ANNALS OF THE FACULTY OF ENGINEERING HUNEDOARA
2005, Tome III, Fascicole 3

THE INFLUENCE OF THE NaCl SOLUTION CONCENTRATION, RESPECTIVELY OF THE TEMPERATURE, UPON THE CORROSION BEHAVIOR OF THE WC COATINGS DEPOSITED BY PLASMA SPRAYING

M.L.BENEA, M.C.BENEA

UNIVERSITY POLITEHNICA TIMIŞOARA,
FACULTY OF ENGINEERING HUNEDOARA

ABSTRACT:
The present paper presents a method to purchase the corrosion behavior of the WC coatings deposited by plasma spraying, on a stainless steel substrate; the method is based on measuring the electrochemical potential of the coating, respectively that of the substrate, immersed in a NaCl solution (corrosive agent), related to a reference calomel electrode. The mathematical processing of the experimental results shows that the dependence between the electrochemical potential difference and the solution temperature is very well described by some curves having equations obtained by parabolic interpolation.

1. INTRODUCTION

The WC – Co coatings are designed to protect machines parts (roll cylinders, turbine shuffles, parts of diesel engines) during the combined wear and chemical corrosion stresses [1,2,3]. The characteristics of the coatings are determined by: the chemical composition of the coating, the nature and processing degree of the substrate and the deposition conditions; the usual techniques to make these depositions are: Air Plasma Spray (APS), Vacuum Plasma Spray (VPS) and High Velocity Oxygen Fuel (HVOF) [4,5,6,7].

The studied coatings within the framework of the present paper have been deposited by Air Plasma Spraying, on a martensitic stainless steel substrate, using a Metco73 spraying powder.

In order to purchase the corrosion behavior of these coatings, in literature there are mentioned the 0.1 M NaOH, 0.1 M H_2SO_4 and also NaCl solutions [7]. We have used different concentrations NaCl solutions.

Our preoccupations to find a parameter to reflect in a sensitive and easy to quantify way the corrosive action of the corrosion agent upon the coating led to the electrochemical potentials of the substrate and the coating immersed into the NaCl solution. Generally, in order to ensure the anti-corrosive action, there are preferred the coating/substrate couples in which the electrochemical potential of the coating is higher than that of the substrate [8,9].

2. EXPERIMENTAL PART
2.1. Experimental conditions at the WC coatings spraying in plasma

The coated metallic substrate is the martensitic stainless steel Z12CNDV12. Before being coated, the surface of the substrate has been prepared by sanding with corundum powder.

The coatings have been made using a Metco 7MB equipment. The powder used is Metco 73, with 83% WC and 17% Co and particle size between 10 and 45 μm.

There have been working using the following parameters:

- Primary plasma gas: argon, 0.62 MPa pressure;
- Secondary plasma gas: helium, 0.62 MPa pressure;
- intensity of the current at the generator: 800A and 45÷55 V tension;
- spraying distance: 80 mm;
- (deposited) powder flow: 2.7 kg/h;
- coating thickness: 0.10 mm

2.2. Corrosion resistance determined by the potentiostatic method

The couple made of the coating (WC-Co) and the substrate (stainless steel) has been immersed in NaCl solutions having concentrations between 1 and 15%, at temperatures between 20 and 48°C. In each case there has been determined the electrochemical potential of the coating and substrate, using as reference electrode the calomel electrode.

The scheme of the used installation is shown in figure 1.

The difference between the electrochemical potential of the coating and that of the substrate represents a measure of the protection degree the coating provides. The greater this difference, the better the protection of the metallic substrate.

3. RESULTS AND DISCUSSION

The results of the experimental determinations are shown in table 1.

