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The Role of Energy and Duration of Discharging Pulse During the Micro Geometry Changing Process of Metallic Parts Surfaces by Applying Electric Discharges in Pulse.

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ABSTRACT

In this paper there are presented the results of experimental researches regarding the meniscus formation as Taylor cones on the parts surfaces with electric discharges in pulse (EDP) application. We search for the influence of the accumulated energy on the capacitor battery and on the pulse duration on the micro geometry. It is being demonstrated that the size of formed meniscuses depend on the energetic regime of processing, the size of the interstice, the duration of electric discharges in pulse and the thermo-physical properties of part material.

Keywords: *electric discharges, electro technologies, layer deposition, micro geometry*

1. Introduction

In the large area of electro technologies a special place belongs to the one of material processing with electric discharge in pulse application.

Nowadays processing with electric discharges in pulse are divided in 2 main directions : dimensional processing that have as a principal interest drawing out small parts of the material surface with the object of form and dimension modifying [1, 2, 3] and formation of deposited layer that has as a main goal the transfer of the draw material from one of the electrode on the other one’s surface for modifying its dimensions, properties and the chemical composition of surface layer of the processed material [4, 5].

The first direction of applying proceeding process has found a diverse aplicability in machine and device building allowing it first the process of that materials that are submissive to classical methods (hard metal materials with high melting temperature of WC, TiC, TaC type), providing surface processing with complex character (drilling, orifices, cavities, etc.) but not the last providing a total automatisation of the process.

The second direction of applying this method regarding the modification of structure and composition surface layer of the parts used in machine and device building, has been divided in:

- forming the deposition layer in compact materials;
- forming the deposition layer in powder and mixing of powders;
- modifying the composition and properties of parts surface layer in absence of modifying parts dimensions or with reducing surface roughness, which in fact is a relatively new direction and in the specialized literature it is found more as a scientific establishment than as a well defined process and practically applied.

In all these cases the small roughness is a common objective, but this parameter is one that determines the durability of processed parts with EDP application and used in the building of moving complex pieces that work under the action of friction strength. From the results of experimental research of paper authors [1-4], we can see that processed surface roughness size depends on the energetic regime of processing and on the parts material properties or on the deposition made.

Unsearching for that, it is necessary to mention that, the roughness of the processed surfaces can be looked at as a good parameter, if the final objectives at parts surface forming with applying EDP are modifying. It is known that, in the case of some physical phenomena like the heat exchange between bodies, radiation capacity of the surfaces, the one of particle emission (vapour, electrons and ions) and radiation absorption of different types, these effects go on much more intense if the surfaces have an extended roughness.

In case of processing with EDP application indifferently of the applied process, being dimensional processing or deposition layer forming, it takes place the melting and drawing of material on electrodes surface with some craters forming as spherical calotte.

By authors of papers [6, 7, 8, and 9] have been registered 3 types of craters all having spherical calotte form: the first one with smooth profile, the second one with rough profile and the third one having a meniscus in the middle. The meniscuses have been observed not only in the middle of the craters but in their neighbor also. Besides this there are also known a list of papers [5, 5, 8] in which it is demonstrated that meniscuses appearance in carters center it is due to disturbances on the liquid metal under the action of high intensity electric field, of superficial strength and of the hardness. In the paper [10] it is studied the geometry of formed craters on the processed surfaces of different conductor materials after applying EDP. It has been mentioned that for steels of 12X18H10T and XBΓ type, in middle of the crater can appear a meniscus, which size mostly depends on the emitted energy in the interstice.

Next it will be presented the results of experimental research regarding surface micro geometry modifying with EDP applying with the extractions of meniscuses from the processed surfaces of wolfram parts.

2. Method of experimental research

The experimental research has been in normal conditions, in the air, at room temperature at a solitary discharge. For making the experimental research it has been used a special installation whose electric scheme is presented in figure 1 [4].

Installation is made off : 1- generator of power impulses of RC type; 2- detonation block; control block which allows synchronizing power impulses and detonating impulses.

