Application of PCD and Boron Doped CVD-Diamond Tool Electrodes in Micro EDM

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Abstract

Micro-Electrical Discharge Machining (μ-EDM) is based on the modification of state of the art process technologies and universal machine tools applied for electrical discharge machining operations [1, 2]. Experimental investigations aim on decreasing the wear of tool electrodes using novel electrode materials like boron doped CVD-diamond (B-CVD) and polycrystalline Diamond with cobalt as bonding material (PCD).

1 Introduction

Due to the recent alteration in the society's demands, micro parts are being extensively introduced in industrial products. For the fabrication of such micro parts or micro structured surfaces, the micromachining technology is employed and needs to be constantly further developed [3, 4].

2 Experimental Investigations

1.1 Materials

Table 1 presents the physical properties of the tool electrodes examined in this paper.

Table 1: Physical prpoerties of tested tool electrode materials (* from Element Six)

Physical Properties	**B-CVD***	**PCD Syndite***	**Cemented Carbide**	**Tungsten Copper**
Specific resistance [Ω.m]	$0.4\text{-}1\text{x}10^{-3}$	$1.4\text{x}10^{-4}$	$2\text{x}10^{-9}$	$6.8\text{x}10^{-9}$
Density [g/cm^3]	3.52	4.12	14.5	15.6
Thermal conductivity [W/m.k]	500-600	459	60-100	140-215
Melting sublimation point [K]	1773	1773	3695	3695
Young's modulus [N/m^2]	1000-1100x10^9	1000-1100x10^9	430-110x10^9	220-340x10^9
Coefficient of thermal expansion [10^{-6}*K^{-1}]	0.9-1.1	4.2	4.6-5	7.6-9.5

From the values presented in the table, it can be observed that the specific resistance of the novel diamond electrodes is much higher compared to conventional electrode materials, which can influence the process behaviour in µ-EDM.

1.2 Single Pulse Discharges

In order to evaluate and compare the discharge behaviour of B-CVD diamond and PCD with state of the art electrodes, respectively cemented carbide and tungsten-copper, single pulse discharges were ignited on polished probes made from 90MnCrV8. Both crater diameter and gap width were measured and the influence of discharge duration and discharge current was analysed.

The experiments were carried out by applying discharge currents from $i_e = 0.8$ A to $i_e = 5.6$ A, open circuit voltage of $u_0 = 60$ V, and a pulse duration from $t_i = 0.78$ µs to $t_i = 100$ µs, and the results are presented in Figure 1.

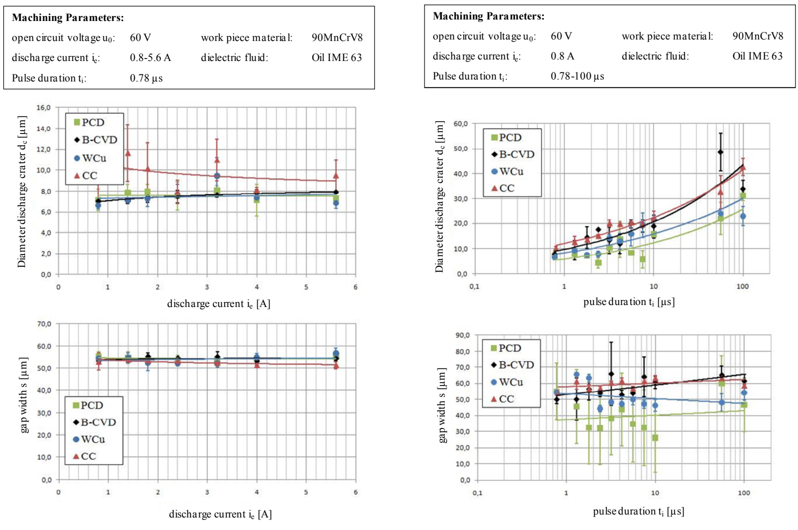

Figure 1: Influence of discharge current and pulse duration on crater diameter and gap width

The trend of increasing crater diameter with increasing pulse duration is similar for all tested electrode materials. The gap width between work piece and electrode does not to vary by increasing pulse duration, but this is influenced by the electrode material itself. The working gap width is higher for B-CVD, CC and WCu compared with PCD diamond. The investigations with increasing discharge current show that the tool electrodes produce nearly constant discharge crater diameters with increasing discharge current. It is assumed that increased discharge current affects discharge crater depth. The gap width also shows constant values for increasing discharge current and is similar for all tool electrodes tested.

1.3 Machining Behaviour

In order to compare the electrode materials and their process behaviour, experiments were carried out whereas cavities with a depth of s = 1mm were machined in 90MnCrV8, by applying EDM parameters for roughing and finishing machining. Relaxation generator was used by applying an open circuit voltage of u_0 = 250 V and discharge capacities of C_{e_finish} = 1 nF and C_{e_rough} = 101 nF. The short discharge durations by applying the relaxation generator of $t_{i\_1\ nF}$ = 0.1 µs and $t_{i\_101\ nF}$ = 1.2 µs lead to discharge energies of W_{e_finish} = 15.9 µJ and W_{e_rough} = 1802 µJ. Figure 2 shows the results for both roughing and finishing operations by applying distinct electrode materials.

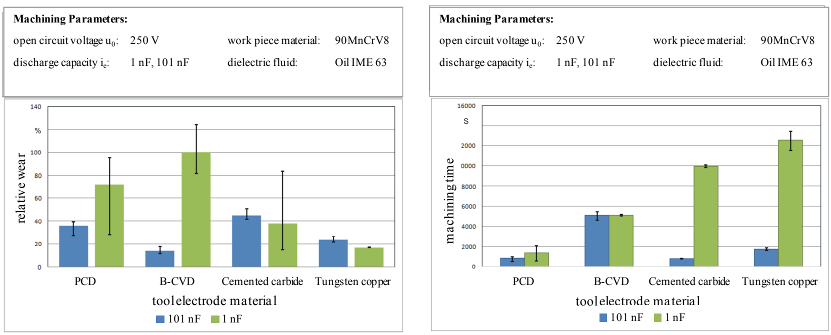

Figure 2: Machining time and relative wear for distinct tool electrodes by roughing and finishing operations

The B-CVD electrodes show low relative wear compared to the other electrodes when applying roughing parameters. A decrease of 50 % when compared to tungsten copper and of 70 % when compared to cemented carbide was observed. Although the relative wear decreased, the machining time for these B-CVD electrodes is nearly three times higher than those of tungsten copper for roughing operations.

During finishing operations the wear of B-CVD and PCD diamond electrodes is higher than the wear of state of the art electrodes. The unique advantage in applying the novel electrodes for finishing operations are the short machining times in comparison to cemented carbide and tungsten-copper.

3 Conclusion

The experimental investigations showed that the discharge duration possess a direct influence at the craters produced on the work piece surface. The discharge current does not influence the crater diameter, but it is assumed that it influences the crater depth. The B-CVD and PCD diamond electrode showed satisfactory results for roughing operations compared to state of the art tool electrodes. The parameters tested must be expanded, in order to identify the process window where these novel tool electrodes can be at their best applied.

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