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ELECTROMACHINING OF TUNGSTEN CARBIDE

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Summary

The study were aimed to determine the machinability of tungsten carbide after electromachining, on the basis of the machined surface roughness measurement, for variable current *I* values. In addition, another series was carried out to determine the differences in surface roughness parameters values (expected values and measured values). After two series, the analysis of the machining process was conducted, taking into account the material removal rate.

Keywords: tungsten carbide, electromachining, surface roughness, machinability

Obróbka elektroerozyjna węglika wolframu

Streszczenie

W pracy określono skrawalność węglika wolframu przy użyciu kryterium parametru chropowatości powierzchni obrobionej, w zakresie zmiennych wartości natężenia prądu w procesie obróbki elektroerozyjnej. Prowadzono dodatkowe badania w celu wyznaczenia różnicy wartości parametrów chropowatości (wartości oczekiwane i rzeczywiste). Wykonano analizę procesu obróbki elektroerozyjnej z uwzględnieniem objętościowej wydajności skrawania.

Słowa kluczowe: węglik wolframu, obróbka elektroerozyjna, chropowatość powierzchni, skrawalność

1. Introduction

Cemented carbides find the application in industry for cutting tools. Some of them also find the application as structural material for parts requiring high wear resistance, especially at the elevated temperature, eg. elements of slide and rolling bearings, nozzles, guides, blades in thermal machines and hydraulic plungers. It can be concluded, that cemented tungsten carbide may be used both as a tool and constructive material.

Because of the properties (high hardness, high flexural and compression strength), tungsten carbide is hard to machine (grinding, milling) [1, 2]. In order to overcome the technical difficulties in conventional machining processes, non-conventional machining processes are increasingly attempted for the machining of WC and its composites (WC–Co), particularly for applications where

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dimensional accuracy with complex geometries are primary requirements. Among the non-conventional methods, electrodischarge machining (EDM) and electrochemical machining (ECM) are the only methods capable of machining WC–Co composites. Electrochemical process generates a resistant oxide layer on the tungsten carbide surface promoting very slow material removal rate (MRR); which is further decreased when high cobalt percentage is used in the alloy [3]. Physical parameters of non-conventional methods have direct influence on material removal rate (MRR) and energy consumption.

Electrodischarge machining (EDM) is the process of machining electrically conductive materials by using precisely controlled sparks that occur between an electrode and a workpiece in the presence of a dielectric fluid [4]. EDM is based on the erosion of electrically conductive materials through the series of spatially discrete high-frequency electrical discharges (sparks) between the tool and the workpiece [5]. Fig. 1 illustrates stages of electromachining process. The spark removes material from both the electrode and the workpiece, which increases the sparking gap (distance between the electrode and the workpiece) at that point. This causes the next spark to occur at the next-closest points between the electrode and the workpiece. As EDM is a thermal process, material is removed by heat. Every discharge (or spark) melts a small amount of material from both of the electrodes. Part of this material is removed by the dielectric fluid and the remaining solidifies on the surface of the electrodes. The net result is that each discharge leaves a small crater on both the workpiece and the tool electrode [6].

The biggest problem during the EDM process of tungsten carbide is the selection of cutting parameters which allow to obtain satisfactory surface roughness quality. This is due to complex composition and structure of the material. Tungsten carbides with high cobalt content are more suspectible to surface cracks. However, lower percentage of cobalt minimizes the resolidified layer, especially at lower pulse duration and thus yields better surface finish in the EDM of WC–Co. The intensity and pulse duration time are the most important factors affecting surface quality. Surface roughness parameters values increase with the increase of intensity and pulse duration time. In this work, the influence of the current value on surface roughness parameters values was determined, as well as the differences between setting and obtained surface roughness parameters were evaluated.

2. Method of research

The study were aimed to determine the machinability of tungsten carbide, based on the machined surface roughness measurement, in terms of variable current values I during electromachining. In addition, another series were carried out in order to designate differences between surface roughness parameter Ra values (setting and obtained values). The material was tungsten carbide (WC) which was obtained by the direct laser deposition technology (DLD – Fig. 2).

