CZU: 621.7

NEW DIRECTIONS IN THE PRACTICAL APPLICATION OF ELECTRO EROSION

Pavel TOPALA[1], Arefa HIRBU[2], Alexandr OJEGOV[3]
[1]Balti Alecu Russo State University, Republic of Moldova, paveltopala@yahoo.com,
[2]Balti Alecu Russo State University, Republic of Moldova, arefahirbu@yahoo.com,
[3]Balti Alecu Russo State University, Republic of Moldova, alexandr.ozhegov@yahoo.com

ABSTRACT: The paper contains the results of experimental investigations regarding the application of electric discharges in high voltage in the modification of metal surface micro geometry. The division of the plasma channel into a multitude of micro channels ensures the simultaneous formation of a great number of meniscuses on the processed surfaces throughout a solitary discharge. It is demonstrated that the formed conic meniscuses increase the processed surface area by 8 times and the power of electronic thermo emission current by 10 times.

KEYWORDS: electro erosion, meniscus, micro geometry, electronic emission

1. INTRODUCTION

Processing by means of electro erosion has forked into two main directions: dimensional processing that aims at drawing one part of the material on the surface of the semi-finished product in order to modify its form and dimensions[1, 2, 7, 10, 12]to obtain the product in imposed thermal conditions and the formation of the deposit layer that aims at transferring the drawn material from the surface of one electrode to the surface of the other one to modify the properties and the chemical and structural composition of the processed piece[4, 6].
The first direction in the use of this procedure of processing has found a rather diverse application in machine and equipment building making it possible to process these materials, a thing that cannot be done by classical methods (metal carbides with high melting temperatures of the type WC, TiC, TaC, semiconductors, etc.) ensuring the processing of surfaces with a complex character (wholes, orifices, cavitations, prominences, etc); it has also ensured total automation of the processing [7].
The second direction in the application of this method related to the chemical and structural modification of the surface layer of pieces used in machine and equipment building has recently branched out as follows:
- formation of deposit layers from compact materials in which the main role in the modification of the surface layer is played by the material drawn from the tool electrode surface [6].
-formation of deposit layers from powder and powder mixtures in which the main role in the modification of the processed piece surface layer properties is played , first of all, by powder materials and, second, by tool electrodes because sometimes the tool material does not influence the powder properties and composition [4,6];
-modification of piece surface layer properties and composition accompanied by lack of piece dimension modification or by decreasing the roughness of the processed surface that is a relatively new direction and in specialized literature it is only mentioned as a scientific observation and not as a well defined technique applied in practice [5];
-modification of the surface micro geometry accompanied by the formation on it of Taylor conic meniscuses with regard to conferring the properties of radiation emission and absorption [3, 14, 16, 17];
-it is supposed that in all cases of applying this method of processing the roughness of the processed surface is directly related to the size of the liquid phase craters that appear on the processed surface; however when deposit layers are formed we can notice an increase of some separate zones of deposits, thus the condition of continuous layer formation is violated. This is due to the appearance of some initial or induced ruggedness that serve as concentrators for the electric field of electric discharges in impulse and influences the control of drawing and transferring the material either from the liquid base of the tool electrode or from the

powder material introduced in the interstice to form deposits with special properties [4, 6].
It should be mentioned that currently another application direction of electro erosion is arising, that is micro-geometry modification of metal surfaces.

2. METHODOLOGY OF EXPERIMENTAL INVESTIGATIONS

The experimental installation scheme which is presented in Fig. 1, consists of: power supply of continuous current that functions at the operating voltage U = 25 kV, the perforator Str., the condenser battery (C), the ballast resistance R, the tool electrode 1 and the workpiece 2. The electrode-tool works according to the principles: it is used to divide the discharge current into several channels. This facilitates the discharge in impulse which leads to the formation of large current densities and thereby increases the efficiency of energy of discharge. The interstice between electrodes is S = 5 mm. The cross section of the tool electrode is 17x7 mm, in which were located a total of 600 isolated copper wires each with a diameter of 0.35 mm.
The measuring of current pulse parameters (duration, shape and amplitude value) [10] and their visualization is done through the memory oscilloscope OSC (C8-13) shunted by resistance Rs = 0.003 Ω [14]. The connection with the earth is made to protect the discharge in impulse that will not be affected by other influences of reactive elements.
The discharge pulse shapes obtained in the research are presented in Fig. 2-4. It is noted that the pulse shape is directly dependent on the amount of capacity and ballast resistance that form the RC type generator. Due to inductance electrode 1 in Fig. 1 we can see the oscillation shape of the pulse discharge obtained in our investigations.

