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Nickel coated single carbon fibre in function of tool electrode in µEDM

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Abstract
In these studies authors present the use of single carbon fibre with nickel coating as a tool electrode in µEDM. Nickel layer is very thin about 0.5µm. Thus, a single carbon fibre with coating has diameter of about 7.5µm whereas uncoated fibre has 7µm.
The performed experiments were focused on wear of such material in micro electrical machining process. Extensive experimental studies with statistical analysis were also carried out. They showed that wear of nickel coated carbon fibres is lower in comparison with those without coating. As carbon fibres have one of their dimensions much longer than the other, the length of carbon fibre rather than standard TWR (tool wear rate) parameter was used to estimate wear of tool electrodes. For the nickel coated electrodes the lowest length eroded was from 0.1 to 1.2 mm in total time - 10 min when at the same time uncoated fibres had wear values ranging from 2.4 to 3 mm. These data corresponds to TWR of about 1539.38 and 18472.56 µm/min for coated electrodes and 36945.13 and 46181.41 µm/min for uncoated ones.
At the same time on the surface of the workpiece greater craters were observed when nickel coated fibres were applied. Thus, lower wear and better efficiency of the process with coated carbon fibres can be noticed.

nickel coated carbon fibres, µEDM, wear of tool electrode, carbon fibres

1. Introduction

Micro-electrical discharge machining is one of the key technologies that has been studied for several years now [1]. However, new materials for electrodes in this manufacturing process are still an important issue widely analysed [2-3]. In the previous works [4-6], authors introduced the novel material - single carbon fibre as a tool electrode. This time another novel material was considered - single carbon fibre covered with thin nickel layer.
The performed experiments with coated carbon fibres were focused on wear of tool electrode in micro electrical machining process. To measure this parameter extensive experimental studies with statistical analysis were carried out. At the same time on the surface of the workpiece greater craters were noticed when nickel coated fibres were applied. Thus, lower wear and better efficiency of the process with coated carbon fibres can be observed.

2. Experimental procedure

To investigate carbon fibres coated with nickel layer under µEDM conditions a special experimental setup was built. All the experiments were performed in a planned way under the same conditions. That enables to obtain comparable data that can be analysed statistically.

2.1. Experimental setup

To perform experiments in a repeatable way the special experimental setup was prepared. It consists of RC generator in which resistance R, voltage U and capacitance C can be selected. Moreover, a special unit, which enables to chose reference voltage that is compared with the selected one, was designed. It was used to send the reference signal to the control unit - figure 1. that can withdraw the electrode in case of a short-circuit.

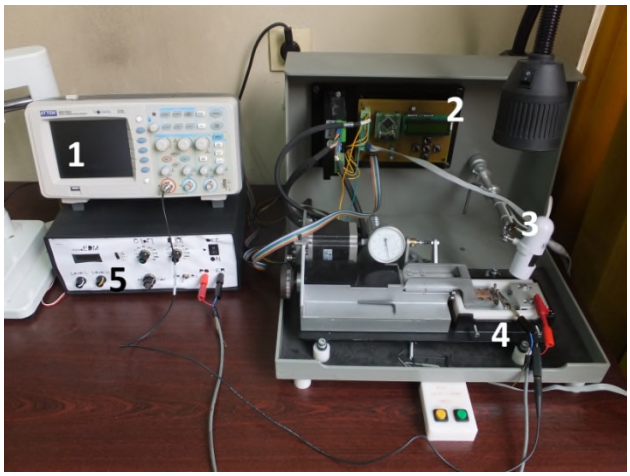

Figure 1. Experimental setup: 1 - Oscilloscope, 2 - Control unit, 3 - Microscope, 4 - Working area, 5 - RC generator

2.2. Conditions of experiments

The input parameters were chosen from the range of available ones in RC generator as follows: voltage U, capacitance C, resistance R. Feed velocity was also changed accordingly. The Hartley PS/DS-P:Ha4 plan of the experiment was selected. It guarantees to achieve relatively high accuracy of searched models despite the limited number of the required experiments [7]. However, all the selected factors must have the same distance from central value what was represented in table 1.
In all the experiments carbon fibres with nickel coating were used. The diameter of single fibre was 7.5µm whereas for uncoated fibre it was 7µm. Before the experiments each fibre was equipped with a shank enabling the installation in a tool holder.

Table 1 Input parameters

Factor	Low level	Central Value	High level
U [V]	100	125	150
R [pF]	22	511	1000
C [kΩ]	22	511	1000
V [μm/s]	80	100	120

3. Experimental results

The experiments performed according to the plan allowed to achieve regression model representing linear wear of tool electrode. This model was used to draw response surfaces. One of the examples is presented in figure 2.

