SOI: 1.1/TAS DOI: 10.15863/TAS
International Scientific Journal
Theoretical & Applied Science
p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)
Year: 2020 **Issue:** 07 **Volume:** 87
Published: 19.07.2020 http://T-Science.org

QR – Issue QR – Article

Denis Chemezov
Vladimir Industrial College
M.Sc.Eng., Corresponding Member of International Academy of Theoretical and Applied Sciences, Lecturer, Russian Federation
https://orcid.org/0000-0002-2747-552X
vic-science@yandex.ru

Vladimir Goremykin
Vladimir Industrial College
Master of Industrial Training, Russian Federation

Aleksey Kuzmichev
Vladimir Industrial College
Head of Workshops, Russian Federation

Irina Pavlukhina
Vladimir Industrial College
Lecturer, Russian Federation

MODES ANALYSIS OF ELECTRICAL DISCHARGE MACHINING WITH COPPER, GRAPHITE AND STEEL ELECTRODES

***Abstract**: Influence of the active electrode surface, peak current and voltage on the material removal rate from the workpiece, relative wear of the electrode and the machined surface roughness during electrical discharge machining of steel, titanium, cemented carbide, copper and aluminium was determined in the article. The modes parameters that most affect the productivity of electrical discharge machining with the copper, graphite and steel electrodes and the quality of the machined surface of the workpiece were determined using the obtained analytical equations.*

***Key words**: the electrode, electrical discharge machining, the workpiece, steel, graphite, copper.*
***Language**: English*
***Citation**:* Chemezov, D., Goremykin, V., Kuzmichev, A., & Pavlukhina, I. (2020). Modes analysis of electrical discharge machining with copper, graphite and steel electrodes. *ISJ Theoretical & Applied Science, 07 (87),* 1-4.
***Soi**:* http://s-o-i.org/1.1/TAS-07-87-1 ***Doi**:* crossref https://dx.doi.org/10.15863/TAS.2020.07.87.1
***Scopus ASCC**: 2209.*

Introduction

Electrical discharge machining (EDM) is not the high productivity technological process. However, cavities of the various geometric shapes on the machined parts can be obtained by means of the special electrode. Providing the electrical discharge machine with the numerical control system allows to perform EDM with high accuracy. Thus, this EDM of various materials is rational to carry out in the conditions of the individual or small-scale productions.

The productivity of EDM is understood as the material volume removed from the workpiece per unit of time. Wear resistance of the electrode affects the quality of the machined surface of the workpiece. Simultaneous combination of the high productivity of EDM and the quality of the machined surface is the complex process, because it is necessary to take into account the large number of the modes, the materials properties of the workpiece and the electrode, the technical requirements for manufacturing the part, etc [1-10]. Mathematical processing of the experimental data will allow to determine the optimal modes for high productive finish EDM of various metals and alloys and make the forecast about wear resistance of the electrode.

Materials and methods

The analysis of the values changing of the material removal rate, relative wear of the electrode and the machined surface roughness of the workpiece in the conditions of the modes changing of EDM was the experiment purpose. EDM was carried out on the *Form 30* electrical discharge machine. Steel was machined with the steel and graphite electrodes; steel, titanium, cemented carbide, aluminum and copper were machined with the copper electrode. The following modes were adopted for machining all considered materials: the active electrode surface (F_p) – 0.0008…20 cm^2; peak current (*I*) – 0.8…104 A; on time (*T*) – 1…749.9 µs; the capacitance (*S-box*) – 0…127 pos; polarity (*Pol*) – -…+; off time (*P*) – 1.2…177.8 µs; compression (*Comp*) – 10.2…40%; the gain (*Gain*) – 8…25 pos; voltage (*U*) – 60…250 V; the ACC/ACO sensitivity (*MS*) – 0%; the mode (*Mode*) – 10…11 pos; the oscillator mode (*OM*) – 3 pos; the servo mode (*SM*) – 0 pos; the planetary rotation speed (*ω*) – 5…10 rpm; the planetary tolerance (*Tol*) – 0.008…0.016 mm; the planetary feed increment (*Inc*) – 0.018…1.4 mm; the impulse undersize (*M*) – 0.006…1.8 mm; the impulse undersize finishing (*2gap*) – 0.006…1.04 mm. F_p, *I*, and *U* were adopted as the independent factors. The material removal rate V_w (mm^3/min), relative wear of the electrode *θ* (%), and the machined surface roughness of the workpiece *Ra* (µm) were adopted as the dependent factors.

Results and discussion

The experiment results were mathematically processed and presented graphically. The dependencies of the material removal rate from the active electrode surface, relative wear of the electrodes from the value of peak current and the machined surface roughness of the workpiece from voltage are presented in the Fig. 1-3.

The removal rate of all materials increases with increasing the active electrodes surface. It was noted that the maximum removal rate occurs during EDM of aluminum with the copper electrode. EDM of cemented carbide is characterized by the low productivity.