In the research process, interstice size between electrodes it is measured with a quadrant comparator with 0,001 precision and it is permanently controlled with MBS-9 microscope and with scanning electronic microscope QUANTA-200 (FEI Philips). The electrodynamics parameters as impulse duration, current variation in pulse, voltage decrease on interstice, as well as the emitted energy at a solitary discharge were determined with oscilloscope [4, 5] according to the scheme in figure 2.

For determining the maximum current in the discharging circuit it is used the coaxial shunt with the resistance R = 0,003Ω

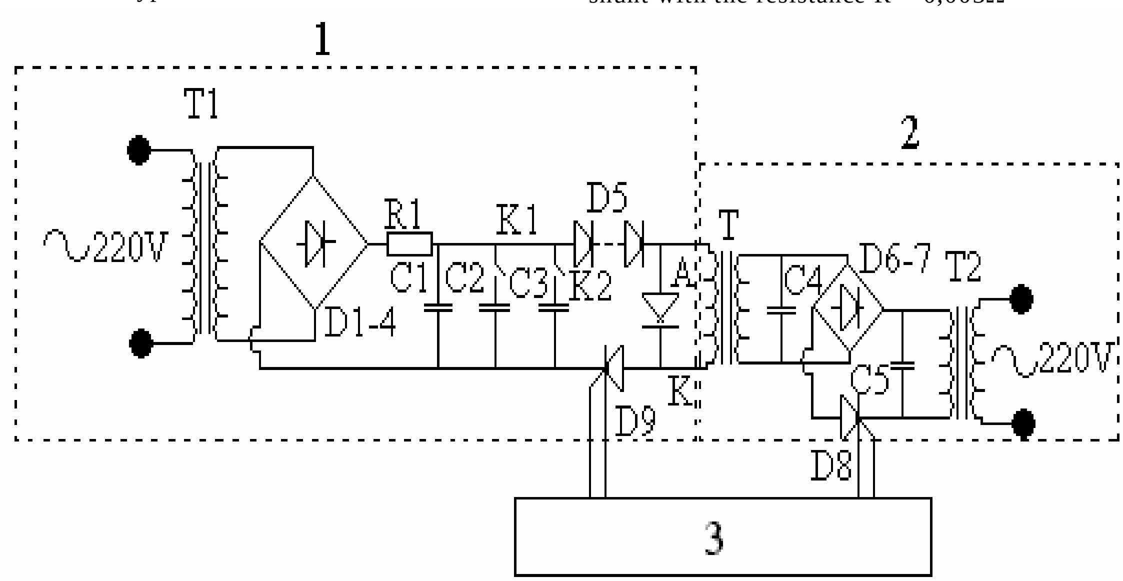


Fig. 1 *Main electric scheme of installation [4]*
1- generator pf power impulses; 2- detonation block;2- control block;

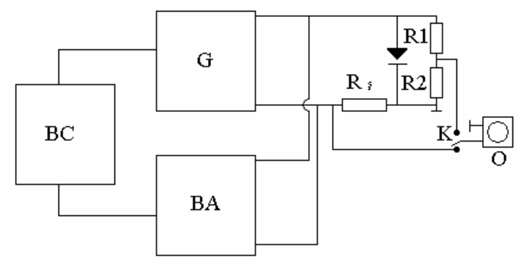


Fig. 2. *Measuring block for electrodynamics characteristics of electrical discharge in pulse [4]:(BC-control block; G-pulse generator; BA-detonating block; O- oscilloscope; $R_ş$-shunt; R1-R2-voltage divider; K- switch.*

For the electrodes we will use wolfram wire with the diameter d=2mm. The electrical discharges took place in the electrode system made of the same material and placed perpendicular one of the other with a interstice S= 0,2 mm, as it is presented in figure 3. For all the cases the anode is placed in the upper part.

