

STUDY OF CORROSION BEHAVIOR OF 1C45 STEEL COATED WITH ALUMINUM AND COPPER

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Abstract: In the context of the judicious use of natural resources, the obtaining of the mechanical, electrical or protection or resistance characteristics necessary for their use and the economic optimization, it is necessary to study new methods. The method of deposition of surface layers with the help of pulsed lasers offers new directions of development. The deposition of aluminum or copper on cheap basic materials is economically justified but it is necessary to study their corrosion behavior. The study was performed on a 1C45 base material and on samples of the same material with a surface layer of aluminum and copper. The immersion of the samples for a period of 195 days provided measurable results which led to conclusions on the behavior of these materials in the marine environment. Contrary to expectations, the corrosion was manifested in copper, and aluminum showed a high protection capacity. However, the effects of the environment on the strength of the treated surface must also be taken into account during use.

Key words: aluminium, copper, corrosion, PLD (Pulsed Laser Deposition), thin layer.

1. INTRODUCTION

A thin film physical vapour deposition (PVD) techniques is named Pulsed Laser Deposition (PLD). Any compound existing in nature or made by theoretical model can be obtained, using the pulsed laser deposition method. This type of layers, deposits of superconducting materials, metals, semiconductors and dielectrics, piezoelectric, ferroelectric materials, nitrides and carbides, oxide binary or tertiary compounds, polymers, or many other materials have been subject for many studies[11].

This paper aim is to determine the behaviour of the sample covered using PLD technique and determine also the corrosion resistance of the thin films on carbon steel.

2. EXPERIMENTAL PROCEDURE

A thin-film deposition layer, as result of this technique, using high-energy laser pulses to vaporize the surface of a solid target inside a vacuum chamber is the PLD process. To form a thin layer, up to a few micrometres in thickness, the vapour are condensing on a substrate of the sample [10].

The pulsed laser deposition plant, PLD, consists mainly of four components: a laser, a reaction chamber, a target and a substrate. During the transfer of material from the target to the substrate, the stoichiometry is preserved, target and a substrate [6]. The material removed from the target is condensed on a substrate and forms a thin film, the

process can take place, depending on the desired environmental conditions: in a vacuum, in an atmosphere of inert gas or reactive gas.

Figure 1 shows a typical PLD process.

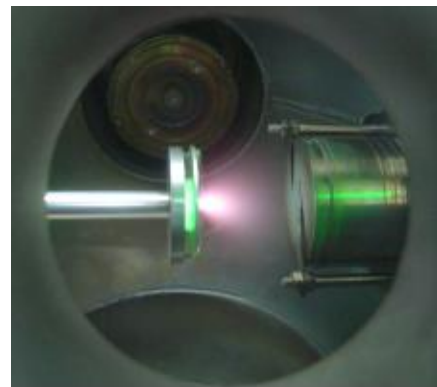


Figure 1 Image during a typical laser deposition process PLD

The kinetic energies of the particles deposited by the laser ablation method are usually high enough to diffuse to the surface of the base material, but not high enough to cause damage. Thus, PLD can create thin film deposits from a wide range of materials: metals, semiconductors and insulators with excellent adhesion to the base material [7]. Because PLD has a high cooling rate during the formation of the surface layer, films with a nano crystalline or amorphous structure result. Some of

these films have been applied in order to create protective barriers for the base material in corrosive environments or as thermal barriers.

For this experimental research we use 1C45 carbon steel as sample and for superficial deposition using pulsed laser deposition [1], [13].

On 1C45 carbon steel samples, with dimensions of 2x20x20 mm, was covered with a single face with thin films. [2], [3]. The material used for laser ablation is aluminium and copper. The samples were immersed for 195 days in static seawater at ambient temperature and was individually weighted on the analytic balance at different time intervals, determining the corrosion process speed.

This material are used to see influence on corrosion resistance in sea water for superficial layers [4].

Through the corrosion research process using the gravimetric method, the parallelepiped samples covered through PLD, with the surface of 0,00127512 m² where suspended with an synthetic line (nylon) of $\phi = 0,2\text{mm}$ in a plastic material tub at 4 cm above the tubes liquid level (see water), being immersed 195 days in static sea water at the environments temperature [2]. The major disadvantage of the gravimetric method is the long holding time of the sample in the corrosion medium [12], necessary to obtain sufficiently large differences in weight between the initial and final weighing, which can be accurately detected at the analytical balance [8]. The corrosion study was also done by electrochemical methods, determining the density of the instantaneous corrosion current and the penetration rates for 1C45 steel and the deposited layers.

3. RESULTS AND DISCUSSIONS

The speed corrosion variation results from immersed samples in sea water (195 days), is presented in figure 2.

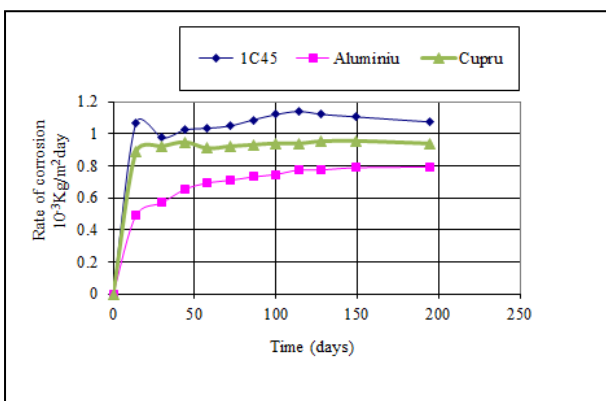


Figure 2 Rate of corrosion

Following the experimental results, analysing the corrosion resistance of 1C45 carbon steel coated by pulsed laser deposition, with aluminium and copper, after the time interval of 30 days it is found that 1C45 steel coated with Al is the most stable.