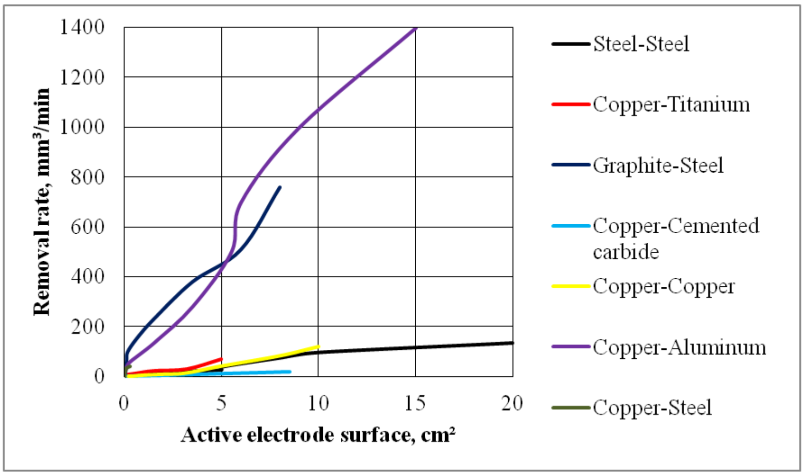

Figure 1 – The dependencies of the material removal rate during EDM from the active electrode surface.

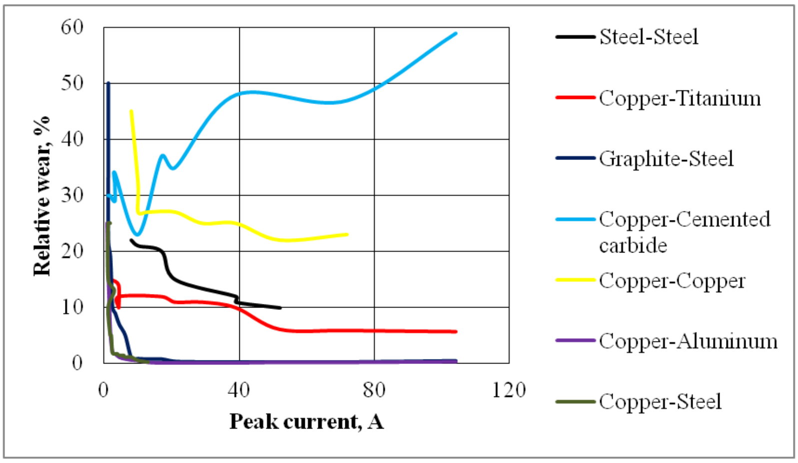

Figure 2 – The dependencies of relative wear of the electrodes from the value of peak current.

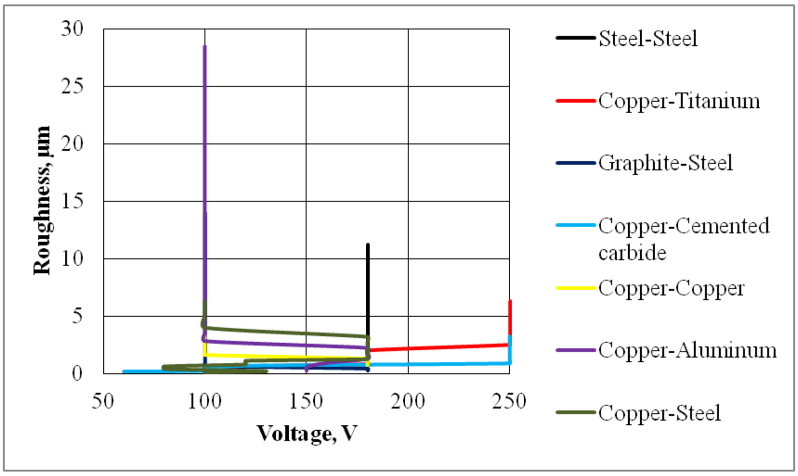

Figure 3 – The dependencies of the machined surface roughness of the workpiece from voltage.

The value of wear of the electrode leads to the similar value of the shape deviation of the machined surface of the workpiece. Relative wear of the electrodes decreases at the large values of peak current. EDM of cemented carbide with the copper electrode is the exception. Minimal wear in this case is observed at peak current of 10 A. Peak current up to 10 A leads to relative wear of the electrodes in the range of 15-50% during EDM of other materials. Aluminum machining is recommended to be performed at peak current of more than 10 A, since relative wear of the copper electrode in this case does not exceed 1%.

Finish EDM is carried out at high voltage (from 200 to 250 V). Semi-finish EDM occurs in the range from 100 to 180 V. Aluminum machining is accompanied by the formation of the high surface roughness of the workpiece. Steel machining with the steel electrode occurs at the single voltage value (180 V).

The multiple regression equations allow to determine the factors that most and least affect the analyzed results. The analytical formulas for the calculation of the material removal rate, relative wear of the electrode and the machined surface roughness of the workpiece and the factors that most affect the productivity of EDM and the quality of the machined surface are presented in the table 1.

