Investigation of dry-EDM micro drilling for high performance ceramics

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Abstract

Due to its thermal working principle allowing an almost force free machining independent of the material´s mechanical properties, Electrical Discharge Machining (EDM) is a well established production technique for manufacturing micro holes. Especially when machining ceramics, a material group that is predestined for the application within the field of micro technology, EDM is of increasing importance. However, the production of precise micro holes with complex geometries and high aspect ratios is associated with a lot of challenges. High tool electrode wear, a small material removal rate and the increasing importance of flushing at high aspect ratios and small gap widths can be observed during this machining process.

The paper shows investigations concerning the manufacturing of micro holes with diameters of around 350 µm in TiN ceramic probes with a thickness of 1 mm by dry-EDM. The dry-EDM micro drilling process with compressed air as dielectric medium is introduced. Additionally, experimental results of a technological optimization of main process parameters are shown, resulting in a reduction of the machining time t_{ero} and the relative tool wear ϑ.

The technological parameters were optimized using a Design of Experiments method (DoE) by varying the EDM process parameters discharge-capacitance C_e, no-load-voltage u_0, ontime t_{on} and offtime t_{off}.

1 Dry-EDM

The conventional dry-EDM micro drilling process takes place either in deionised water or in oil as dielectric fluid. The material removal is based on electrical discharges between the electrode and the work piece inside a gas bubble. For the improvement of the dry-EDM micro drilling process, gases such as air, oxygen, helium, nitrogen and argon or a mixture of the above instead of a liquid dielectric

fluid are used. The gas is applied through the electrode with a high velocity. Thereby the gas-flow removes melted material from inside the working gap and cools down the electrode as well as the work piece.

The results of such investigations described in literature are heterogeneous, motivating further research in this area. First experiments by Kunieda et al. [1] described basic properties of the dry-EDM process. It was found that the material removal rate (MRR) when using oxygen as dielectric fluid is comparable to the MRR of machining with liquid dielectric fluid.

By using the conventional EDM cutting process, Kao et al. [2] show that the application of deionized water as dielectric fluid leads to a higher MRR than the usage of air or an air-water-mixture.

Due to continuing short-circuit states in the dry-EDM cutting process, Kunieda et al. [3] didn´t achieve a material removal that is comparable to the MRR of deionized water.

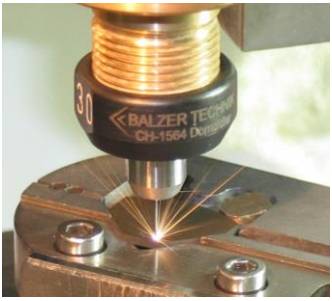
Kao et al. [4] also received a low MRR and a high electrode wear by the dry-EDM milling process. Moreover the machined drill holes show a high conicity.

Investigations made by Yu et al. [5] Showed a better machining result when applying the EDM process in a dry way instead of in oil dielectrics. Also the MRR using air was six times higher than using oil.

2 First investigation of dry-EDM micro drilling

The task of the investigation was to manufacture through holes with a depth of 1 mm using tubular tool electrodes with a diameter of 300 µm made of cemented carbide in high performance ceramics (silicon-nitride, 45 % Si_3N_4 and titanium-nitride, 55 % TiN) and with air as dielectric fluid. Within the first experiment a RC-type generator was used. The parameters were set to a no-load voltage of $u_0 = 80$ V, a discharge-capacity $C_e = 15$ nF, an Ontime of $t_{on} = 4.2$ µs, and an Offtime of $t_{off} = 27.4$ µs. First results showed a machining time t_{ero} of $t_{ero} = 543$ s and a relative tool wear of $\vartheta = 40$ %. By optimizing specific process parameters with DoE methods, the machining time had been reduced to $t_{ero} = 120$ s and the relative tool wear ϑ had been reduced to $\vartheta = 10$ % (see Figure 1). Figure 1 shows the results concerning the

machiningtime t_{ero} (a) and the relative electrode wear ϑ (b) of the start and the optimized parameter.



work piece material:	titanium nitride ceramic
electrode:	tungsten carbide d = 300 µm
drilling depth:	1 mm
dielectric fluid:	air
flushing pressure:	p = 11 bar
no-load-voltage:	u_0 = 80 V
discharge capacy:	C_e = 15 nF
ontime:	t_{on} = 4.2 µs
offtime:	t_{off} = 27.4 µs
generator:	RC-generator

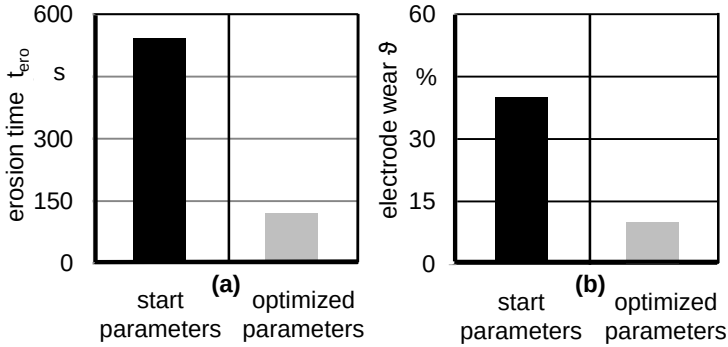


Figure 1: Results achieved with the optimized process parameter set

Further research included the DoE process optimization. The results showed that the process parameters, having a main effect on the machining-time t_{ero} and the relative tool wear ϑ when using dry-EDM, differ from the conventional EDM process with deionized water as dielectric fluid.

For example the most important process parameter peak current didn´t show any effect on the machining time t_{ero} and the relative tool wear ϑ. On the other hand, it is possible to influence the machining results by variation of the flushing pressure.

3 Optimization of dry-EDM drilling process

Based on first investigations, an optimization of the main process parameters was conducted. The increase of the flushing pressure p from p = 11 bar to p = 80 bar and a continuous adaption of the process parameters made it possible to reduce the

machining time t_{ero} from $t_{ero} = 543$ s to $t_{ero} = 16$ s. In addition, micro holes were created with electrodes of a diameter between d = 100 µm and d = 500 µm. Figure 2 shows the machining results of dry-EDM micro drilling.

work piece material:	titanium ceramic
electrode:	tungsten carbide d = 300 µm
drilling depth:	1 mm
dielectric fluid:	air
flushing pressure:	p = 80 bar
generator:	RC-generator

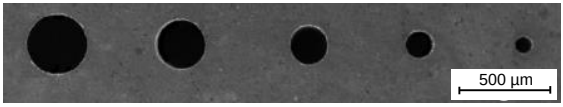


Figure 2: Machining results of micro holes in TiN fabricated with dry-EDM

4 Acknowledgments

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