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INFLUENCE OF PROCESSING MODES ON WEAR RESISTANCE OF COPPER AND GRAPHITE ELECTRODES

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ABSTRACT

Wear resistance of electrodes in dependence on materials from which they are made and modes of electrical discharge machining is researched in the experiment.

Keywords *– an electrode, electrical discharge machining, wear.*

I. Introduction

Replacement of traditional methods of mechanical processing of the machine parts to physic-chemical processing methods (without the use of cutting edge tools) is due to the use in engineering of metallic alloys possessing by the special properties (heat-resistant steels, cemented carbides, tool steels and etc.), high accuracy of mating surfaces and complex configuration of the parts. These technical requirements are observed in conditions of electrical discharge machining (EDM) of the part. EDM of the part is performed by an electrode which is made of conductive materials [1]. The EDM process is the destruction of the workpiece material under the action of electrical discharges occurring between the workpiece and the electrode. The destruction of the electrode leads to a change of its initial sizes (absolute wear). Intensity of electrode wear depends on the modes of EDM and tool material [2; 3; 4]. Wear resistance of the electrode is determined only approximately due to the complexity of the wear process. The research of wear resistance of the electrodes in dependence on materials from which they are made and modes of EDM will allow to select a tool which is provided the highest machining productivity, high dimensional accuracy and surfaces quality of the part.

II. Material and method

For performing of the experiment 6 tool-electrodes was made: 3 copper electrodes (copper 1108, copper 1107 and copper 1106) and 3 graphite electrodes (graphite 3108, graphite 3107 and graphite 3106). The outer diameter of the working part of all the electrodes is 6 mm. Configuration of the electrodes is presented in the Fig. 1.

Fig. 1. Copper and graphite electrodes before EDM.

Die tool steel X37CrMoV5-1 (EN) was used as processed material. This steel is often used in the manufacture of working parts of moulds for pressure casting. Before EDM the workpiece of this steel was exposed by heat treatment to hardness 45...48 HRC and was grinded with both sides.
EDM of 6 blind holes by the copper and graphite electrodes was performed on the electric discharge machine Mondo Star 20 (Elox Corporation, USA). General view of the electric discharge machine and its technical parameters are presented in the Fig. 2 and in the table 1, respectively.

Fig. 2. The electric discharge machine Mondo Star 20.

TABLE I. THE TECHNICAL PARAMETERS OF THE ELECTRIC DISCHARGE MACHINE MONDO STAR 20.

External dimensions (width × depth × height)	
1550×1130×2360 mm	
Operating weight	
1580 kg	
Connection	
Operating power consumption	9.9 KVA
Maximum current consumption	15 A
Mains voltage	3×400V, 50/60 Hz
Mains quality	± 10 % (IEC 38) without interruption
Cos, φ	> 8
Water connection / temperature / water quantity / pressure	Ø 16 mm / Ambient temperature – 7 °C / 15 lpm / 2 – 7 Bar

Exhauster connection	Ø 100 mm
Maximum sizes of workpiece (width × depth × height)	
630×400×165 mm	
Working part of table (length × width)	
400×300 mm	
X-Y-Z range	
300/250/250 mm	
Movable sleeve (min/max)	
188/438 mm	
Maximum weight of workpiece	
200 kg	
Maximum weight of electrode	
25 kg	
Actuator	
Axes X/Y/Z	DC – servomotor
Minimum programmable movement	0.001 mm
Movement speed	720 mm/min
Accuracy	
VDI 3441 [5]	
Positioning error (Z) Pa	0.01/250
Positioning error (X, Y) Pa	0.01/300
Average range of positioning variations Ps	0.003 mm
Average error of reverse motion U	0.003 mm
Remote control (setup function)	
Standard	
Flushing	
Number of channels flushing	3
Pressure flushing and automatic pulse pressure flushing	2
Flushing by suction	1
Connection of programmable flushing	1
DA-dielectric assembly	
Type	Embedded
Fill volume	300 l
Type of used filters	Paper (cartridge filters)
Autonomous operation of filters	30 hours at 30 A
C-axis for indexing, rotation and erosion in a spiral	
Maximum weight of electrodes	25 kg
Maximum permissible current	60 A
Maximum number of turns	0 – 55 RPM
Positioning error Pa	0.01°
Average range of positioning variations Ps	0.005°
Average error of reverse motion U	0.005°
ELM – electrodes magazine (option)	
Number of electrodes	4 to the right
Maximum sizes of electrode (length × width × height)	70/80/165 mm
Maximum weight of all electrodes in magazine	9 kg
Air pressure	7 Bar
Futura V	
Generator / control / user shell	
Generator	
Maximum operating current	64 A
Number of channels	1
Removal rate according to values AGIE	

Vw Cu / St	380 mm^3/min at 64 A
Vw Gr / St	500 mm^3/min at 64 A
Environment requirements	
20 °C / temperature changes ≤ 0.5 °C per hour, ≤ 2 °C per day / without vibrations, draughts and heat sources	

For the experiment there were taken three modes of EDM (rough machining, semi-finish machining and finish machining) which are differ by feed rate, accuracy and quality. Modes of EDM of holes by the copper and graphite electrodes are presented in the table 2.

