CVD Diamond Grinding Tools Lead to Increasing Cutting Performance during Microgrinding of Ceramics

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1 Introduction

This paper presents results for grinding piezo ceramics, zirconium oxide and aluminum oxide with CVD diamond coated and electroplated diamond microgrinding pins. The cutting behavior of electroplated tools and CVD diamond tools were investigated. The experiments were realized in consideration of process forces, surface roughness, form and shape accuracy, tool life as well as edge breakouts at the produced grooves.

2 Diamond grinding tools

Figure 1 shows scanning electron microscope (SEM) images of the unused tools.

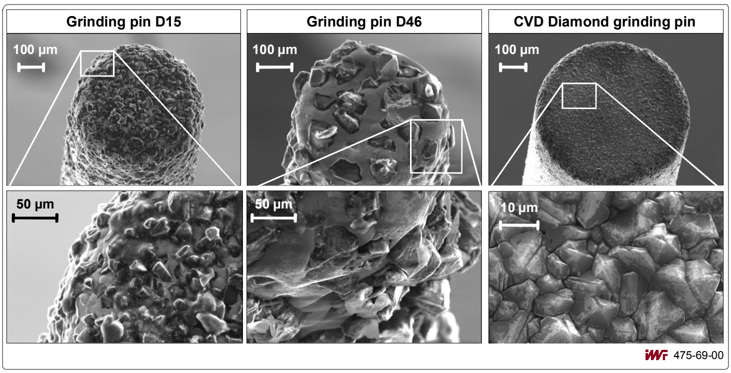

Figure 1: Diamond grinding tools

3 Experiments and results

The experiments were conducted by ceramic materials zirconium oxide, piezo ceramic and aluminum oxide. Each grinding tool was tested with the same set of parameters for the different workpiece materials. The feed rate was variegated and the cutting behavior was investigated. During the grinding experiments a piezo-based force measurement device type MiniDyn by Kistler was used to record the cutting forces (Figure 2).

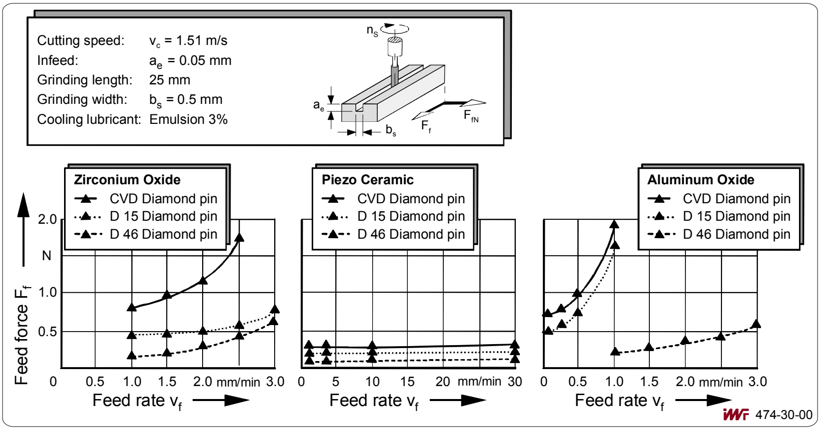

Figure 2: Process forces during machining with different diamond grinding pins

The experiments for grinding with electroplated D 46 diamond tools caused the lowest cutting force for each of the workpieces. In contrast to this CVD diamond pins reach the highest force. During machining zirconium oxide and aluminum oxide, cutting forces significantly increase at smaller diamond grain sizes. This occurs with respect to the increasing amount of diamond grains in the contact zone. The forces increase with rising feed rates due to the increasing chip thickness. Grinding piezo ceramic leads to constantly low process forces. Within the experiments the feed rate for grinding piezo ceramic could be increased up to ten times faster than the one for zirconium oxide and even 30 times faster than the one for grinding aluminum oxide. The analysis shows that aluminum oxide generally reaches the highest force values for each diamond tool. Piezo ceramic reaches the lowest values. This result can be explained by the hardness of the workpieces. The Vickers Hardness for aluminum oxide reaches approx. 1.700 HV whereas zirconium oxide reaches approx. 1.150 HV. At a value of approx. 380 HV piezo ceramic has the least hardness of the analyzed workpieces. The process forces after grinding with CVD diamond tools reached higher values, the surface roughness and edge breakouts were reduced compared to the other tools. The edge breakouts and surface roughness were measured using a confocal microscope. To do so, each structure was evaluated at different positions and the mean value was calculated [1].