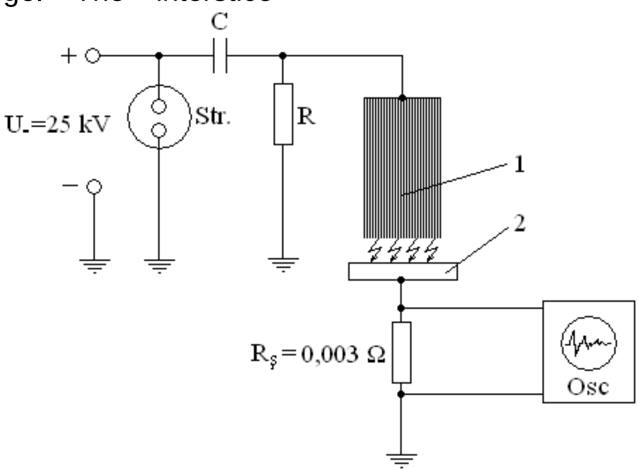


Fig. 1. The main scheme of the experimental installation and of measuring the pulse discharge parameters: Str. – perforator; Osc – oscilloscope with memory; $R_ş$ – shunt resistance; 1 – tool electrode, 2 – workpiece

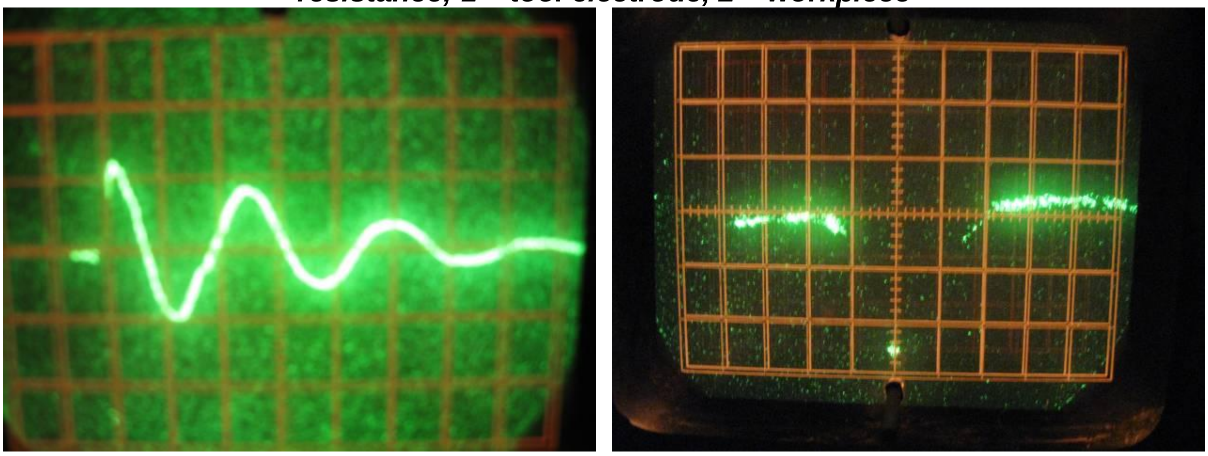


Fig. 2. Overview of the pulse current for the capacity value C = 1/12 μF, the ballast resistance R = 8.2 MΩ: a) time division size 1 μs/div, voltage division size 100 V/div; b) time division size 0.1 μs/div, voltage division size 100 V/div

