A new Approach for the Simultaneous Grinding of Cubic Microstructures in Brittle-Hard Materials

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1 Introduction

Beside with photolithographic processes microstructures can be machined in brittle-hard materials by grinding. Metallic bonded multilayered grinding wheels offer high potential for low part shape tolerances in micro machining due to their low wear and good profile holding properties [1]. But those tools are difficult to dress. Furthermore, multiple micro profiled grinding wheels are used very seldom in micro grinding because no adequate micro dressing processes are available. The wear of mechanical micro dressing tools is too high for a profile generation at the grinding wheel. Thus, predominantly thin and simple profiled resin bonded grinding wheels are used for the machining of microstructures. However, the low stiffness of these grinding wheels usually leads to an axial tool deflection. Consequently, the machined flutes are up to ten percent wider than the grinding wheel thickness [2]. Furthermore, the flutes can only be machined in serial, which results in long machining times and requires the compensation of the grinding wheel wear due to the long total grinding length.

To machine several microstructures simultaneous with low tool wear grinding with multiple micro profiled metal bonded diamond grinding wheels is investigated in this paper. Electro contact discharge dressing (ECDD) with micro wire electrodes is used for the micro profiling of these grinding tools [3].

2 Axial deflection of the multiple micro profiles

Several bars with a width between about 60 µm and about 350 µm, separated by flutes with a width of about 360 µm and a depth of about 400 µm, are dressed at two grinding wheels with different bond hardness to investigate the influence of the profile bar width on the profile stiffness. Both grinding wheels were applied to machine microstructures with a height of 200 µm in cemented carbide. The width of the ground microstructures in cemented carbide as well as the bar width at the grinding wheel have been evaluated and the relative flute oversize is calculated as shown in Figure 1. The relative flute oversize increases with decreasing bar width at both bond hardness. It can be assumed that the stiffness of the bars decreases with decreasing bar width which results in an increasing axial deflection. Furthermore, the relative flute oversize at medium bond hardness is smaller than in machining with Dicing-Blades at all investigated bar widths. This can be deduced from the relative flute oversize of the machined flutes which is about 10 % at Dicing-Blades [2] and about 3 % to 8 % at the grinding wheel with medium bond hardness. The relative flute oversize is in the range of 7 % to 20 % at high bond hardness.

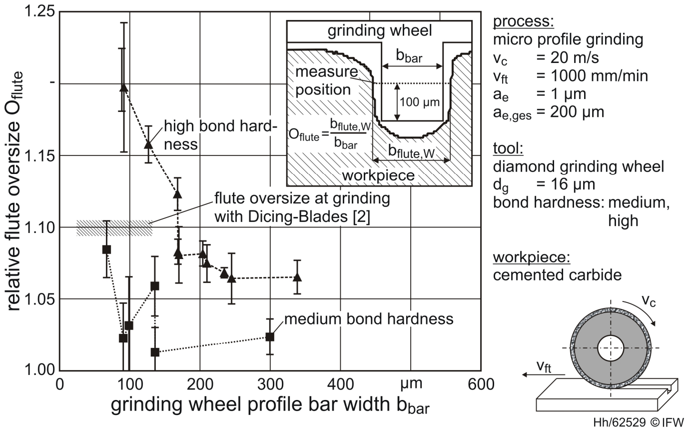

Figure 1: Relative flute oversize at different grinding wheel profile bar widths

3 Radial wear of the grinding wheel

Another important factor on the geometrical accuracy of the machined microstructures is the grinding wheel profile wear. Figure 2 shows the grinding wheel wear in relation to the specific material removal for medium and high bond hardness. The grinding wheel wear is measured at imprints of the grinding wheel micro profile. These imprints have been made at different specific material removals. Figure 2 shows that the initial grinding wheel profile wear is comparable at both bond hardnesses. The grinding wheel profile wear raises with increasing specific material removal at both bond hardnesses. However, the grinding wheel wear rate is significantly lower at high bond hardness than medium bond hardness. Thus, at a specific material removal of 110 mm³/mm the radial wear of the grinding wheel is about 12 µm at high bond hardness and about 25 µm at medium bond hardness.

