TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 11
Number 4
December 2017
DOI: 10.12716/1001.11.04.07

The Anode Material Selection for Electrospark Alloying (ESA) and its Mass Transition Phenomena

Z.Z. Sharifov & F.N. Gurbanov
Azerbaijan State Maritime Academy, Baku, Azerbaijan

ABSTRACT: The expression used in this article is to take into account the inverse transition of electrode's material when it is selected in electro-spark processing; a formula is derived that estimates the ratio of solid-phase and liquid-vapor constituents of erosion.
It is determined that as the selection criteria for the anode increase, the amount of transition of its material to the cathode in the liquid-vapor phase increases as well. When choosing the electrode material, the most important task to be taken into account is the solid-phase constituents of erosion.

1 INTRODUCTION

The main difficulty in Electro spark alloying (ESA) process, is selection of material of alloying electrods. Until recently they were made of standard solid brand like VC Tungsten-cobalt alloys and TK Titanium-tungsten-cobalt alloys. But the expansion of the spheres where application of electro-spark coating is in use, and difficulty in finding of the raw tungsten, lead to search for a new electrode materials based on refractory compounds.

The above-mentioned difficalty is including the necessity to be taken into accoaunt of numerous factors that influence to the formation of alloying coat:

Erosion of organizational solid phase, physicochemical interaction of the electrodes' materials, the creation of a second structure on the anode's working surface, main (from cathode to anode) mass transition, conditionality collection of unusual erosion's electrode materials [1]

In the ESA process not only the anode's material, but also makes cathode erosion. Its erosion, as a rule not taken into account, which can lead to errors in anode's erosion and cathode's increase determination. In addition, the inverse transition of materials is one of the reasons of formation of the second structure on the electrode's working surface [2].

For the first time the material transition from cathode to anode, in the spectral analysis of materials and alloys, as well as in measuring process parameters of Electro-spark discharge, and reverse process of the ESA differing by contacting parameters of electrode pairs, its quantity and its impact on the characteristics of the process had been evaluated in the work [3]

It was shown that during ESA process based on transition materials the quantity of such a transition for the electrode pairs is not more than 10% compared to the alloying metal's erosion.

Group IV Chemically active metals (as a consequence gripping of electrodes) low thermal conductivity easy-melting metals (with effect of vapor phase of anode in cathode) easy-removebale from the

surface due to the increase in the volume of the liquid phase is exceptional.

Therefore, it is important to offer an assessment of the choosing parameter of alloying electrode. This assessment can be done by advantage provision transitioning of the electrode to cathode.

This provision is controlled by the ratio heat-physical constants of materials of the electrodes, which is taken according to the criteria of L. S. Palatnikin [4]

A similar criterion for the selection of material in plasma sprinkling "melting difficulties" the parameter applied materials and its heat-physical rate confirms the importance of their physical and chemical interactions.

2 THE DISCUSSION OF THE RESULTS

Summarizing of results of the erosion legitimacy researches [5], taking into account the inverse transition of the material in multi-impulse processing brings to the following erosion expression:

$$\Delta_a(t) = (\Delta_a + \Delta_b + \Delta_{bk} \pm \Delta_k - \Delta_{\partial k}) R_t R_R \quad (1)$$

R_t,R_R – are the ratios with consideration to the second structure's mode and formation;
Δ_M, Δ_b, Δ_{bk} - contribution of erosion's solid and liquid-vapor constituents;
Δ_k - transition of contact-bridge of substances;
$\Delta_{ək}$- the inverse transition of substances.

Contact-bridge transition of the models achieves during moment of contact of electrodes, possible in both directions and determined with the help of Thompson, Koller and Pelte [6] effects.

In expression (1) the contribution Δ_{bk} - as a result of brittle failures of the number of impulses build up from the single discharge, the spherical erosion's volume and cavity correlation can be assessed.

The radius of the cavity ($R_ç$) approximate internal thermal tensions σ (E) subject to the distance R from the dotty impulse heat source, as per formula of B.N. Zolotıxın [7] can be found if the $R_ç$ is compatible with the degree of resilience of the material.

Such a dependancy calculated for the iron is given on Figure 1.

For the iron $\sigma_d \approx$ 48MPa [8] as a term (during ESA procces at high tempretures taking into account the heating of the anode) we get $r_ç$=12mkm.

$R_ç$ quantity comparisoned with experimental will be reduced, because real erosion cavity is formed under effect of appeared tensions and in consequence of brittle failures, contribution given to this process and to erosin's liquid-vapor constituents.

