Investigation of the Cutting Behavior of Piezoelectric Ceramics during Grinding with Diamond Pins

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1 Introduction

Microsystems technology is applied to several business fields such as automotive industry, communication and medicine with a continuously growing importance [1]. Very small tool dimensions, in particular the diameter of tools associated with their inherent fragility, complicate the detection of tool failure. Accordingly, tool failure cannot be seen until the produced structure is checked with an optical inspection system.

Thus, a force measurement device was integrated into a microgrinding machine in order to provide an in-process monitoring system during the machining of micro parts. The correlation between the measured data of the in-process measurement system and the tool failure was investigated.

2 Properties of the diamond grinding tools

The experiments were performed with electroplated diamond grinding pins with a grain size of 15 µm (D 15) and 46 µm (D 46). The grinding pins were analyzed with a scanning electron microscope (SEM) (Figure 1).

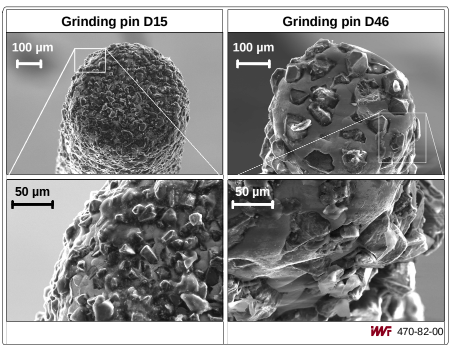

Figure 1: Grinding tools

3 Experiments and results

The cutting behavior for grinding piezo ceramics, zirconium oxide and aluminum oxide has been investigated at varying sets of grinding parameters. The process forces were recorded during the grinding experiments. Figure 2 shows the results of the force measurement during microgrinding of zirconium oxide and piezo ceramics with a grain size of 15 µm.

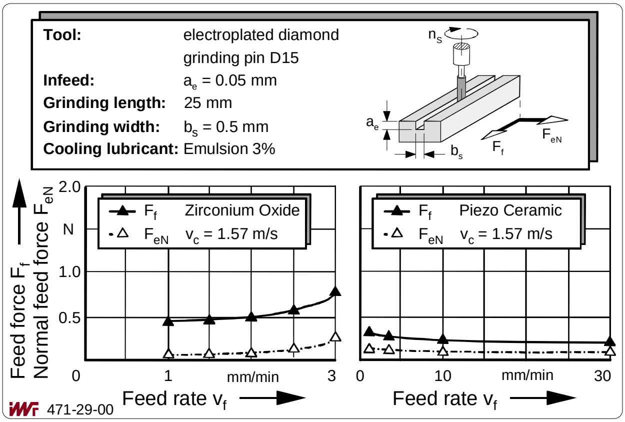

Figure 2: Process forces during grinding of different ceramics

The process forces for manufacturing these materials were significantly lower than 1 N. Increasing feed rates led to increasing cutting forces when grinding zirconium oxide. In contrast to this, the process forces for grinding piezo ceramics decreased with increasing feed rates. Moreover, the feed rate was ten times higher than the one for zirconium oxide. Further investigations of the recorded data showed a characteristical development of force signals over the grinding length (Figure 3). The influence of the grain size on the cutting forces could be monitored and led to a different development of force signals. During the grinding experiments the monitoring system allowed the detection of maximum force signals leading to a tool breakage. Moreover, the grinding length showed a correlating behavior to the tool life depending on the variation of the cutting forces. Grinding zirconium oxide with D 15 tools led to a force signal development that could be divided into 5 different phases. The changes of the process forces could be traced to the tool wear [2]. The experiments performed with D 46 grinding tools at the same specific set of parameters led to significantly lower process forces.

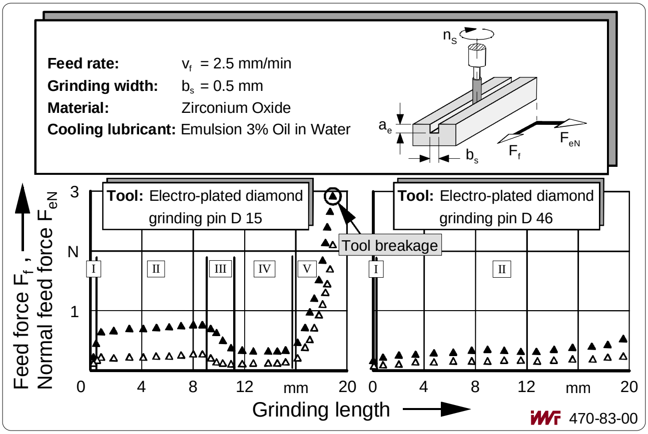

Figure 3: Development of process forces over the grinding length

The development of the force signals could be divided in 2 different phases. After the tool was completely engaged, first phase, the process forces reached a constant force level with a sligthly increasing development over the grinding length, second phase. It can be concluded that increasing grain sizes lead to decreasing cutting forces during microgrinding. Furthermore, the tools with a grain size of 15 µm are able to load a maximum feed force of approximately 3 N and a maximum normal feed force of approximately 2 N.

After manufacturing, SEM images were taken from selected tools to analyze the influence of grinding parameters on the cutting behavior (Figure 4).

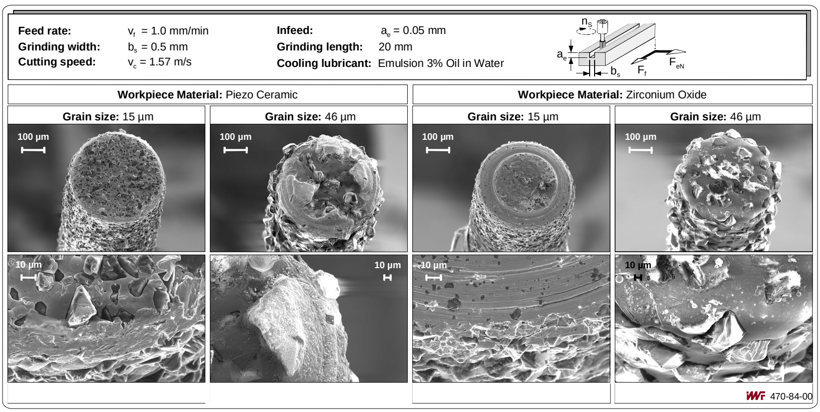

Figure 4: Tool wear after grinding ceramics with different diamond grinding pins

According to the SEM images the D 15 grinding pin used for machining piezo ceramics showed only little tool wear and was sligthly loaded with lubricant and chips. The average edge breakout at the produced structure of the workpiece was 3 µm. In contrast to this the grinding tool with 46 µm grain size is completely loaded with lubricant and chips. The average edge breakout was higher due to the increased diamond grain size. Grinding zirconium oxide with D 15 tools showed a completely worn tool edge with an average edge breakout of 4 µm whereas the D 46 tools showed only slightly worn tool edges but higher edge breakouts at the workpiece.

4 Conclusions

Microgrinding is an appropriate method for microstructuring hard and brittle materials. Using D 15 electroplated diamond grinding pins caused cutting forces significantly lower than 1 N. Comparative experiments with D 46 grinding tools generated even lower cutting forces. Increasing grain sizes led to increasing edge breakout and surface roughness. Grinding zirconium oxide with a D 46 grinding pin caused less tool wear compared to D 15 diamond tools. It can be summarized that the in-process monitoring system can be used to correlate the force signals to the tool life and thus increase the process stability.

Further experiments will be conducted with CVD diamond grinding pins in order to reduce the edge breakout and the surface roughness.

Acknowledgement

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