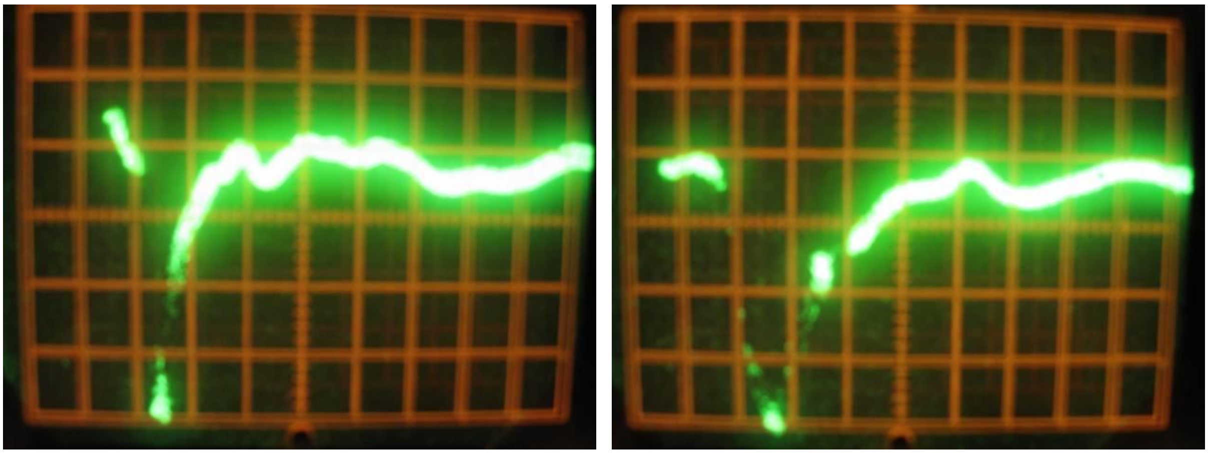


Fig. 3. Overview of the pulse current the for capacity value C = 5 nF, the ballast resistance R = 8.2 MΩ: a) the size of time divisions 0.2 μs/div, voltage division size 20 V/div; b) the size of time divisions 0.1 μs/div, voltage division size 20 V/div

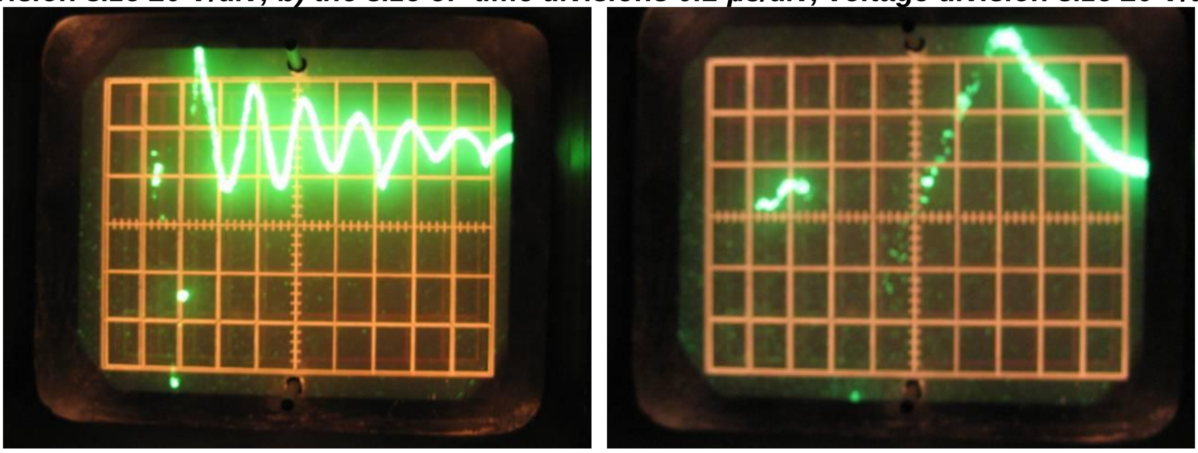


Fig. 4. Overview of the pulse current for the capacity value C=17.5 nF, the ballast resistance R=8.2 MΩ: a) the size of time divisions 1 μs/div, voltage division size 20 V/div; b) the size of time divisions 0.1 μs/div, voltage division size 20 V/div

Analyzing the shape of pulses from the oscillograms the conclusion was made that it depends on certain parameters of the generator operating scheme, firstly on the capacity of the condenser battery (see tab. 1). Thus, when the capacity was 1/12 μF current amplitude was 100 kA. Accordingly, the amplitude decreases when the size of the condenser battery capacity is reduced.

Table 1. Characteristics of electric discharge pulses in the installation.

No	Condenser capacity C, μF	Energy accumulated on the capacity W_C, J	Pulse duration τ_{imp}, μs	Pulse amplitude on the oscilloscope U_{osc}, V	Current pulse amplitude I_s, kA	Current intensity in the interstice $\int_0^{\tau} i_s dt$, kA·s
1.	1/12	8	0,2	300	100	50
2.	$5 \cdot 10^{-3}$	0,78	0,1	80	27	4
3.	$17,5 \cdot 10^{-3}$	2,73	0,15	120	40	7

The accumulated energy on the condenser battery ($W_C = \frac{CU^2}{2}$) is approximately equal to 26 J. As the scheme is unipolar and because of the losses on electric circuit elements, around 8 J is turned into thermal energy. The equation of thermal balance sheet for the isobar process can be written as follows:

$$Q = \frac{i+2}{2} \frac{m}{\mu} R\Delta T \qquad (1)$$

where *i* is the number of freedom degrees of air molecules (i = 5), *m* is the mass of the space active part between electrodes.

