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PRESS RELEASE

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Drag finishing in microproduction

At the Institute of Machine Tools and Factory Management (IWF) at the Technische Universität Berlin in collaboration with the OTEC company based in Straubenhardt, new areas of application for the drag finishing process are demonstrated and researched. The scientific focus of the study is twofold: preparing the cutting edge of microcutting tools and deburring and surface treatment of microstructures.

Drag finishing

In the drag finishing process, the workpieces or cutting tools to be processed are clamped in motorised satellite holders and describe a complex path as they are dragged through an abrasive medium by means of a rotor plate. In addition, the tool holders are motorised in order to ensure that all areas of the workpiece are uniformly processed. The kinematics is shown in fig. 1 (right). The relative motion between the process media and the workpiece causes the medium to strike and glance off the surface of the workpiece, resulting in the desired finishing effect.

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Fig. 1: OTEC DF-3 Tools drag finishing unit

OTEC drag finishing units enable several workpieces to be processed at the same time (see fig. 1). This makes the process extremely economical for large-scale production.
The classical applications for the drag finishing process are:

- The toolmaking industry, e.g. for rounding cutting edges and polishing the flutes of carbide tools or the contact and forming surfaces of forming tools
- The pharmaceutical industry for polishing the pressing surfaces of tablet punches,
- Developments for motor racing, e.g. for smoothing and polishing gear wheels, valves and finger followers
- The watchmaking industry e.g. for the grinding and mirror-finish polishing of watch cases in stainless steel, gold and porcelain
- The medical device sector e.g. for the grinding and mirror-finish polishing of knee implants
- The metalworking industry, e.g. for smoothing high-speed spindles.

A variety of different abrasive media, from von aluminium oxide and silicon carbide to fine combinations of walnut shell granulate and e.g. diamond powder can be used as process media. In the latter case, the walnut shell granulate serves as a carrier medium for the abrasive diamond component. The most important parameters in the selection of process media are grain size, hardness and the density of the media.

Fig. 2: HSC 1/300 Superfinish granulate from OTEC

Preparing the cutting edge of microtools

The purpose of preparing the cutting part of chip-removing tools with a geometrically defined cutting edge is to generate a specific edge contour, mostly taking the form of a cutting edge radius r_β [TIK09]. This enables the cutting edge to be stabilised and the surface quality to be improved. This results in a reduction of friction between the tool and the discharged chips and surface of the component. In addition, the conditions created give a better bond when the tool surface is coated. This considerably reduces tool wear and significantly improves the performance of the prepared tools, which in turn gives longer tool life and greater process reliability [RIS06, TIK09, UHL09a].

In order for the cutting edge to be prepared, it is crucial that the tools are uniformly ground and stable. This has a significant effect on the subsequent tool quality. Unlike in the macro range, in which drag finishing is already firmly established, applying its principles in the context of microproduction presents a major technological and economic challenge. Since the nature of the process means that only very small radii with correspondently fine tolerances come into question, the preparation results must be especially reproducible. Critical factors here are tool design on the one hand and the reliable manufacture of miniature end mills on the other. Both of these are the focus of research at the IWF [SCH06, UHL06, UHL09b].

Working in collaboration with the OTEC company, the drag finishing process was used at the IWF to achieve and verify a uniform cutting edge rounding in the range $r_\beta \approx 6$ µm on miniature end mills with a nominal diameter of $D = 0.5$ mm.

