the coating has the same composition as the 40Cr130 wire used for the deposition.

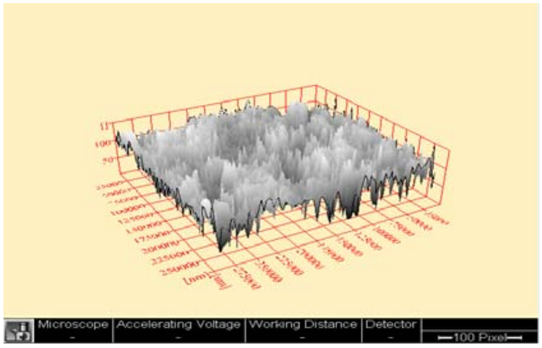

Fig.6. Coating surface topography

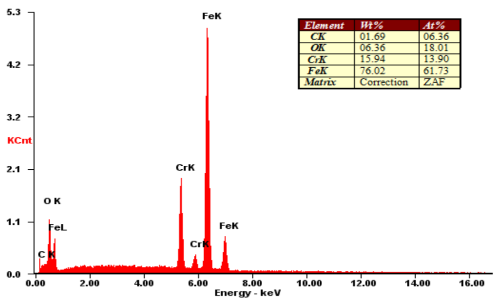

Fig.7. Elementary chemical analyses EDAX.

To highlight all the chemical elements present on the layer surface a distribution map of the elements was made on which the specific elements of the coating are presented (Fig. 8).

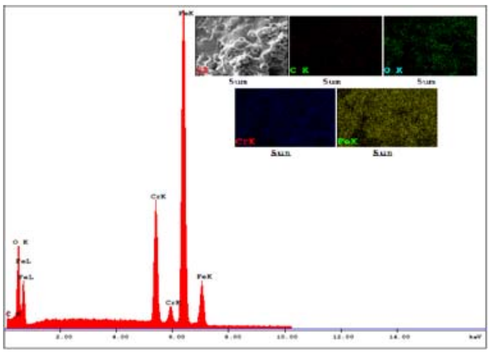

Fig.8. The distribution map of the chemical elements

Also, by using electron microscopy, measurements were made in the cross section of the coating. The purpose of the measurements was to determine the thickness of the coating. The thickness of the layer varies from 43 - 60 µm as can be seen in Fig. 9.

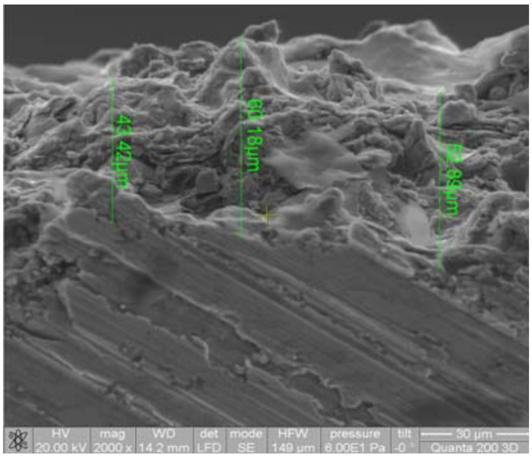

Fig.9. SEM cross section of the coating with thickness measurements

The layer presented in Fig. 10 is characterized by a lenticular structure specific to electric arc deposited coatings.

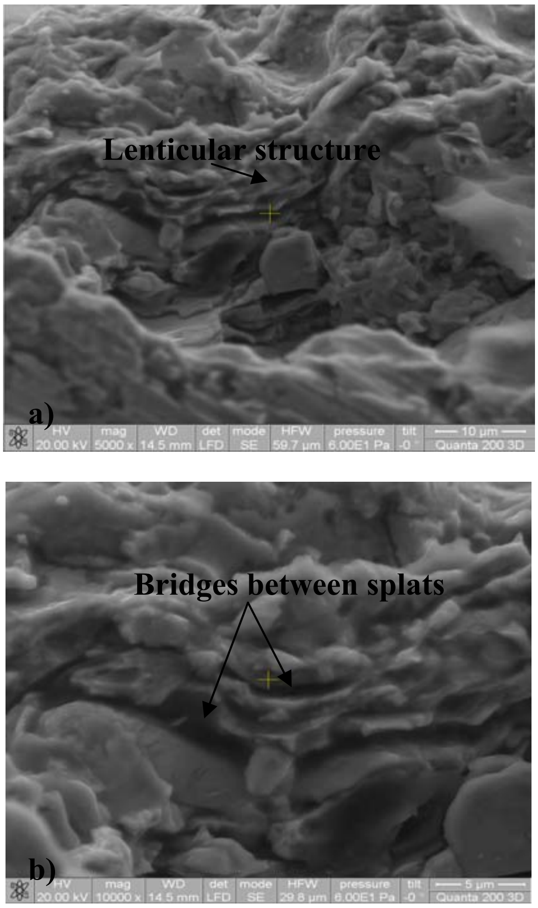

Fig.10. SEM microstructure in the cross section: a) 5000X and b) 10000 X

The splats have a small dimensional structure. The interface between splats and pores is very well highlighted. The inter-splat pores are dominant in the layer (Fig. 10-a). At high magnification bridges between splats can be observed (Fig. 10-b).