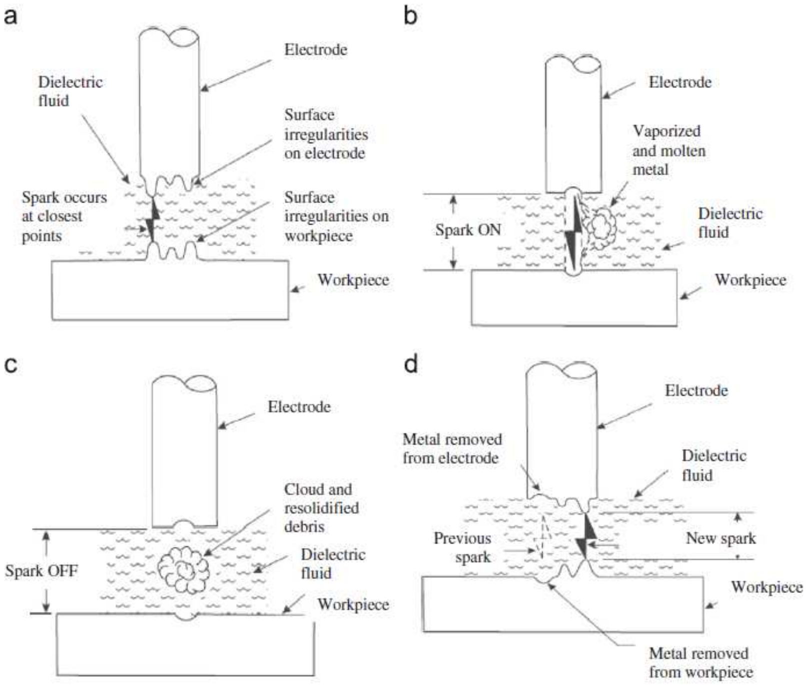

Fig. 1. Steps of the EDM process: (a) occurrence of spark at the closest point between the workpiece and the electrode, (b) melting and vaporization of the workpiece and the electrode materials during spark on-time, (c) vaporized cloud of materials suspended in the dielectric fluid, and (d) removal of molten metal and occurrence of next spark, on the basis of [2]

Fig. 2. The view of the machined sample

SP1U AgieCharmilles machine was applied. The tool was 10 mm width copper electrode. The electromachining set-up was shown in Fig. 3.

The 3D surface topographies and the results were obtained using Hommelwerke T8000 surface profiler and Turbo DataWin software. The measurement area was 1.47x1.5 mm. The following parameters values were obtained: *St* – total height of the surface, *Sq* – mean square deviation, *Sa* – arithmetical mean height of the surface, *Sz* – maximum height of the surface including 10 points. Machining parameters are shown in Table 1 and 2.

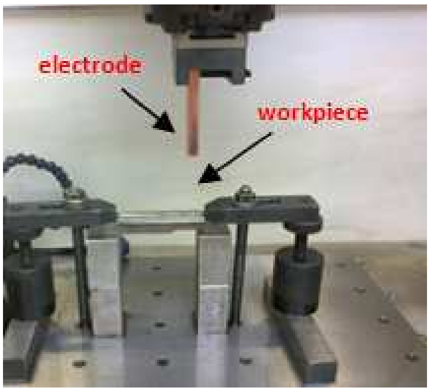

Fig. 3. The EDM set-up

Table 1. Machining parameters in the range of constant current *I* values

electrode material	copper M1E		
machining strategy	minimum wear		
gap size, mm	0.2		
current *I*, A	11		
pulse duration time, µs	15		
active surface area of the electrode F_P, cm^2	0.85		
polarization	+		
erosion time, s	30		
setting values of *Ra*, µm	5	2	0.1
a_P, mm	0.4		

Table 2. Machining parameters in the range of variable current *I* values

electrode material	copper M1E			
machining strategy	minimum wear			
gap size, mm	0.2			
current *I*, A	3	6	9	12
pulse duration time, µs	15			
active surface area of the electrode F_P, cm^2	0.85			
polarization	+			
erosion time, s	30			
setting values *Ra*, µm	5			
a_P , mm	0.2			

3. Research results

Figures 4-7 show 3D surface topographies and charts of autocorrelation function obtained after electromachining of tungsten carbide. The surface texture after electromachining is random, what provides rapidly disappearing, symmetrical to the central axis autocorrelation function (unilateral, shortwave disappearance of autocorrelation function) (Fig. 5, 7). Relatively small directionality of the surface texture may be the result of the periodic movement (feed) of copper electrode.

a) b)