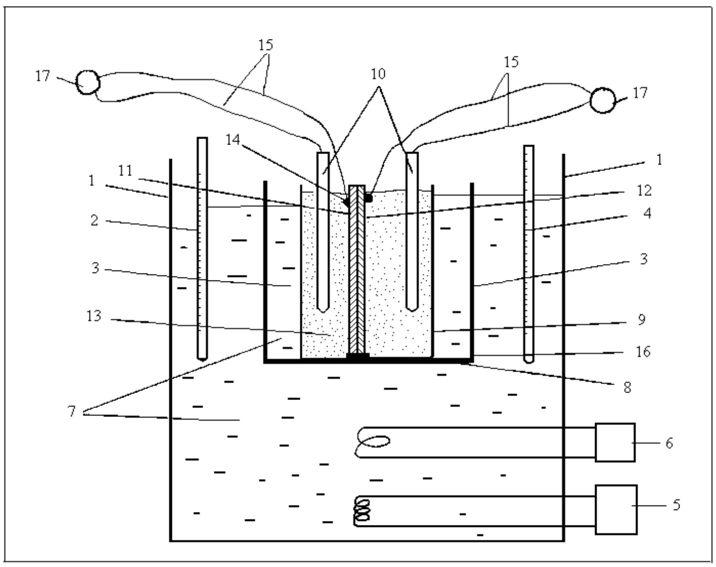


FIG. 1. THE ASSEMBLY MADE FOR THE DETERMINATION OF THE CORROSION RESISTANCE.
1-Thermostate;
2-Measurement thermometer;
3-Fixing device of the support;
4-Contact thermometer;
5-Heater;
6-Water recycling pump;
7-Water; 8-Support;
9-Berzelius glass;
10-Reference (calomel) electrodes;
11-Coating;
12-Metallic substrate;
13-Electrolite (NaCl solution);
14-Contact; 15-Conductors;
16-Silicon (adhesive for sealing);
17-Milivoltmeter

In order to obtain some mathematical correlations between the corrosion behavior – estimated by the electrochemical potential differences and the concentration of the NaCl solution (for each temperature), the experimental data have been processed with Matlab program.

For each concentration of the NaCl solution it has been established the dependence: electrochemical potential differences between the coating and the substrate, noted as deps (y), and the temperature of the NaCl solution (x), by parabolic interpolation. Table 2 shows the results of this interpolation.

In figures 2 -16 there are graphically represented the variations of the electrochemical potential differences between the Metco 73 coating and the metallic substrate related to the temperature of the NaCl solution, for constant concentrations.

The square medium deviation for the parabolic interpolations has been calculated with the relation (1).

$$s = s_2 = \sqrt{\frac{1}{15}\sum_{i=1}^{15}\left(y_i - ax_i^2 - bx_i - c\right)^2} \qquad (1)$$

where a, b and c are the coefficients in the obtained regression equations, and y_i, x_i are pairs made of the values of the electrochemical potential differences between the coating and the metallic substrate and the temperature of the NaCl solution, for the same concentration.

TABLE 1 - THE VALUES OF THE ELECTROCHEMICAL POTENTIAL DIFFERENCES [MV] BETWEEN THE COATING AND THE SUBSTRATE, WHEN VARYING THE TEMPERATURE AND THE CONCENTRATION OF THE NACL SOLUTION.

[%]	The electrochemical potential difference [mV] for different temperatures of the NaCl solution [°C]														
	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
1	253	250	248	245	240	245	237	235	233	225	225	225	225	227	227
2	225	215	209	205	198	199	195	194	192	191	190	188	190	198	191
3	210	200	195	190	180	175	174	180	172	171	170	170	172	172	173
4	195	179	168	170	159	159	157	155	152	154	149	152	152	154	155
5	190	176	161	150	142	144	143	142	141	141	140	140	141	142	142
6	185	160	152	150	141	142	135	134	133	132	132	133	133	135	137
7	184	181	165	151	140	135	134	132	132	131	130	131	132	132	133
8	183	165	150	143	140	137	133	132	132	131	131	132	133	134	134
9	184	160	155	145	142	138	137	140	133	132	132	133	135	136	136
10	183	160	160	143	140	135	134	133	132	131	131	132	133	135	137
11	183	177	168	157	150	143	142	140	137	135	132	132	133	137	140
12	183	170	159	155	140	137	135	135	133	133	131	132	132	137	140
13	183	172	165	151	145	142	139	138	140	134	133	135	138	139	140
14	183	170	160	153	150	148	142	139	136	135	135	137	140	139	140
15	180	168	157	150	145	143	140	137	136	135	135	137	139	140	142

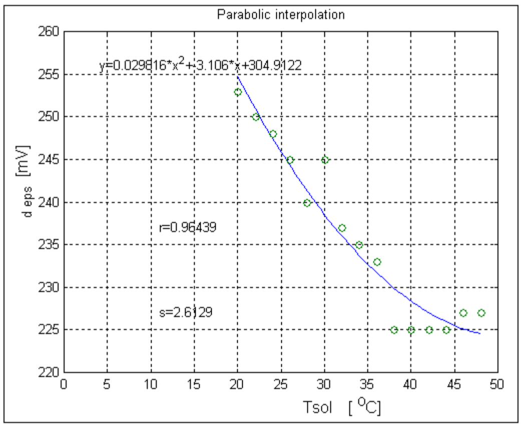


Fig. 2. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 1%.