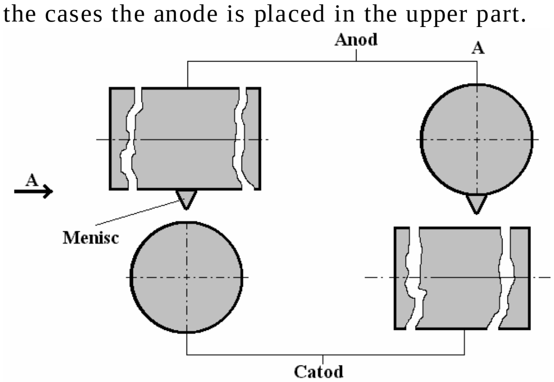


Fig. 3. *Positioning electrodes scheme in the experimental research process*

For all the trying the interstice size is S=0,2 mm. Capacity of capacitor battery is modifying in steps (with a step of 100 µF) in the limits of 100 – 600 µF for some values of the capacitor battery charging voltage. These voltage values, for special cases were up to 60 V, 100 V, 150 V şi 200 V

For determining the influence of pulse duration on Taylor cones geometry in the EPD process, we modify the accumulated energy on the capacitor battery by maintaining constant pulse duration. Researches were made for more values of the discharging pulse duration: 100 µs, 125 µs, 160 µs, 180 µs, 200 µs and 220 µs. Researches were repeated more times for obtaining precise results.

3. Experimental results and the interpretation.

In the research process we have searched for the influence of accumulated energy on the capacitor battery and on the duration pulse above the forming of meniscuses (Taylor cones) in anodes surfaces when they were positioned like in scheme from figure 3. For all the cases the anode is in the upper position because during the meniscuses (Taylor cones) forming a special role it plays the gravity it is down oriented, a fact that leads to increasing the height of meniscuses and decreasing the diameter size of meniscuses bases. It is necessary to mention that, in the experimental researches the meniscuses have been found on the anode's surface, as well as on the cathode's one. Usually on the anode they have big dimensions, fact that can be explained based on Palatnik criterion, due to electro erosion polarity, as well as to redistribution phenomenon of draw energy in the interstice during one discharge between electrodes surfaces and the active resistance of the interstice.

In figure 4 there are presented the oscilograms obtained in the research program for wolfram. As we can see the oscilograms, in the determination process of accumulated energy influence on the capacitor battery upon the meniscuses geometry (Taylor cones) , this capacity is modifying. On its turn capacity variation determines the change of maximum current in the discharge circuit, of the energy and of the discharge pulse duration.

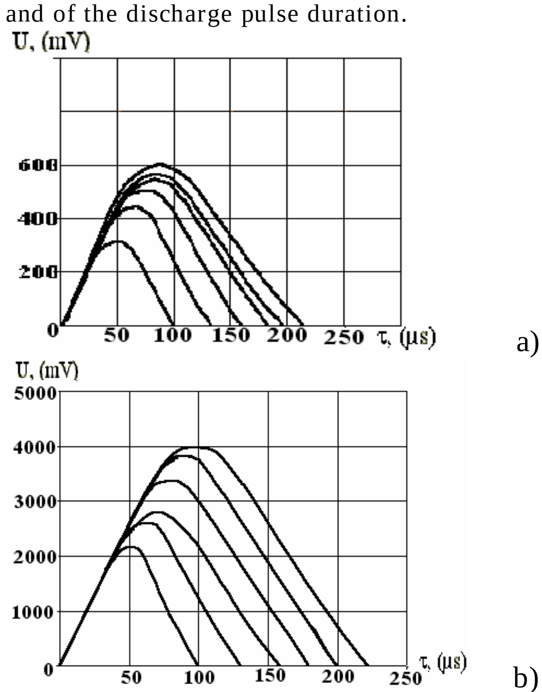
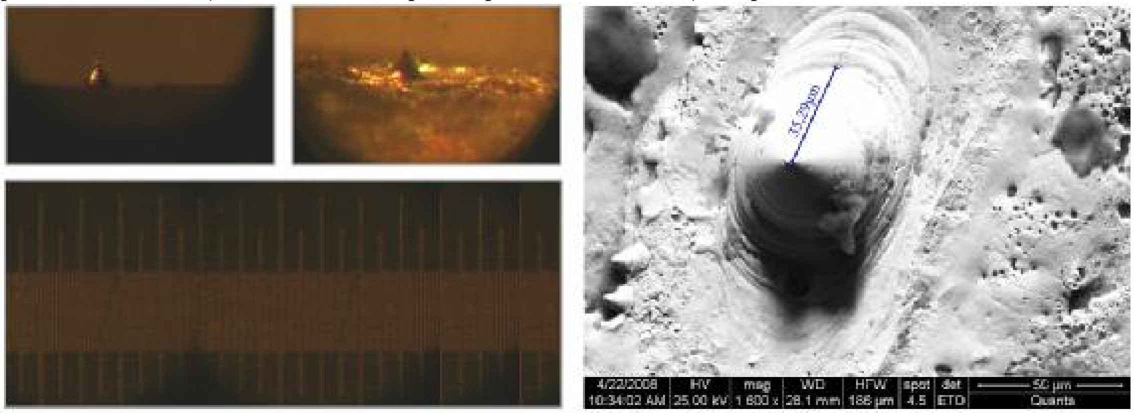


