Research Journal of Applied Sciences 9 (10): 691-695, 2014
ISSN: 1815-932X

Development of Complex Criterion of Efficiency of Process of an Electroerosive Insertion of Small Openings at Research of Interrelations of Basic Components of Process

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Abstract: In the majority of studied options of processing with increase in energy and frequency of impulses the effectiveness ratio decreases that is explained by distinction of dynamics of change of output parameters of process: productivity increases to a lesser extent, than wear of an electrode tool grows. It is found out that the exception makes option for an electrode tool diameter 20 mkm when with increase in frequency of impulses the effectiveness ratio slightly increases by 13.6%. Thus, for small diameters of an electrode tool it is necessary to use higher frequencies of impulses of small energiya.

Key words: Process effectiveness ratio, electrode tool, microopening, wear, productivity

INTRODUCTION

As practice and the numerous experiments (Boyko, 1989) connected with optimization of modes of an electro erosive insertion of small openings showed, the choice of electric modes of processing always led to invariable results: more a little worn-out modes had also lower productivity (Korenblyum, 1980). There was a scientific problem of a complex assessment of process when using various modes of processing for the purpose of definition of the most effective ways of its improvement.

For a complex assessment of efficiency of process in this work the criterion called effectiveness ratio and representing the relation of productivity of Q (micron/sec) opening insertions to relative linear wear γ was offered electrode tool (%):

$$K_э = \frac{Q}{\gamma} \times 100\% \quad (1)$$

It is obvious that the effectiveness ratio of subjects is higher, than productivity is more and wear of an electrode tool is less. Thus, the offered criterion considers two major days off of parameter of process and allows to estimate technological process of an insertion in a complex and also to choose its most effective option. Due to stated, represents scientific interest establishment of dependence of effectiveness ratio from parameters of process of an electro erosive insertion of openings.

Electric parameters energy and frequency of impulses of current and geometrical parameters diameter of an electrode tool and opening depth are among the most important input parameters of process (Altynbayev and Geykin, 2003). For simplification of an objective of the forefront opening depth in researches was accepted invariable and equal 500 mkm. Modes of vibration of an electrode tool were established: frequency of vibration is 330 Hz, amplitude 12 mkm. Experiments were made on the electroerosive machine of model 04ЭП-10М (Boyko *et al.*, 1983), processed material is steel 12×18H10T, electrode tool material is tungsten and working liquid is tap water (Boyko, 2011).

MAIN PART

Two series of experiments (Lesovik and Chernyshov, 2010) were carried out. In the first series, the electrode tool as diameter of d = 20 mkm, in the second d = 50 mkm was chosen. In both series dependence of relative wear γ an electrode tool and Q productivity from energy of E and frequency of f of impulses was investigated. Thus in dependences of Q(E) and γ(E) energy of impulses accepted value: 6.17, 9.25, 13.18, 28.4, 50.47 mkDg and the frequency of impulses remained invariable: f = 25 kHz. In researches of dependence of Q(f) and γ(f) the frequency of impulses accepted value: 25, 33, 50 and 100 kHz and energy of impulses remained constant and equal E = 9.25 mkDg.

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Table 1: Results of experiments on establishment of dependences of Q(E), γ(E), $K_Э$(E) with a constant frequency of f = 25 kHz for diameter d = 20 mkm

E (mkDg)	γ (%)	Q (mkm sec^{-1})	$K_Э$
6.17	72.35	17.22	23.80
9.25	100.15	23.55	23.51
13.18	129.36	29.97	23.17
28.4	197.56	43.79	22.17
50.47	233.69	49.98	21.39

Table 2: Results of experiment on establishment of dependences of Q(f), γ(f), $K_Э$(f) at constant energy E = 9.25 kDg for diameter d = 20 mkm

f (kHz)	γ (%)	Q (mkm sec^{-1})	$K_Э$
25	97.7	20.40	20.88
33	109.3	23.50	21.50
50	122.0	27.45	22.50
100	129.5	30.72	23.72

Results of a series of experiments with an electrode the tool with diameter 20 mkm are reduced in Table 1 and 2.