In the early stages of corrosion (0-30 days) the corrosion rate increases rapidly, and the results of short-term corrosion tests are inconclusive for long-term corrosion [9], [5].

On the surface layers exposed in sea water, at the beginning it is found that the corrosion rate increases progressively, this being due to the deposition of the layers only on one side.

Instantaneous corrosion current density was calculated with Equation[14]

$$J_{\text{corr}} = \frac{b_a \cdot b_c}{2.303(b_a + b_c) \cdot R_p} \text{ [mA/cm}^2\text{]} \quad (1)$$

The values of the Tafel slopes (b_a and b_c) the polarization resistance (R_p) and the instantaneous corrosion current density (J_{cor}) [15], [16] for the studied samples are presented in tables 1 and 2.

Table 1. Corrosion parameters for support steel

Parameter	OLC-45
Tafel anodic slope, (b_a), [mV]	24
Tafel cathode slope, (b_c), [mV]	-67
Polarizing resistance, R_p [ohm.cm ²]	1400
Instantaneous corrosion current, J_{cor} , [mA/cm ²],	0,00548

Table 2. Corrosion parameters for the covered sample

Parameter	Al	Cu
b_a , mV/decade	30	40
b_c , mV/decade	-60	-70
R_p , ohm.cm ²	10000	2250
J_{corr} , mA/cm ²	0,00087	0,00491

The densities of the instantaneous corrosion current (which are obtained by simply immersing the sample in the electrolyte) [16] are compared in Figure 3

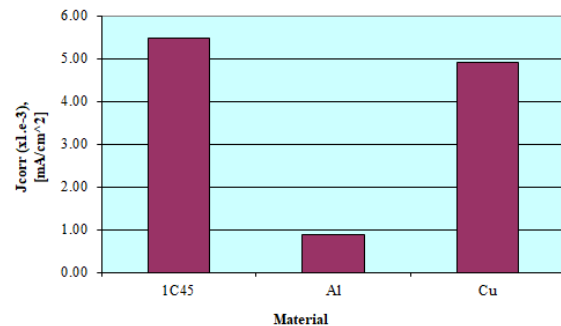


Figure 3 Instantaneous corrosion current density for 1C45 and deposition layers

The corrosion rate, expressed as penetration rate (expressed in mm / year) was calculated with the relation (2), considering for the instantaneous current density the values from table 1 and table 2[17].

$$v_p = 3,27 \cdot \left(\frac{A}{z} \right) \cdot \frac{J_{cor}}{\rho} \quad (2)$$

In the calculations the constants given in table 3 were used:

Table 3. Constants used in determining the penetration rate

Metal	Masa (g/mol)	Density (g/cm ³)	z
Fe	55,85	7,80	3
Al	27,00	2,70	3
Cu	63,50	8,96	2

In the case of the supports, only iron was taken into account and for the sparked samples only the deposited material.

The penetration rate values are shown in Table 4 and are compared in Figure 4.

Table 4. Corrosion rate for substrate and coated materials

Material	Corrosion speed [mm/year]
1C45	0,043
Al	0,009
Cu	0,057

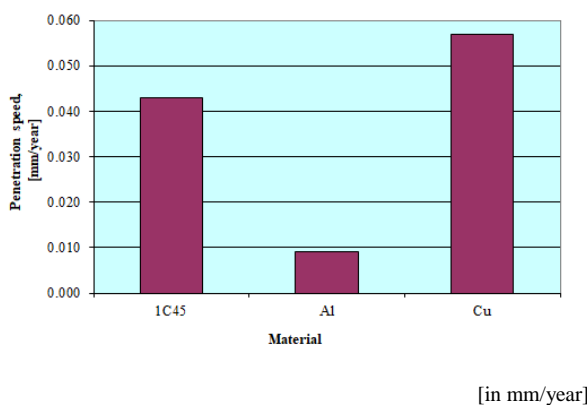


Figure 4 Speed penetration for 1C45 and deposition layers.

Contrary to expectations, the highest corrosion current was obtained for copper-coated samples and the lowest for aluminium-coated samples [18].

This is not surprising because the corrosion potential implies a steady state, while the penetration speed is directly related to the process kinetics and depends on many factors, such as: solubility of corrosion

products, adhesion of insoluble products to the surface of the alloy, transfer of substance to and from the electrode in solution, ion mobility, etc.

4. CONCLUSIONS

As a general conclusion regarding the process of corrosion of metals coated with sparks by metals, it can be appreciated that this process does not ensure a marked increase of the corrosion resistance.

This should not necessarily be considered as a shortcoming as spark coating does not have the ultimate goal of reducing corrosion but of modifying mechanical and aesthetic properties. However, the effects of the environment on the resistance of the treated surface to the environment must also be taken into account during use.

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