Micro – EDM: Process Effects on the Tool Wear Ratio

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Abstract

The fabrication of high aspect ratio microstructures is very challenging, especially when the work piece material is hard to machine. Electro Discharge Machining (EDM) offers a contact- and nearly force free way of micromachining and is therefore an appropriate means to producing microstructures. One key obstacle for a precise machining by micro-EDM is the tool wear. When ED-machining microstructures process speed, stability and thus tool wear are related to the aspect ratio of the structures. In this study, tool wear ratio within different stages of the EDM process is analysed when machining high aspect ratio micro bores in steel. Experiments with bores of different depths show the correlation between the stage of the process and the flushing conditions on the one hand and the tool wear ratio on the other hand. Thus, it is possible to find and apply optimized parameters for the different process stages. A better understanding of the tool wear will help to minimize it, reducing the cost of the tools and enhancing the precision of the process. This also shall allow an enhancement of the process speed because the need for flushing material out of the bore is reduced by the amount of tool material that can be saved.

1 Introduction

Electro discharge machining allows for a noncontact and almost force free machining of electrically conductive materials, which makes it ideal for micro machining, when neither tool nor workpiece can sustain high forces. The process is based on a thermal ablation of material caused by repeated short electrical discharges between tool and workpiece electrode. By optimizing pulse duration and shape, material removal on the tool can be minimized.

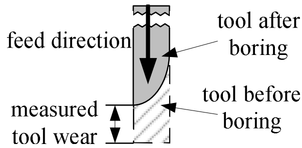

Figure 1 – tungsten carbide electrode tool Ø 80 µm with frontal and side wear

Figure 2 – schematic of the tool wear

Especially in the field of micro EDM, where very short pulses are needed, the tool wear is still high, see figure 1. The electrodes are submerged in a dielectric. This dielectric, mostly deionized water or dielectric oil, flushes the ablated particles away and prepares the gap for the next discharge. A constant flushing is needed to keep the process stable and to minimize process situations - such as arc discharges - that lead to high tool wear. Flushing can be intensified by several approaches, e.g. by planetary movement of the tool electrode [1] and, in the case of circular tools, tool rotation. Tool wear is also dependent on the thermal capacity of the micro tool. The use of a planetary movement results in the need to use a smaller tool, which will cause a higher tool wear due to the lower thermal capacity of the tool. This work investigates the correlation between tool wear and flushing conditions, altered by tool diameter, tool rotational speed, planetary movement and the aspect ratio of the machined structures.

2 Experimental setup

Experiments are carried out on a Posalux FP1 Micro EDM machine, where through holes of different depth are machined. The depth of the holes ranges from 0.5 mm to 2.5 mm in 0.5 mm steps. The machine setup is adjusted to generate short discharge pulses with durations of 100 ns and a peak current below 10 A. Only planetary movement and tool electrode rotational speed are varied during the experiments. Cemented tungsten carbide rods with 80 µm and 100 µm diameter are used as tool electrode. The target bore diameter is set to 130 µm for all setups. Two stages of planetary movement are examined, affecting flushing conditions as well as allowing to adjust the bore diameters and therefore the bore volumes (figure 3). Tool rotational speed is altered, too, resulting in a change of the flushing regime.

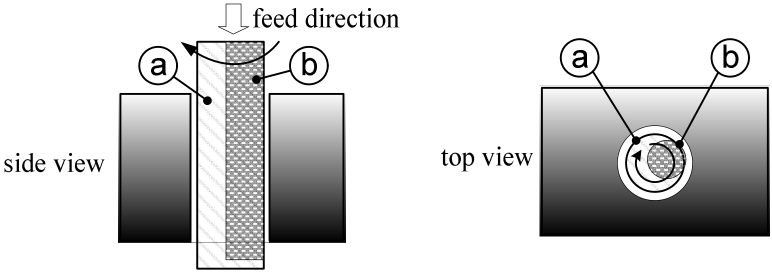

Figure 3 – machining bores of the same diameter with different tools: a) large tool diameter with no planetary movement, b) small tool diameter and planetary movement

As a result, four different stages of flushing, influenced by different combinations of planetary movement and electrode rotational speed are investigated. Measuring the bore diameter enables the evaluation of the amount of ablated material. To evaluate the tool wear, the tool length is measured after each bore. The tool wear ratio is represented by the volume ablated from the tool compared to the volume ablated from the workpiece.

3 Results and discussion

The best choice of the tool electrode diameter and the flushing regime regarding minimized tool wear depends highly on the aspect ratio of the machined structures (figure 4). When machining bores with depth 0.5 mm, which equals aspect ratio 3.9, the tool wear of the electrodes with 80 µm diameter reaches its highest level at about 8.7 %. The lowest wear ratio, about 6 %, is achieved by using the 100 µm electrode with low rotational speed, indicating that in this case the need for enhancing the flushing is low. The start up process with its large quantity of arcing [2] dominates the tool wear effects of bores with low aspect ratio. Therefore high thermal capacity as well as a greater surface of the tool are crucial to minimize the tool wear, resulting in a high tool wear of smaller tools. A rise of the aspect ratio decreases the influence of the start up process. Enhancing the flushing becomes more important. At a bore depth of 1 mm or an aspect ratio of 7.7 the tool wear ratios of all investigated cases are close together at values between 5 % and 6.3 %.

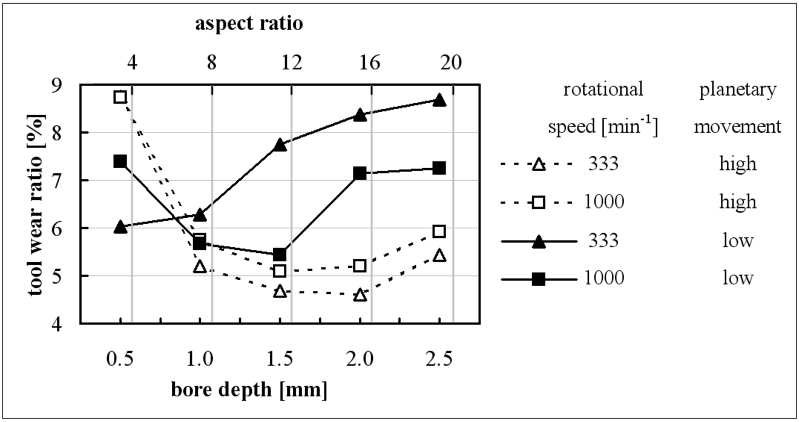

Figure 4 – influence of the bore depth and aspect ratio on the tool wear

To minimize the tool wear for bores of depth above 1.5 mm, respective aspect ratios above 10, the need of enhancing the flushing by tool rotation and, more important, planetary movement is high. At the highest investigated bore depth the tool wear of the 80 µm diameter tool electrode is kept below 6 % while the wear of the tool electrode with 100 µm diameter and low rotational speed is 8.7 %. Therefore the selection of the tool diameter depends on the aspect ratio of the structure that is machined.

4 Conclusion

The correct choice of the tool diameter allows for the reduction of up to one third of the tool wear ratio. Structures of low aspect ratios are optimally machined with tools of high diameter, while structures of higher aspect ratios are ideally machined with a combination of smaller tools and higher planetary movement.

References:

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