THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^{0}. 4 – 2010, ISSN 1453 – 083X

THIN LAYERS OBTAINED BY ELECTRIC SPARK IN LIQUID MEDIUM

Ion HOPULELE, Carmen NEJNERU, Manuela Cristina PERJU, Mihai AXINTE
Technical University "Gheorghe Asachi" of Iasi, Romania

ABSTRACT

This paper is a study about the thin layers obtained by metallic deposition method in liquid medium. For this we studied the structure and composition of different deposition regimes, in different liquid mediums. Liquid medium is chosen depending on the purpose. Thus, use was made of protective environments that aim at achieving a more compact layer without many oxides, reactive environments whose components, due to sparkle reactions, combine with elements of basic material to obtain carbides and complex carbonitrides with good wear resistance properties.

KEY WORDS**:** thin layers, liquid mediums, vibrating electrode

1. Introduction

Electrical processing of metallic materials based on electrophysical and electrochemical phenomena includes a wide variety of technological fields. Because the application of electrical processes is not always an advantage, such devices can not replace the heating treatments, only in limited cases. These methods are defined on one side of the current state in science development, and secondly by the quality requirements in building machinery [4].

Electrotechnological metal processing methods can be divided into two main categories:

- processing methods which change shape or properties of the metal piece. These treatments do not alter the volume of materials (plastic deformation and heat treatment);
- processing methods which change the piece volume (cutting or deposition of material).

To achieve material processing operations are performed by electric spark in order to remove a part of the material (cutting, drilling, polishing, etc.) using direct polarity where the piece is the anode. For deposition the piece is the cathode (layers deposition).

The processes can take place in the air, protective gas environment or liquid medium. Comparing to other metal coating methods, deposition and metal surfaces alloying method by electric spark has some advantages [1]:

- It provides a layer with good adhesion to the base material;
- There is no need for special surface preparation;
- High melting point metals depositions can be made (Mo, W, Ti);
- Alloying elements may be supplemented in the discharge environment (nitrogen, carbon, boron);
- Quenching occurs from the liquid phase of metal deposition.

It follows that the electric spark deposition principle creates a layer with special properties according to used electrodes and discharge environment.

An important requirement of the method is the electric spark discharge energy in the space between the electrode and the piece. The process starts by approaching the electrode from the part. To a specified distance the space is broken by the electric spark, which continues until the electrode-part contact.

Due to electric spark energy, erosion craters appear on the electrode surface, caused by melting and evaporation. The material deposits on the work piece surface under the action of hydrodynamic pressure plasma jet. The process has a particular electrode vibration frequency and determined vibration amplitude. By electric spark deposition it alters its chemical composition and mechanical properties. Total depth for treated layer is 0,02 mm to 0,25 mm containing 20 to 30% of the cathode material and discharge environment [3].

Environmental influence between electrodes to the electric spark process is manifested in two ways. On the one hand, high temperatures in the discharge areas, the electrode gas ionization, and on the other, the presence of vaporized and liquid phases contribute to increasing interaction between electrode material and medium elements therefore they change the physical and chemical properties of the layer. Electric spark process in mediums such as: hydrogen, argon, nitrogen or other protective environments allows us to obtain high quality layers. Magnetic fields and electrical discharge overlapping effects substantially alter the deposited layer features; ultrasonic oscillations have also a positive influence.

2. Obtaining electric spark deposition layers

Compared to other metallic coating achieving methods, electric spark metal deposition is based on using simple equipment and technologies. The installation contains a DC source and an electric spark discharge circuit (Fig. 1). Power supply has a voltage below 60 V and a current of 1 ÷ 20 A depending on the working regime. The discharge circuit includes a variable resistance and a capacitor. The electrode is vibrated at a frequency of 50 ÷ 200 Hz.