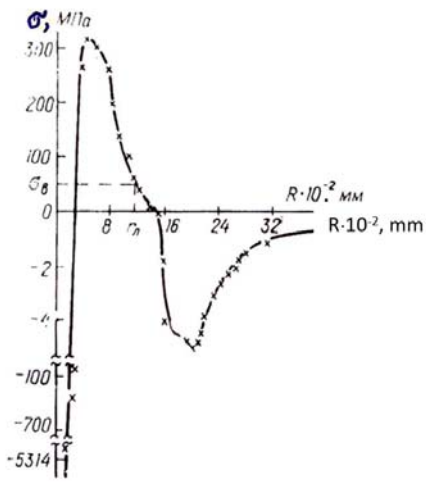

Figure 1. Dependancy up to point impulse heat source of internal thermal tensions for iron. A pulsed energy 5C, endurance 10^{-4}s

Taking into account the contribution of chemical communication of homopolar components, heat-physical and mechanical characteristics of Material of the electrode, the ratio of solid-phase and liquid-vapor constituents Of the Erosion can be assessed:

$$\frac{\Delta_{bk}}{\Delta_b + \Delta_b} = \frac{(T_m - T_c)^2 \ \alpha^*}{(T_m + T_b)^2} \cdot \frac{\sigma(E)}{\sigma_d}, \quad (2)$$

α^* - the movement of dislocations in the crystal lattice parameter to characterize the resistance [9];
σ (E) - The maximum internal tensions;
T_m, T_b, T_c – melting, boiling and breaking cold temperatures.

Taking into account the criteria of L.S.Palatnikin [4] in proportion to the quantity of cathode erosion the value of Δ_{om} can be written as follows:

$$\Delta_{om} \approx 1/C_k \rho_k \lambda_k \quad (T_ə^k - T_s^k)^2, \quad (3)$$

C_k, S_k, λ_k –heat capacity, dencity and heat conductivity of cathode's material.

It should be noted that the established patterns of erosion as well as metal cathodes for metal anodes are kept, specifically: their erosion in the air is higher than in argon, also by increasing tendency of the melting and boiling temperatures of them, its exposure to a decrease in the number of transition metals from group IV to group VI.

The main condition of effectiveness of the ESA is the prevailing transition of material from anode to cathode, and controlled by Δ_a of anode and Δ_k of cathode materials erosion ratio:

$$\Delta_a >> \Delta_k, \quad (4)$$

$\Delta_k = \Delta_{bk}^k + \Delta_{er}^k$ (Δ_{bk}^k and Δ_{er}^k - erosion of cathode in solid and liquid-vapor phase)

Taking into account previously proposed formula for relative sustainability of erosion [10] the formula (4) can be written as follows:

$$\frac{\Delta_a}{\Delta_{bk}^k + \Delta_{er}^k} = \frac{C_k\ \rho_k \lambda_k (T_R^{\text{д}} T_s^k)^2}{C_a \rho_a\ \lambda_a\ (T_R^{\Phi} - T_s^a)^2} \succ\succ 1 \qquad (5)$$

This expression proves adopted experimental conditions of anode material to cathode prevailing transition [5]:

$$\lambda_a \leq (5\text{-}6)\ \lambda_k \quad \text{və} \quad T_ə^a \leq (3\text{-}4) T_ə^k \qquad (6)$$

Taking into account the interatomic covalent interactions of materials of the Anode (α_a^*) and cathode (α_k^*) and its communication, then (2.5) alloying electrode's material selection criteria is determined - D_m:

$$D_m = \frac{C_k\ \rho_k \lambda_k (T_R^K - T_s^k)^2}{C_a\ \rho_a \lambda_a\ (T_R^k - T_s^k)^2} \cdot \frac{r_k}{[r_a - r_k]} \cdot \frac{1}{\alpha_a^* \cdot \alpha_k^*} \qquad (7)$$

The more significant quantity of D_m, the more quantity of Anode's material is transfering to cathode at liquid - vapor phase; The effect of the last is taken into account by $1/\alpha_a^* \cdot \alpha_k^*$ coefficient. If the electrodes are metal this ratio as well as the anode (r_a) of the metals, and cathode's (r_k) metals measured atom radius ratio interact plays a key role. Homogeneous metals in ESA $r_k = r_a$ and $D_m \to \infty$, it meets the maximum efficiency of ESA. [5]. Refractory compounds are characterized by Low mutual solubility of metals. in determining prevailing erosion of their solid phase covalent communication the interatomic covalent interactions plays a key role. Therefore, the expression (7) for such compounds takes the following form:

$$D_m = \frac{C_k\ \rho_k \lambda_k (T_R^K - T_s^k)^2}{C_a\ \rho_a \lambda_a\ (T_R^k - T_s^k)^2} \frac{1}{\alpha_a^* \cdot \alpha_k^*} \qquad (8)$$

Using the information [9,11] regarding heat-physical characteristics of the materials, the D_m parameter for the most widely used metals and ESA condition of iron with carbides are calculated (the table below) according to formulas (7), (8)

It appears from the information provided, the biggest D_m parameter of iron with unlimited solid solution of chromium, while the smallest D_m parameter is for titanium, characterized by maximum covalent of interatomic interactions in it.

