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PHYSICO-CHEMICAL EFFECTS PROVOKED IN THE PIECE SURFACES DURING MACHINING BY APPLYING ELECTRICAL DISCHARGES IN IMPULSE

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Abstract: The work presents an analysis of the results of experimental investigations on physico-chemical effects which are produced in the piece surfaces machined by applying electrical discharges in impulse (EDI). It analyzes the process of priming pulsed electric discharges, accompanied by processes of gas ionization and the electronic emissions of particulate metal powders It demonstrates that the ionization process and restore the active resistance of the gap is a function of battery voltage capacitor pulse power generator.It is stated that EDI cause micro metallurgical phenomena, diffusion effects, chemical and structural modification of the machined surface composition and of its micro geometry. All this contributes to increasing the hardness, active surface and absorption properties of different types of radiation.
Key words: electrical discharges in impulse, surface, diffusion, hardness, electroerosion.

1. INTRODUCTION

Electroerosion as a phenomenon found its application first in the dimensional machining of conductible materials (Mitskevichi et al., 1977; Sandeep Dhanik, Suhas S. Joshi, 2005), then in the formation of compact material (Ghitlevichi et al., 1985) and powder deposits (Topala et al., 2008). Lately this phenomenon has been applied in the thermo chemical treatment of surfaces (Topala & Stoicev, 2008), the formation of pellicles of oxides (Topala & Stoicev, 2008) and graphite, and in the modification of their micro geometry (Topala & Stoicev, 2008; Tosun N., Cogun C., Pihtili H, 2003). The domains of applying this phenomenon raise the question about its nature, whether it is a purely physical phenomenon or it also has some chemical components or it is an electro physico- chemical phenomenon. So far all the results of experimental investigations obtained by different researchers were interpreted only from the point of view of physics. That is why some of them remained only documented statements. The physical view of this phenomenon developed by the representatives of the classical method B.R. Lazarenko and N.I. Lazarenko cannot explain some experimental results recently obtained.

2. METHODS OF EXPERIMENTAL INVESTIGATIONS

The phenomena of induction and developing the plasma canal in the interstice were studied through the method of ultra rapid shooting. The quantitative and qualitative determination of factors that characterise erosive effects on machined surfaces was realised through the method of optic microscopy while the surface chemical composition and morphology through the method of electronic microscopy. The diffusion processes that occur in electrode surfaces were studied through the method of radioactive isotopes. Processes and phenomena in the gap were coated with ultra-fast camera speed of 32,000 frames per second. The investigations concerning the determination of mechanic properties and micro hardness were realised through the metallographic study on transversal microsections and electron microscopy SEM.

3. RESULTS AND THEIR ANALYSIS

The process of electric discharges in impulse may be divided into several stages: induction, development of the plasma canal, interaction between the plasma canal with electrode surfaces and the working medium, and completion of discharges at the exhaustion of energy accumulated on the condencer battery of current impulse generator.It is a well known fact that the voltage of induction depends on the size of interstice nd the pressure of gases P and it is described according to F.Paschen's law that may be interpreted on the basis of Charles H. Townes' theory of perforation. In conformity with this law the minimum voltage of perforation in the air at normal pressure, depending on the material of electrodes, constitutes approximately 250...300V. Simultaneously, in the case of forming deposits of compact material with a break in the contact, the diapason of used voltages is only 15...200V, the size of the interstice may reach 5...10 μm.

Having analysed the induction of electric discharges on account of auto emission current the authors of papers (Topala & Stoicev, 2008) highlighted the idea that in this case it is necessary to take into account the action of the electro static field that may provoke considerable mechanic voltages and these will go beyond the limit of resistence of ejectrode material. For example, for the electric voltage of interstice perforation the mechanic voltage used on electrode surfaces may be calculated using the relation $\tau = \frac{E^2}{8\pi}$ and it constitutes about 450 Mpa, it means that in some cases the erosion in a solid state is possible.

Based on the analysis of the phenomena produced in the interstice we offer a new physical model of the process of induction and development of the plasma canal in the interstice in the presence of powder particles. In conformity with the results obtained during the ultra rapid filming (32000 frames/sec)of the plasma canal in the iterstice during the formation of powder deposits, the physical view of the plasma canal induction and development may be interpreted as follows:

-the canal of induction in most cases is closed by the powder particles due to the fact that they provoke an increase of the electric field intensity. The induction canal may have a non linear form. This is due to the closing of the conductivity canal with the powder particles which are in fact a part of it (fig. 1, a). In this case the inhomogeneous development of the

