

PHYSICAL AND CHEMICAL PROCESSES DURING THE MACHINING BY MEANS OF THE ELECTRO-EROSIVE METHOD

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Abstract: We have analyzed the processes that take place in the interstice and in the electrode surfaces during machining by electro-erosion. It is demonstrated that machining by electro-erosion is accompanied by a series of physical phenomena which occur at high temperature; simultaneously a series of chemical phenomena develop and are produced. Chemical phenomena contribute to the formation of new structures and compounds that cannot be obtained under ordinary conditions.

Keywords: electro-erosion, deposits, effects, chemical structure, electrodes, oxidation, hydrooxidation, diffusion processes, electrophysical, electrochemical.

1. INTRODUCTION

The phenomenon of electro-erosion is basic for many methods of material processing using electric discharges in impulse (EDI) some of these methods are: dimensional processing by means of electro-erosion [1, 26], formation of compact material deposits [2, 3] and powder [2, 3, 4], modification of surface microgeometry, modification of chemical structure and composition in piece surface strata [4, 5, 6, 10, 12, 14, 20].

All these methods make use of the thermal energy generated by electric discharges in impulse, electric fields energy generated by them when electroerosive effects are realized, the convective effects that appear when powder and compact material deposits are formed, diffusion effects of elements from the working medium or those that derive from the material of the opposite electrode in the electrode active surfaces, etc. It is important to mention that practically all these processing methods are accompanied by structure and chemical composition modifications in the surface strata. The chemical composition is modified either by implanting medium elements of one of the electrodes in the surface or by a previous deposit on the surface that is subjected to processing or a deposit formed by material transfer from the surface of one of the electrodes. In all these cases, the chemical composition modification is

accompanied by diffusion processes [4, 5, 8, 11, 15] and correspondingly by a mixture depending on the physical state of the materials in which the processing takes place.

2. ANALYSIS OF SCIENTIFIC RESULTS OBTAINED NOWADAYS CONCERNING THE FORMATION OF SURFACE STRATA BY THE APPLICATION OF EDI

According to the conditions described in the paper [4, 15, 24, 25] the effective diffusion coefficient of elements D_{ef} when electric discharges are applied may be determined by the relation:

$$D_{ef} = N(D_1 t_1 + D_2 t_2), \quad (1)$$

in which N is the number of processing cycles; D_1 and D_2 are correspondingly the diffusion coefficients throughout the electric discharge in impulse and during the interval between the two discharges; t_1 and t_2 are the periods of duration of electric discharges in impulse and of the pause.

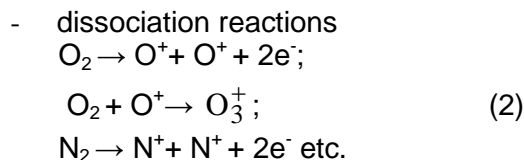
It is mentioned in some of the papers that deal with formation of deposited strata [2, 3, 3, 7, 9, 10, 14] that this process is accompanied by micrometallurgic processes but these processes are obscure under this expression. It is logical to ask the question: „Which of the electro-chemical processes accompany electroerosive phenomena?”

To answer this question it is necessary to remember the phenomenology of electroerosion. Even in the first papers in this domain [1], they mentioned that irrespective of the mechanism of piercing the interstice the formation of the conductivity channel (plasma) is conditioned by the presence of elementary particles, bearers of electric charge, such as electrons and ions. The formation of the latter in a liquid medium (in dimensional processing) and in a gaseous one (deposit formation) is possible during the mechanical interaction of elementary particles (atom and molecule bombing) under the influence of strong electric fields at a phase of electric discharges in impulse fusion (EDI) and dissociation of the working medium components accompanied by breaking the electrons or adding them to high temperatures and under the influence of strong electric fields.

It is necessary to mention that the described processes take place at high temperatures of about 10^4 K [1, 2] compared to that of the sun surface, that can produce certain phenomena of nuclear desintegration. The latter are accompanied by radiations contained in the visible and invisible spectrums. Unfortunately these are only theoretical hypotheses that are not supported by direct experimental measurement.

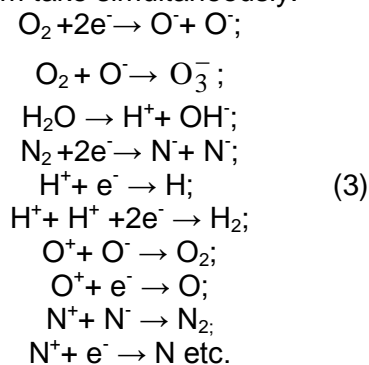
If we were to analyse what is being produced in the interstice and on electrode surfaces under conditions of electric discharges in impulse we would take into consideration the following [1, 2, 4, 16-20]: the appearance of free electrons and possibly ions at the fusing phase of EDI; heating the working medium up to the plasma state; heating, melting and vaporization of the working material of electrodes in the zone of interaction with electrode spots with the help of which these are coupled in the discharging contour with the help of the plasma channel; excitation of capillary waves and drawing the material in the three aggregation states from the surface of electrodes under the influence of electric fields and high temperature created by punctiform sources, such as electrode spots, the transfer of the drawn material to the working medium and on the electrode surfaces under the influence of electric fields; the transfer of negative charge bearers (electrons, ions, molecules and material particles) to the anode surface and of the positive charge bearers (ions, molecules and

electrified material particles) to the cathode surface. Taking the above said into consideration we can group the types of reactions that accompany electroerosive phenomena into:



At the moment of piercing the interstice the electrons drawn from the cathode surface turn towards the anode. The electrons are accelerated in the interstice electric field, they collide with gas molecules and atoms in the interstice and produce the ionization of the working medium.