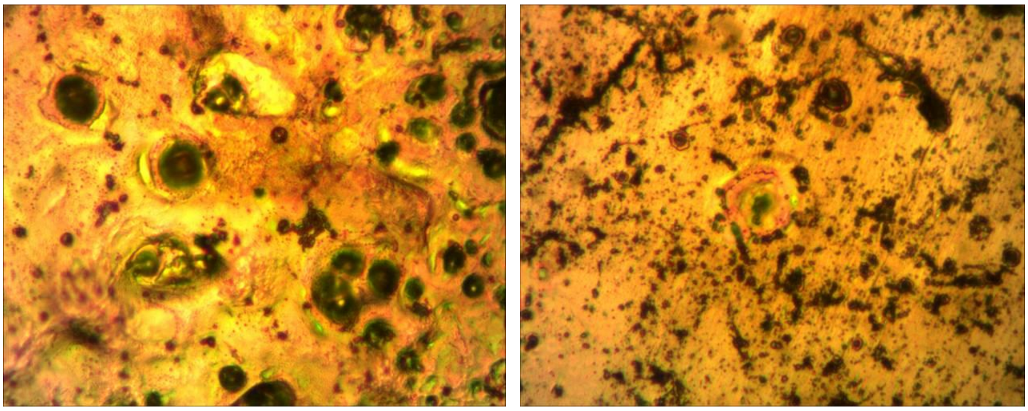
$$Q = \eta W_c . \qquad (2)$$

Thus at short time electric discharges in impulse the interstice temperature variation in the air medium constitutes $\Delta T \approx 10^{4\circ} K$.

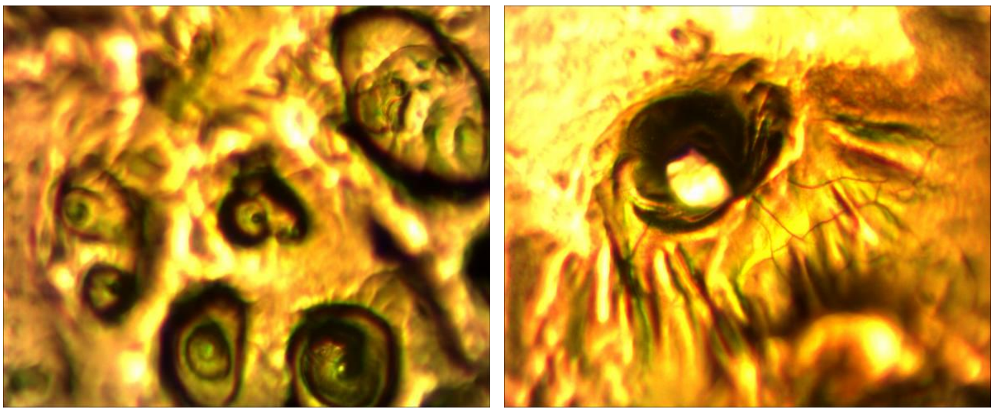
3. EXPERIMENTAL RESEARCH RESULTS AND THEIR ANALYSIS

Sample surfaces were prepared by polishing to a mirror state and after processing they were subjected to certain modifications: zones of thermal influence of the freshly scaled metal colour were attested on them (processes of enriching with elements that are contained in the working medium are produced there (Fig. 7); zones where the surface melting occurred were attested too (the latter were craters or meniscuses extracted and frozen under the shape of conic ruggedness (Fig. 5, 6).

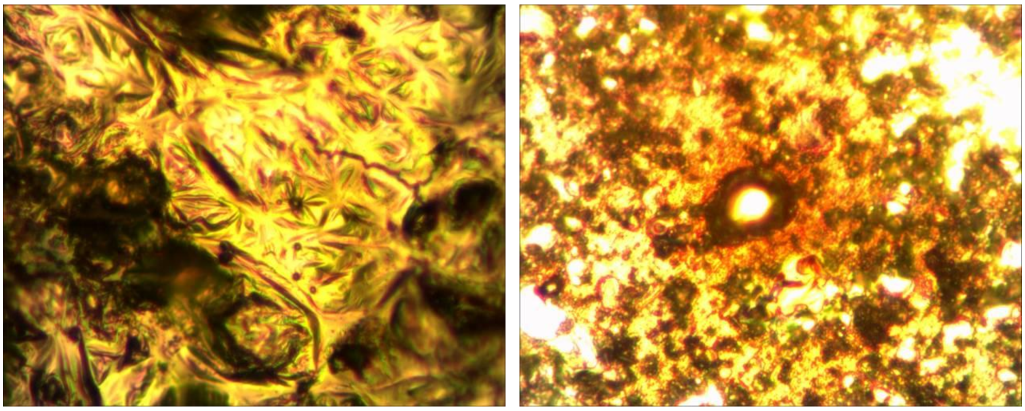
The metallographic microscope XJM600T equipped with the digital system of information .registration was used to photograph the structures and the micro geometry of surfaces obtained as a result of electric discharges in impulse.