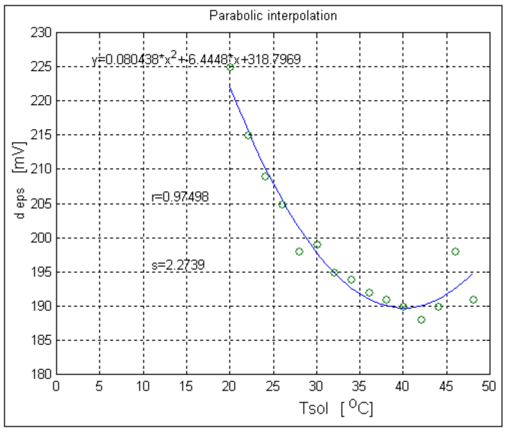


Fig. 3. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 2%.

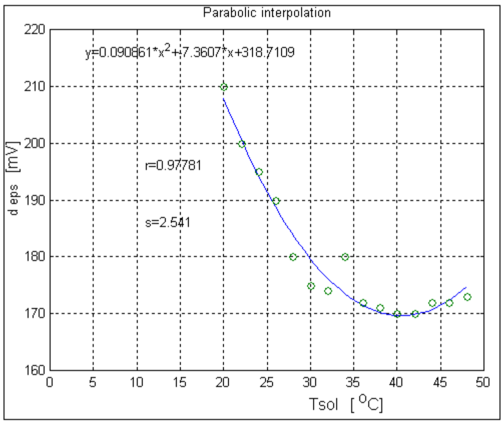


Fig. 4. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 3%.

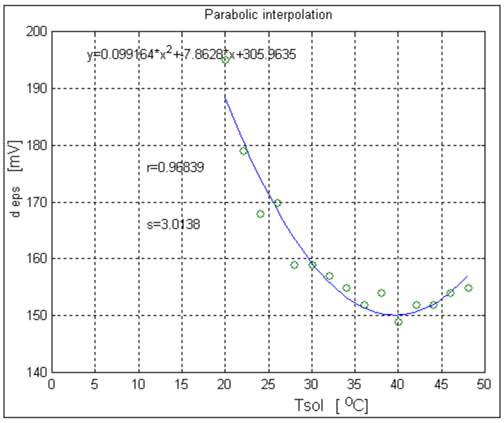


Fig. 5. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 4%.

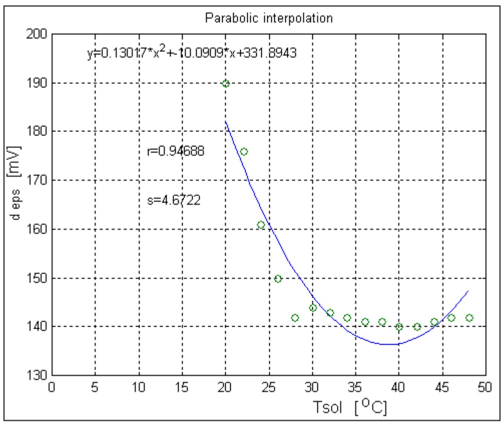


Fig. 6. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 5%.

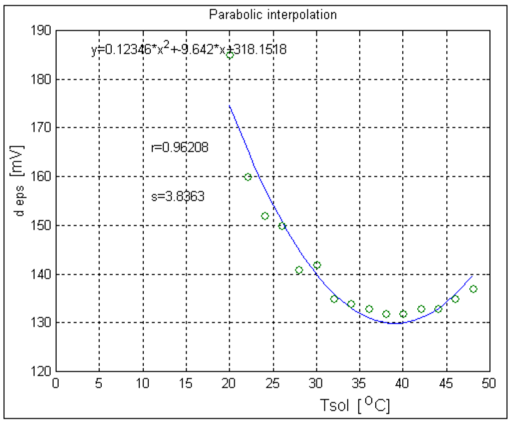


Fig. 7. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 6%.