TABLE II. MODES OF EDM.

Rough machining			
Electrode material	*Voltage U, V*	*Current strength I, A*	*Power current P*
Copper 1108	100	8	3
Graphite 3108	100	8	8
Semi-finish machining			
Electrode material	*Voltage U, V*	*Current strength I, A*	*Power current P*
Copper 1107	100	7	2
Graphite 3107	100	7	8
Finish machining			
Electrode material	*Voltage U, V*	*Current strength I, A*	*Power current P*
Copper 1106	100	6	2
Graphite 3106	100	6	6

Machining within an hour with two breaks for measuring of depth of the processed hole and wear of the tool was carried out by the each electrode.

III. RESULT AND DISCUSSION

The results of the performed experiment are presented by the dependencies of EDM rates of the holes by the copper and graphite electrodes from the adopted modes (the Fig. 3 A – 8 A). The dependencies of wear of the copper and graphite electrodes from depth and time of EDM are presented in the Fig. 3 B, C – 8 B, C.

Rate of EDM of the hole by the copper electrode (rough machining) was amounted to 7.43 mm/h. The dependence of depth of EDM from time is close to linear. Rate of electrode wear is gradually increased. The surfaces smoothness of the hole and machining accuracy are low. For the accuracy in this case is taken that how insofar the processed surface coincides with geometry of the electrode before machining.

Rate of EDM of the hole during semi-finish machining by the copper electrode was amounted to 4.21 mm/h. The dependence of depth of EDM from time is close to linear.

Rate of EDM of the hole during finish machining by the copper electrode was amounted to 1 mm/h. Rate of electrode wear from time of EDM is reduced. This is due to the accelerated burning of asperity of the electrode surface and the gradual change of geometry of the end surface of the tool (to the full machining area). The surfaces smoothness of the hole and machining accuracy are high.

Rate of EDM of the hole during rough machining by the graphite electrode was amounted to 8.23 mm/h. The dependence of depth of EDM from time is close to linear, and rate of electrode wear is gradually reduced.

Rates of EDM of the holes during semi-finish and finish machining by the graphite electrodes were amounted to 2.54 mm/h and 1.34 mm/h respectively. When finish machining it is achieved only high accuracy of the hole.

Wear *u* of the copper electrode 1108 from time *t* and depth *h* of EDM of the workpiece material can be presented by the following equations (1):

$$\begin{cases} u = 0.0031t^{0.8145} \\ u = 0.0093h^{1.1144} \end{cases} \quad (1)$$

Wear of the copper electrode 1107 from time and depth of EDM of the workpiece material can be presented by the following equations (2):

$$\begin{cases} u = 0.0038t^{0.6818} \\ u = 0.0253h^{0.6272} \end{cases} \quad (2)$$

Wear of the copper electrode 1106 from time and depth of EDM of the workpiece material can be presented by the following equations (3):

$$\begin{cases} u = 0.0001t^{1.3382} \\ u = 0.0281h^{1.2182} \end{cases} \quad (3)$$

Wear of the graphite electrode 3108 from time and depth of EDM of the workpiece material can be presented by the following equations (4):

$$\begin{cases} u = 0.0014t^{1.2352} \\ u = 0.0054h^{1.7679} \end{cases} \quad (4)$$

Wear of the graphite electrode 3107 from time and depth of EDM of the workpiece material can be presented by the following equations (5):

$$\begin{cases} u = 0.0021t^{0.8851} \\ u = 0.0414h^{0.6793} \end{cases} \quad (5)$$

Wear of the graphite electrode 3106 from time and depth of EDM of the workpiece material can be presented by the following equations (6):

$$\begin{cases} u = 7 \times 10^{-5} t^{1.2576} \\ u = 0.0087h^{1.1509} \end{cases} \quad (6)$$