Using as initial mathematical model the equation of an exponential type and a method of the smallest squares for finding of constant coefficients in the environment of MathCAD, required dependences for diameter of an electrode tool 20 mkm were received:

$$\gamma_{20}(E) = 248.61(1 - e^{-0.05574 \cdot E}) \tag{2}$$

$$Q_{20}(E) = 51.9(1 - e^{-0.06536 \cdot E}) \tag{3}$$

$$\gamma_{20}(f) = 130(1 - e^{-0.0557 \cdot f}) \tag{4}$$

$$Q_{20}(f) = 31.16(1 - e^{-0.04257 \cdot f}) \tag{5}$$

For establishment of dependences of $K_Э$(E) and $K_Э$(f) as initial mathematical models the equations of a sedate type, after finding of which constant coefficients (Lesovik and Chernyshov, 2010) were used, they assumed an air:

$$K_{э20}(E) = 24.44 - 0.11E + 9.38\times10^{-4}E^2 + 8.17\times10^{-6}E^3 - 1.46\times10^{-7}E^4 \tag{6}$$

$$K_{э20}(f) = 18.19 + 0.132 \cdot f - 1.08\times10^{-3} \cdot f^2 + 3.11\times10^{-6} \cdot f^3 \tag{7}$$

The second series of experiments with an electrode tool with diameter 50 mkm which results are reduced in Table 3 and 4 was similarly carried out.

Using the above techniques of mathematical modeling, the following dependences for diameter of an electrode tool 50 mkm were received:

Table 3: Results of experiments on establishment of dependences of Q(E), γ(E), $K_Э$(E) with a constant frequency of f = 25 kHz for diameter d = 50 mkm

E (mkDg)	γ (%)	Q (mkm sec^{-1})	$K_Э$
6.17	19.75	15.99	80.96
9.25	28.15	21.32	75.73
13.18	37.65	26.36	70.01
28.4	64.40	35.56	55.22
50.47	85.08	38.48	45.23

Table 4: Results of experiments on establishment of dependences of Q(f), γ(f), $K_Э$(f) at constant energy E = 9.25 mkDg for diameter d = 50 mkm

f (kHz)	γ (%)	Q (mkm sec^{-1})	$K_Э$
25	29.63	20.42	68.92
33	35.02	23.14	66.08
50	42.72	26.34	61.66
100	51.04	28.56	55.96

$$\gamma_{50}(E) = 103.28(1 - e^{-0.0344 \cdot E}) \tag{8}$$

$$Q_{50}(E) = 39(1 - e^{-0.0855 \cdot E}) \tag{9}$$

$$\gamma_{50}(f) = 53.06(1 - e^{-0.0327 \cdot f}) \tag{10}$$

$$Q_{50}(E) = 28.76(1 - e^{-0.0495 \cdot f}) \tag{11}$$

$$K_{э50}(E) = 93.79 - 2.37E + 0.05E^2 - 6.07\times10^{-4}E^3 + 3.27\times10^{-4}E^4 \tag{12}$$

$$K_{э50}(f) = 81.82 - 0.656 \cdot f + 6.13\times10^{-3} \cdot f^2 - 2.16\times10^{-5} \cdot f^3 \tag{13}$$

For the visual analysis of the received dependences two-dimensional schedules of dependences were constructed:

- Figure 1: for dependences γ(E) (Eq. 2 and 8)
- Figure 2: for dependences Q(E) (Eq. 3 and 9)
- Figure 3: for dependences γ(f) (Eq. 4 and 10)
- Figure 4: for dependences Q(f) (Eq. 5 and 11)
- Figure 5: for dependences $K_Э$(E) (Eq. 6 and 12)
- Figure 6: for dependences $E_Э$(f) (Eq. 7 and 13)

The schedules represented in Fig. 1-6, convincingly show that for both diameters with increase in energy and frequency of impulses productivity and wear of an electrode tool at the same time increase and the effectiveness ratio decreases, except for dependence of $E_{Э20}$(f) for which the small growth of effectiveness ratio is characteristic at increase in frequency of impulses.