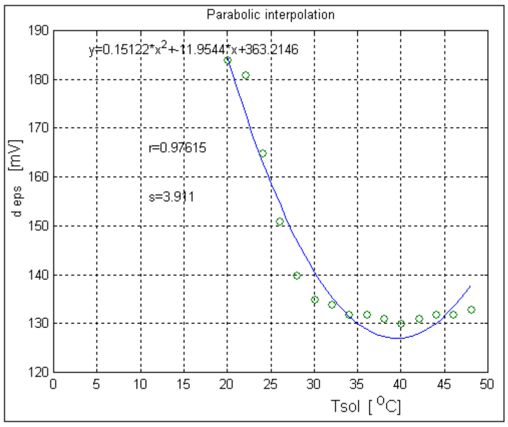


Fig. 8. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 7%.

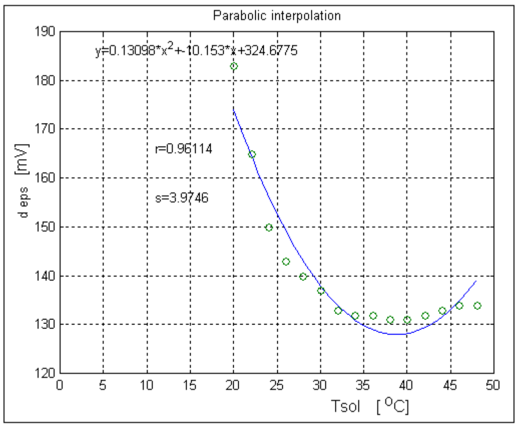


Fig. 9. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 8%.

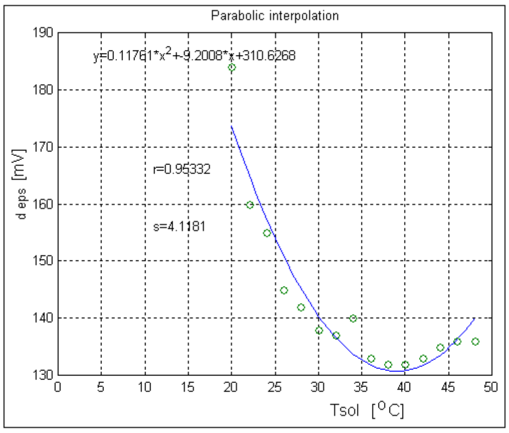


Fig. 10. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 9%.

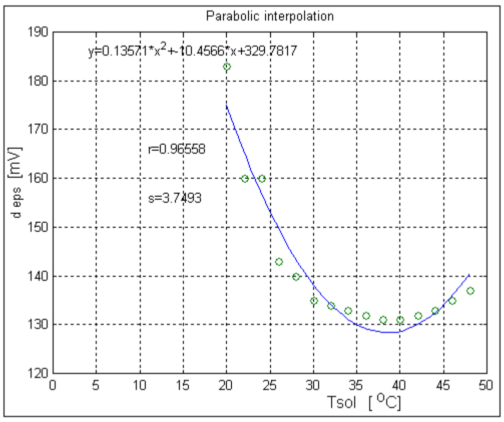


Fig. 11. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 10%.

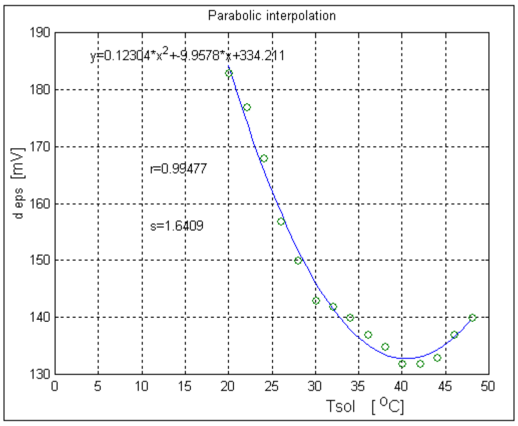
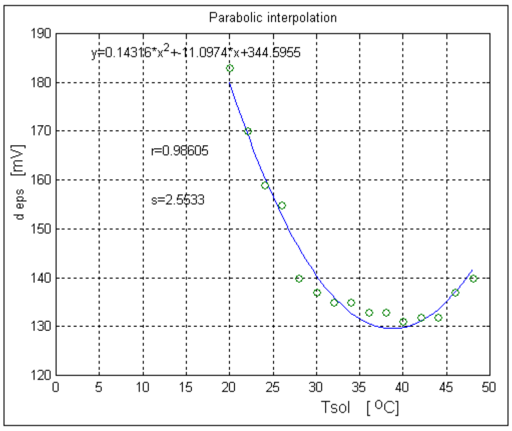