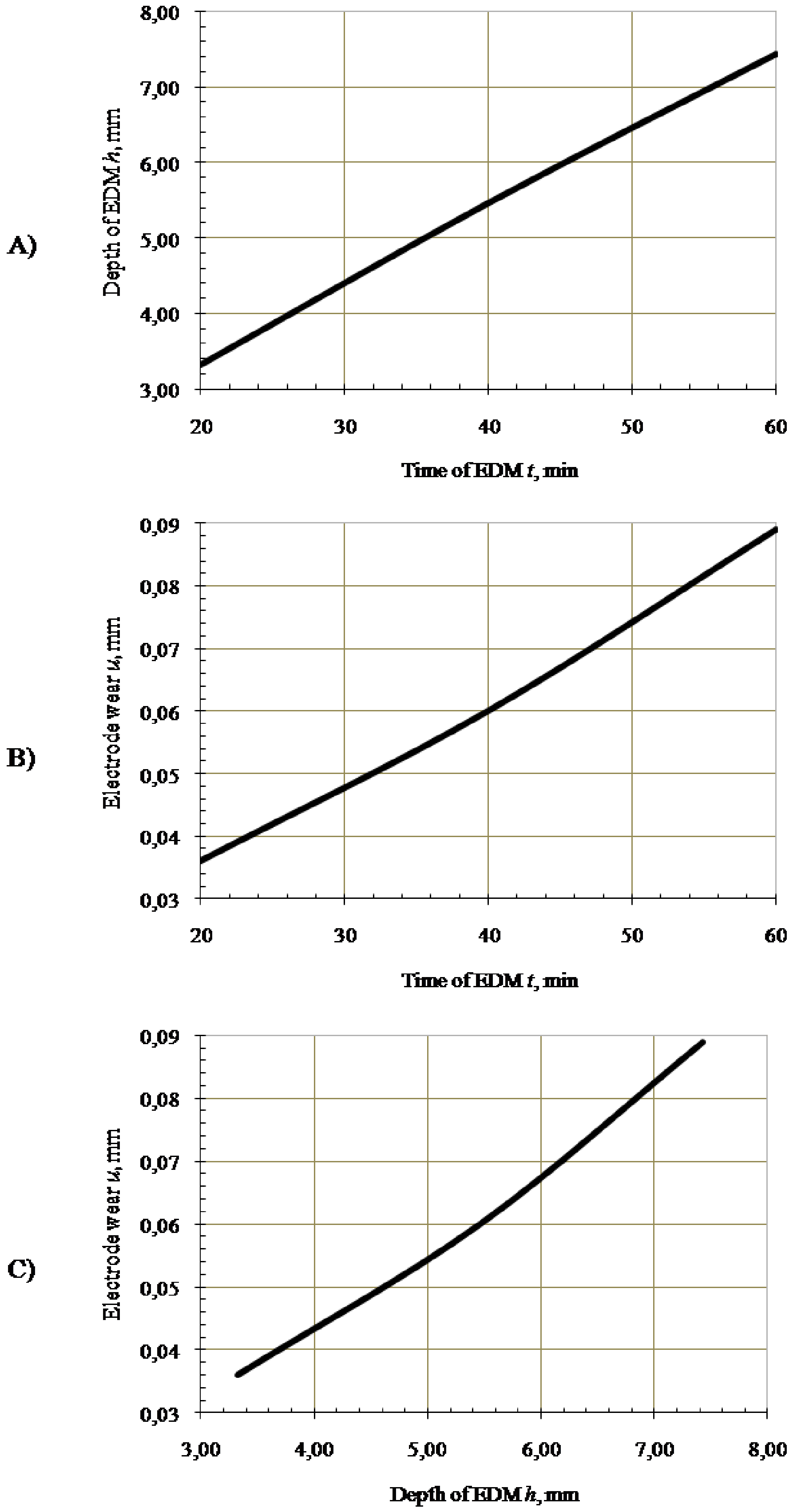

Fig. 3. Rough EDM of material by the copper electrode 1108: A – the dependence of depth of EDM from time of EDM, B – the dependence of electrode wear from time of EDM, C – the dependence of electrode wear from depth of EDM.