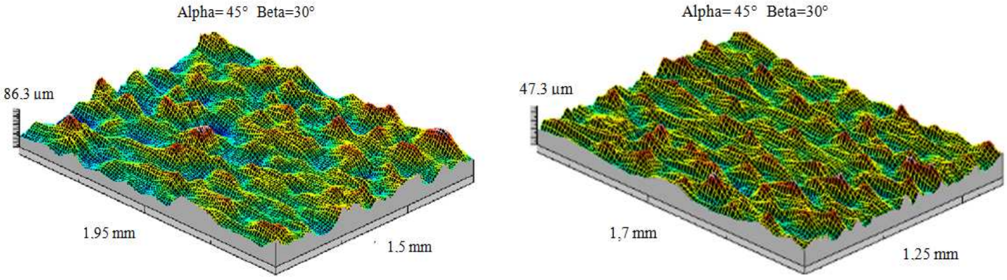

Fig. 4. 3D surface topographies after electromachining of tungsten carbide with two different setting values of *Ra*: a) 5 µm, b) 0.1 µm

a) b)

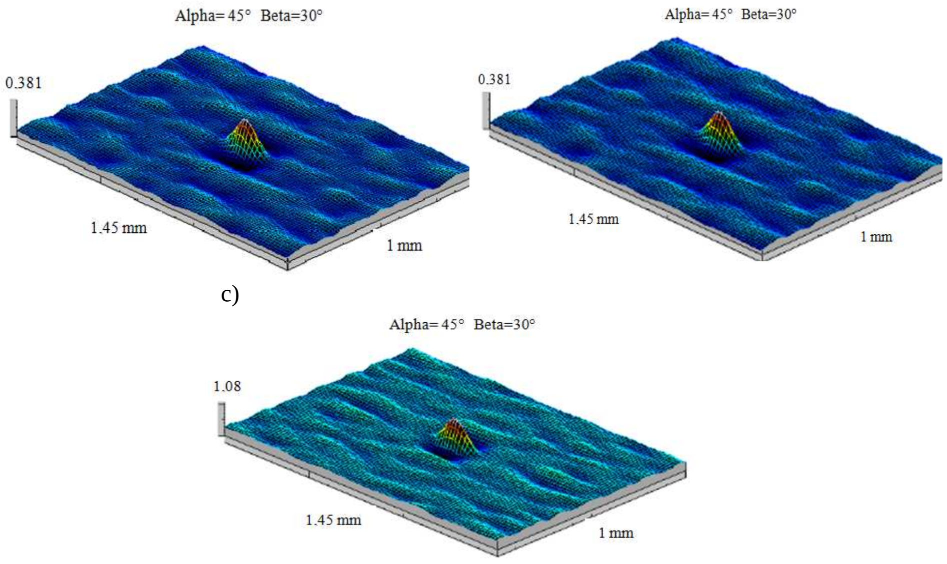

Fig. 5. Autocorrelation functions obtained after machining of tungsten carbide with three different setting values of *Ra*: a) 5 µm, b) 2µm, c) 0.1 µm

The difference between *St* and *Sz* parameters is unconsiderable, character of random peaks and indentations is negligibly small (stability of spark discharges).

The relationship between *St* and *Sq* parameters is not nearing to the theoretical relationship which appears in normal and t-student distributions ($St = 6\ Sq$) which is characteristic to ordinate distribution of surface texture. Analyzed surface has a lot of sharp local altitudes which appear almost on all surfaces after electromachining (Fig. 4, 6). Arithmetical mean height of the surface is equal to $Sa = 2.59$ µm and mean square deviation is equal to $Sq = 3.34$ µm.

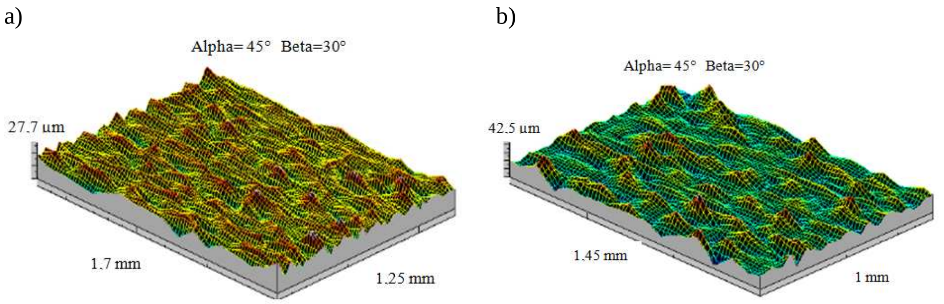

Fig. 6. 3D surface topographies obtained after machining of tungsten carbide with two different current values *I*: a) 6 A, b) 12 A

The highest values of surface roughness parameters were obtained after machining of tungsten carbide with current equal to $I = 9–12$ A (Fig. 8), therefore it is advisable to use small values of the current in order to improve better quality of the machined sample.