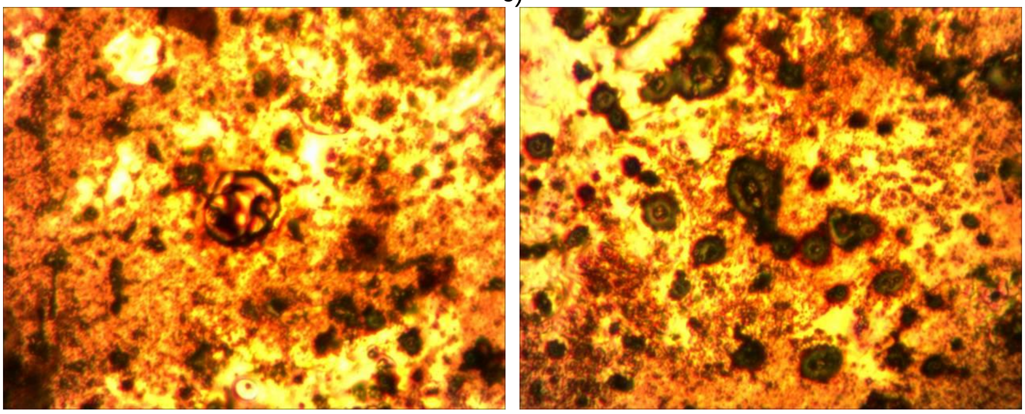
a)



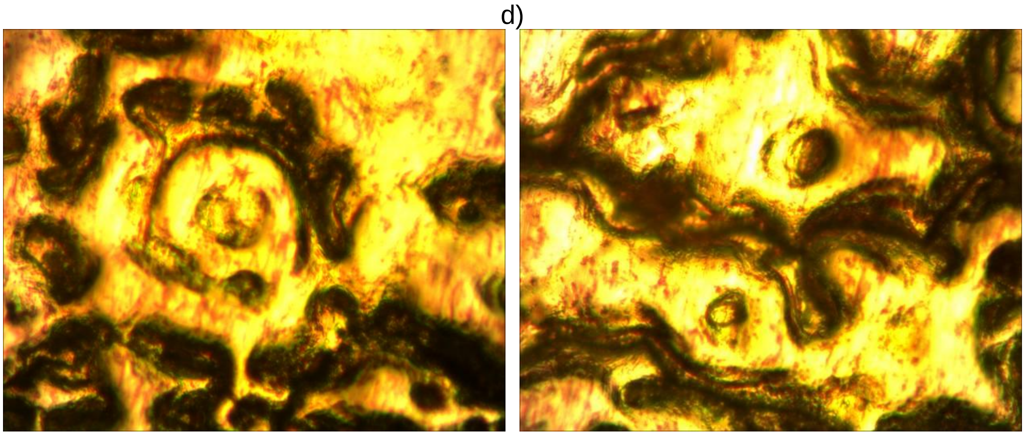
b)



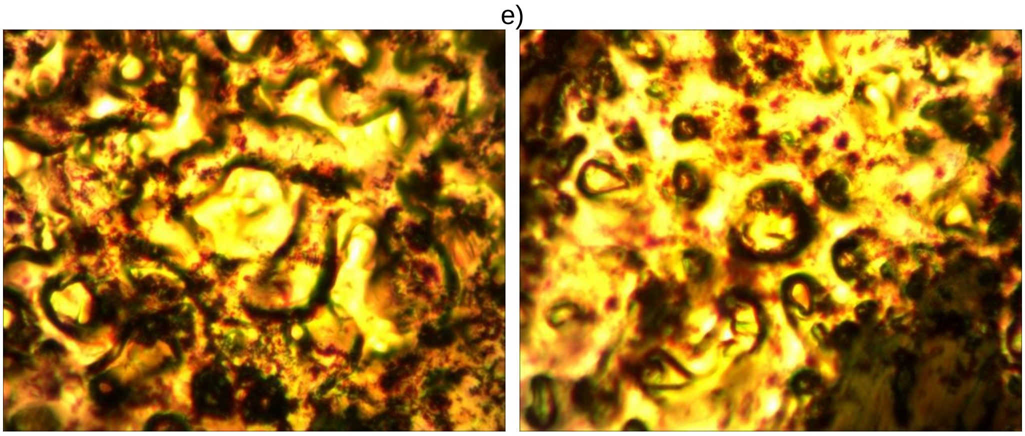
c)



d)