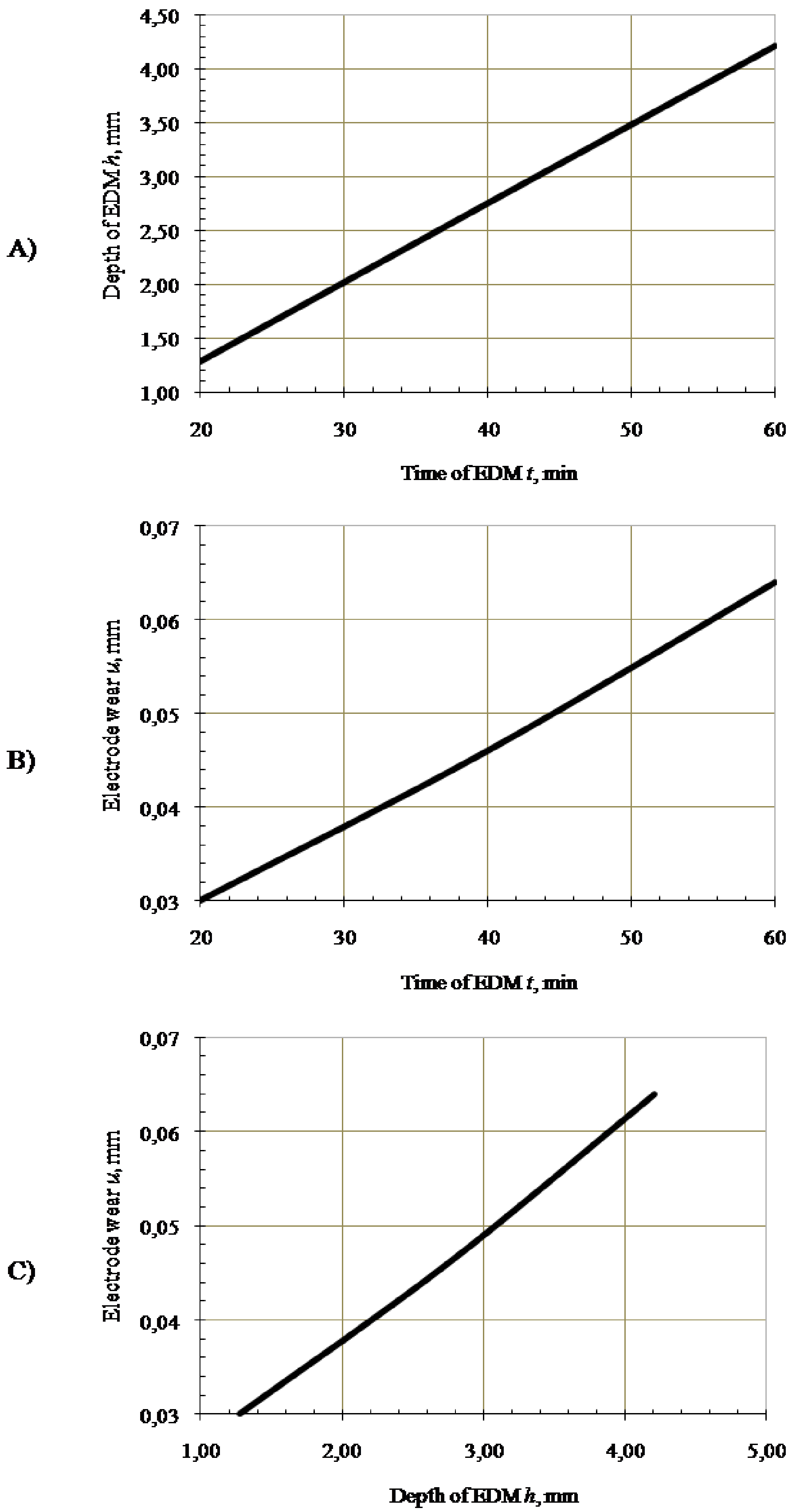

Fig. 4. Semi-finish EDM of material by the copper electrode 1107: A – the dependence of depth of EDM from time of EDM, B – the dependence of electrode wear from time of EDM, C – the dependence of electrode wear from depth of EDM.

