GRINDING HARD AND BRITTLE MATERIALS WITH CVD-DIAMOND MICROGRINDING WHEELS

Hans-Werner Hoffmeister\textsuperscript{1} and Ronald Wittmer\textsuperscript{1}
\textsuperscript{1}Institute of Machine Tools and Production Technology
Technische Universität Braunschweig
Braunschweig, Germany

INTRODUCTION

Microcutting operations are distinguished from other processes like lithography by their high flexibility, short manufacturing time as well as the machinability of a broad spectrum of materials. Thus, they are very appropriate for the manufacturing of high-precision structures and components of microsystems technology \cite{1}. This is shown by the example of coated single layer CVD-diamond grinding wheels. This paper provides the results of novel CVD-diamond microgrinding wheels. The microgrinding process with diamond microgrinding wheels enables a fast and high-quality fabrication of microstructures in various hard and brittle materials \cite{1, 2, 3}.

CVD-coated tools for microgrinding operations were formerly only used for shaft tools, i.e. for peripheral grinding \cite{4}. The advantages of CVD-coatings, which have been known for many years, had to be transferred to miniaturised grinding wheels \cite{5, 6}. They have the same advantages as CVD-mounted points, but they can even be used with higher cutting velocities and higher material removal rates. Furthermore, according to their small grain size, hard and brittle materials can be machined with low edge breakouts when optimized machine parameters are used. This means that micro cracks and chipping can be minimized and better surface qualities can be achieved.

This paper is divided into two parts. At first, the tool manufacturing consisting of machining the cemented carbide tool body and the characteristics of the CVD-layer are described, and finally, the results of their application in machining hard and brittle materials are presented. The development of these tools offers new possibilities of microstructuring hard and brittle materials \cite{7, 8}.

Figure 1: Examples of microstructured surfaces: Ground pillars in glass

TOOL MANUFACTURING AND SPECIFICATION

First of all, the configuration of the microgrinding wheels is described. They consist of a cemented carbide tool body and a rough CVD-diamond coating. After designing an appropriate geometry for these novel microgrinding tools (fig. 2), the inner diameter with fit size was ground. Afterwards, the tool body was fixed and oriented on a workholding device.

Figure 2: Geometry of the cemented carbide tool body

Subsequently, the cemented carbide tool bodies were produced with cup wheels, while the machine table was rotating. They have a diameter of 48 mm and a width of 0.16 mm. The design, which has already been tested, is a grinding wheel of the type “1A1”. The tool bodies were machined at the Institute of Machine Tools and
Production Technology (IWF) and afterwards coated with a chemical vapour deposition (CVD) process at the Fraunhofer Institute for Surface Engineering and Thin Films. The CVD-diamond microgrinding wheels were analyzed with a scanning electron microscope (SEM). The diamond crystals have an average width of 5 μm (fig. 3).

Fig. 3: CVD-layer of the microgrinding wheel

The normal forces during the tests were approximately twice as high as the tangential forces. Moreover, it can be stated that the forces decrease when the cutting speed is increased. This is due to the fact that the equivalent chipping thickness decreases for higher cutting speeds [3].

Figure 5: Cutting forces

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Figure 6 shows the development of the cutting forces in dependency of the related volume removed by microgrinding aluminum oxide. The normal and tangential force are relatively stable for the area of a specific material removal rate of 600 mm³/mm and afterwards there is a slight increase of the cutting force. These values can be used to rate the wear behavior of the microgrinding wheels. As there is only a small increase, the process and wear behavior of the CVD-diamond microgrinding wheel is satisfying. The process behavior of the tool is rated by SEM-pictures (fig. 7).

Figure 6: Development of cutting forces
The material aluminum oxide was chosen for these tests, because it was the hardest of the investigated materials. For this reason, was expected that wear could occur. In the upper line, the topview of the peripheral surface of a new CVD-microgrinding wheel is shown for several magnifications. The crystalline, sharp-edged structure of the CVD-diamond grains is clearly visible. The pictures of the middle line show similar pictures after a specific material removal rate of 600 mm³/mm, the pictures in the lower line, the ones after a specific material removal rate of 1200 mm³/mm. The structure of the crystallites stays well preserved, and except for few adhesions of cooling lubricants and chips the configuration of the CVD-layer hardly changed. Only the small increase of the normal force for higher specific material removal rates by cutting suggests little wear.

As further results of the grinding tests, it can be summarized that there was a maximum edge breakout of 5 µm at the workpiece. They were 1 µm for grinding cemented carbide and 5 µm for grinding glass. The value of the edge breakouts is higher for up-grinding than for down-grinding and increases exponentially with higher cutting speeds [9].

CONCLUSIONS

Microgrinding with CVD-diamond grinding wheels is an appropriate method for microstructuring hard and brittle materials. In order to improve the machining quality when grinding these materials, new CVD-diamond microgrinding wheels were developed and the basic technological parameters were studied. Their use by grinding silicon and aluminum nitride caused cutting forces lower than 1 N. Moreover, even at the hardest investigated material aluminum oxide, they did not cause visible wear, which means that they have a long tool life. Further advantages of these microgrinding wheels are low surface roughnesses at the flute base and marginal edge breakouts.

In addition to the mentioned materials, further hard and brittle materials can be used for microgrinding and -structuring operations. Based on the successful application of these tools, grinding wheels with convex and concave profiles are currently developed to broaden the spectrum of the machinable geometries.
Besides several different geometries of the tool body, the specifications of the coating will be varied. The focus will be on the ideal crystallite size for grinding operations. If they are too small, they do not offer enough chip space. On the other hand, if they are too large, they cause large edge breakouts at the workpiece and the surface roughness of the flute base will be too high.

The next aspect concerning these novel tools will be to regard the coatability of the tool bodies. The geometry of the tool body has to be chosen and machined in such a way that it can be coated reproducably and that the coating does not strip.

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REFERENCES