Fig. 4. *Oscilogrames obtained in the research process (material-wolfram; a)U_c = 60V; b) U_c =200V))*

General view of meniscuses (Taylor cones) extracted from the anodes surface in laboratory conditions at a solitary discharge is presented in **figure 5**.

The geometric parameters of meniscuses (Taylor cones) as well as the electrodynamics parameter values (value of current pulse, pulse duration, voltage charge of the capacitor battery, and value of discharge voltage o the interstice) are presented in **table 1**.



a) b)

Fig. 5 *Meniscuses extracted from the W surface in laboratory conditions*
C = 100 µF; Wc = 0,18 J; S = 0,2 mm; I_m = 100 A; U_c = 60 V; [price of a division 0,01mm] – photographs obtained at MBS9 microscope;
a) C = 200 µF; W_c = 0,36 J; S = 0,2 mm; I_m = 146,6 A; U_c = 60 V; - photographs obtained at scanning electronic microscope QUANTA-200.

Table 1:
The height of meniscuses depends on the capacity of capacitor battery, its charging voltage and duration of discharge pulse.

Nr.	C, (µF)	U_c, (V)	I_m, (A)	W_c, (J)	t, (µs)	U_s, (V)	h_m, (µm)
1.	100		100,0	0,18	100		28
2.	200		146,6	0,36	125		35,29
3.	300	60	166,6	0,54	160		42
4.	400		180,0	0,72	180		56
5.	500		186,6	0,9	200		63
6.	600		200,0	1,08	220		70
7.	100		283,3	0,5	100		56
8.	200		416,6	1	125		70
9.	300	100	450,0	1,5	160		84
10.	400		500,0	2	180		98
11.	500		533,3	2,5	200		112
12.	600		583,3	3	220	21	126
13.	100		616,6	1,125	100		70
14.	200		666,6	2,25	125		105
15.	300	150	733,3	3,375	160		133
16.	400		816,6	4,5	180		147
17.	500		833,3	5,625	200		140
18.	600		933,3	6,75	220		112
19.	100		766,6	2	100		98
20.	200		933,3	4	125		126
21.	300	200	1100	6	160		140
22.	400		1233	8	180		133
23.	500		1266	10	200		112
24.	600		1333	12	220		91

It is necessary to mention that the meniscuses forming presented in figure 5 takes place after the table proposed by the authors of papers [5, 6]. This fact is clear with the thing that, in the research process has been recorded meniscuses that had in the top a spherical drop in crystallized state which contradicts the classic table proposed by Lazarenco. Indeed, in the electrical discharge process the draw material takes place on the top surfaces of Taylor cones under separated particles form or under elementary particles due to electric field but not under the action of depressurize formed in the gas drop.

In figure 6 there are presented the dependences of meniscuses height on the accumulated energy on the capacitor battery (discharge pulse duration) for different values of capacitor battery charge voltage.