All calculated equations have three independent variables, with the exception of the equations for determining the steel removal rate, relative wear of the steel electrode, and the machined surface roughness of the steel workpiece. The value of the active electrode surface has the most influence on relative wear of the tool. The value of peak current affects the machined surface roughness of the workpiece. The value of the removal rate will depend on machined material. Peak current affects the removal rate of steel, the value of the active electrode surface affects the removal rate of other materials.

Table 1. The analytical formulas for the calculation of the material removal rate, relative wear of the electrode and the machined surface roughness of the workpiece.

Steel-Steel	**V_w**	**θ**	**Ra**
The equation	$0.336F_p + 0.671I$	$0.45F_p – 1.378I$	$0.52F_p + 0.426I$
The factor that most affects the result	I	F_p	F_p
Copper-Titanium	**V_w**	**θ**	**Ra**
The equation	$0.651F_p + 0.346I – 0.0133U$	$-0.339F_p – 0.267I – 0.391U$	$-0.364F_p + 1.143I + 0.236U$
The factor that most affects the result	F_p	I	I
Graphite-Steel	**V_w**	**θ**	**Ra**
The equation	$0.314F_p + 0.695I + 0.0141U$	$1.025F_p – 1.244I + 0.744U$	$-0.731F_p + 1.637I – 0.0902U$
The factor that most affects the result	I	F_p	I
Copper-Cemented carbide	**V_w**	**θ**	**Ra**

The equation	$0.782F_p + 0.218I + 0.0036U$	$1.839F_p – 0.97I + 0.133U$	$-0.339F_p + 0.98I + 0.458U$
The factor that most affects the result	F_p	F_p	I
Copper-Copper	**V_w**	**θ**	**Ra**
The equation	$0.947F_p + 0.199I + 0.239U$	$-2.799F_p + 2.28I + 0.204U$	$0.842F_p + 0.0881I – 0.0893U$
The factor that most affects the result	F_p	I	F_p
Copper-Aluminum	**V_w**	**θ**	**Ra**
The equation	$0.533F_p + 0.468I + 0.011U$	$2.601F_p – 2.85I + 0.253U$	$-2.795F_p + 3.412I – 0.0245U$
The factor that most affects the result	F_p	F_p	I
Copper-Steel	**V_w**	**θ**	**Ra**
The equation	$0.119F_p + 0.853I – 0.151U$	$0.185F_p – 0.744I – 0.492U$	$0.0211F_p + 0.972I + 0.0626U$
The factor that most affects the result	I	F_p	I

Conclusion

The low productivity of EDM of cemented carbide and large wear of the copper electrode is compensated by low roughness of the machined surface of the workpiece. EDM of aluminum occurs with the high productivity and slight wear of the copper electrode under the specified conditions. However, these calculated modes are suitable for semi-finish EDM. The quality of the machined surface of the workpiece depends on changing the peak current value (the exception: if materials of the electrode and the workpiece are the same). The voltage value does not significantly affect the considered dependent parameters of EDM.

References:

1. Hockenberry, T. O., & Williams, E. M. (1967). *Dynamic evolution of events accompanying the low-voltage discharge employed in EDM*. IEEE Trans. on Industry and General Applications, IGA-3, 4, 302-309.
2. Singh, S., Maheshwari, S., & Pandey, P. C. (2004). Some investigations into the electric discharge machining of hardened tool steel using different electrode materials. *Journal of Materials Processing Technology*, 149, 272-277.
3. Bojorquez, B., Marloth, R. T., & Es-Said, O. S. (2002). Formation of a crater in the workpiece on an electrical discharge machine. *Engineering Failure Analysis*, 9, 93-97.
4. Marafona, J., & Wykes, C. (2000). A new method of optimizing material removal rate using EDM with copper tungsten electrodes. *Int. J. Mach. Tools Manuf.*, 40(2), 153-164.
5. Altpeter, F., & Perez, R. (2004). Relevant topics in wire electrical discharge machining control. *Journal of Materials Processing Technology*, 149, 1-3, 147-151.
6. Wong, Y. S., Lim, L. C., & Lee, L. C. (1995). Effect of flushing on electro-discharge machined surfaces. *Journal of Materials Processing Technology*, 48, 299-305.
7. Orlov, Yu., et al. (2019). Influence of processing modes on wear resistance of copper and graphite electrodes. *International Journal of Innovation Engineering and Science Research*, volume 3, issue 2, 1-13.
8. Chemezov, D., et al. (2019). Stability analysis of electrical discharge machining with brass wire. *ISJ Theoretical & Applied Scienc*e, 11 (79), 101-104.
9. Chemezov, D., et al. (2020). To the question of electrical discharge machining of the steel workpiece with the steel electrode. *ISJ Theoretical & Applied Science*, 06 (86), 545-550.
10. Marafona, J., & Chousal, A. G. (2006). A finite element model of EDM based on the Joule effect. Int. J. Mach. Tools Manuf., 46 (6), 595-602.