Investigation of the effect flushing the working gap the effects of electrical discharge machining (EDM)

Badania wpływu przepłukiwania szczeliny roboczej na efekty obróbki elektroerozyjnej (EDM)

SŁAWOMIR SPADŁO
DOMINIK DUDEK *

DOI: https://doi.org/10.17814/mechanik.2017.1.20

This paper discusses experimental results of research on the assessment of the impact of working gap flushing effects processing. The study was conducted for drill trepanation at two variants feed fluid in the treatment zone (injection and extraction working fluid). The influence of productivity, surface topography.
KEYWORDS: electrical discharge machining, surface topography

Electrodischarge machining is one of the methods for processing the hard-working materials. In this process, the removal of micro-material from the workpiece occurs as a result of electrical discharges between the work electrode and the workpiece. The machining process takes place in a dielectric working fluid. The working electrode is spaced from the workpiece by a distance known as the work gap. No direct contact between the work electrode and the workpiece occurs under conditions of the correct working process (workpiece feed control systems detect short-circuits and reduce feedrate or retract working electrode from machining area) and after the boundary voltage has been crossed between the work electrode and the workpiece, electrons are arranged in an orderly fashion [5, 6]. Electrons from the electrode collide with the atoms of the interelectrode medium, causing them to ionize. As a result of the avalanche rise of the described phenomena, electron-filled high-temperature plasma ducts are produced. The effect of high temperature on the workpiece surface causes melting of the material's micro-volume and its partial evaporation. Electrically charged processes produce a discharge of molten material from the discharge area of the molten material that sprays in the spherical fluid. Craters are the final effect of the discharge on the surface of the workpiece [2, 3, 4].

The results of Electrodischarge machining tests are the subject of numerous publications. Due to the lack of theoretical models describing the phenomena in the inter-electrode gap satisfactorily, research is being conducted to increase the knowledge of the EDM process. Solutions are sought that will optimize the process while maintaining the requirements for, among others, surface layer status, performance indicators for electrodischarge machining and process economics.

* Dr hab. inż. Sławomir Spadło prof. PŚk (sspadlo@tu.kielce.pl), dr inż. Dominik Dudek (dominik_dudek@op.pl) –Politechnika Śląska

Methodology of research

The purpose of the experimental research was to determine the influence of the method of flushing the interelectrode gap in the electrodischarge machining zone on the process efficiency, surface topography and state of the surface layer. Two ways of feeding liquid were investigated: injection and suction.

▪ **Subject of study.** The specimens were made of 145Cr6 steel in the form of cylinders with a diameter of 24.9 mm and a height of 25 mm. The samples were subjected to heat treatment - quenching and tempering - and a hardness of 62 HRC was obtained. Steel 145Cr6 is a tool steel for cold working. It is characterized by slight deformation during hardening and high abrasion resistance. It is used as a material for: deep drawing dies, dies (cutting boards), measuring instruments.

▪ **Test conditions.** Comparative analysis was performed at constant current parameters (current amplitude 25A, pulse time 210 μs, pause time 20 μs) and two dielectric feeding patterns (injection and suction). Performance indicators were derived from the results of three trials for constant current parameters and for suction and injection of working fluid. The dielectric in the drilling process was cosmetic kerosene. As a working electrode, a copper tube with an external diameter of 11.5 mm was used. Talysurf CCI Lite profiler was used for surface topography. Observation of the microstructure of the surface layer was carried out on the wrinkles by Nicon Eclipse MA 200 reversed metallographic microscope.

Research results and their analysis

Two performance indicators were analyzed, i.e. volume efficiency *Vww* (defined as the ratio of the volume of material removed by erosion to the process duration) and the labor-consumption volumetric factor θ (expressed as a percentage and defined as the ratio of volumetric consumption of the electrode to the volume of material removed by erosion). A summary of the obtained performance indicators of the process is given in Table I.

TABLE I. Results of performance indicators measurement for suction and injection of working fluid (CR)

Sample	Suction CR		Injection CR	
	V_{ww}, mm^3/min	ϑ, %	V_{ww}, mm^3/min	ϑ, %
1	31,49	2,97	64,07	6,18
2	31,15	2,75	63,42	6,12
3	30,75	3,13	64,23	6,15
Arithmetic mean	31,13	2,95	63,91	6,15

Analysis of the test results indicates that in a variant with the injection of working fluid into the treatment zone, the volume yield was twice as large as in the case of suction. For the case of working fluid injection, the coefficient of volumetric consumption of the working electrode increased approximately twice. This dependence is caused by much shorter processing time when the working fluid is pressed. In this variant, it was easier to remove the erosion products, resulting in a much higher drilling intensity than the first flush variant.

