Geometrical Deviation in Micro-Sinking-EDM for Precision Manufacturing

F. Klocke[1], J. Dieckmann[1], M. Garzón[1]
Laboratory for Machine Tools and Production Engineering, WZL, RWTH Aachen University, Germany

J.Dieckmann@wzl.rwth-aachen.de

Abstract

The machining of filigree cavities is a common task for products in the industrial sector of tool and mould manufacture. In the range of required (micro-) geometries in combination with the applied workpiece materials micro-EDM often is the production technology of choice. To guarantee best functionality the geometry of each mould has to ensure narrow tolerances and assure to avoid undercuts which damage the release properties of the injected part. The realising of these filigree cavities is nowadays still carried out by Wire-EDM since the danger of occurring undercuts is lower. But this is only possible as long the geometries are through-holes. The starting hole for that purpose however has to be machined by Sinking-EDM. Thus, to shorten the manufacturing time of through holes the Wire-EDM process should be substituted by an optimised Sinking-EDM process. An optimisation requires a good knowledge about the influencing variables that may lead to shape deviations in Sinking EDM.

1 Introduction

It has already been shown that the EDM process is not completely free of forces [1,2]. Forces related to occurring discharges on the lateral area of an electrode can bend it if the electrode is a filigree one. The occurring forces have been measured by several scientists. The occurring forces of a single discharge last considerably longer than the electrical discharge itself and are in magnitude about a few hundredths of N on micro-Sinking-EDM electrodes [3, 4]. Furthermore it has been shown, that the mechanical system of the electrode in its clamping has to be considered regarding its natural frequency. If the mean frequency of discharges hits the natural frequency the electrode will oscillate in resonance and thus the machined cavity will be widened.

The mentioned research has been focused on bending effects caused by lateral discharges. This paper deals with other possible causes for shape deviations in micro-Sinking-EDM and shows that buckling has not to be neglected when very thin electrodes are used. In addition to buckling caused by high process forces it can realistically occur in deep holes when high pressure by inner flushing in combination with small gaps is being set. Moreover an experiment was set up to analyse the flow inside the cavity concerning turbulences.

2 Theories, Experimentation and Results

In traditional Sinking-EDM operations most discharges take place not in the lateral but in the frontal gap. The force of the discharge acting on the electrode can be assumed to be of the same order of magnitude as measured [1] for lateral discharges. A typical application of micro machining was assumed to calculate whether buckling is likely to occur. Brass or Cemented Carbides (CC) tube electrodes with outer diameters of 130 µm and inner diameters of 55 µm made were used (see Figure 1, left). The corresponding critical buckling forces can be calculated (see Figure 1, right).

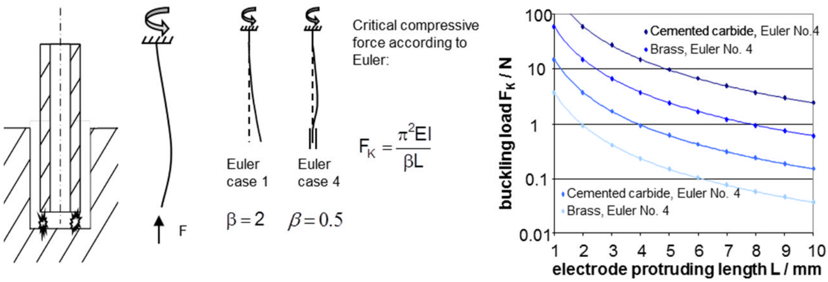

Figure 1: Buckling caused by frontal discharges

In cases of deep drilling with aspect ratios of 10 and more the critical forces at least for Euler's case no. 1 are smaller than 1 N or in the case of brass electrode even smaller than 0.1 N. Those magnitudes of forces already have been observed for electrical discharges [3, 4] and are mainly dependent on the discharge energy. The discharge current has been found to be the most influential factor. A second aspect is to have a closer look to hydrodynamic induced forces that may lead to buckling.

When the frontal gap is smaller than optimal (e.g. in the case of short cuts) the pressure inside the gap will increase. The resulting axial force then is high enough to buckle the very small electrode.