Fig. 12. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 11%.

Fig. 13. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 12%.



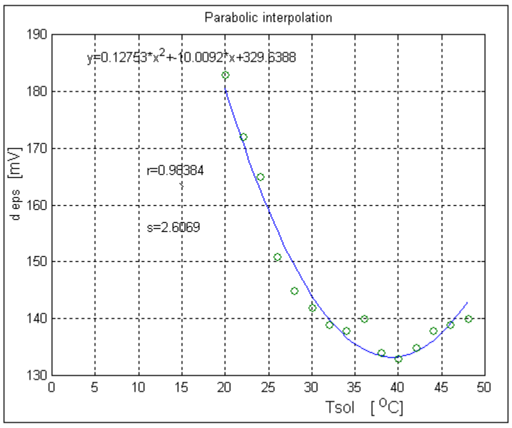
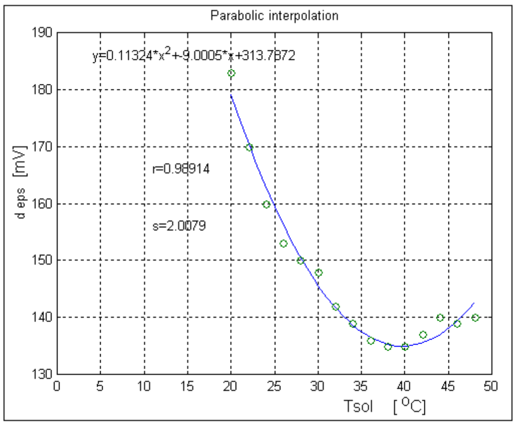


Fig. 14. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 13%.

Fig. 15. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 14%.



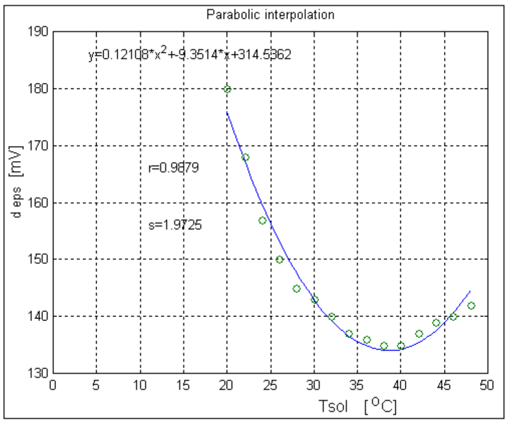


Fig. 16. The variation of the potential difference deps [mV] depending on the temperature of the NaCl solution, for a concentration of 15%.

TABLE 2 - THE RESULTS OF THE CUBIC INTERPOLATION AT THE VARIATION OF THE ELECTROCHEMICAL POTENTIAL DIFFERENCES BETWEEN THE COATING AND THE METALLIC SUBSTRATE AND THE TEMPERATURE OF THE NACL SOLUTION, FOR THE SAME CONCENTRATION.