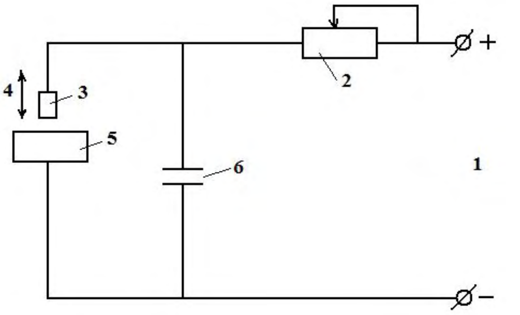


Fig. 1. *The method principle for electric spark deposition layers, 1- current source, 2-electrical resistance, 3-electrode, 4-vibrator electrode, 5-piece, 6-capacitor*

Electrical discharge can be achieved in air, in different gases, in liquid medium or by deposition on the piece surface of a fixed composition zone. In the case of discharge the liquid medium, it can be used a liquid insulator or an electrolyte with a given composition, according to alloying elements needed into the layer. The electrolyte can be stationary or a jet on the piece surface. Electric spark alloying and deposition facilities are manufactured in a wide range of types and models according to the treated parts and used technologies. Installations can be manual, mechanical or automatic.

3. Experimental researches

Artistic or household items made by plastic deformation or machining ask to have some rough-looking surfaces. This can be achieved by using the deposition electric spark method.

Thin layers were obtained using the electric spark deposition device type Elitron 22A [5]. Nickel electrode was used as filler material. Glossy surface treatment of stainless steel with nickel electrode provides both artistic appearance and corrosion protection. We used 20Cr130 type steel as a base material to determine the liquid environment influence to electric spark deposition with nickel electrode.

Chemical composition was determined with Foundry Master spetrometer and it was presented in Table 1 [2]:

Table 1. *The chemical composition of the base material 20Cr130*

C	Si	Mn	Cr	Ni%
[%]				
0.2	0.2	0.3	12.4	0.2

The study was to compare the effects of environments in which we worked. Both the environments were:

-the gas medium-air;

-the liquid medium - oil.

Photographs of surface areas obtained for the surface quality highlight were made by scanning electron microscopy (SEM).

Deposions made in air were with a layer and two layers, and the oil depositions were made with two layers.

3.1. Air medium deposition with nickel electrode, one layer

It is observed an uneven layer to one layer air medium deposition, confirmed also by nickel distribution (Figures 2 and 3).

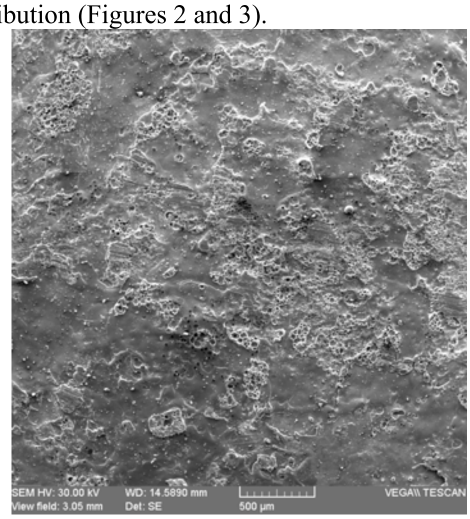


Fig. 2. *SEM photographs for relief highlight, 500 µm.*

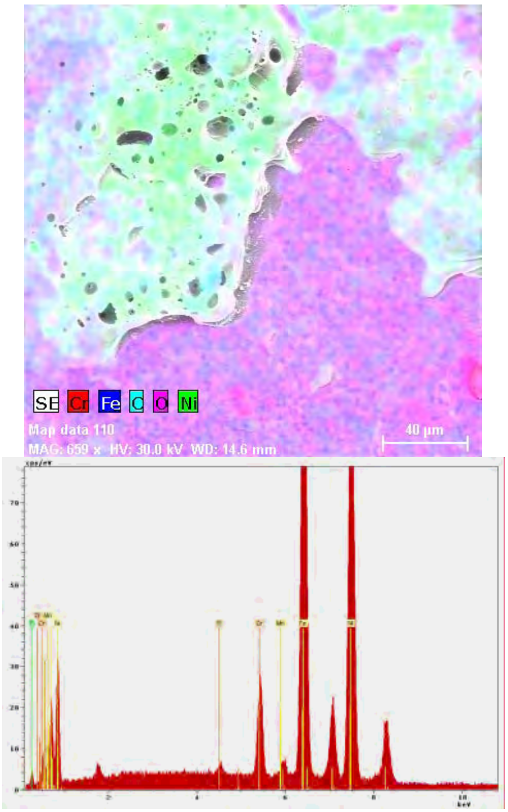


Fig. 3. *Elements distribution: Cr, Fe, C, A, Ni.*

The analyzed area chemical composition is given in Table 2.