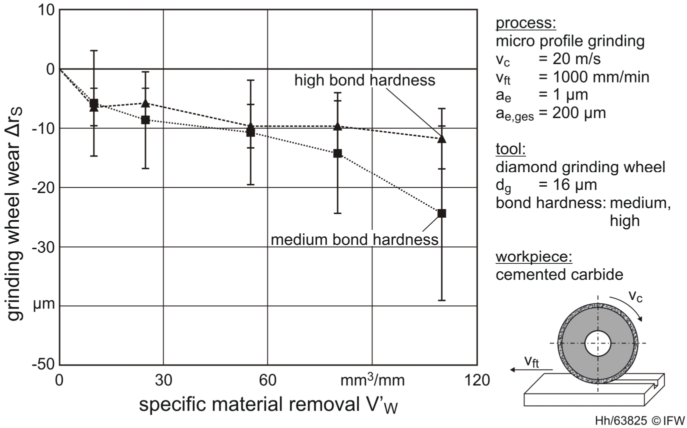

Figure 2: Grinding wheel wear versus specific material removal

4 Simultaneous grinding of cubic microstructures

Several cubic microstructures can by ground simultaneously with multiple micro profiled grinding wheels by carrying out only two orthogonal grinding paths. The SEM micrograph in the left part of Figure 3 shows a segment of the micro profiled grinding wheel layer.

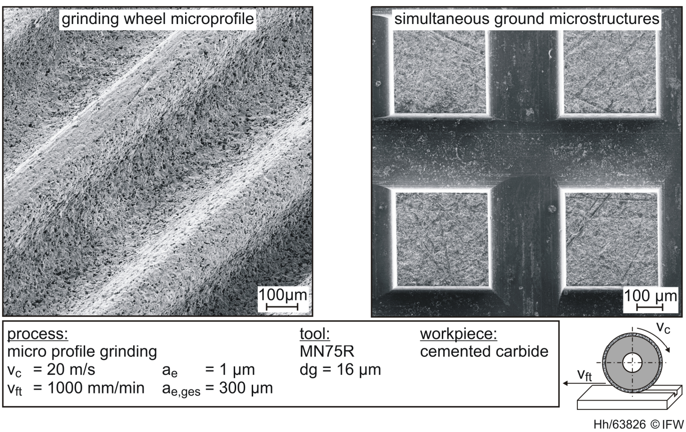

Figure 3: Grinding wheel micro profile and ground microstructures

Totally twelve bars with a width of about 170 µm, separated by eleven flutes with a width of about 360 µm and a depth of about 400 µm have been dressed on the 6 mm wide grinding wheel. This grinding wheel was applied to machine cubic microstructures with a height of 200 µm in cemented carbide. The SEM micrograph in the right part shows four of overall 121 microstructures that have been machined by using only two orthogonal grinding paths. Aspect ratios up to six were gained applying further grinding strategies at higher infeeds.

5 Conclusions

The application of multiple micro profiled metal bonded grinding wheels offers a high potential in the machining of microstructures in brittle-hard materials. On the one hand, the productivity can be increased due to the simultaneous grinding of several microstructures in one grinding path. On the other hand, the geometrical accuracy can be enhanced because of higher tool stiffness, low wear and high profile retention. The relative flute oversize, caused by axial tool deflection in grinding, is about 10 % using Dicing-Blades and about 3 % to 8 % using a multiple micro profiled grinding wheel with medium bond hardness. The relative flute oversize is in the range of 7 % to 20 % at high bond hardness. Furthermore, the wear of the grinding wheel is quite low. The radial wear of the grinding wheel is about 12 µm at high bond hardness and about 25 µm at medium bond hardness at a specific material removal of 110 mm^3/mm.

6 Acknowledgement

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