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ELECTRICAL CHARGE AS MEASURE FOR THE REMOVED METAL MASS AT THE ELECTRICAL DISCHARGE MACHINING

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ABSTRACT.
The paper presents some authors considerations concerning the drop voltage in the work gap during the electrical discharge machining. The author considers that the mass quantity of material removed by a single electrical discharge depends on the charge quantity which passes in the work gap.

KEYWORDS: electrical discharge machining, discharge energy, work gap, voltage drop

1. INTRODUCTION

The development of the modenr science and technique supposes the introducing new materials which need adequate machining technologies. A solution to solve the problem of material machining is the applying generally the non-conventional technologies and particularly the electrical discharge machining. In the case of the electrical discharge machining processes, at the dimensional machining [1, 2] or at the generatin the deposition layers [3], the melting and removal of the material existing on the electrodes surfaces occur and the getting of some cavities having spherical calottes. The researchers working in this field tend to establish the relation between the quantity of the melted and removed material as a function of different parameters: pulses frequency, the gap size, then properties of the electrodes materials, the average intensity of electric current in pulse, the energy of the electrical discharges etc.

Usually, the absolute majority nof the researchers appreciate that the main parameter significantly influencing the erosive processes is the energetic factor of the electrical discharges in pulse. Thus, some researchers proposed to be used the relations:

$$d_c = kW \qquad (1)$$

$$h_c = kW \qquad (2)$$

$$\Delta\gamma = k\frac{CU^2}{2} \qquad (3)$$

$$\Delta\gamma = kW \qquad (4)$$

In which d_c is the diameter of the cavity obtained as the result of the single electrical discharge, h_c – the depth of the cavity, Δ_y – the quantity of removed or deposited material, k – proportional coefficint depending on the electrodes materials properties and on the working conditions., C – the capacity of the capacitors included in the pulse generator circuit, U – the voltage for charging the capacitors, W – the energy of the electrical discharges in pulse. The relations (1), (2), (3) and (4) are relatively simple, but simoultanously they are not sufficient clare and as consequence, the results obtained by different researchers could not be adequately interpreted. If we analyze the relation (3), we will see that the energy accumulated in the capacitors battery can not be used as a technological index, because all the discharges circuits include active, capacitive,and inductive resistances and, respectively, during the pulse electrical discharge process, a part of the energy accumulated on the capacitors battery is dissipated by it (table 1), and the energy lost is a function of many factors (the correloation between the inductance and capacity, the modality to introduce the inductance and the capacity in circuit, the gradient of energy introduced in the gap in a certain time unity etc.).

In the relations (1), (2) and (4), by the concepts of pulse electrical discharge energy W, we understand different aspects as the following:

$$W = u_e i_e t_d \qquad (5)$$

$$W_s = \int_0^{\tau} I(t) U_s(t)\, dt \qquad (6)$$

In the relation (5), W, u_e, i_e and t_d are, respectively, the pulse energy, the pulse drop voltage, the pulse current intensity and the pulse duration and in the relation (6), Ws_1, $I(t)_1$, $Us(t)_1$, τ – are, respectively, the energu dissipated in the gap during the single discharge, the size of the instantaneus of the dischrge current intensity, the drop voltage on the gap and the duration of the pulse electricl discharge. The relation (6) is very adequated to be applied in researches and technologies because it ensures the validity of the information concerning the influence of the energy directly delvered in the gap on the erosive phenomena.

2. EPERIMENTAL RESULTS AND THEIR ANALYZE

The paper presents some researches concerning the establishing of the pulse duration, drop voltage, accumulated energy in the capacitors battery, the energy dissipated in the gap as a function of the gap size. The determination of the electrical discharge parameters was made by means of the oscilloscope, in accordanc withe the above mentioned methodology and applying the scheme presented in figure 1. As registering apparatus, the osciloscop with memory type СЧ-1-10 [5]. The energy quantity delivered in the gap at a single electrical discharge can be determined by the using of the relation (6). To determine the drop voltage on the gap, at the changing its size, the current intensity in the puls keeps its size by the changing the energy cquantity accumulated in the capacitors battery (table 1).