Table 2. *The chemical composition for the analyzed area, %*

Element	Atomic Number	Mass percent	Atomic percent
		[%]	
Nickel	28	50.940	46.261
Iron	26	40.882	39.019
Chromium	24	5.017	5.143
Carbon	6	1.852	8.220
Titanium	22	0.604	0.672

Studying the inline analysis, it appears that nickel has a massive presence, but with little continuity, violent reaction to deposition and gas releasing.

This gives the surface a spongy appearance. Oxides are also observed, highlighted in Figure 4.

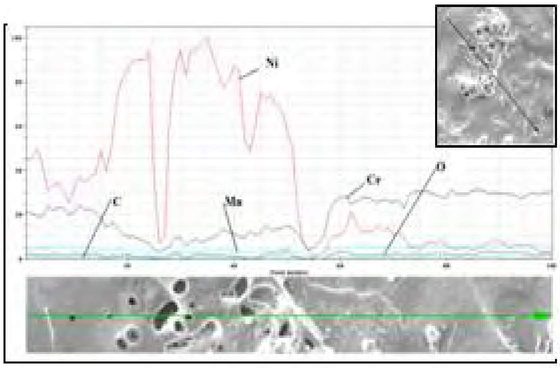


Fig. 4. *Inline analysis for one layer nickel electrode deposition.*

3.2. Air medium deposition with nickel electrode, two layers

The two-layer deposition (Fig. 5) produces uniformly deposited layer, achieving a more uniform distribution of nickel (Fig. 6).

For macrostructure analysis of a single layer deposition (Fig. 7.a) showed inconsistent filling, but to the two-layer deposition (Fig. 7.b) the unevenness is partially removed.

This makes the area look much more pleasant.

For the two layers deposition, the second layer had the effect of remelting to the first filing.

Nickel drops which weren't trapped into the micro area of the first passages were embedded in the melted metal by the second pass.