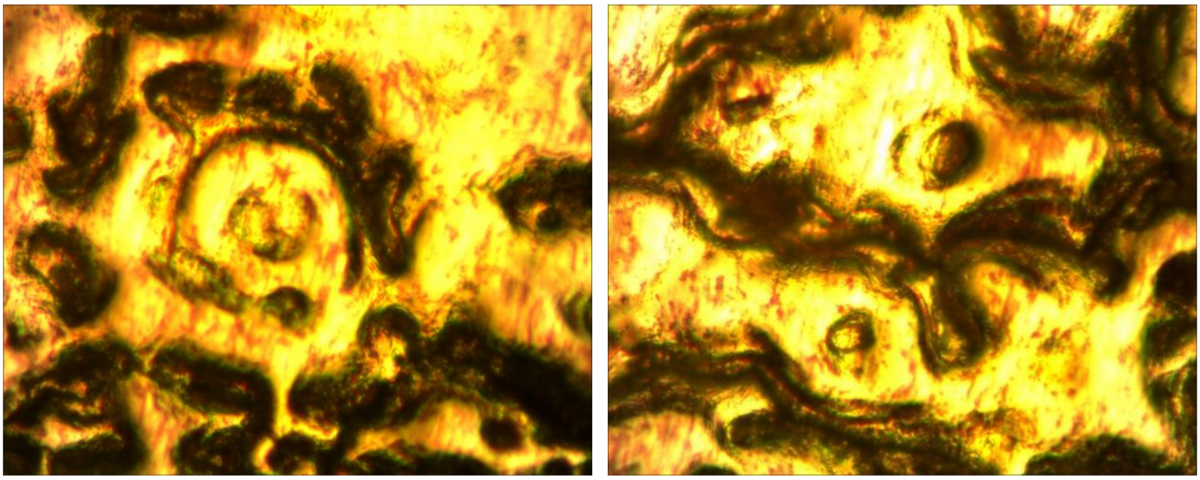


e)

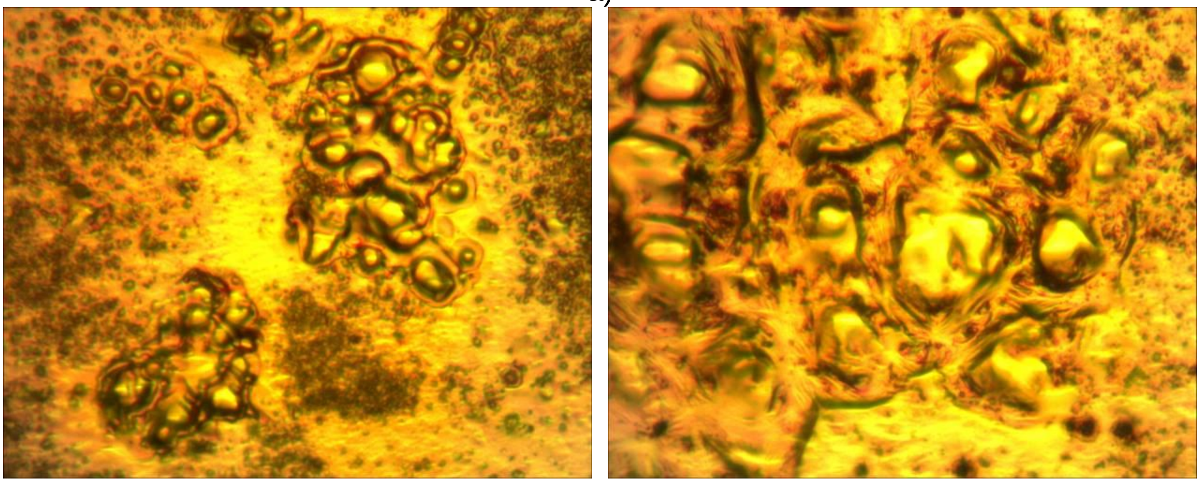


f)

Fig. 5. Overview of the piece surface machined with electric discharges in impulse (the energy released in the interstice W = 8J; the interstice size S = 5 mm, the impulse duration τ_{imp} = 0.2 μ s, the number of pulses - 30; the piece- anode), x 400: a - steel 45, b - titanium alloy VT-8, c - aluminium alloy (duralumin) D16; d - technically pure copper M0; e - brass L63; f - bronze BrB2



a)



b)

Fig. 6. Overview of L63 brass surface processed with electric discharges in impulse (energy released in the interstice W = 8J, the size of the interstice S = 5mm, the impulse duration τ_{imp} = 0.2 μ s number of impulses - 30) × 400: a –anode piece, b-cathode piece