3.2. Structural analyses using X-ray diffraction The X-ray diffractometer is equipped with a X-ray anode tube made of Cu kα, λ = 1.54 Å, to which a voltage of 45 kV with a current of 40 A has been applied, at an angle of diffraction (2θ) ranging from 30 to 120º. X-ray diffraction analysis was performed in order to observe and highlight the structural composition of the coating (Fig. 12).

The wavelengths of the X-ray diffraction are: K Alpha 1 [Å]: 1.54060, K-Alpha 2.1,54443, K-Beta [Å]: 1.39225, K-A2 / K-A1 Ratio: 0.50000.

Structural analysis were performed using a dedicated software (Xpert High Score Plus) thought which the crystallographic parameters were identified (lattice type, network constant values a, b and c, angles of the elementary cell alpha, beta and gamma, elementary cell volume, density) and the possible compositional parameters. For the precise choosing of the stoichiometric compositions.

The steel alloy deposited coating has a martensitic structure with a tetragonal crystalline lattice (a = 2,8560 Å, c = 2,9600 Å si β = 90,0000°).

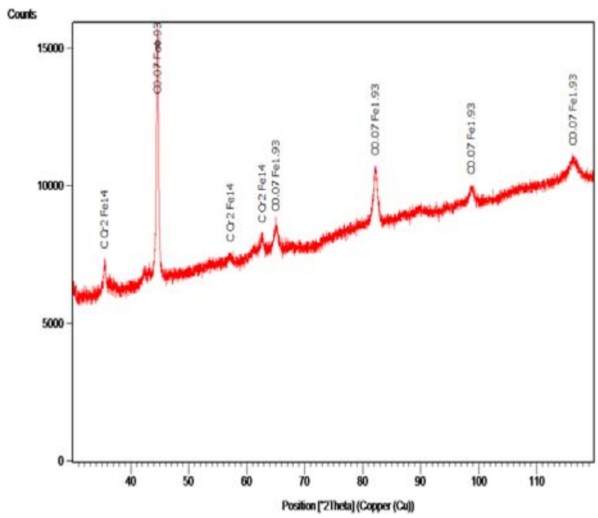

Fig.11. XRD spectrum of the layer

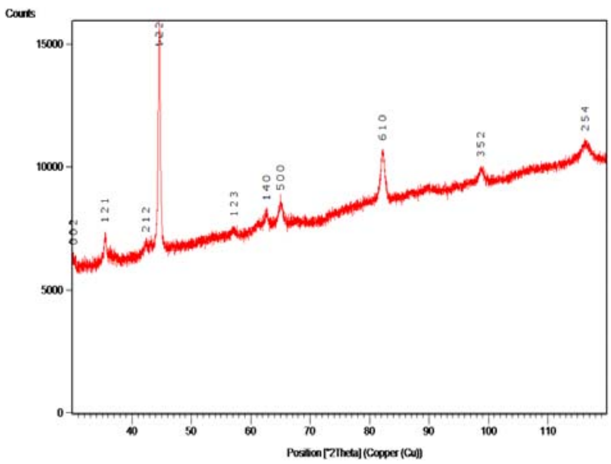

Fig.12. X-ray diffraction of the *40Cr130 coating at a diffraction angle of 2θ=30…120°*

3.3. The scratch method used to determine the adhesion of the layer There are three characteristic zones of the scratch indentation: the initiation zone (corresponding to the application of force from 0 N to 8 N), an intermediate zone (8-13,5 N) and the final (13,5 to 19 N). These zones were used to observe the behavior of the coating at progressive loading. After the scratch testing on the first samples it can be observed that the destruction of the layer starts from the final zone (corresponding to approximately 13 N of force after approximately 45 sec.). This can be seen in Fig. 13 on the SEM images and especially using the energy - dispersive X-ray spectroscopy performed on the final scratch, as can be observed in Fig. 14.

The third analysis performed is drawing the profilometry of the initial segment (Fig. 15) and final segment of the scratch (Fig. 16). It can be seen that the destruction of the layer has a width of 1.2 mm and a depth of 35 μm (Fig. 16).

By using the data from the chart presented in Fig. 17, calculations were carried out from which resulted that the exfoliation begun in the 45 second which corresponds to a force of 13,5 N.