It has been noticed that for the charge voltage of capacitor battery of U_c = 60V with the increase of energy on 0,18...1,08J limits, the meniscuses height linear increases. A similar phenomenon takes place for voltage U_c = 100V when the accumulated energy on the capacitor battery varies in limits 0,5...3J. For higher voltages U_c = 150V and U_c = 200V, with the energy increase, Taylor cones height increases to a certain value afterwards begins to decrease (fig. 6). This fact is being presented by the thing that the electrodes, in this case, are being transmitted most part of the energy due to what takes place the drawing of a certain quantity of material on the disturbed surface material till the complete formation of the meniscuses. More, the initial volume of the melted metal in disturbed state gets smaller. Besides this, an important role plays the pulse duration. In paper [11] has been mentioned that if the pulse duration is τ <10 μs than almost 90% of metal is doing away as vapors. Once the pulse duration increases the metal quantity taken away as vapors is decreasing. So, for searched cases, the material draw takes place not only as vapors, as well as under liquid state.

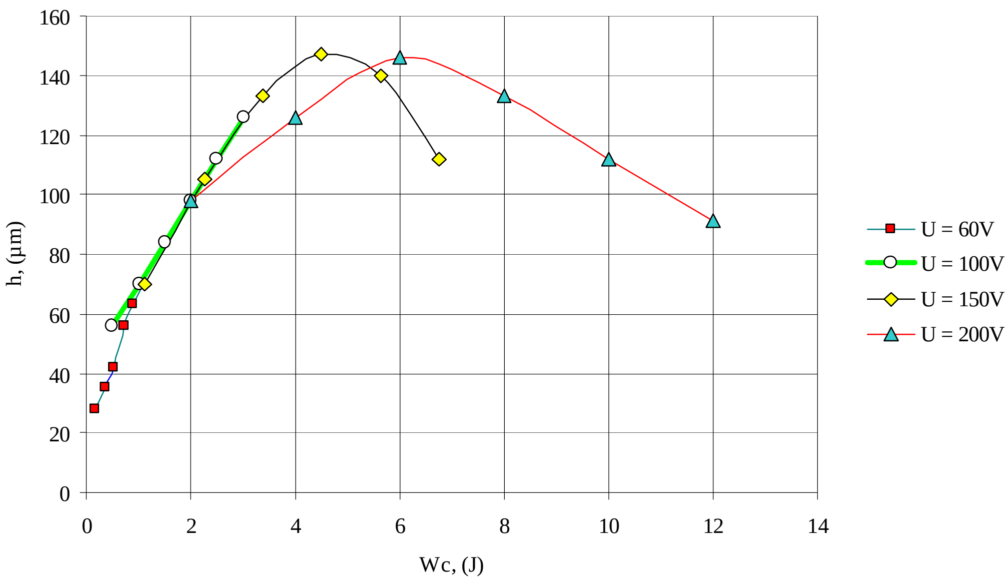


Fig. 6. *Dependence of meniscus height on the energy accumulated on the capacitor battery (the duration of discharge impulse is charged simultaneously with the energy).*

In the process of experimental research it has been noticed that the discharge pulse duration influences the meniscuses height. There have been established that for constant values of discharging pulse duration the meniscuses height increases once with the increase of the accumulated energy on capacitor battery (tab.1). If we maintain constant the accumulated energy on the capacitor battery, but we increase the discharging pulse duration, we obtain the same table. So the meniscuses heights formed on the anode surface increases (fig.7) depending on the pulse duration. This phenomenon can be explained by the inactive process, caused by the electrode material properties and duration of strength electrical field action.

In table 2 are presented the geometric parameters (height) of meniscuses as a function of discharge pulse duration.

It is necessary to mention that the discharge pulse duration influences not only the meniscuses height as well as the diameter size of meniscuses bases. We can say that the increase of discharge pulse duration leads to the increase of meniscuses diameter size. When the discharge pulse duration is a constant value and the energy accumulated on the capacitor battery increases, we can see the same phenomenon (fig.8).

Table 2.
The height of meniscuses depends on the duration of discharge impulse.