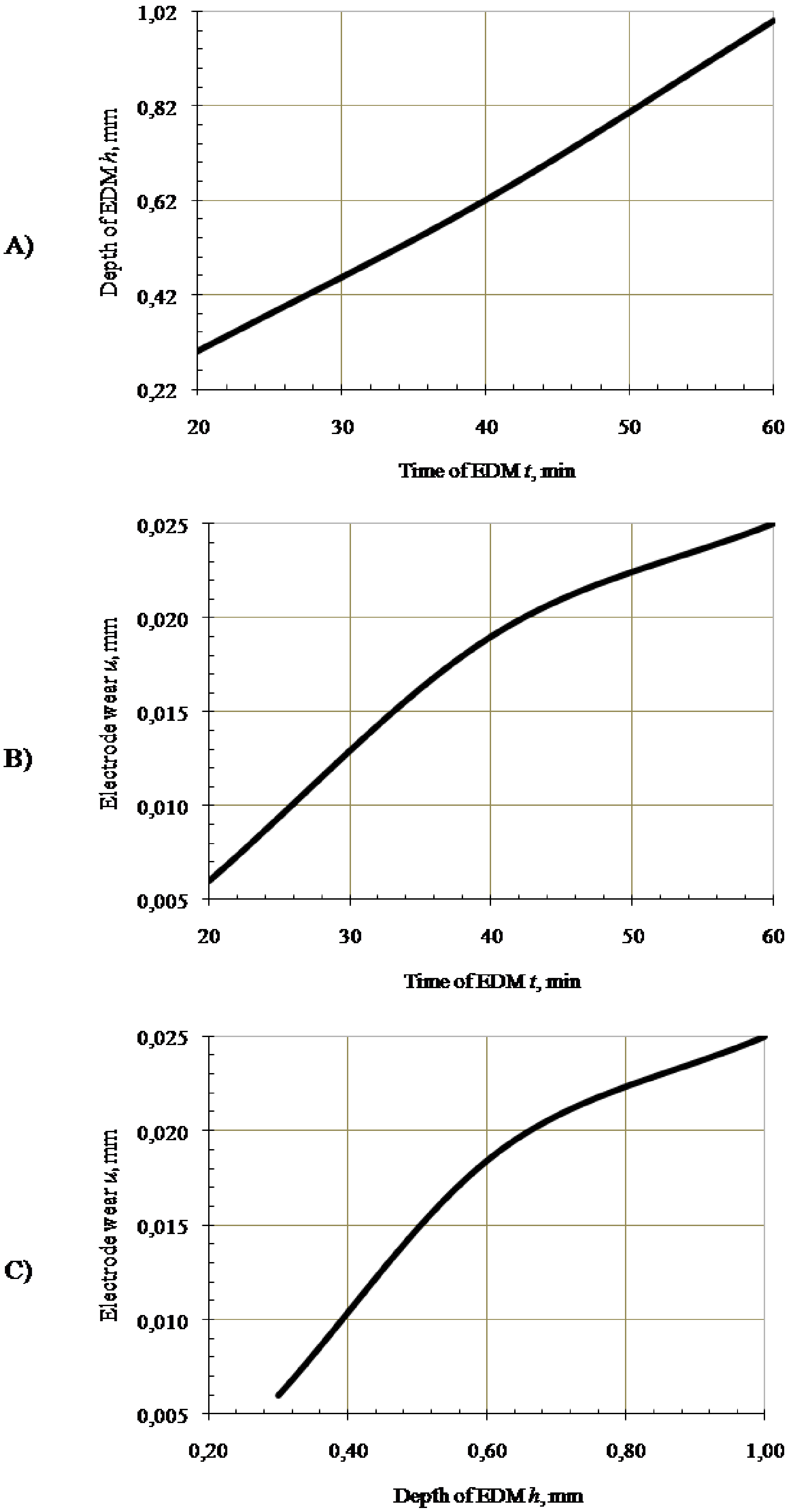

Fig. 5. Finish EDM of material by the copper electrode 1106: A – the dependence of depth of EDM from time of EDM, B – the dependence of electrode wear from time of EDM, C – the dependence of electrode wear from depth of EDM.

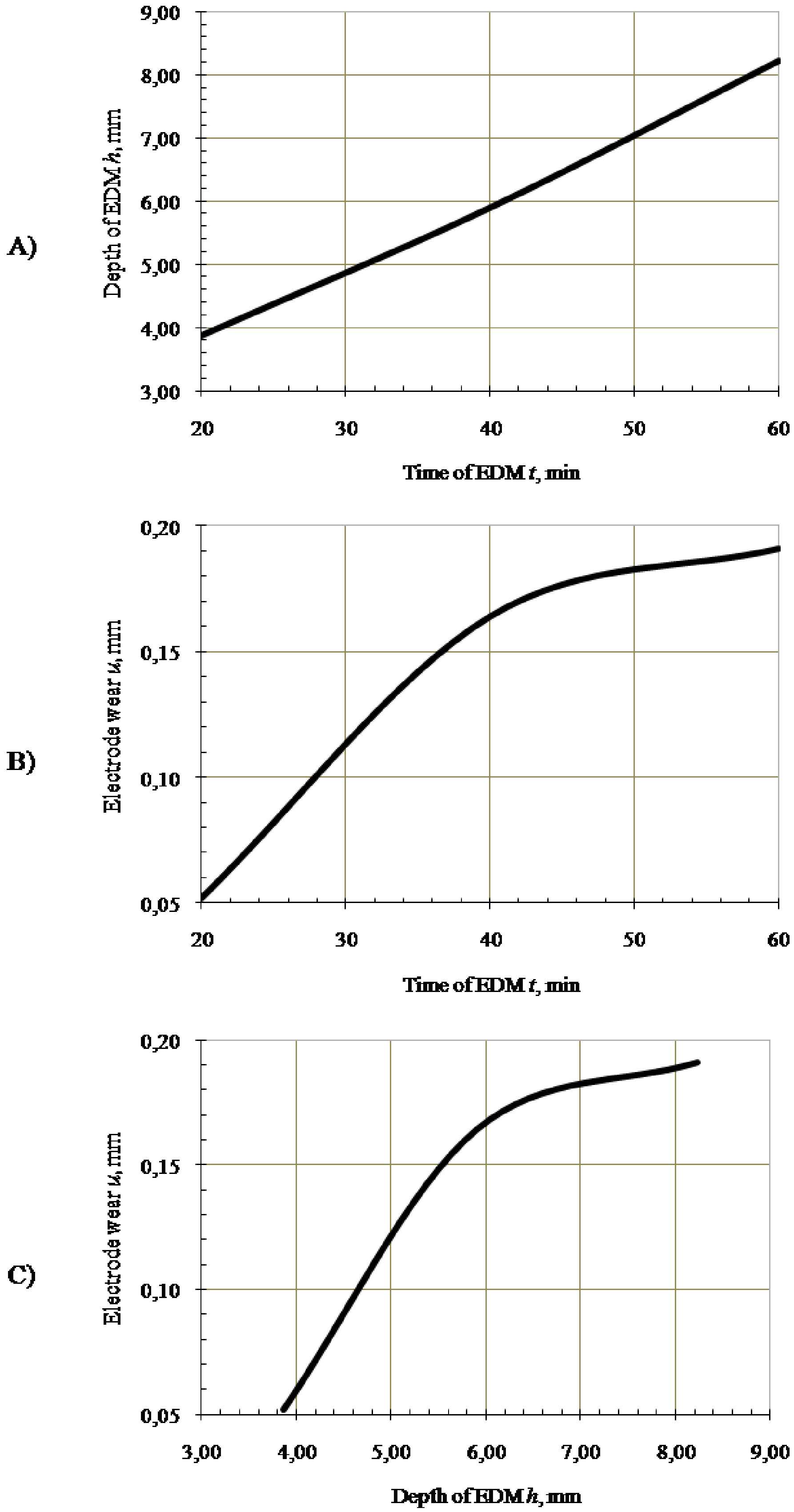

Fig. 6. Rough EDM of material by the graphite electrode 3108: A – the dependence of depth of EDM from time of EDM, B – the dependence of electrode wear from time of EDM, C – the dependence of electrode wear from depth of EDM.