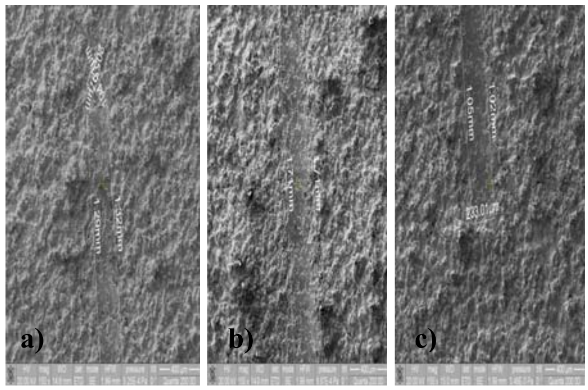

Fig.13. SEM imagines of the scratch marks on the sample: a) initial zone (0 – 8 N), b) intermediate zone (8 – 13,5 N) and c) final zone (13,5 – 19 N)

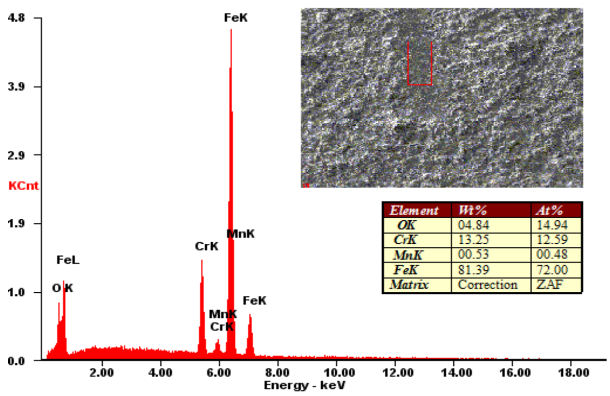

Fig.14. Spectral analyses of the final mark of the scratch

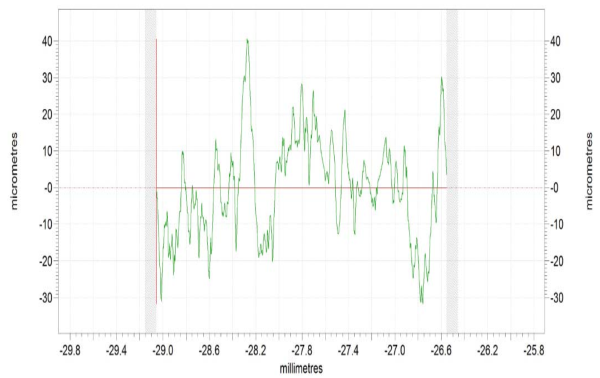

Fig.15. The profile of the initial scratch

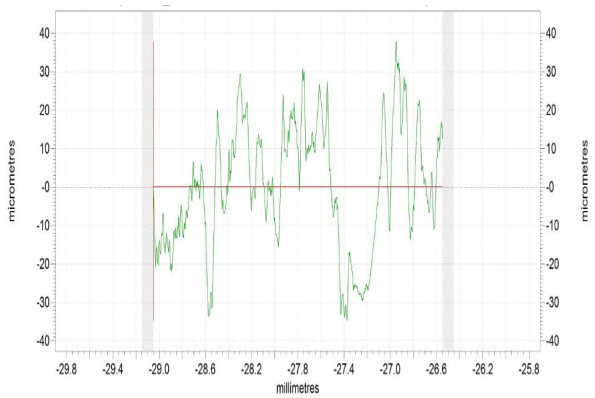

Fig.16. The profile of the final scratch

On the same chart high variation of the friction coefficient are observed. The maximum value of the friction coefficient is 0,179. The variation of the friction coefficient is due to the porosity of the layer and the leticular stratified structure of the material. The friction coefficient drops to the value of 0,06 when the indenter reaches the base material.

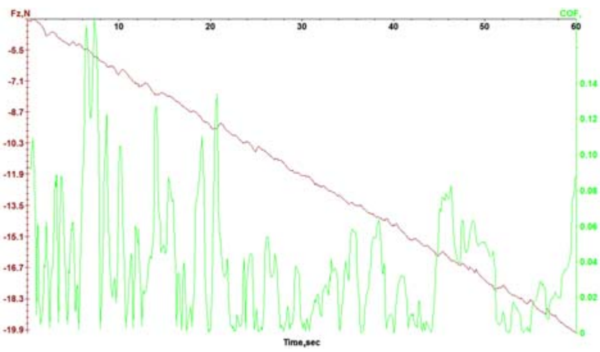

Fig.17. The variation of the friction coefficient due to the progressive applied force

4. CONCLUSIONS & ACKNOWLEDGMENT

The 40Cr130 deposited coating has a leticular structure with high porosity and a tetragonal crystalline lattice.

At the technological parameters used for the electric arc deposition the coating has an average thickness of 50 µm.

From the SEM images results that no oxidation zones appear at the interface between the metallic coating and the base material.

The coating adhesion testing was performed with the scratch method. The obtained results were conclusive regarding the adhesion of the layer and its minimal thickness. It is recommended that the deposited coating have a thickness greater than 50 µm.

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