This result is matching the results of high efficiency of iron and steels alloying with chrome in ESA process, and low results of alloying by titanium carbide. [5].

Thus, the problem of the creation and selection of electrode materials for the ESA, reflects experimental study of the most important moment, like solid-phase constituents of erosion, taking into account the materials' mutual solution, and its transition from cathode to anode.

3 RESULTS

1 The selection of electrode material for ESA and mass transition kinetics of this process have been investigated. Considering the possibility of inverse transition of material In Multi-pulse ESA, the mathematical expression of the occurring erosion had been obtained. The proportional formula for erosion of Cathode was derived.
Analytic expression which determines the rate of the erosions occurring in cathode and anode have been identified.

2 The criterion formula for selection of alloying electrode's material with taking into account the type of interatomic communication of materials of the anode and cathode and their mutual solution was obtained. It was determined that as the selection criteria grows, the amount of transfered anode's material to cathode in liquid-vapor-phase increases as well.

3 It was determined that, the solid-phase constituents of erosion is not considered as the most important issue in the problem of making and selection of electrode's material for ESA, and reflects experimental study of materials' transition from cathode to anode and their mutual solution.

Table 1. The calculation of rational criteria for the selection of electrode material for iron ESA

Electrode material	C kol/ (mol-degree)	ρ, q/sm³	R, kal/ (sm·s·degree)	$T_ə$, K	T_s, K	α^* [68]	$\frac{r_k}{r_k - r_a}$	D_m
α-Fe	6,01	7,87	0,356	1812	~273	~1	$\to \infty$	$\to \infty$
Cr	5,57	7,19	0,737	2176	~700	1,05	127	~75,1
W	5,93	19,26	0,116	3650	~900	~1	9,1	~3,64
Ti	5,98	4,5	0,209	1938	$\prec\prec$ 273	~1	7,1	>13,4
Ta	5,83	16,6	0,535	3270	83	1,06	6,7	4,41
TiC	8,04	4,92	0,0162	3530	1173	8,4	-	0,59
WC	8,53	15,77	0,07	3058	-	5,49	-	2,49

REFERENCES

[1] A.D.Verkhoturov, I.M.Mukha Electrospark alloying technology. Kiev: Technique, 2002, 182p.

[2] A.D.Verkhoturov, M.S.Kovalchenko, M.M.May and others. Influence of the structure of titanium dichloride on the conditions for the formation of coatings during electric spark alloying of steels / Powder Metallurgy, 2013, No.7 / 8, p.35-39.

[3] E.P.Ignatenko, A.D.Verkhoturov, M.Z.Markman Formation of the surface layer during electro-alloy doping with low-melting metals.-Electron processing of materials, 2009, №3, p.18-20.

[4] Polatnik L.S. Phase transformations in electro spark metal processing and experience in establishing the criterion of observed interactions- Rep. Academy of Sciences of the USSR, 1983, 89, No. 3, p.455-458.

[5] Verhoturov A.D. Investigation of electrode materials for electro spark alloying and the principles of their creation. Preprint No. 5.- Kiev .: IPM NASU, 2010, 63 p.

[6] Buravlev Yu.M., Rudnevsky NK, Grikit IA Spectral analysis of metals and alloys. Kiev: Technique,1996.-192p.

[7] Zolotykh B.N. The main issues of the theory of the electrical environment. - Author's abstract. Diss. Doct. Tech. M.-M.: MIEM, 1998, p. 52

[8] Physical and chemical properties of elements: Handbook / Ed. G.Samsonova.-Kiev: Nauk Dumka, 1995.-807p.

[9] Trefilov VI, Milman SE., Firstov SA. Physical basis of strength of refractory metals.-Kiev: Nauk. Dumka, 1995, p. 315

[10] Verhoturov A.D. Erosion resistance of refractory metals. In: The electronic structure and physico-chemical properties of refractory metals and compounds. Kiev.: Sciences. Dumka, 2000, p.455-458.

[11] Samsonov GV, Vinitsky IM Refractory compounds: Handbook.-M .: Metallurgy, p.1996.-556