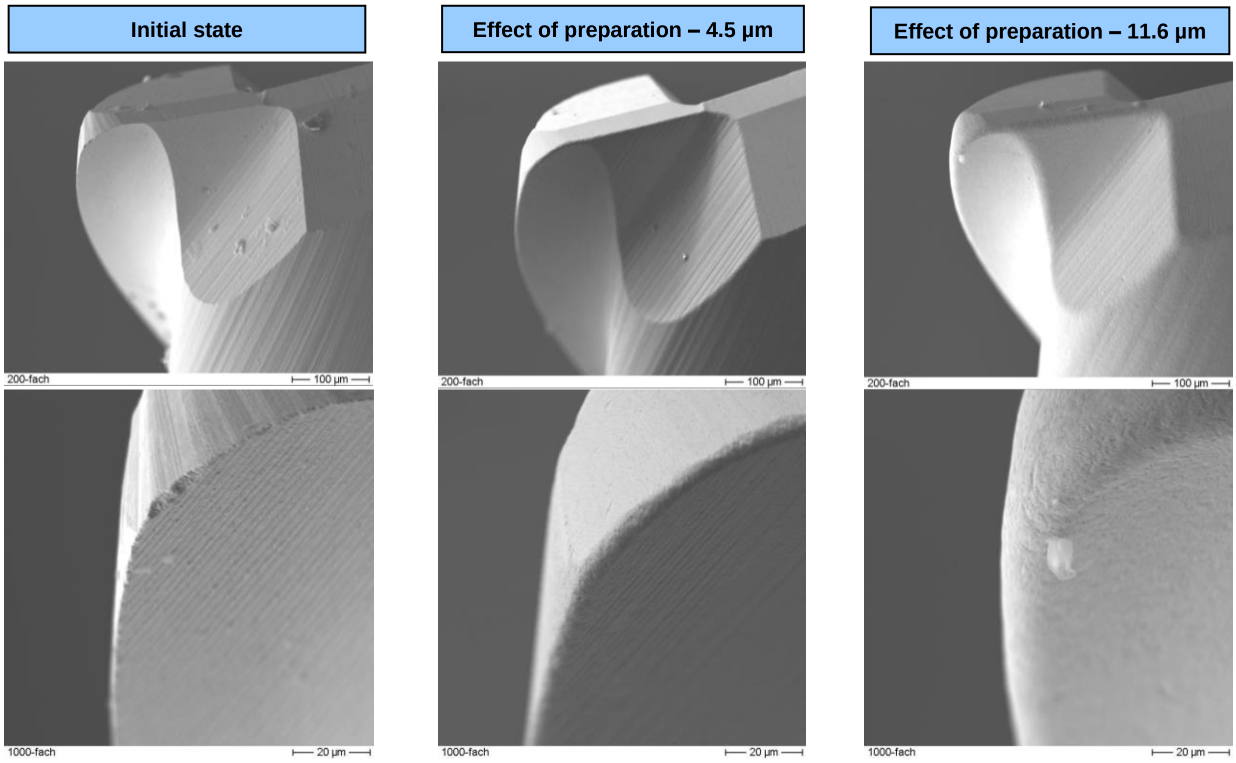

Fig. 3: SEM images of miniature end mills

By preparing the cutting edge, the jaggedness at the cutting edge and the surface roughness at the rake face were considerably reduced in comparison with unprepared tools (see fig. 3). Furthermore, the potential for optimising the microcutting process through defined rounding of the cutting edges of miniature end mills was demonstrated by means of comprehensive milling tests. The test machine used for this purpose was a high-precision milling machine Type Gamma 303 High Performance from Wissner. This machine is fitted with a force measurement platform for recording the dynamic cutting forces and an integrated high-resolution CCD camera to provide sequential monitoring of relief surface wear. When cutting powder metallurgically manufactured martensitic chrome steel (PM X 190 CrVMo 20, 55 HRC), the workpieces which had been prepared by drag finishing showed considerably less tool wear than unprepared tools. Compared with unprepared tools, a 69% reduction of the maximum width of wear marks on the relief face was observed after a tool service life of L_{cut} = 19.2 m.

Analysis of wear on the relief face

Process parameters:

a_e	=	0.1	mm
a_p	=	0.04	mm
n	=	15,000	min^{-1}
v_f	=	120	mm/min

Miniature end mills:

D x *l* = 0.5 mm x 2.5 mm

Ultra-fine grain carbide - uncoated

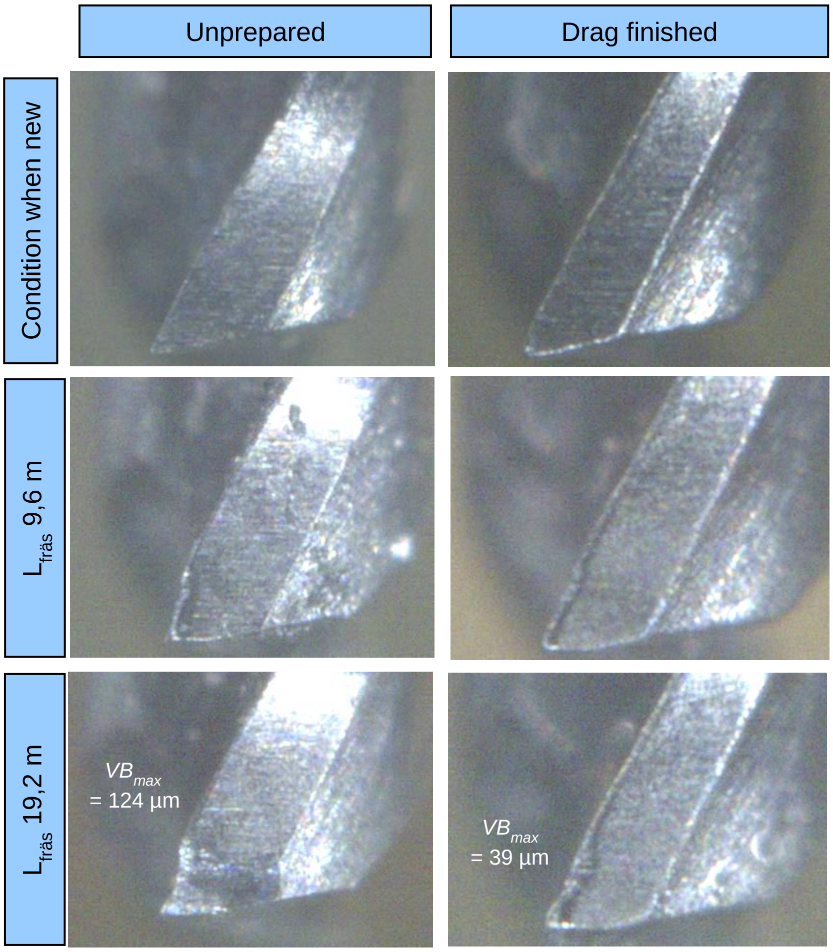

Fig. 4: Photographs showing the state of wear on the test tools

Deburring and polishing of microstructures and microcomponents

In addition to the selective preparation of geometric features, deburring and surface treatment are of great importance, especially in the case of components with intricate structures. As an example, the following illustrates the potential for using the drag finishing process for the deburring of microholes. During the course of this study, test discs were treated by drag finishing in order to selectively improve the surface quality. Measurements to monitor the surface roughness were made after each interval of *t* = 30 min. In order to measure the arithmetic average roughness *R*a and the mean roughness depth *R*z, a ZYGO white light interferometer type NewView 5010 was used.

Fig. 5: Sample treated

First, the ground blanks were processed. Fig. 5 shows the improvement in the surface quality of the samples in relation to the polishing time during drag finishing. Even after a processing time of only 30 minutes, the roughness Ra improves by 26% and Rz by 28%. In the subsequent processing steps, the surface quality asymptotically approaches the threshold values Ra = 0.13 µm and Rz = 1.1 µm. The roughness values achieved are largely dependent on two factors: the properties of the HSC 1/300 process media used (see fig. 2) and the process parameters, both of which have a significant influence on the processing results. After the surface finishing was complete, holes with a diameter of D = 80 µm were made by means of electrical discharge machining. The SEM images show chip particles adhering to the hole exit as well as minute traces of burring. The surface was also slightly soiled by the electrical discharge machining process. In order to debur and clean the surface, the test discs were therefore once more subjected to a drag finishing process. The cleaned surfaces and fully deburred hole exits can be seen in fig. 6. In order to avoid unwanted rounding of the hole entries and exits, process parameters were selected so as to give especially gentle finishing. For this application, a processing time of only two minutes has been shown to be favourable.

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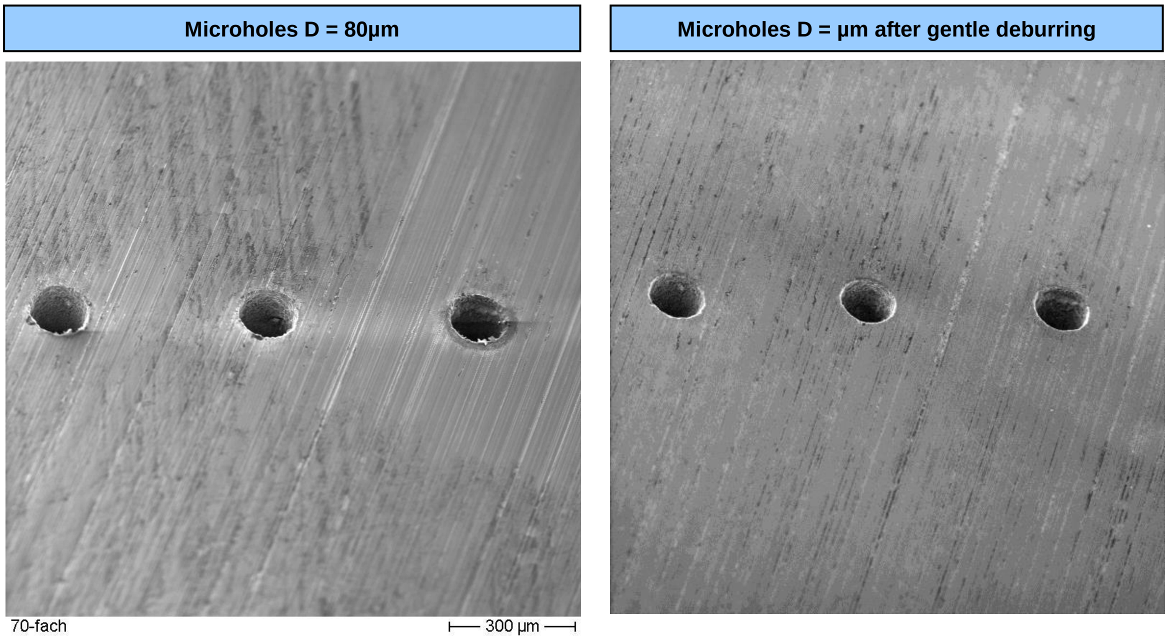