Surface roughness after electromachining of tungsten carbide is the result of mutually overlapped craters. The height of irregularities increases with the increase of value of the energy of individual pulses. It is possibile to obtain the value of surface roughness parameter Sz < 0.1 µm but it is associated with the need to use very low values of the energy during individual discharges.

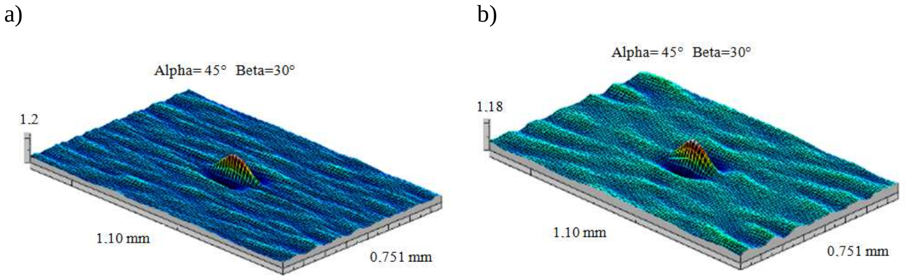

Fig. 7. Autocorrelation functions obtained after machining of tungsten carbide with two different current values I: a) 3 A, b) 12 A

Setting values of surface roughness parameter *Ra* after electromachining of tungsten carbide were equal to 5 µm, 2 µm and 0.1 µm. Surface roughness parameter *Ra* obtained as a results of experimental studies was equal to 4–8 µm. The research show, that the differences between setting and obtained values of surface roughness parameter *Ra* are significant (Fig. 9).

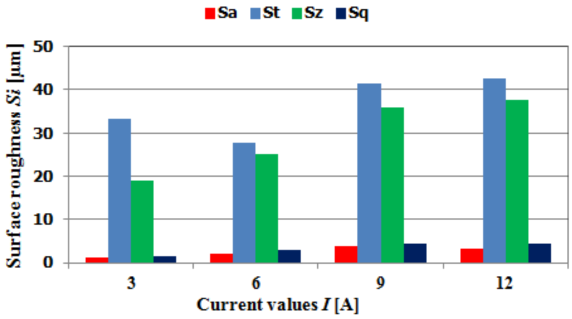

Fig. 8. Surface roughness parameters values in a function of current values

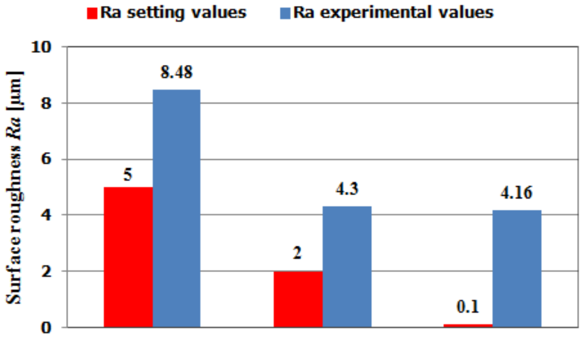

Fig. 9. The differences between setting and experimental values of surface roughness *Ra* parameter (I = 11 A)

4. Conclusions

The rational selection of electrical parameters is one of the most important aspects during EDM. The value of the current plays a significant role during the electromachining process. Surface roughness parameter *Ra* values increase with the increase of current values. The microareas of erosion are larger with an increase of local discharge energy.

Setting and experimental values of the surface roughness differ significantly. It is not possible to obtain the assumed values of the surface roughness parameter *Ra*.

Due to the increasing use of tungsten carbide in mechanical engineering, it is necessary to know surface texture parameters and the influence of their changes on the quality of the machined surface. Determination of these quantities allows to better insight of cutting mechanics of this material. It can contribute to the advancement of the machining of difficult-to-cut materials discipline. Furthermore, determination of these indicators enables appropriate selection of cutting conditions, enabling desired technological effects.

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