For an assessment of depth and nature of correlation dependence between productivity and wear of an electrode tool we will calculate correlation coefficient K for four above described experiments on a formula (Lesovik and Chernyshov, 2010):

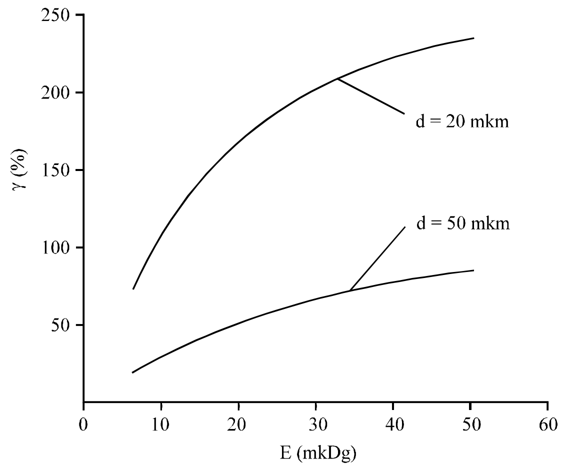

Fig. 1: Schedules of dependence of relative linear wear from energy of an impulse for electrodes tools with diameters of 20 and 50 microns

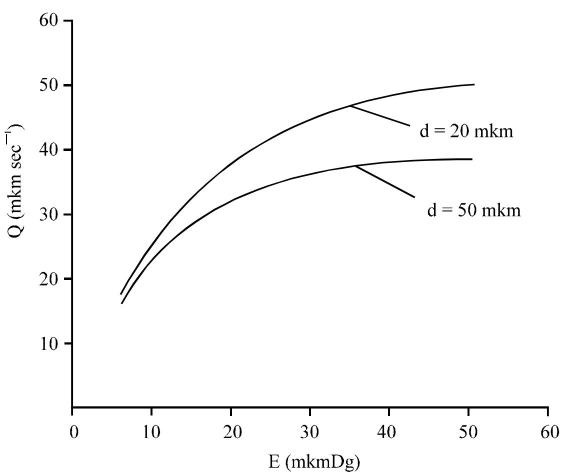

Fig. 2: Schedules of dependence of productivity from energy of an impulse for electrodes tools with diameters of 20 and 50 microns

$$K = \frac{n\sum Q\cdot\gamma - \sum Q\cdot\sum\gamma}{\sqrt{n\sum Q^2-\left(\sum Q\right)^2}\cdot\sqrt{n\sum\gamma^2-\left(\sum\gamma\right)^2}} \quad (14)$$

where, n is number of experiences; for dependences Q(E) and γ(E) n = 5 (Table 1 and 3); for dependences Q(f) and γ(f) n = 4 (Table 2 and 4).

- For diameter of an electrode tool 20 mkm, a varied factor energy of impulses of E = 6.17-50, 47 mkDg and the invariable frequency of impulses of f = 25 kHz, using these Table 1, on a Eq. 14, we will receive K1 = 0.990

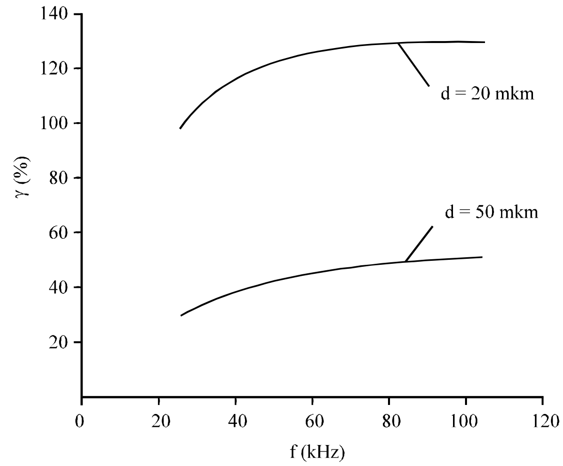

Fig. 3: Schedules of dependence of relative linear wear from impulse frequency for electrodes tools with diameters of 20 and 50 microns