The edge breakouts for piezo ceramic could be reduced from more than 15 µm (D 46) down to approx. 5 µm by applying CVD diamond grinding pins. The quality of the surface roughness could be increased from about 400 nm (D 46) to 280 nm (CVD). Machining piezo ceramics with CVD grinding pins only sligthly increases surface quality and edge breakouts compared to D 15 grinding pins. In contrast to this machining zirconium oxide with CVD diamond grinding tools shows significantly better surface quality and edge breakouts. The surface roughness could be reduced from 300 nm (D 46) to approximately 250 nm (D 15) respectively 120 nm (CVD). The edge breakouts could be reduced from approximately 10 µm (D 46) respectively 6.8 µm (D 15) to 2.19 µm (CVD). Grinding aluminum oxide with CVD diamond tools also leads to reduced surface roughnesses of approx. 600 nm and edge breakouts of 9.8 µm. Further analysis of process forces showed a characteristic development of force levels (Figure 3).

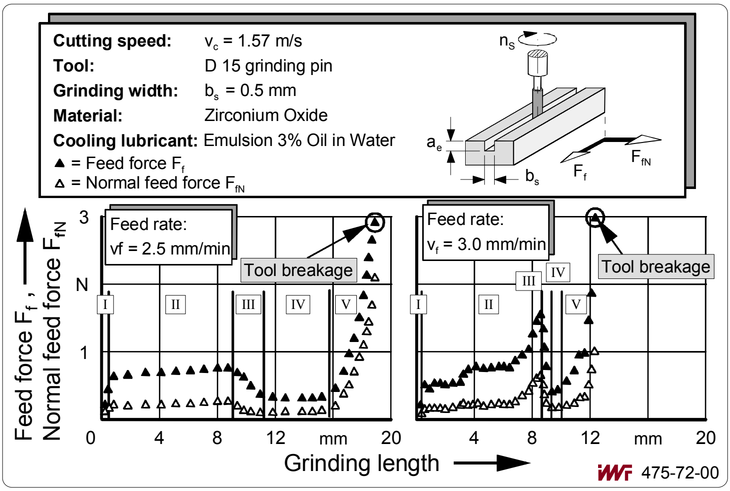

Figure 3: Process forces during machining

The development of forces for grinding zirconium oxide at a feed rate of 2.5 mm/min was classified into different phases [2]. The analysis shows that this characteristic development of forces also occurs at different parameter combinations and workpieces. Figure 3 shows the grinding forces at the workpiece length at two different feed rates. At a higher feed rate a less workpiece length can be machined due to the break down of the grinding pin. The force signals can be divided into different phases whereas the forces within each phase are on comparable levels. The experiments with CVD diamond tools show longer tool life compared to the ones with electroplated diamond grinding pins. This can be explained with the higher hardness of binderless CVD diamond crystallites. The electroplated diamond pins show significant grain outbreaks which lead to decreasing tool life. In contrast to this, CVD diamond tools have no coating system and diamond crystallites do not break out. Electroplated diamond pins show grain outbreak as a significant wear behavior [2].

4 Conclusions

The experiments show that the application of CVD diamond grinding pins leads to reduced edge breakouts and surface roughnesses, especially for machining zirconium oxide and aluminum oxide. Cutting forces significantly increase at a decreasing grain size whereas grinding piezo ceramic leads to almost equally low forces for all different grain sizes. Furthermore the CVD diamond tools have a longer tool life compared to the electroplated diamond grinding pins.

Acknowledgement

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