Nr.	W_c, (J)	U_s, (V)	t, (μs)	h, (μm)
1			100	28
2			125	33
3	0,18	21	160	39
4			180	46
5			200	55
6			220	63
1			100	30
2			125	35
3	0,36	21	160	40
4			180	50
5			200	58
6			220	65
1			100	33
2			125	38
3	0,54	21	160	42
4			180	54
5			200	60
6			220	65
1			100	34
2			125	40
3	0,72	21	160	46
4			180	56
5			200	61
6			220	67
1			100	36
2			125	43
3	0,90	21	160	50
4			180	58
5			200	63
6			220	68
1			100	38
2			125	46
3	1,08	21	160	53
4			180	60
5			200	66
6			220	70

As we can see in **table 1**, **table 2** and the graphics presented in figures 6, 7, 8, the energy and the pulse duration are very important parameters that influence meniscuses forming on metal surfaces.

The obtained results can be explained by the fact that, electrode spot through what the conductivity channel of EDP contacts the processed surface is on a certain height of this, on one hand, and the discharge current size depends on the processed material properties [5, 13].

The meniscuses diameter bases increase for the cases when the discharge pulse duration maintains constant and the accumulated energy on the capacitor battery increase, is being cleared out by the fact that the increase of energy leads to widening of discharge channel [12] and to the increase of the electrodes spots which form a connection between the plasma channel and the anode surface.

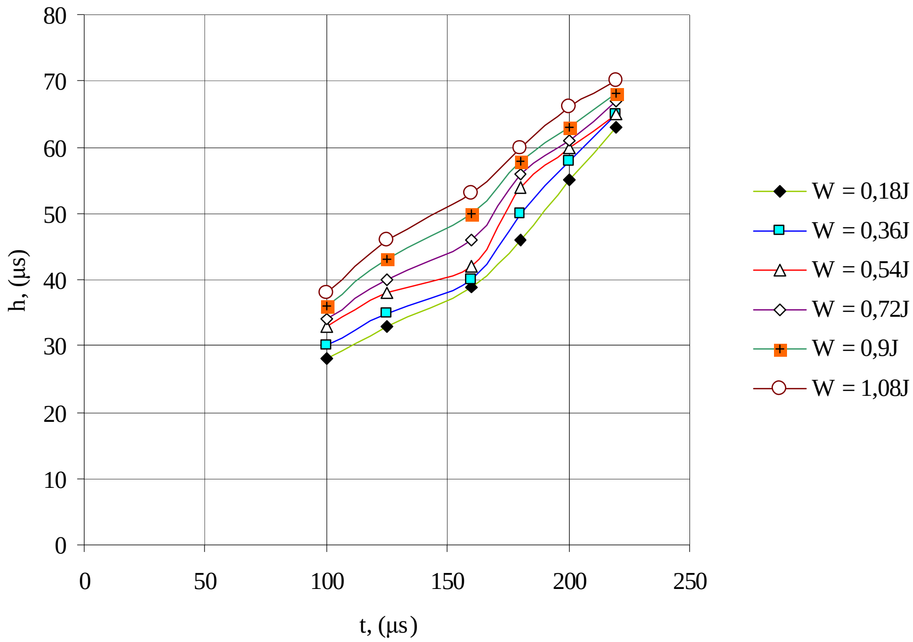


Fig. 7. *Dependence of meniscuses height on the duration of discharge impulse.*
(S = 0,2 mm; W = const.)