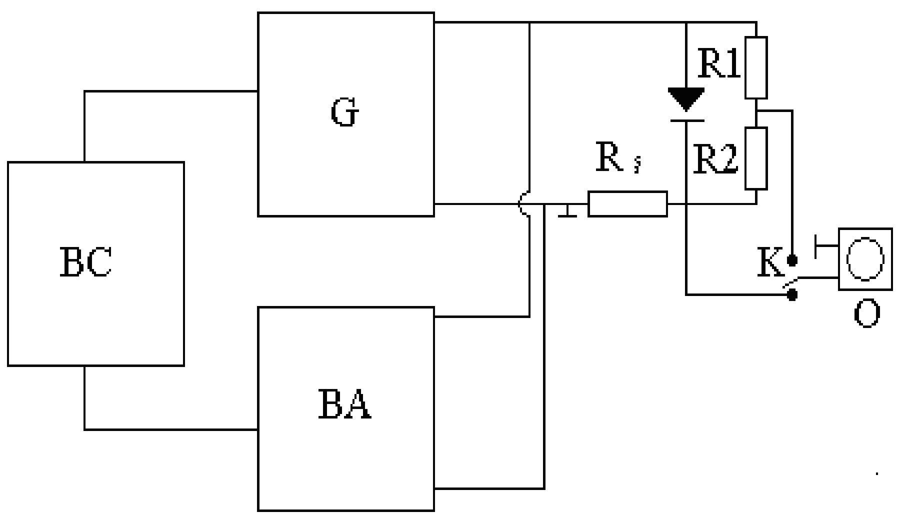

Fig. 1. Electrical scheme for measuring the electrodynamic characteristics of the pulse electrical discharges (BC- controll block, G – pulse generater, BA initiating block, O – oscilloscope, Rş – electrical shunt , R1 – R2, voltage divizor, K – commutator

Table 1. The drop voltage, the energy accumalated and dissipated in the gap for a constant size of the pulse current amplitude

Nr. exp.	S (mm)	U_c(V)	I_a, (A)	τ_i (μs)	U_s (V)	W_c, (J)	W_s, (J)	$\int_0^\tau i_s(t)dt$
1	0.1	148	1350	250	20	6.57	2.94	0,147
2	0.3	150			21	6.75	3.04	0,1447
3	0.4	157			23	7.38	3.10	0,1347
4	0.5	157			25	7.38	3.17	0,1268
5	0.6	159			29	7.5	3.25	0,1120
6	0.8	160			30	7.68	3.33	0,111
7	1.0	160			36	7.68	3.40	0,0944
8	1.25	160			38	7.68	3.47	0,0913
9	1.5	162			43	7.87	3.58	0,0832
10	1.7	163			46	7.97	3.87	0,0841
11	1.85	165			50	8.1	3.82	0,0764
12	2.0	170			54	8.67	3.90	0,0722

The same measurements were made also in the case when the energy accumulated on the capacitors battery is a constant size (table 2), W_c=constant for different sizes of the voltage for charging the capacitors battery (c=160…). To measure the discharge current intensity and the pulse duration, a coaxial shunt with an active resistance R_s=0.003 ohm was used.

Table 2. The drop voltage, the energy accumulated and dissipated in the gap as a function of the its size and the charging voltage of the generator capacitors battery

S, (mm)	U_c, (V)	t_i, (μs)	I_{max}, (A)	U_s (V)	W_c, (J)	W_s, (J)	$\int_0^\tau i_s(t)dt$
0.1	160	250	1350	21	7.68	3.04	0,144
	240		1500	20.05	17.28	4.3	0,214
	320		1950	20.55	30.72	4.8	0,233
	400		2375	20.8	48	6.82	0,327
0.5	160		1300	26	7.68	3.17	0,121
	240		1400	25.2	17.28	4.5	0,178
	320		1795	258	30.72	5.3	0,205
	400		2210	26.1	48	7.2	0,275
1	160		1159	30.5	7.68	3.4	0,111
	240		1315	31.1	17.28	4.9	0,157
	320		1700	30.0	30.72	5.5	0,183
	400		2105	30.0	48	7.7	0,256

1.5	160		1100	37.9	7.68	3.58	0,094
	240		1230	38.2	17.28	5.3	0,138
	320		1700	38.0	30.72	5.7	0,150
	400		2050	38.5	48	7.01	0,182
2.0	160		985	49.5	7.68	3.9	0,078
	240		1039	50.0	17.28	5.27	0,105
	320		1465	51.3	30.72	7.9	0,153
	400		1832	50.0	48	7.95	0,159

If we succinctly analyze the results presented in the tables 1 and 2, we can see that the size of the pulse durationt remains constant for all the sizes of the charging voltage of the capacitors battery. This fact is determined by the constance of the discharge circuit parameters.

If we analyze the results presented in the table 1 and table 2, we can notice that the size of the discharge pulse duration t_i remains practically constant for all the sizes of the charge voltage of the capacitors battery. This fact occurs because the parameters of the discharge circuits are constant.

Analyzing the results concerning the quantity of energy delivered in the gap as a function of the energy accumulated in the capacitors battery of the pulse generator, we can see that the smaller the quantity of accumulated energy is, the entire energy delivered in the gap is more complete and this fact is due to the increasing of the active resistence of tha plasma channel. Simulanously with the phenomenon of decreasing of the useful energy delivered in the gap simultanously with the increasing of the energy acumulated on the capacitors batery coould be explained by the increasing of the reactive component simultanously with the increasing of the gradient corresponding to the energy delivered in the gap (the recharging of the capacitors battery at an inverse polarity is proved).