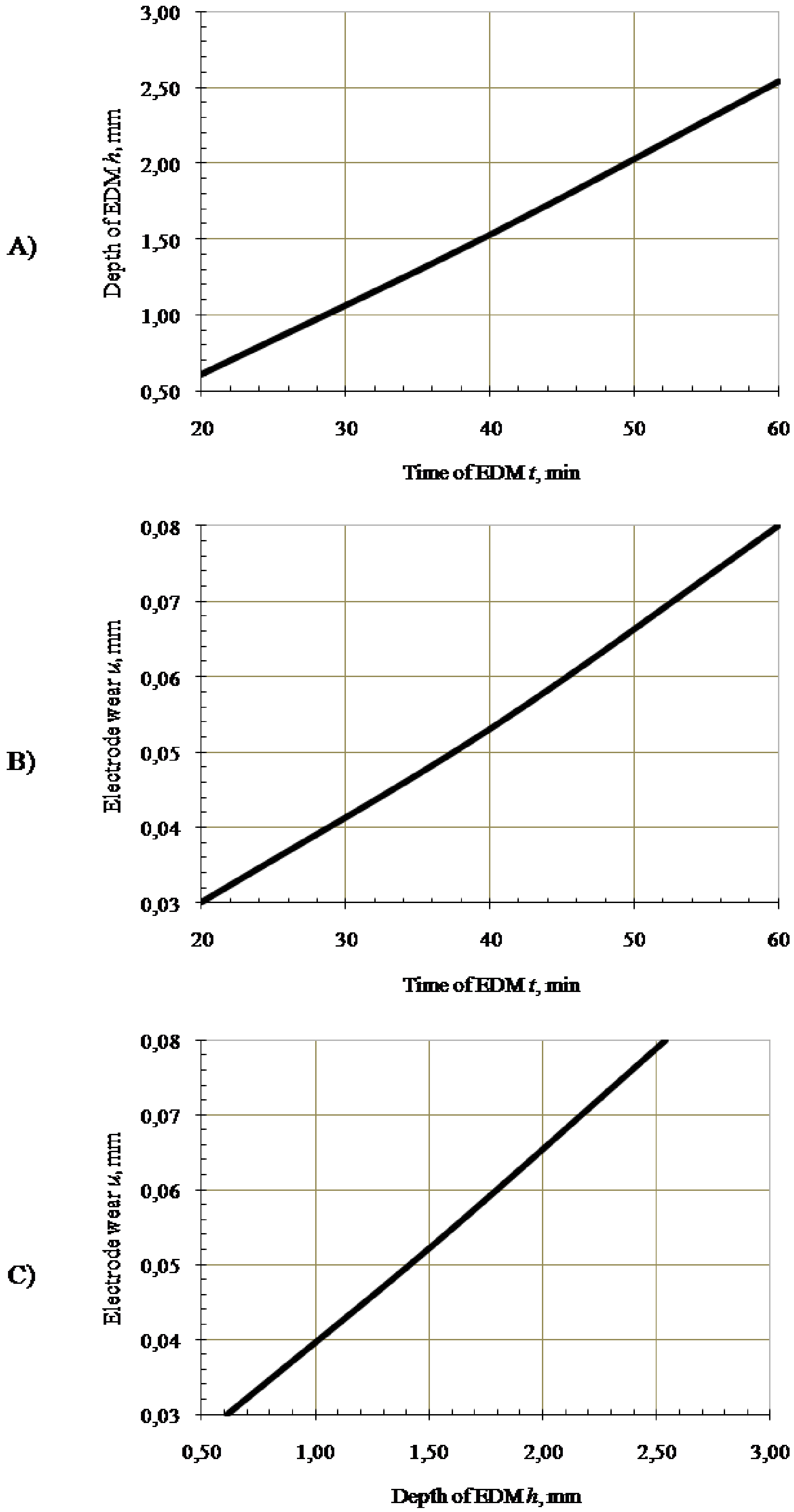

Fig. 7. Semi-finish EDM of material by the graphite electrode 3107: A – the dependence of depth of EDM from time of EDM, B – the dependence of electrode wear from time of EDM, C – the dependence of electrode wear from depth of EDM.