Concentration of the NaCl solution [%]	The dependence relation: electrochemical potential difference between the coating and substrate (y) and the temperature of the NaCl solution(x)	Correlation coefficient r	Square medium deviation s
0	1	2	**3**
1	$y = 0{,}029816x^2 + 3{,}106x + 304{,}9122$	0,96439	2,6129
2	$y = 0{,}080438x^2 + 6{,}4448x + 318{,}7969$	0,97498	2,22739
3	$y = 0{,}090861x^2 + 7{,}3607x + 318{,}7109$	0,97781	2,541
4	$\mathbf{y = 0{,}099164x^2 + 7{,}8628x + 305{,}9635}$	0,96839	3,0138
5	$y = 0{,}13017x^2 + 10{,}0909x + 331{,}8943$	0,94688	4,6722
6	$\mathbf{y = 0{,}12346x^2 + 9{,}642x + 318{,}1518}$	0,96208	3,8363
7	$y = 0{,}15122x^2 + 11{,}9544x + 363{,}2146$	0,97615	3,911
8	$y = 0{,}13098x^2 + 10{,}153x + 324{,}675$	0,96114	3,9746
9	$y = 0{,}11761x^2 + 9{,}2008x + 310{,}6268$	0,95332	4,1181
10	$y = 0{,}13571x^2 + 10{,}4566x + 329{,}7817$	0,96558	3,7493
0	1	2	**3**
11	$y = 0{,}12304x^2 + 9{,}9578x + 334{,}211$	0,99477	1,6409
12	$y = 0{,}14316x^2 + 11{,}0974x + 344{,}5955$	0,98605	2,5533
13	$y = 0{,}12753x^2 + 10{,}0092x + 329{,}6388$	0,98384	2,6069
14	$y = 0{,}11324x^2 + 9{,}0005x + 313{,}7872$	0,98914	2,0079
15	$y = 0{,}12108x^2 + 9{,}3514x + 314{,}5362$	0,9879	1,9725

4. CONCLUSIONS

- The paper presents an original method to purchase the corrosion behavior of the WC coatings deposited by plasma spraying, on a stainless steel substrate; the method is based on measuring the electrochemical potential of the coating, respectively that of the substrate, immersed in a NaCl solution (corrosive agent), related to a reference calomel electrode.
- The obtained experimental results show that the coating/substrate electrochemical potential difference is a sensible parameter, which reflects the protection provided by the coating and may be used in quantifying coatings protection activity, in constant conditions concerning the nature of the couple coating/substrate and the spraying parameters.
- The values of the potential differences between the coating and the substrate are decreasing when raising the temperature and the concentration of the NaCl solution, which shows a decrease of the protection provided by the coating.
- The mathematical processing of the experimental results shows that for all the concentrations of the used NaCl solutions, the dependence between the electrochemical potential difference and the solutions temperature is very well described by some curves having equations obtained by parabolic interpolation with the coefficients varying between 0.95332 and 0.99477.

5. REFERENCES

[1.] S. Kasai, A. Yanogisawa, A. Ichihara, Y. Shimoyama, K. Ochiai, H. Onishi - Proceedings, 1th Plasma –Technik- Symposium, Vol. I, Lucerne/Switzerland, May, 205, (1988).

[2.] R. W. Smith, Z. Z. Mutasim – Journal of Thermal Spray Technology, ASM International, 57 (1992).

[3.] I. Kvernes, E. Lugscheider, O. Norholm, Proceedings - 1th Plasma –Technik- Symposium, Vol. 3, Lucerne/Switzerland, May, 41, (1988).

[4.] A. Scrivani, R. Groppetti, U. Bardi, A. Lavacchi, F. Niccolai, G. Rizzi – A Comparative Study On HVOF, Vacuum Plasma Spray and Air Plasma Spray for CoNiCrAlY alloy deposition, document placed on line on June 2001, http://www.unifi.it/unifi/surfchem/solid/bardi/tbcs/mcraly/CoNiCrAlYart12jun01.html

[5.] *** Commission on Engineering and Technical Systems, National Research Council – Coatings for High-Temperature Structural Materials: trends And Opportunities, National Academy Press, Washington D. C. (1996).

[6.] R. Suryanarayanan – Plasma Spraying-Theory and Applications, World Scientific, June (1993)

[7.] D. Toma, W. Brandl, G. Mărginean – Wear and Corrosion Behavior of Thermally Sprayed Cermet Coatings-Surface and Coatings Technology, 138 (2001).

[8.] M. L. Benea, Ş. Maksay, 6th International Symposium Interdisciplinary Regional Research Hungary-Romania-Yugoslavia, Novi Sad, oct. (2002).

[9.] M. L. Benea, Ş. Maksay, Analele Facultăţii de Inginerie din Hunedoara, Tomul IV, Fascicola 1, 129, (2002).