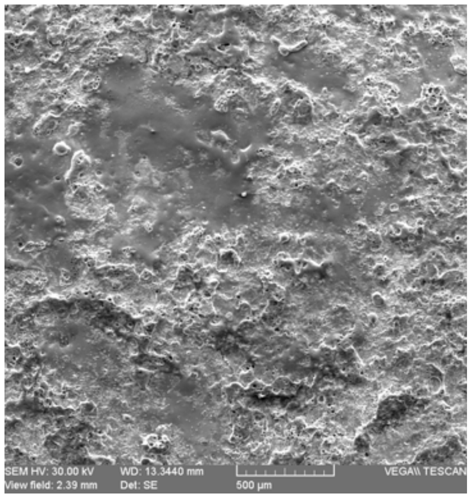


Fig. 5. *SEM photographs of the highlight relief, 500 µm.*

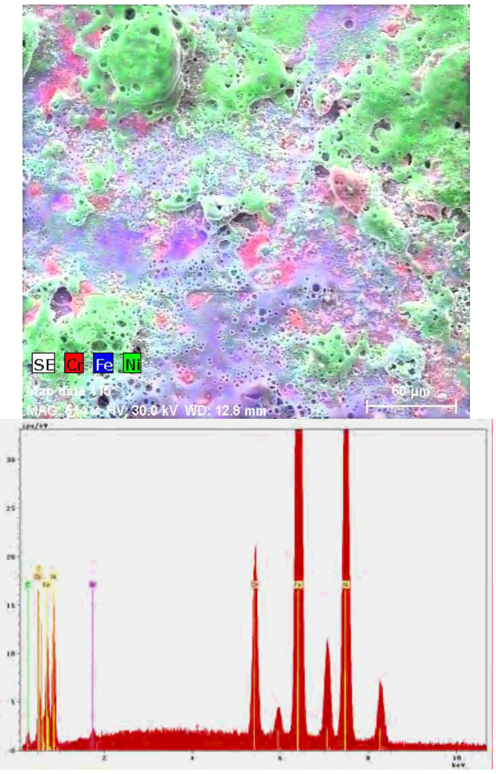
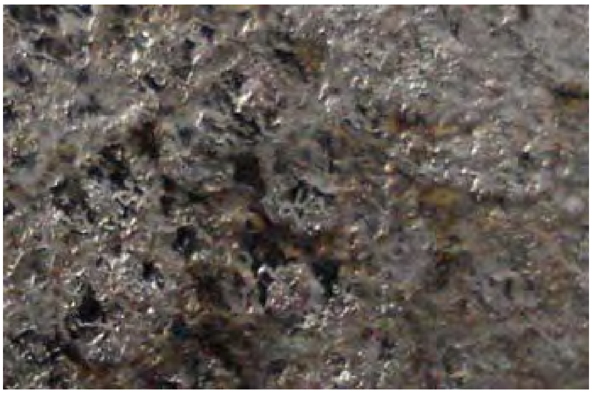
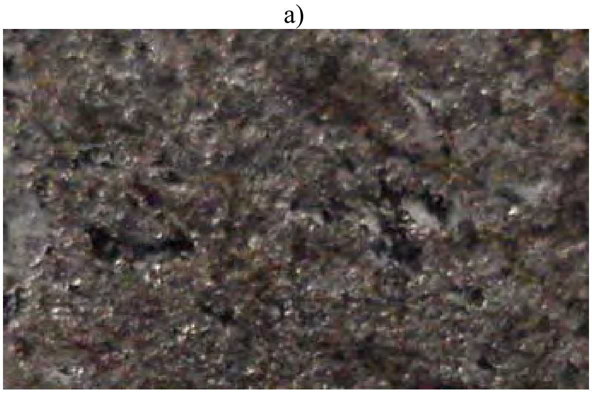


Fig. 6. *Elements distribution: Cr, Fe, Ni*



a)



b)

Fig. 7. *Macrostructure photos obtained upon deposition in the air environment; a) one layer deposition, b) two-layer deposition.*

In this case also, a chemical composition analysis was made (Table 3), for the investigated area using scanning electron microscope.

Table 3. *The chemical composition for the analyzed area*

Element	Atomic Number	Mass percent. [%]	Atomic percent. [%]
Nickel	28	41.694	35.819
Iron	26	45.694	41.038
Chromium	24	7.601	7.332
Carbon	6	1.667	6.965
Titanium	22	2.426	7.606

Nickel is more evenly represented than the one layer deposition case, but the appearance remains spongy because of intense degassing effect due to reactions occurring on the work piece surface. The relatively high quantity of oxygen presence (2.426%) is highlighted.

3.3. Oil medium deposition with nickel electrode, two layers

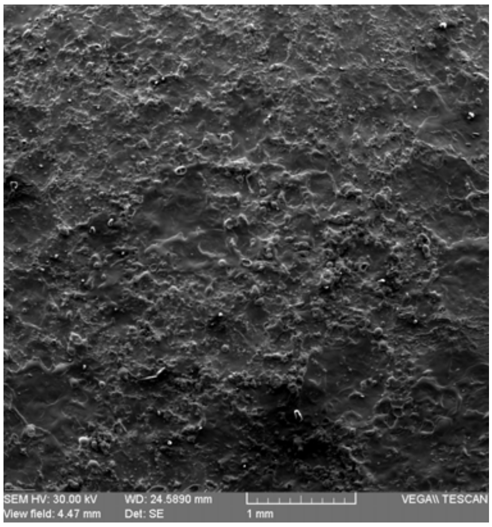


Fig. 8. *SEM photographs of the highlight relief, 1 mm.*

To improve the quality of the deposited layer, two-layer depositions into oil medium were made resulting in a more uniform surface (Fig. 8) and a more uniform distribution of nickel (Fig. 9).

Into the liquid medium deposition process, layer absorbed a larger amount of carbon, which resulted in increased hardness by quenching from the liquid phase. Chemical composition for the analyzed area is presented in Table 4.