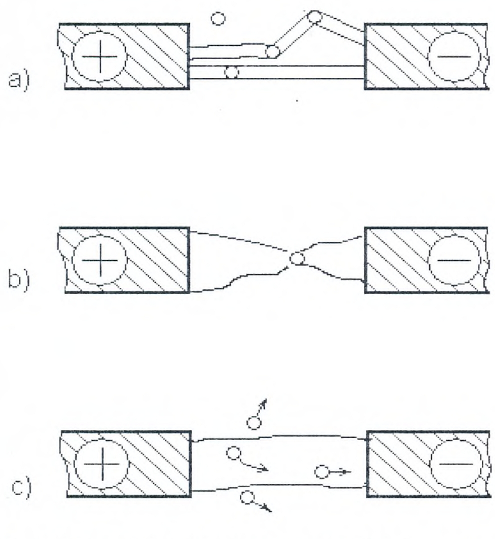

Fig. 1. Scheme of the discharge canal development and its interaction with the powder particles:
a) perforation of the interstice accompanied by the formation of the conductibility canal;
b) plasma development in the electrode zone;
c) possible variants of interaction between powder and the discharging canal

The induction of electric discharges is accompanied by the warming and explosive vaporization of both plasma canal of power electric discharges is possible when the interstice is unhomogeneously filled with plasma.

the electrode surfaces and of powder particles, this also provokes the localization of zones of intensive development of plasma in electrodes, a fact that causes a decrease on the electrode surfaces (Ghitlevichi et al., 1985).

In the induction of discharges with high voltage impulse the duration of induction is 2,0-2,5·10^{-6} s.

After the synchronic and continuous ionization of the interstice the discharge of power starts (low voltage) and the plasma canal appears and develops due to the emitted energy. The dilation speed of the plasma canal is about 2·10^{2} m/s. Due to this fact the plasma fills the interstice within a period of 20 μs. The plasma canal dimensions depend on the energy emitted in the interstice. The canal may develop uniformly (fig.1, c) or at first in the electrode zones (fig.1, b) not uniformly as a result of continuous filling the interstice. This scheme of the plasma canal development is characteristic of discharges, particularly when there is no sufficient induction voltage.

The results of measuring the voltage falls on the interstice in the air may be described using the relation:

$$U_s=19.206+14.235S \qquad (1)$$

The voltage variation that depends on the size of the interstice starts in point U_s (for S=0) that is a constant value for a pair rof electrodes (e.g. anode Cu and steel-3 cathode).

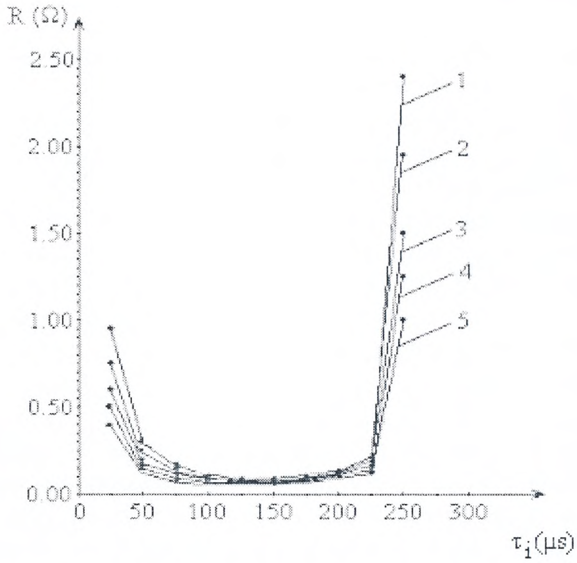

Fig. 2. Interstice resistence variation depending on the impulse duration
(U_c=480V (1); U_c=400V (2); U_c=320V (3); U_c=240V (4); U_c=160V (5))

The variation of resistance in the interstice throughout a solitary electric discharge was determined from syncronic oscillograms of $U_i(t)$ and

$i_i(t)$, the dependence $R_s = f(t)$ for the whole duration of the discharge was built(fig. 2).

In the first 20μs the curves are not presented graphically due to the fact that during this period the process of induction of discharge in the interstice occurs, the value of the current is extremely small and the registering apparatus cannot fix these values. The gas ionization in the interstice occurs in the first 20μs.

We can assert that while the plasma canal develops in the interstice resistance of the interstice decreases. Judging by curve slopes 1, 2, 3, 4, 5 (fig. 2) we can easily notice that the lower the charging voltage of the condenser battery of the power impulse the slower the decrease of the discharge canal resistance and vice versa. It is stated in paper (Topala & Stoicev, 2008) that the capacity of the generator condenser battery and the resistance of the discharge contour influence directly proportionally both the degree of interstice ionization and the plasma canal dilation, as a result its resistance decreases. Curves 1-5 (fig.2) point out that at a higher voltage of charging the condenser battery the ionization of the medium in the interstice occurs more rapidly (Ghitlevichi et al., 1988). For a period of time between 50 and 125 μs the value of the active resistance of the interstice changes very little (within the limits $0.15 \div 0.3$ şi $0.1 \div 0.2\ \Omega$) due to the dilation of the plasma canal.