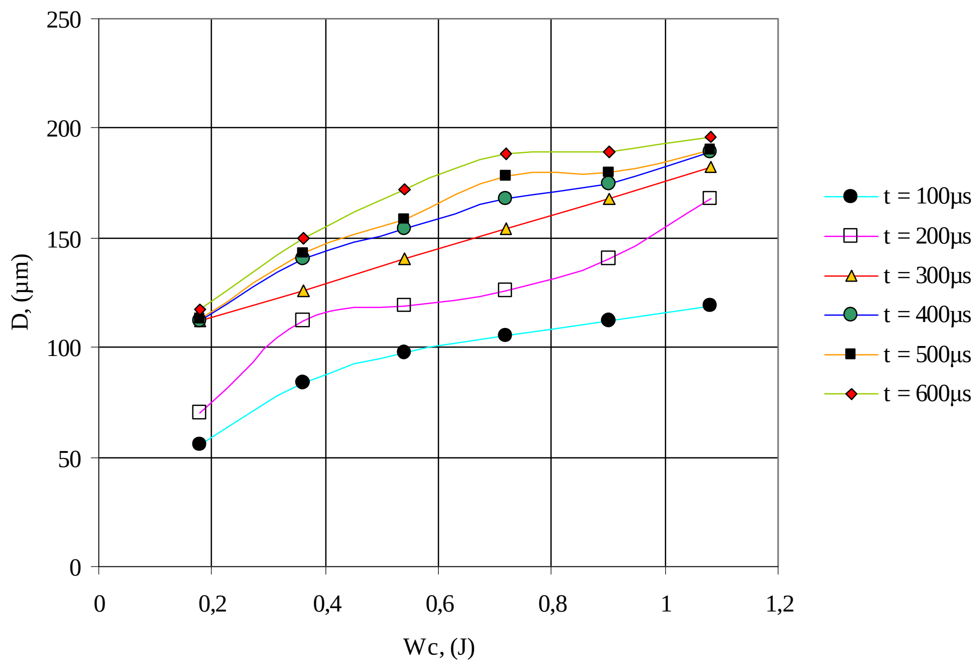


Fig. 8. *Dependence of meniscuses base diameter on the energy accumulated on the capacitor battery for different values of discharge impulse duration.*

The meniscuses diameter bases increase for the cases when the discharge pulse duration maintains constant and the accumulated energy on the capacitor battery increase, is being cleared out by the fact that the increase of energy leads to widening of discharge channel [12] and to the increase of the electrodes spots which form a connection between the plasma channel and the anode surface.

Appearance of meniscuses, their orientation, as well as their dimensions for the case of a solitary discharge, directly indicate that they cannot appear because of the depressurize in the plasma channel and are being caused by the electric field action along the vector ray from the electrode spot to the part processed surface.

Conclusions

Analyzing the experimental results and the theoretical findings made by other researchers, as well as my own results we can say that:

- in conditions of applying electrical discharge pulse on the metallic surfaces there are being created the necessary conditions and sufficient for extracting and freezing the conic meniscuses;
- meniscuses forming (Taylor cones) can be seen on the anode surface as well as on the cathode surface;
- linear dimensions of meniscuses (bases diameter and the height) are function of the energetic processing regime, pulse duration and the physical-mechanical properties of the electrode material;
- depending on the processing regime on the metallic surfaces can be created precise micro geometrical modifications.

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Despre rolul energiei şi a duratei impulsului de descărcare în procesul modificării microgeometriei suprafețelor pieselor metalice cu aplicarea descărcărilor electrice în impuls

Rezumat

În lucrare sunt prezentate rezultatele cercetărilor experimentale privind formarea meniscurilor sub formă de conuri Taylor pe suprafețele pieselor cu aplicarea descărcărilor electrice în impuls. Se precaută influența energiei acumulate pe bateria de condensatoare şi a duratei impulsului asupra geometriei acestora. Se demonstrează că, dimensiunile meniscurilor formate sunt funcție de regimul energetic de prelucrare, mărimea interstițiului, durata descărcării electrice în impuls şi propriitățile termo-fizice a materialului de execuție al piesei.

Le rôle de l'énergie et de la durée de décharger l'impulsion pendant le processus changeant de la géométrie micro des surfaces métalliques de pièces en appliquant des décharges électriques dans l'impulsion

Résume

En ce document on présente les résultats d'expérimental recherche concernant la formation de ménisque comme cônes de Taylor sur les surfaces de pièces avec des décharges électriques dans l'application de l'impulsion (informatique). Nous recherchons l'influence de l'énergie accumulée sur la batterie de condensateur et sur la durée d'impulsion sur la géométrie micro. On le démontre que la taille des ménisques formés dépend du régime énergique du traitement, de la taille de l'interstice, de la durée des décharges électriques dans l'impulsion et des propriétés thermo-physiques du matériel de partie.