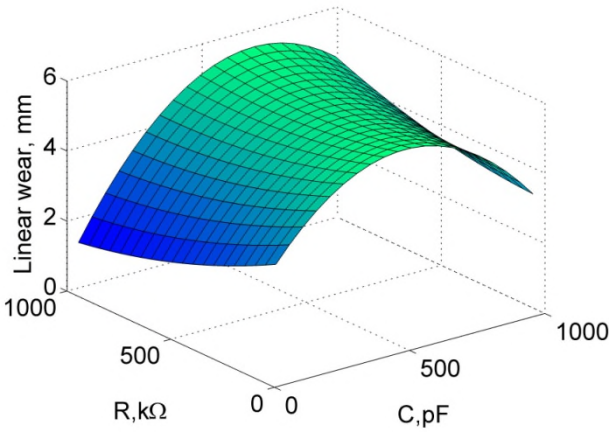

Figure 2. Linear wear of tool electrode vs. resistance and capacitance, V =80 μm/s, U=150 V

Linear wear was chosen because carbon fibres have one of the dimensions much longer than the other. So the length of carbon fibre rather than standard TWR (tool wear rate) parameter was used to estimate wear of tool electrodes made of this material.

As it is seen in figure 2., for higher value of capacitance the parameter of linear wear gets higher. However, as C is also responsible for frequency of discharges, not only for energy (in case of RC generators), the wear is becoming lower with the increase of this parameter. Resistance is also, similarly to C, responsible for discharge frequency. Thus, slightly noticeable similar influence of this parameter can be observed.

Calculations performed with the regression model were compared with experimental values. Selected analysed tests are presented in figure 3.

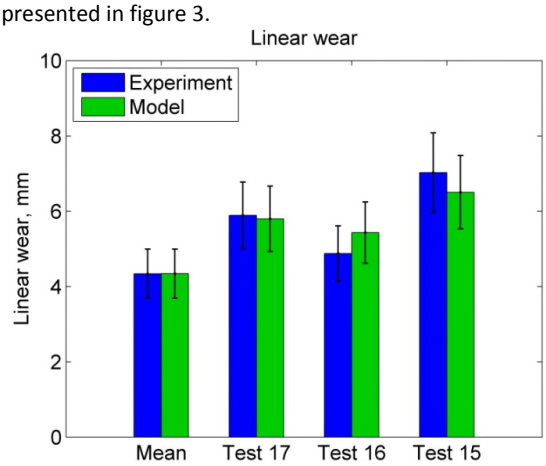

Figure 3. Example of comparison between experimental wear and calculated from model for selected tests

As it is presented in figure 3, values obtained from model and experimental ones are similar. Also means calculated from all the tests are alike. Error bars from the graph represent 15% range of considered value.

4. Crater manufactured with nickel coated carbon fibres

After the tests a surface observation was performed. Example of crater measured with SEM is presented in figure 4.

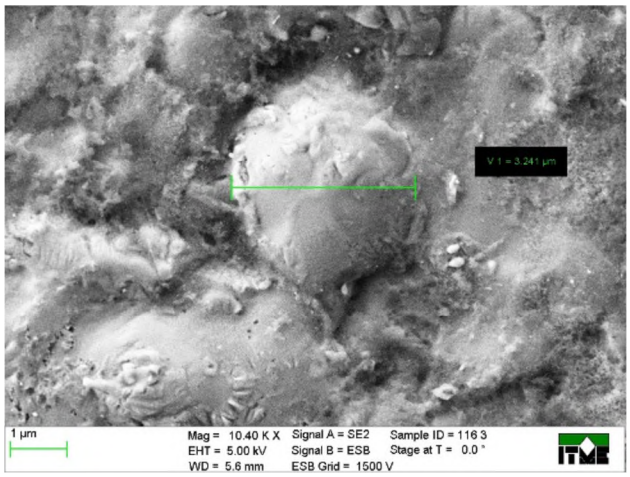

Figure 4. Example of single crater observed on the workpiece surface

The surface of crater is very irregular. It indicates that the material of workpiece was widely melted and next embedded into the bottom of the manufactured microhole. The craters compared with those fabricated with electrodes without coating are larger. That can be explained by the occurrence of higher energy observed during single discharges.

5. Summary

Experiments revealed that carbon fibres with nickel coating can work as tool electrodes. Analysed wear was well predicted by the statistical model. Although wear is still high, it is lower than for uncoated fibres. Thus, the layer of nickel protects the tool electrode from fast erosion. At the same time greater diameter of single craters on the workpiece surface is observed. Therefore, better yield is expected.

5. Acknowledgement

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