We can state from the experimental results that the ionization process is more difficult and requires a longer period of time while the deionization of the interstice occurs twice quicker. The investigations done by the authors of papers (Ghitlevichi et al., 1988; Topala & Vishnevskii, 1989) point out that the electrode material practically does not influence the character of changing the interstice active resistance.

The interaction of the plasma canal with the electrode surfaces leads to the warming, melting and vaporization of their material. Due to the very small diameter of the electric discharge canal in the point of interaction (spot) with the electrode the current density is high (10^7-10^8 A/cm^2), this provokes warming and explosive vaporization of the electrode material. After drawing through explosive vaporization, the canal is placed on another portion of the surface. The integral result of erosion at one discharge is determined by the sum of elementary erosions provoked by the multitude of ‚migratory' canals (Topala & Stoicev, 2008). Two types of spots, ‚cold' and ‚warm', called electrode spots appear on the contact points of plasma in the discharge canals with the electrode surfaces, depending on the condition of discharge evolution. The ‚cold' spots appear immediately after the perforation of the interstice and move very quickly (the erosive trace has the form of small separate craters (fig.3), without obvious signs of melting), as for the ‚warm' spots, they appear later in the place of the cold ones; they have a lower speed ‚of movement' and produce an erosion considerably greater than the first ones (the liquid phase of the electrode material in their action points (Topala & Stoicev, 2008; Ghitlevichi et al., 1988).

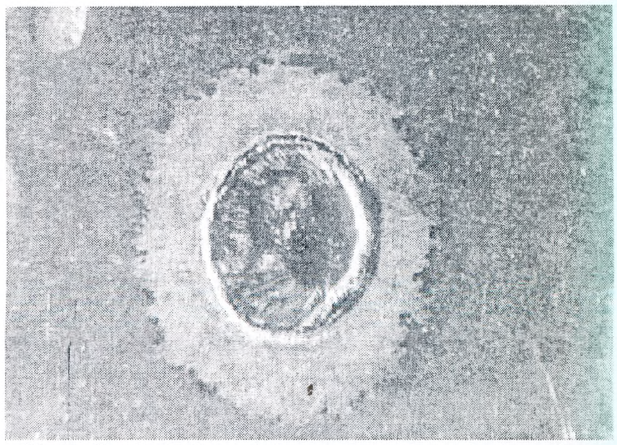

Fig.3. General view of the crater on the cathode surface (made of BT-1-0 titanium) with two zones: the central one with the liquid phase (the ‚warm' spots) the zone of thermal action (the ‚cold' spots)

The experimental results show that in different cases either the ‚cold' spots or the ‚warm' ones prevail. This leads to a change in the character of the electric erosion and the thermal effects of plasma interaction with electrodes depend on the interstice size, the discharge parameters and other factors that can help to determine the machining aspect. The erosion of electrode material occurs with a polar transfer from one electrode to another under the influence of the forces of weight, of superficial voltage and the electro dynamic ones. This statement is supported by the works (Topala, 2005; Topala, 2006; Topala, 2007; Topala & Stoicev, 2008) 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 erossed 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:

$$m = k\rho U_s \int_0^{\tau} i(t)dt \qquad (2)$$

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. The investigations done with the help of an electronic microscope have demonstrated that the electrode surfaces contain both elements of the counter electrode material and those of the working medium (Dushenko et al., 1980). Thus we can conclude that not only physical phenomena but also chemical reactions that result in the formation of intermatallic phases, carbides, oxides, hidro oxides and nitrides occur both in the interstice and in the electrode surfaces (Topala & Vishnevskii, 1989; Ghitlevichi et al., 1989). According to the conditions described in the paper (Topala & Stoicev, 2008, Topala, 2005; Topala, 2007; Topala et al., 2008) the effective diffusion coefficient of elements D_{ef} when electric discharges are applied may be determined by the relation:

$$D_{ef} = N(D_1 t_1 + D_2 t_2), \qquad (3)$$

in which N is the number of processing cycles; D_1 and D_2 are corespondingly 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 ef electric discharges in impulse and of the pause. The described procedures were applied in the development of chemico thermal treatment technologies aiming at the formation of oxide and graphite pellicles accompanied by superficial cementing with graphite electrodes or gas medium (Topala, 2006; Topala, 2007).

4. CONCLUSIONS

In conclusion we may state that:

- the machining process based on the method of electro erosion is a complex one and is accompanied simultaneously by physical and chemical phenomena;
- processes of separation and ionization of the working medium components take place in the interstice;
- erosion effects in solid, liquid and vapour state occur in the electrode surfaces;
- the polar transfer of materials and their diffusion in the electrode surfaces take place under the influence of temperature fields and high intensity electric ones.

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