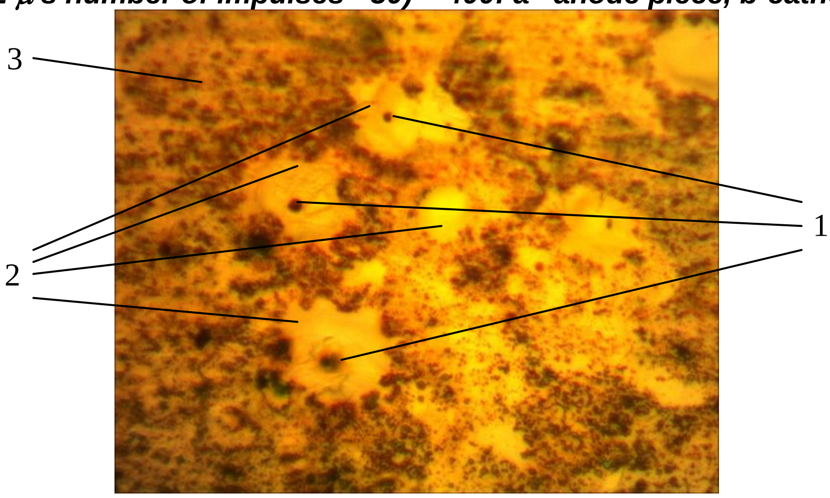


Fig. 7. A portion of the brass surface L63 machined with electric discharges in impulse (the energy released in the interstice W = 8J, the interstice size S = 5mm gap size, impulse duration τ_{imp}=0,2 μs the piece- cathode), × 400: 1 - meniscuses formed as a result of the "warm" electrode spots; 2 - the zone of thermal influence formed as a result of the "cold" electrode spots; 3 - the raw zone

From this we see that electric impulses even of extremely short duration provoke local melting on the surface subjected to the interaction with the plasma channel. Conic shaped meniscuses that, as a result of ultra rapid cooling, are frozen on the machined surface are extracted from the melting zones under the influence of the discharge electric field.

Considering the results obtained earlier by the authors [9], this should not happen, because melting takes place under the influence of "warm electrode spots " whose birth and life time greatly exceeds the pulse duration applied by us. Due to these reasons we consider that the question about the origin, essence and life of the electrode spots will remain open for a long time.

It is important to note that micro-cracks are observed in the immediate vicinity of the meniscuses on the machined surface. Given that the thermal conductivity of metals is relatively high and the amount of melted metal per an area unit is very small we can determine the speed of the cooling. This is the order of $5 \cdot 10^4$ K/μs that may cause the formation of metal glass in amorphous state.

The division of the plasma channel into a multitude of micro-channels ensures the formation of a great number of meniscuses on the machined surface. The research carried out previously [3, 16, 17] has shown that a single meniscus removed from a portion of the surface causes the increase of its area by 8 times. If we were to talk of the emission or absorption capacity of the surfaces, it is clear that it is directly proportional to the body surface active area, and in this case the results are beneficial for application in this field. If when applying low voltage electric discharges in impulse (10^2 V) surface area processed at a solitary discharge constitutes $10…10^2$ μm^2 [17, 18] the application of high voltage electric discharges and the short time of duration allow to increase the machining by many times (5...100 mm^2). Investigating the electronic emission capacity of the cathode surfaces applied in building electron cannons [18] it was stated that under the same operating conditions, the cathodes with a micro-geometry shaped as meniscuses ensures the formation of electron fascicles with an intensity that is 10 times stronger compared to those with a smooth surface.

4. CONCLUSIONS

1. Due to the fact that the energy in the processing area is released within a very short time (0.2 μs) and the minimum discharge energy density exceeds about 10 times its critical value of transition from solid into liquid state(~ 4 J / μs), one can observe the formation of Taylor cones on the surfaces of investigated materials.
2. As the thermal coefficient of titanium and its alloys linear dilation is much lower than that of other materials subjected to the experiment on the surface of regular shaped micro-cracks were observed on its surface; the cracks were probably , caused by the crystalline structure of the respective alloy.
3. The extremely rapid cooling of the metal on the sample surface may cause its crystallization in amorphous state.

REFERENCES

[1] Laurenţiu Slătineanu, Tehnologii neconvenţionale în construcţia de maşini, Tehnica Info, Chişinău, 2000, p.252.

[2] Artamonov B.A., Volkov Iu.S., Drojalova V.I. I dr. Elektrofiziceskie i electrohimiceskie metodî obrabotki materialov, T. 1, Moskva ,“Vîsşaia şkola”, 1983, s. 242.