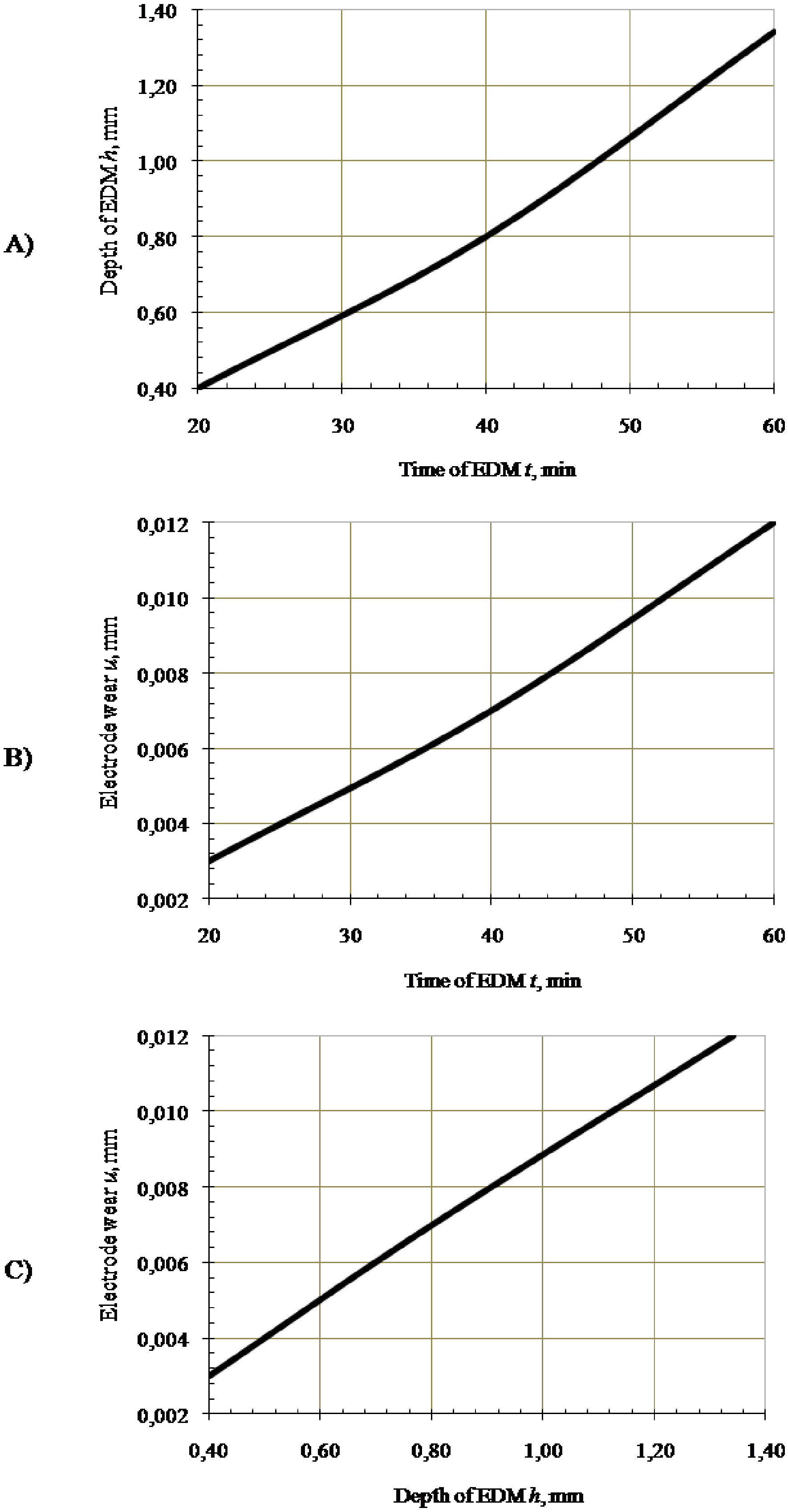

Fig. 8. Finish EDM of material by the graphite electrode 3106: A – the dependence of depth of EDM from time of EDM, B – the dependence of electrode wear from time of EDM, C – the dependence of electrode wear from depth of EDM.

Wear of the copper and graphite electrodes after EDM of the holes is presented in the Fig. 9 and 10. Surfaces quality of the holes after EDM is presented in the Fig. 11.

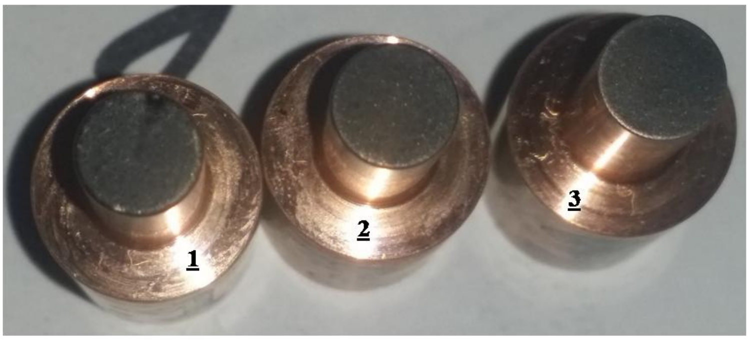

Fig. 9. Wear of the copper electrodes after EDM: 1 – copper 1108 (rough machining), 2 – copper 1107 (semi-finish machining), 3 – copper 1106 (finish machining).