The dissociation and recombination of the interstice medium take simultaneously:



The dissociated electrons and ions are influenced by electric field forces:

$$\begin{aligned} F_e &= eE; \\ F_q &= qE, \end{aligned} \quad (4)$$

in which e and q are correspondingly the elementary charge and the charge of the ion or the electrified material particles.

Due to the high temperature in the plasma channel the molecules, atoms and ions participate in a chaotic accelerated movement with speeds determined by plasma temperature and the mass of elementary particles that may be expressed by the relation:

$$\begin{aligned} \frac{mv^2}{2} &= kT. \\ v &= \sqrt{\frac{3kT}{m}} \end{aligned} \quad (5)$$

Both the speed and the movement direction of particles, bearers of electric charge, may be modified under the influence of Lorentz force caused by the electric currents of high voltage that cross the interstice.

The action of gravitational forces and of the columbien ones between elementary particles on their process of movement may be ignored.

The resultant of all forces that influence the charges particles, molecules and atoms in the interstice direct most of the towards the surface of electrodes. They may penetrate into the surface strata of electrodes forming important elements, they may interact with the material of the piece-electrode surface and that of the tool-electrode forming oxides, hydro-oxides, nitrides etc.

As it has already been mentioned deposits are formed by ion and vapour like particles, and solid ones. These may be sections of material drawn from electrode surfaces in a solid form under the influence of high voltage electric fields (e.g. for the electric voltage of piercing the interstice the mechanic voltage used on the surface of electrodes

may be calculated using the relation $\tau = \frac{E^2}{8\pi}$

and int constitutes about 450Mpa and sometimes considerably exceeds the limit of mechanic resistance of the electrode material) or the powder particles introduced into the interstice from the outside.

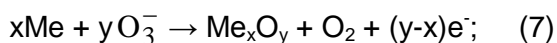
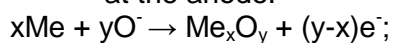
The solid particles in the interstice get electrified and are subjected to movement under the influence of the electrodynamic, weight and resistance forces of the working medium. Depending on the size of the interstice (S), the applied voltage (U_s), the equivalent radius of the particle (R) and the density of the material used to produce the particle the relation for their moving speed may be expressed by:

$$V = V_0 + \alpha US\rho^\gamma (R + \delta \ln R) \quad (6)$$

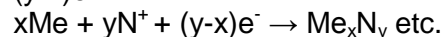
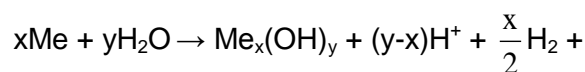
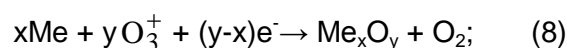
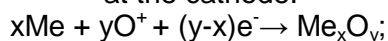
where V_0 is the initial speed of introducing the particle into the interstice, α is the coefficient of proportionality.

The reaction that occur at the surfaces of electrodes are those of oxidation, hydrooxidation and nitride and may be described as follows:

- at the anode:

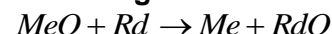


- at the cathode:



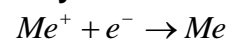
The above said is supported by the results obtained during the study of phase and chemical composition obtained by other authors [2, 4, 13, 15, 20-23] using spectrometric and electronic analyses and royntgen radiation ef electrode surfaces from 1 to n cycles of dimensional processing and deposit formation.

- **reactions of reduction that may be presented using the relation:**



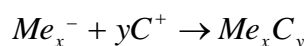
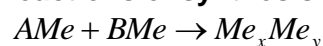
Graphite and special elements introduced in the depositing material serve as reducers

- **recombinatory reactions:**



This kind of reactions may be reffered to those of reconstituting the state of balance on electrode surfaces during processes of deposit formation or their saturation with elements that are contained in the working medium;

- **reactions of synthesis:**



These types of reactions may be produced both at the cathode surface and that of the anode depending on the propoities of materials used for electrodes and the ways they are connected to the discharge contour of the current impulse generator.

The process of forming surface strata by applying electric discharges in impulse may be also regarded as one of electrolysis that occurs at high temperatures similar to that of extracting aluminium from melted salts at high temperatures but in this process the material transfer does not occur in a liquid medium but in a plasma one at superior temperatures. The question may appear: „How can we compare these two processes if the material transfer in electrochemical processes occurs at the level of positively charged ions white in deposit formation by means of electric discharges in impulse the material transfer occurs simultancously in three phases (solid, liquid and gaseous) of the tool-electrode material?”

To answer this question it is necessary to take into account the fact that the particles that participate in the material transfer irrespective of what phase it is in are electrified through the existence of temperature fields and electric one of high tension [4]. The movement of transferred particles on the processed piece surface is conditioned by electric fields similar to the case of electrolysis.

This statement is supported by the works [4, 15, 17, 19] according to which deposits are formed from compact materials the quantity of materials transferred from the tool-electrode surface (anode) to that of the piece (cathode) is directly proportional to the quantity of charge that crossed the interstice during the processing. In cases of electric erosion at solitary discharges the mass of material (m) drawn from the surface of the electrode may be calculated using the relation:

$$m = k\rho U_s \int_0^{\tau} i(t) dt, \quad (9)$$

where k is the coefficient of proportionality, ρ is the density of electrode material, U_s is the voltage fall in the interstice, $i(t)$ is the momentary value of the electric discharge in the impulse current.

3. CONCLUSIONS

In the first phase the processes occur at electrode surfaces and it has an electrophysical character.

The processes of mass transfer and those of surface stratum formation in the liquid and gaseous phases have an electrochemical character that occurs at high temperatures. The final phase of surface stratum formation is a micrometallurgical one where both physical and chemical phenomena combine.

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