Fig. 6: SEM images of the microholes *D* = 80 µm

In addition to the microholes, the effect of the drag finishing process on miniature lands and cavities in copper, steel and graphite was investigated. Here, the process was found to be equally suitable for the deburring of microcomponents. In the case of steel and copper, the lands and cavities could be reliably deburred without any detriment or damage to the structures (fig. 7).
However, in order to avoid damage during processing, microstructures in graphite must fulfil certain geometric requirements as shown in fig. 8. The combination of low strength and high degree of brittleness makes graphite components especially sensitive to the forces occurring during processing. The tests show that only miniature lands with an aspect ratio < 4 (land height / land width) can be reliably processed by drag finishing. With all components tested, an improvement of surface quality was observed as a result of the drag finishing process.

Fig. 7: Overview of groove structures (steel 90MnCrV8, copper and graphite SGL R8500)

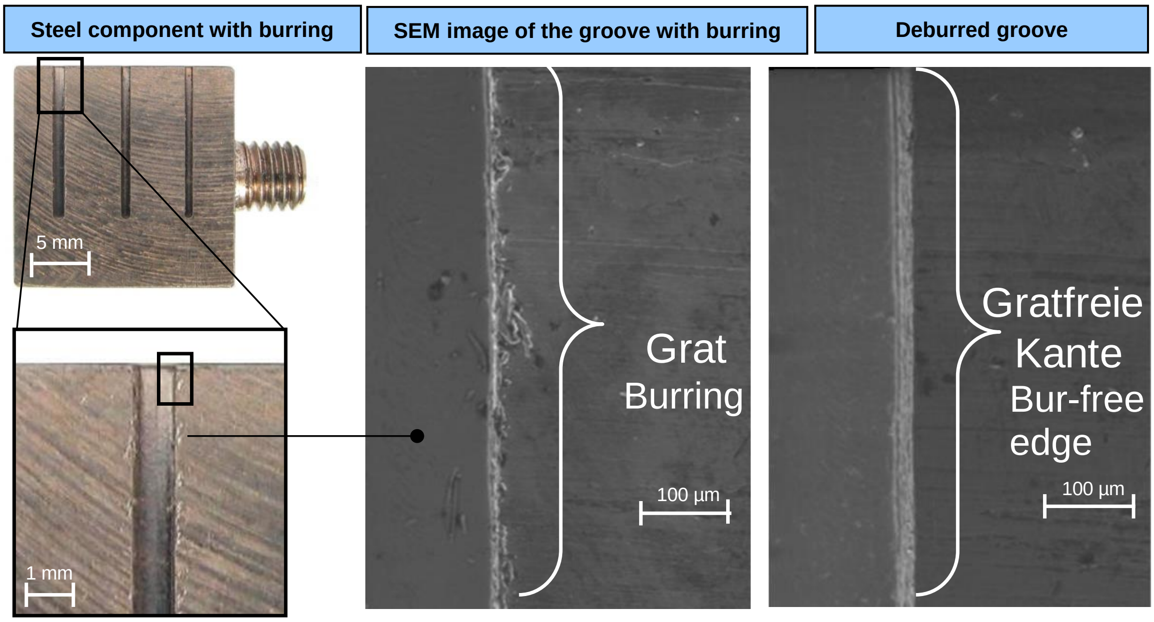

Fig. 8: Processed component in steel 90MnCrV8

Summary
At the Institute for Machine Tools and Factory Operation (IWF) at the Technische Universität, Berlin, the drag finishing process was successfully implemented to achieve defined edge preparation of miniature end mills. To this end, the necessary process parameters and abrasive media were adjusted accordingly.

It was shown by means of comprehensive milling tests that the prepared tools demonstrated increased resistance to wear. One advantage of the drag finishing process in this respect is that no complex, multi-axis process path is required for the finishing of complex rotary tools.
In addition, results were presented concerning the use of the drag finishing process for the polishing and deburring of microstructures in graphite and tool steel.
The further development of the drag finishing process and adapting it to the specific challenges of microproduction technology is the subject of current and future research projects at the IWF.

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