Micro-EDM-device for Machining Tungsten Carbide in a Desktop Machine Tool

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Abstract

A micro electrical discharge machining (µEDM) device developed to machine tungsten carbide is presented. The device is down-scaled in its dimensions and integrated in an existing high-precision desktop tool grinding machine. The cylindrical µEDM-electrodes are made of tungsten carbide and have diameters down to 10 µm at a length of 100 µm. During the µEDM process, the tungsten carbide shaft is mounted in a spindle with an aerostatic bearing, propelled by an air turbine drive. The rotation leads to exceptionally centred holes. The µEDM-source is realized by a low power pulse generator which is mounted on the machine desk. With this µEDM device, a wide range of electro conductive materials can be machined. Furthermore, the entire device is designed to optimize the shape of micro pencil grinding tools by machining a small cavity into the tool tip. The presented µEDM device allows to process micro pencil grinding tools with diameters down to 20 µm.

1 Introduction and motivation

For the generation of complex 3-dimentional microstructures in brittle materials micro pencil grinding tools are applied [1]. At the Institute for Manufacturing Technology and Production Systems micro pencil grinding tools with diameters down to 10 µm are manufactured and used for grinding tungsten carbide (WC), ceramics or other brittle materials [1]. The analysis of the machined grooves shows that the slot ground is non planar. On the bottom surface some deeper marks are localised in the centre of the slot (Figure 1). The reason for this could be the different engagement of single abrasive grains placed on different radii on the tool face side. To solve this

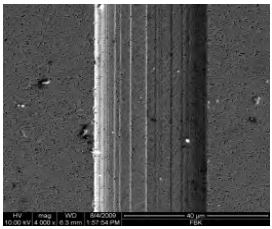

Figure 1: Machined tungsten carbide slot

problem the micro pencil grinding tools are optimized in their tool design. Therefore, the abrasiv grain on the toolface centre has to be removed, to avoid that no grains on the tool face centre are involved in the grinding process. To remove the grains on tool face centre of the verry small and fragile WC tool blank a µEDM process is chosen, due to the very low process forces [2].

2 µEDM device

The conception of the µEDM device is based on the integration facility into the existent desktop tool grinding machine and the simultaneous integration into the entire micro pencil grinding tool manufacturing process. Therefore a µEDM device, see Figure 2, was manufactured. The main component of the µEDM device is the carrier, which is hold in a bracket. In the carrier contains a deionized water supplier, the circuit points, the electrode clamping, and the contacting system. On the carriers top the work tank is placed. The water supplier and the pulse generator are sourced out and mounted under the machine desk due to their size.

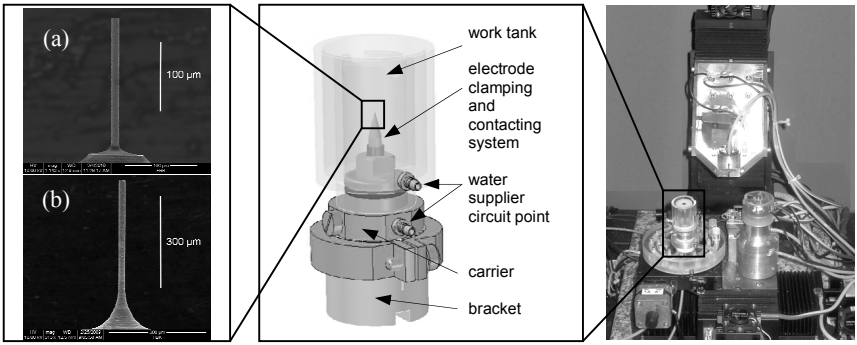

Figure 2: µEDM WC electrode (left), micro EDM device (model) (middle), EDM device integrated in the desktop tool grinding machine (right)

3 µEDM electrode

The machining of micro pencil grinding tool with diameters down to 20 µm with µEDM demands µEDM electrodes of a very high precision [3]. Especially the electrodes diameter has to be smaller than the tool diameter. Furthermore the electrode material has to be analyzed in regard to electrodes wear and machinability.