Table 4. *The chemical composition for the analyzed area*

Element	Atomic Number	Mass percentage	Atomic percentage
		[%]	
Nichel	28	25,345	22,022
Fier	26	62,154	56,757
Crom	24	9,239	9,061
Carbon	6	2,566	10,898
Siliciu	22	0,693	1,259

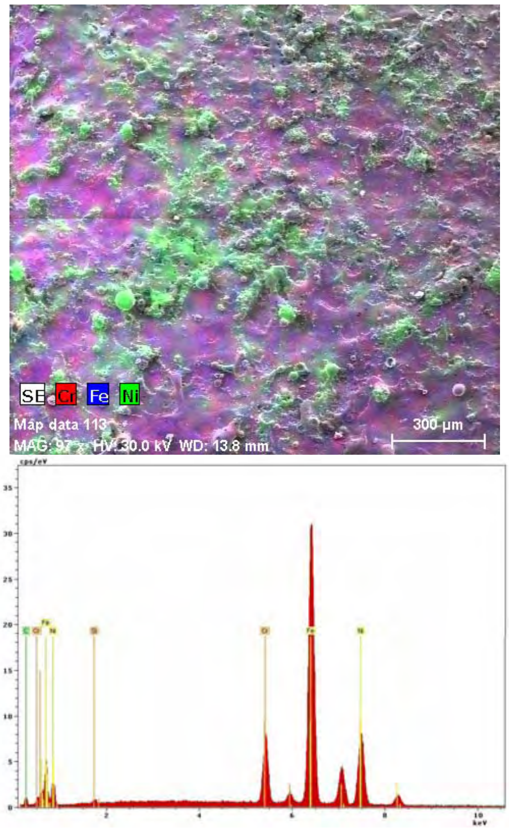


Fig. 9. *Elements distribution: Cr, Fe, Ni.*

A positive aspect of the oil deposit is accurate filling, strong environmental protection work due the lack of oxygen. Thus, oxidation disappears, contrary to the air medium deposition case.

From the macrostructure analysis, it result a uniform layer, without oxides (Fig. 10).

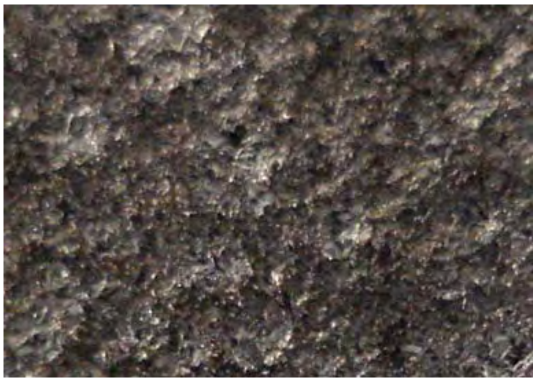


Fig. 10. *Macrostructure photograph obtained with oil medium deposition method, two layers*

The main problem in oil medium deposition by electrical spark method is that once the process is started black carbon occurs which disturbs the process visibility.

4. Conclusions

1. Electric spark treated artistic objects and household gain a pleasant casting aspect, with low roughness.
2. Stainless parts surfaces treated through electric spark maintain their stainless characteristics.
3. Oil medium electric spark method provides better quality for treated surfaces, protecting them from oxides.

References

[1]. Alexandru A., Strugaru S. I. - *Alierea şi depunerea superficială prin scânteie electrică - Influenţa tratamentelor termice asupra caracteristicilor straturilor,* Editura Tehnopress, Iaşi, 2008, pg. 5-30

[2]. Perju Manuela, Nejneru Carmen, Răileanu Tudor, Axinte Mihai, Hopulele Ion - *Researches concerning the hardening of the grey cast iron through the vibrating electrode method using a WC electrode and in combination with TiC and Ti electrode,* The Annals of “Dunarea de Jos” University of Galati, Fascicle IX. Metallurgy And Materials Science N0. 1, 2008, ISSN 1453-083X, pg.55-59

[3]. Topală Pavel - *Electrical charges as mesure for removed metal mass the eelectrical discharge machining*, Iasi, Editura PIM, Nonconventional Tehnolgies Reviev, nr.4, 2007, pg. 103-108

[4]. Vermesan, G., Vermesan, E., Jichisan-Matiesan, D., Cretu, A., Negrea, G., Vermesan, H., Vlad, M. - *Introducere în ingineria suprafeţelor*, Editura Dacia, 1999, pg. 272

[5]. *** *Instalatie Elitron 22*, Academia de Stiinte, Republica Moldova, Chisinau, 1992.