[3] Topală Pavel, Olaru Ion, Rusnac Vladislav, Noi secvenţe la tabloul fizic al electroeroziunii, Culegere de lucrări ştiinţifice, Tehnologii Moderne, Calitate restructurare, Chişinău, 2005, p. 239-242.

[4] Topala Pavel, Stoicev Petru, Tehnologii de prelucrare a materialelor conductibile cu aplicarea descărcărilor electrice în impuls., Chişinău, Tehnica Info, 2008, p.265.

[5] Topala, P., Stoicev P., Epureanu A., Beşliu V., O vozmojnosti legirovania metaliceskih poverhnostei na ustanovkah dlea electroiscrovoi obrabotki v rejime nedonapreajenia, maşinostroenie i tehnisfera XXI veka., Materialî Mejdunarodnoi naucno-tehniceskoi konferenţii. Doneţk. 2006., s. 266-269.

[6] Ghitlevici, A. E., Mihailov, V. V., Parkanskii, N. Ia., Revuţkii, V. M., Electroiscrovoie leghirovanie metaliceschih poverhnostei, Chişinev, Ştiinţa, 1985, s. 196.

[7] Gavrilaş, I., Marinescu, N. I., Prelucrarea prin electroeroziune şi electrochimic-abrazivă., vol. 1 şi 2, Bucureşti, Editura Tehnică, 1980.

[8] Constantin Diaconescu, Cercetări privind structura generatoarelor de impulsuri cu adaptare flexibilă, în timpul real, la condiţiile procesului de prelucrare prin roziune electrică, Rezumatul tezei de doctorat, Universitatea ,, Lucian Blaga” din Sibiu 2008, p. 37.

[9] Miţkevici, M.K.; Buşic, A.I.; Bakuto, I.A.; Şilov, V.A; Divoino, I.Gh., Elektroerozionnaia obrabotka metallov. Minsk, Nauka i tehnik, 1988.

[10] Ţîţu, M., Nanu, D,. Oprean, C,. Diaconescu, C,. Ţîţu, Gh. A., Echipament electronic pentru

generarea unor descărcări singulare, electrice în impuls, Brevet OSIM nr. 118687, 2003, Medalia de aur la Salonul Mondial al Invenţiilor Tehniciilor şi Produselor noi, Geneva 1008.
[11] Marinescu N.I., Sturzu A., Visan A., Gavrilaş I., Tehnologii moderne în construcţia de maşini, Bucureşti 1984, p.199.
[12] Topală Pavel, Aplicări ale electroeroziunii în dezvoltarea tehnologiilor fine de prelucrare superficială a pieselor, Analele Ştiinţifice, Serie Nouă, Fascicolul A., Tomul XX, Bălţi, 2004, p. 66 – 69.
[13] Aurel Nanu, Dan Nanu, Prelucrarea dimensională prin eroziune electrică în câmp magnetic, Editura Facla, Timişoara, 1981, p. 307.
[14] I. Grigoriev, S. O. Şireeva, D. F. Belonojko, A. V. Klimov, O forme ,, conusa Teilora „ i haracternom vremeni ego rosta, Electronaia obrabotca materialov, 2004, 4, s. 34 - 40.
[15] Topală Pavel. The energy distribution in the gap at the gap technological applying of the electrical discharges in impulses, Iaşi, Editura PIM, Nonconventional tehnologies reviev, 2007, Nr.1, p. 129 – 132.
[16] Topala Pavel, Rusnac Vladislav, Experimental investigations concerning the extraction of cone meniscus on metal surfaces with electrical discharge machining (EDM) adhibition, Buletin of the Polytehnic Institute of Iassy, T. Liv, 2008, p.
[17] Vladislav Rusnac, Cercetări experimentale privind modificarea microgeometriei suprafeţelor pieselor metalice prin metoda electroeroziunii, Fizica şi Tehnica: Procese, modele, experimente, nr.1, 2008.
[18] Vladislav Rusnac, Establishing the emission properties of conductible surfaces machined by applying EDI. Proceedings of the 15th International Conference, Modern Technologies, Quality and Innovation. 25-27 May, 2011, Vadul lui Vodă, Chişinău, Republic of Moldova, p. 1161-1164. ISSN 2066-3919.

AUTHORS

Professor, PhD, Pavel TOPALA, Balti Alecu Russo State University, Republic of Moldova, paveltopala@yahoo.com, +373079622510
Arefa HIRBU, Balti Alecu Russo State University, Republic of Moldova, arefahirbu@yahoo.com, +37369322424
Alexandr OJEGOV, Balti Alecu Russo State University, Republic of Moldova, alexandr.ozhegov@yahoo.com, +37379215624