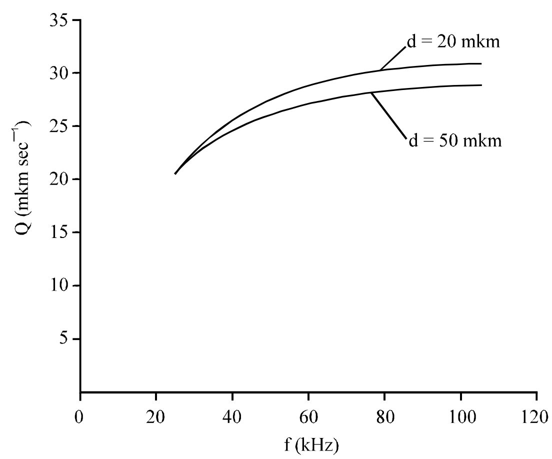

Fig. 4: Schedules of dependence of productivity from impulse frequency for electrodes tools with diameters of 20 and 50 microns

- For diameter of an electrode tool 20 mkm, a varied factor the frequency of impulses of f = 25-100 kHz and invariable energy of impulses E = 9.25 mkDg, using these Table 2, on a Eq. 14, we will receive K2 = 0.995
- For diameter of an electrode tool 50 mkm, a varied factor energy of impulses of E = 6.17-50.47 mkDg and the invariable frequency of impulses of f = 25 kHz, using these Table 3, on a Eq. 14, we will receive K3 = 0.970
- For diameter of an electrode tool 20 mkm, a varied factor the frequency of impulses of f = 25-100 kHz and invariable energy of impulses E = 9.25 mkDg, using these Table 2, on a Eq. 14, we will receive K4 = 0.991

Table 5: Assessment of the importance of correlation communication between productivity of Q and wear γ an electrode tool

	Numerical values of parameters in experiments[#]			
Name of basic data and settlement parameters	1 (Table 1)	2 (Table 2)	3 (Table 3)	4 (Table 4)
Number of experiences of n in experiment	5	4	5	4
Coefficient of correlation of k	0.990	0.995	0.970	0.991
Calculated value of t-criterion	12.12	14.09	6.91	10.47
Number of degrees of freedom of f	3	2	3	2
Tabular value of t-criterion	3.18	4.3	3.18	4.3
The importance of communication between Q and γ	The significant	The significant	The significant	The significant

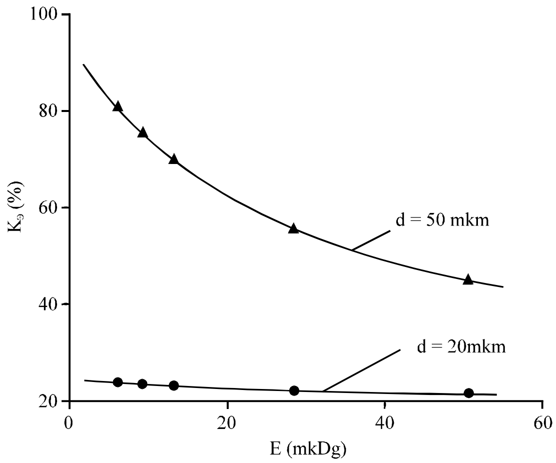

Fig. 5: Schedules of dependence of effectiveness ratio from energy of an impulse for electrodes tools with diameters of 20 and 50 microns

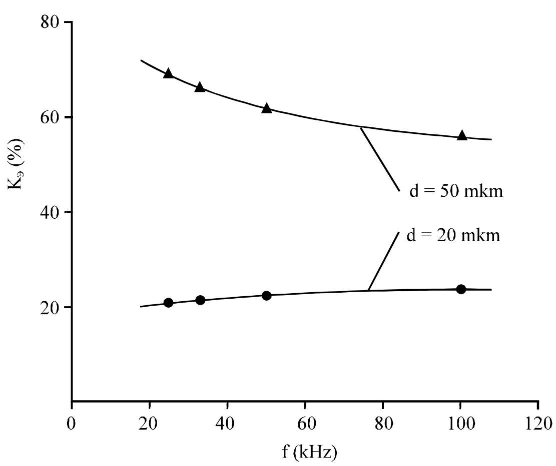

Fig. 6: Schedules of dependence of effectiveness ratio from impulse frequency for electrodes tools with diameters of 20 and 50 microns