Another issue is to calculate the flow speed of the dielectric in the lateral gap in order to answer whether there is laminar or turbulent flow in the gap. The latter is in order to analyse if a shape deviation inside a deep hole can be due to accumulation of debris as a result of turbulent flow. Basic work was done by Piltz [5], which was adapted to the shown situation. An experiment was set up to measure the flux as a function of electrodes complete length (not only the protruding length). Results are given in Figure 2.

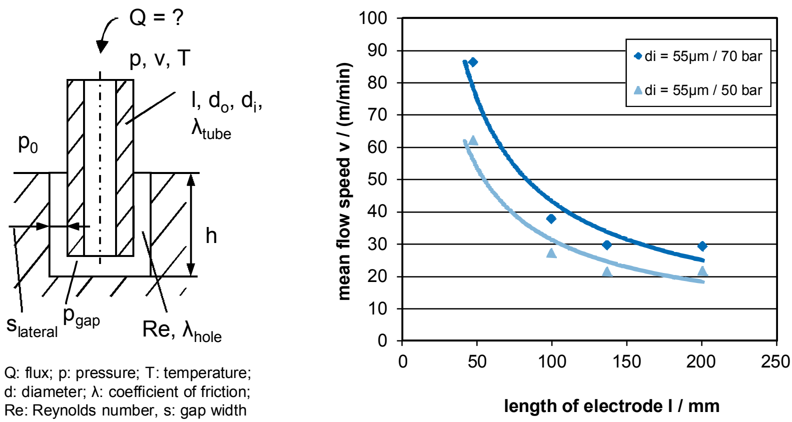

Figure 2: Hydrodynamic analysis and testing on micro-Sinking-EDM electrodes

For the shown flow speeds the fluid behaves as a complete laminar flow (Re < 10). On the part of transport of debris the complete range of different flow rates are acceptable. Then again for uniform wear the changing process conditions are obstructive. This is a new point to be analysed. All these considerations lead to a new analytical approach in EDM and especially for the simulation of micro-EDM process.

3 Conclusion

A deviation of the electrode position caused by buckling is a possible mechanism. For filigree electrodes and micro-EDM in general the process forces (either induced by discharge forces or hydrodynamic forces) do play an important role. If process planning based on the methods shown in this work indicate that buckling can occur, the acting process forces have to be reduced. For forces that are induced by discharges the first counteraction has to be reducing the discharge current. For hydrodynamic induced forces among other measures the flushing pressure has to be reduced. Experiments have confirmed that especially the flow rate varies as a function of the complete remaining electrode length. Therefore, the dielectric flux (restricted by a maximum pressure) should be the controlled process variable to obtain a more stable process. Future work will include the HS-Camera observation of hydrodynamic aspects in the working gap for high aspect ratio electrodes in order to confirm and expand the knowledge about process forces on EDM.

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References:

[1] Klocke, F.; Garzón, M.; Veselovac, D.; Dieckmann, J.: Vibration Analysis of Slender Sinking EDM Electrodes for the Precision Manufacturing of High Aspect Ratio Cavities. Proceedings of the 10th international conference of the EUSPEN, pp. 347-350, Delft, 2010

[2] Kunieda, M., Tohi, M., Ohsako, Y., 2003, Reaction Forces Observed in Pulse Discharges of EDM, International Journal of Electrical Machining No. 8, p. 51-56

[3] Klocke, F.; Garzón, M.; Dieckmann, J.; Klink, A.: Process Force Analysis on Sinking-EDM Electrodes for the Precision Manufacturing. Production Engineering - Research and Development, Bd. 2/2011, pp. 183-190, 2011

[4] Klocke, F., Thomaidis, D., Garzón, M., 2007, Force Measurements in the Micro Spark Erosion with various electrode materials, polarities and working media, Proceedings of the 15th International Symposium on Electromachining, p. 263-268

[5] Piltz, S.: Grundlagen und Prozessstrategien der Mikrofunkenerosion mit rotierenden Elektroden. TU Berlin, Dissertation, 2006