To choose the best electrode material some electrodes with a conical tip (tip radius = 3 - 4 µm) were fabricated of different materials like tungsten carbide (WC), copper (Cu), wolfram copper (WCu) and graphite (C). These different electrodes were tested

in the µEDM device. To analyze the results the workpiece material removal is compared to the electrode wear.

Table1: Electrode wear compared to workpiece material removal against polarity of electrode

	$X_{(WCu)}$	$X_{(Cu)}$	$X_{(C)}$	$X_{(WC)}$
straight polarity	3.6	4.3	1.9	2,1
reverse polarity	0.8	2.1	4.1	0,83

$$X = \frac{\text{electrode wear}}{\text{workpeace material removal}}$$

In Table 1, the WCu and WC at reverse polarity are the best materials to machine WC workpiece in the µEDM device are shown. Because of the good machinability of WC compared to WCu, WC is selected for further manufacturing of µEDM electrode. The WC EDM electrodes were manufactured in a micro pencil grinding tool production process as introduced in [5]. The tools were ground on tool carriers of ultra-fine grained WC shanks with diameter of 3.175 mm. This WC shanks have a good roundness and are used as the rotor of the micro air bearing spindle of the desktop machine. The spindle has a very low run-out below 0.1 µm. Based on this monolithic tool-rotor-body, the tools run-out depend only on the spindle accuracy [4]. A grinding module consisting of an air bearing spindle with a rotor diameter of 12 mm and two attached grinding wheels are mounted on the desktop machine. The grinding wheels have different grain sizes for pre- and fine-grinding [1]. It is possible to make WC electrodes with diameters down to 10 µm at a length of 200 µm. In Figure 2 (left) a WC electrode with diameter 10 µm and approximately 200 µm length (a), and a WC electrode with diameter of 18 µm and approximately 400 µm length (b) is shown.

6 Manufacturing process of optimized micro pencil grinding tools

After clamping the electrode into the µEDM device, the manufacturing process of micro pencil grinding tool is started. On the rotating WC shank a cylindrical micro pin is directly ground. After this grinding process the tool blank is machined in the µEDM device. Therefore, the micro tool blank is positioned automatically over the µEDM electrode in the dielectric reservoir. The automatically alignment is realised by detecting the electrical field excited by applied AC voltage with frequency of 1000 Hz between WC tool blank and EDM electrode. The electrodes tip has to be nearly the centre of the cylindrical tool tip in a distance of 8-10 µm. After alignment of the tool to the electrode the pulse generator is started. During the EDM process, the tungsten

carbide shaft is propelled through the spindle air turbine. The rotation leads to exceptionally centred holes (Figure 4). The Z-axis is moved against the electrode with a feed of 1.5 µm/sec. After the detection of the first discharge the WC is moved down automatically with a feed of 0.8 µm/sec and the material on tool face centre is removed. Then the WC micro pin is electroplated with diamond or CBN grains (Figure 4). The whole manufacturing process of the optimized micro pencil grinding tool takes 15-20 min.

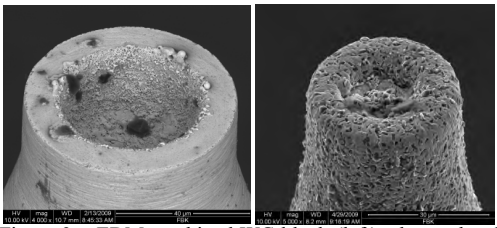

Figure 3: µEDM machined WC blank (left), electroplated micro pencil grinding tool (right)

4. Conclusion and Outlook

A µEDM device to optimise the tool design of micro pencil grinding tools with diameters down to 20 µm was discribed. To machine the micro tools the µEDM device had to be integrate in the existing desktop tool grinding machine. A suitable material to manufacture µEDM electrodes was identified and selected by experiments. With the presented µEDM device the design optimization of micro pencil grinding tools is possible. Grains at the toolface centre, with nearly no cutting speed, are avoided. In further work the optimized tools will be tested in regard to process parameters, surface roughness and grooves ground evenness.

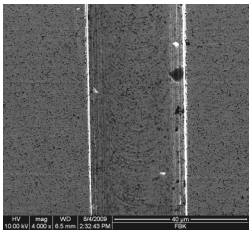

Figure 4: Groove in WC with EDM optimized tool

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