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

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1 Introduction

Piezoelectric ceramics are materials of great importance used in many applications. Acceleration and force sensors in machine tools are only two examples. Newer approaches use piezoelectric ceramics as actuators in order to realize an active vibration damping in machine tools. The devices used for these applications are characterized by a simple geometry with planar faces. These geometries do not allow sustaining shear forces.

In the future, machine tools for micro components will adjust to the component size and thus become smaller. This effect requires an adjustment of the machine components such as sensors and actuators. Thus, a microstructuring of piezoelectric ceramics becomes necessary. Furthermore, a structuring of actor components will allow a frictional connection and achieve an actuator which resists shear force. Besides that, the cutting behavior of piezoelectric ceramics is not sufficiently described in literature. Within this study, a grinding process was chosen to machine grooves into the ceramics using electro-plated diamond grinding pins. During grinding, the cutting forces were measured. This paper presents the results of the experiments in machining hard and brittle materials. For classifying the cutting behavior of piezoelectric ceramics, comparative tests were performed with aluminium oxide, which is known to have a low stress intensity factor, and zirconium oxide, which can be ground in a more ductile mode.

2 Properties of the machined piezoelectric ceramics and grinding pins

The piezoelectric ceramic that was used for grinding is a modified lead zirconate – lead titanate material (PIC 181).

These ceramics are used in resonance-mode ultrasonic applications and in piezomotor drives. [1]

The grinding experiments were performed with two conventional electro-plated diamond grinding pins. The grinding tools that were used in the first place had a diameter of 0.8 mm and a grain size of D91. The second grinding tools that were used had a diameter of 1.5 mm and a grain size of D15. The electro-plated diamond grinding pins were analyzed with a scanning electron microscope (SEM) (fig. 1).

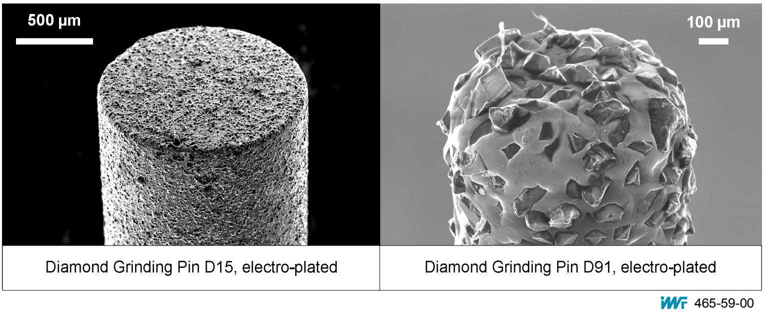

Figure 1: Grinding tools

3 Experiments and results

The micro grinding tools were evaluated with regard to their process behavior by machining aluminum oxide, zirconium oxide and piezoelectric ceramics. The main focus was to determine cutting forces, chipping and tool wear.

Figure 2 shows the feed forces for grinding these materials with an electro-plated diamond grinding pin with a diameter of 0.8 mm and a grain size of D91. Generally, the feed forces are lower than 1.5 N. The feed forces for aluminum oxide are nearly on the same level as for piezoelectric ceramic.

Moreover, the machined grooves were analyzed. The maximum chipping in piezoelectric ceramic was about 10 µm, when grinding with a feed rate of 1 mm/min. Aluminum oxide showed a similar chipping level whereas the chipping level of zirconium oxide was significantly lower.

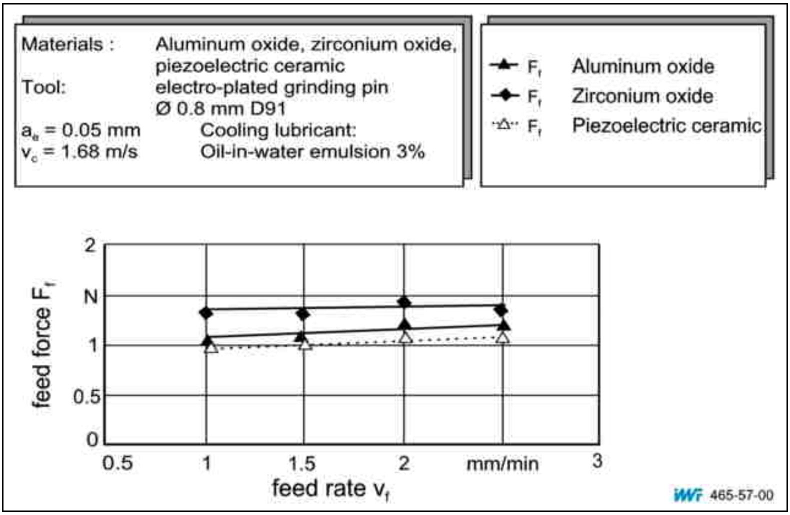

Figure 2: Cutting forces

Further experiments were performed with 1.5 mm D15 electro-plated grinding pins. Figure 3 shows the grinding tools after machining a groove into aluminum oxide and zirconium oxide. The forces that were measured during the grinding processes reached a higher level than the grinding pins with a grain size of 91 µm. The abrasive layer of the grinding pins that were used to machine grooves into aluminum oxide is worn out. The grinding pins that were used to machine zirconium oxide were clogged with sediments.

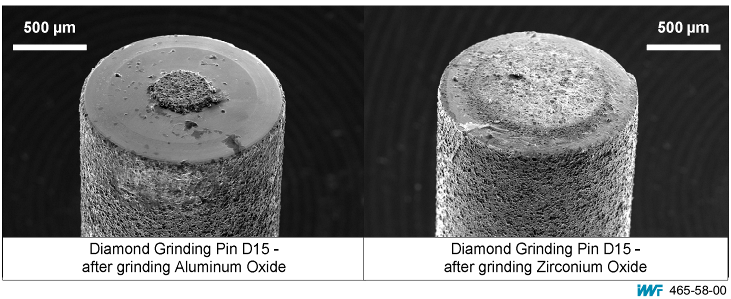

Figure 3: Grinding tools after machining

4 Conclusions

In order to improve the machining quality when grinding hard and brittle materials, electro-plated diamond micro grinding pins were used and the basic technological parameters were studied. The highest feed force of 1.5 N was detected when grinding zirconium oxide. Grinding piezoelectric ceramics lead to a maximum chipping lower than 10 µm. The chipping level of hard and brittle materials can be reduced when grinding in the material's ductile mode [2]. However, ductile mode grinding can only be put into practice at specific process parameters. Therefore, the cutting speed and the feed rate of electro-plated diamond grinding pins have to increase significantly which was not yet possible because of tool breakage. Further experiments will focus on the use of grinding wheels as these tools are potentially able to achieve the necessary cutting speed and feed rate for cutting in the materials' ductile mode.

The feed force of 1 N, when machining piezoelectric ceramic, was the same as in grinding aluminium oxide. The high chipping level of piezoelectric ceramics combined with the similar feed force lead to the assumption that the grinding behaviour is more like that of aluminum oxide rather than zirconium oxide. Following experiments will deal with the application of CVD grinding pins to improve the grinding ability of piezoelectric ceramics. CVD diamond grinding tools are supposed to offer new possibilities in micro structuring of hard and brittle materials as they allow minimizing chipping and surface roughnesses [3, 4].

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