The assessment of the importance correlation was made by comparison of a calculated value of t-criterion of Student with tabular (Lesovik and Chernyshov, 2010). The calculated value of criterion was determined by a equation:

$$t_p = \frac{k\sqrt{n-2}}{\sqrt{1-k^2}} \qquad (15)$$

Tabular values of criterion were defined for number of degrees of freedom of f = n-2 and confidential probability 0.95. Communication between parameters Q and γ is significant if the calculated value of t-criterion is more tabular.

Results of calculations on an assessment of the importance of correlation communication are shown in Table 5.

CONCLUSION

Thus, in all four experiments on existing technology correlation communication between productivity and wear of an electrode tool significant is close to direct proportionality. The scientific and technical task of decrease in the specified communication was set. Decrease in this communication to zero (K = 0) would be the best result. In this case, there would be possible an increase in productivity without increase in wear of an electrode tool which directly influences processing accuracy. That is, there would be possible an improvement of quantitative indices of process without deterioration of products (Blinova *et al*., 2009). But practically it can't be reached for the basic reasons connected with features of physics of process: the increase in productivity provided, generally by increase in energy and frequency of working impulses, steadily involves increase in thermal loading at an electrode tool (Blinova *et al*., 2009; Pogonin and Korop, 2010) and as a result, conducts to growth of its wear. However, it is obviously possible also expedient to reduce narrowness of communication between these parameters. It is interesting to estimate boundary value of coefficient of correlation K_{rp} below which communication will be insignificant. Boundary value can be brought out of dependence (Eq. 15):

$$|K_{rp}| = \frac{t}{\sqrt{t^2+n-2}} \qquad (16)$$

For dependences γ(E) and Q(E) with number of experiences of n = 5 and t = 3.18, we receive K_{rp} = 0.878. For dependences γ and Q(f) with number of experiences of n = 4 and t = 4.3, we receive (f) K_{rp} = 0.95.

In all range of studied factorial space with increase in energy and frequency of impulses at the same time with growth of productivity wear of an electrode tool also increases.

For both diameters of an electrode tool of regularity of growth and value of productivity are rather close, however wear of an electrode tool with diameter 20 mkm in three and more times is higher in comparison with diameter 50 mkm at identical modes of processing that is explained by higher specific thermal load of an electrode tool of smaller diameter.

For the same reason and approximately in the same proportions lower is the effectiveness ratio for diameter of an electrode tool 20 mkm. In the majority of studied options of processing with increase in energy and frequency of impulses the effectiveness ratio decreases that is explained by distinction of dynamics of change of output parameters of process: productivity increases to a lesser extent, than wear of an electrode tool grows. The exception makes option for an electrode tool with diameter 20 mkm when with increase in frequency of impulses the effectiveness ratio slightly increases by 13.6%. Thus, for small diameters of an electrode tool it is necessary to use higher frequencies of impulses of small energy.

For all studied options more intensive growth of productivity in the range of increase in smaller values of energy and frequency of impulses is observed. This phenomenon is explained by that with increase in energy and frequency of impulses the volume of products of processing in unit of time and their concentration grows in a working zone. Process of their evacuation of an interelectrode interval becomes complicated, the quantity of inefficient digit impulses through bald-headed particles increases, there is their repeated dispergating that conducts to decrease in intensity of growth of productivity of process.

It is established that on existing technology correlation communication between productivity and wear of an electrode tool significant on t-criterion, the coefficient of correlation reaches 0.99 and therefore, communication is close to direct proportionality. The task was set to decrease coefficient of correlation to boundary value 0.88-0.95 below which communication becomes insignificant.

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