In the case of modifying the voltage size in the gap (fig. 2) simultanously with the variation of the size gap, we can see that the voltage increases proportionally with its size. As consequence of the analyzing the obtained results in the papers [4, 5], the voltage drop in the gap (as a function of the gap size) can be expressed by the relation:

$$U_i = A(t) + B(t) \cdot S \qquad (7)$$

where $A(t) = U_a(t) + U_c(t)$, U_s and U_t are the anodic and, respectively, cathodic drop voltage.

The drop voltage on the anode and cahtode surface A(t) from the relation () is a constant size (fig. 2); if we aggree with this situation, then the size of the energy delivered on their surfaces is a function of the intensity current crossing these surfaces and the effects are deteremined by the current size and density.

Thus, in accordance with [5]m the voltage drop on the anodic and cathodic zones of the discharge and the potential gradient in the plasma channel could be given by:

$$B_t = \frac{\partial U(t)}{\partial S} = E_s(t) \qquad (8)$$

The results of measurements and their graphical representation are not dependent on the charging the capacitors battery (fig. 2) and the following relation could be written:

$$U_s = 19.206 + 14.235S \qquad (9)$$

The function corresponding to the changing the size of the gap starts from the poing U_s (for S=0) placed on the abscissa axis and represents a constant size for the both electrodes in accordance with the the materials used to make the electrodes (for example, in the case presented in figure 2 and in the tables 1 and 2, the anode is made of copper technical pure and the cathode is made of steel).

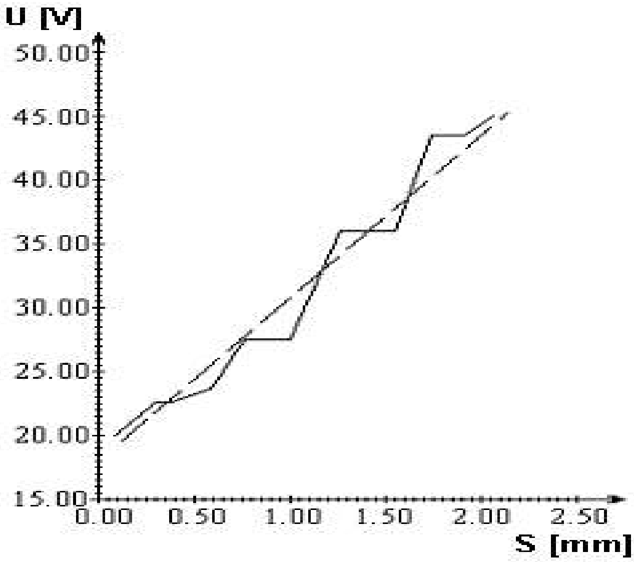

Fig. 2. The influence exerted by the gap size on the voltage in the gap

The relation (90) shows us that the voltage drop changes simultaneously with the changing of the gap size in accordance with approximately linear or exponential relation. From the relation (8), we can conclude that simultaneously with the increasing of the gap size, the increasing of the electric field intensity in the gap is necessary, to ensure the current circulation.
Thus, we experimentally established that for constant sizes of the gap, the voltage drops represents constant sizes and, therefore, by taking into consideration these results, we can write the relation (6) in the following manner:

$$W_s = U_s \int_0^{\tau} i_s(t)dt \qquad (10)$$

In the last relation, the integrale defined on the field (0... τ) represents the current quantity that passed by the gap during a single discharge. The authors of the papers [6, 7 and 8] established that between the erosion crater and the energy delivered in the gap thre is the following relation:

$$V_c = kW_e \qquad (11)$$

If we multiply the both parts of this equality with ρ (the density of the electrodes material) and we take into consideration the fact that for a certain size of the gap, the voltage drop is really a constant size, then we can write a new equality:

$$V_c \rho = k\rho W_e \qquad (12)$$

$$m = k\rho U_s \int_0^{\tau} i(t)dt \qquad (13)$$

This last relation shows that the quantity of material removed by electrical discharge machining is directly proportional with the current quantity that passes the gap during the pules; the relation is valid for the cases when in the gap there are conditions for the gatting the liquid phase. If the electroerosion occurs in the solid phase or both in the solid phase and liquid phase, the relation includes two components, each of them modifying in accordance with the concrete machining conditions. The validity of this relation for the case of the erosion in solid phase was confirmed by some researches [9, 10, 11] for the case of technical graphit, in function of the energy delivered in the gap and, respectively, of the current quantity which passed along the discharge circuit.

3. CONCLUSIONS

Analysing the results of the experimental researches made by the author and by other researchears, we can conclude that:

- The voltage drop on the electrodes surfaces is a constant size and it depends on the electrode materials;
- The voltage drop on the plasma channel in the gap depends on the gap size and practically does not depend on the voltage of the capacitors battery;
- The applied machining process (dimensional machining, layers deposition, grinding in solid state), the quantity of the removed material depends on the current quantity that passes by the gap during a single discharge.

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