Surface topography evaluations were made on the basis of 3D measurements. Measurements were made at three points of the hole, i.e. in its upper, middle and lower parts. Three parameters were analyzed: *Sp* - height of the highest peak of a limited area, *Sv* - depth of the lowest area of a finite scale, and *Sa* - arithmetic mean of the area of limited scale. Table II presents results of the measurements for variant with the suction of the working fluid [1].

TABLE II. Results of 3D measurement of roughness parameters for the variant with working fluid suction

Measurement site	*Sp*, µm	*Sv*, µm	*Sa*, µm
Upper part of the hole	98,77	100,50	15,30
Middle part of the hole	97,23	98,13	15,27
Lower part of the hole	141,31	117,86	18,20

Analysis of results shows that in the variant with the working fluid suction, higher values of surface roughness parameters were recorded. This is due to the difficulty of removing erosion products from the interelectrode gap. Due to the possibility of causing slight pressure drops in the interelectrode gap, the efficiency (and thus the flow rate) is limited under the suction conditions of the working fluid. In addition, these difficulties increase with increasing the channel length (drilling depth).

Surface topography studies were supplemented with height maps of roughness profiles and polar graphs of its distribution.

Exemplary 3D surface topography charts for a variant with a suction of the working fluid from the machining area for the upper part of the sample are shown in fig. 1.

Analysis of 3D roughness charts indicates that at the test points at different heights of the hole, the surfaces are characterized by isotropicity of roughness distribution. The lack of directionality of the surface geometry is a typical feature of the surface after electrodischarge [1].

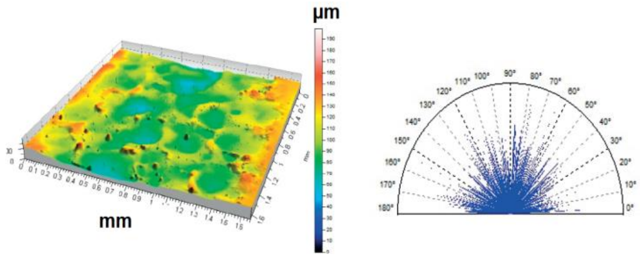

Fig. 1. The 3D surface topography and polarization roughness graph for the working fluid suction variant - upper part of the sample opening (I_w = 25A, t_i = 210 µs; t_0 = 20 µs)

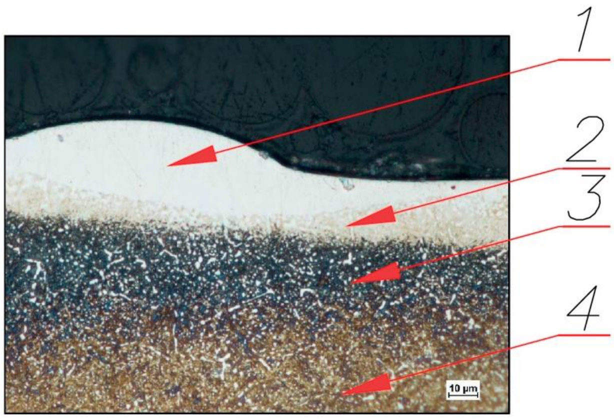

Fig. 2. Micro-photo (over 500 ×) of the surface of the electrodischarge machining surface (I_w = 25A, t_i = 210 µs; t_0 = 20 µs) in the variant with injection of the working fluid into the treatment zone: 1 - white layer, 2 – thermal influences zone, 3 - tempered layer, 4 - native material. Workpiece: 145Cr6

Fig. 2 shows an example of micro-photo of the metallographic top layer structure. An analysis of the obtained micro-photos allows for visualization of the metallographic microstructure on the surface being treated by the electrodischarge machining.

On the micro-photos for the variant with the injection of the working fluid into the treatment zone; a white layer lacking microcracks on the examined surface area can be observed. This condition may be due to a lower intensity of thermal effects in the treatment zone. In the case of the injection of working fluid into the treatment zone, more efficient (due to the higher flow rate) rinsing the inter-electrode gap as compared to the case of suction of the working fluid, occurs.

Conclusions

Direction of the working fluid delivery into the treatment zone is an important element of the electrodischarge machining process. Incorporation of the working fluid into the inter-electrode gap allows the hydraulic resistance of the viscosity to be overcome, which in turn, results in more rinsing of the slit and removal of the erosion products. This has a direct impact, among others, on the process performance, working electrode wear, surface topography, and surface condition after electrodischarge machining.

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