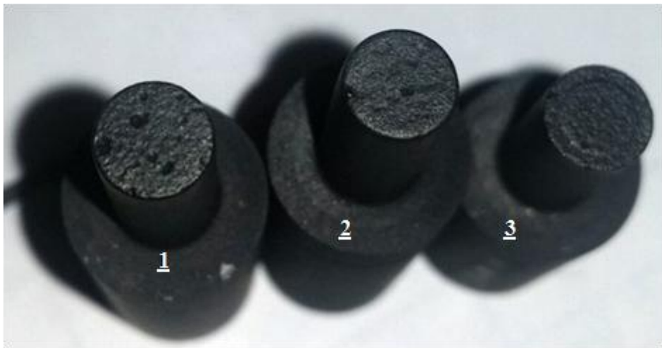

Fig. 10. Wear of the graphite electrodes after EDM: 1 – graphite 3108 (rough machining), 2 – graphite 3107 (semi-finish machining), 3 – graphite 3106 (finish machining).

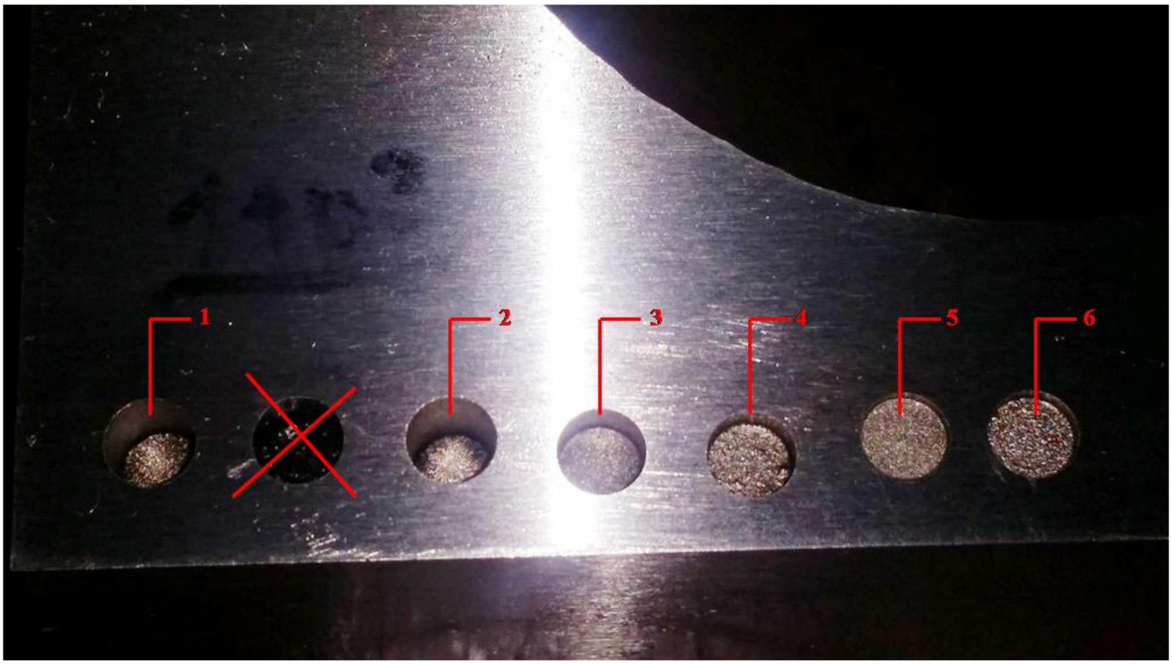

Fig. 11. Surface quality of the holes after EDM: 1 – machining by the copper electrode 1108, 2 – machining by the graphite electrode 3108, 3 – machining by the copper electrode 1107, 4 – machining by the graphite electrode 3107, 5 – machining by the copper electrode 1106, 6 – machining by the graphite electrode 3106.

IV. Conclusion

Wear resistance of the electrodes during EDM is depended on the tool material, machining modes and the volume of processed material.

It is determined that when rough machining the graphite electrode is used more effective. For equal amount of time the graphite electrode has been removed more material than the copper electrode (8.23 mm vs. 7.43 mm). Herewith, the greatest absolute wear was defined for the graphite electrode (0.191 mm vs. 0.089 mm). The copper electrode should be applied when semi-finish machining. When finish machining the graphite electrode has been removed 30 % more material than the copper electrode, but a roughness class of the processed surface of the hole is turned out below. In conditions of finish machining, wear resistance of working part of the graphite electrode in two times more than wear resistance of working part of the copper electrode.

The selection of the aforementioned parameters should be performed based on the technical specifications on manufacture of the part, such as dimensional accuracy, surface roughness, processability. For machining of working parts of the mould with high requirements to dimensional accuracy and surfaces roughness, it is necessary to use the copper electrodes in finishing modes. Technical requirements for the part manufacturing in this case are provided, but productivity of EDM is reduced (1 mm/h). In this case, it is economically advantageous to make two electrodes: one is graphite for rough machining with an allowance and one is copper for finish machining. Thereby, time of EDM of the main volume of the workpiece material will be reduced in 8.2 times.

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