On Characterization of Dressing Process in ELID-Grinding

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Abstract

In conventional grinding of hard materials such as ceramics, there is always a following polishing process necessary for achieving high surface quality. The polishing has a negative effect on the form accuracy and thus a new grinding step is required to correct the workpiece shape. This cycle reiterates until both the desired surface quality and form accuracy are met, which leads to long processing times and high manufacturing costs. This situation is particularly applicable when generating freeform surfaces, where the polishing process will deteriorate the form accuracy even more compared to the polishing of flat workpieces. As a consequence, freeform surfaces on hard materials are still hardly affordable nowadays, which limits many possible applications. With the Electrolytic In-process Dressing (ELID) technique, traditionally hard-to-machine engineering materials such as hard steels, cermets and ceramics can be ground with very good surface quality [1]. This process significantly reduces the necessity of a polishing step after the grinding operation.

Research is underway at KULeuven to integrate the ELID-grinding principle into an ultra-precision machine [2]. The first step is to investigate thoroughly the ELID-process to obtain a comprehensive understanding of it.

1 The ELID-setup

Figure 1 gives an overview of the operational ELID-setup at the KULeuven. The ball-shaped grinding wheel (with the rust colour) is a #4000 cast-iron bonded wheel with diamond grits (2-4 µm average grit size) and is driven by an aerostatic spindle. The electrode is a rotating cup electrode covering part of the grinding wheel. This gives a more uniform electrolysis on the wheel. The setup is a flat-grinder with a total machine loop stiffness of about 8 N/µm. Nevertheless, this relatively compliant machine gives very good results in terms of surface quality of the workpiece.

High depths of cut (DOC) cause big grinding forces and cause damage to both the

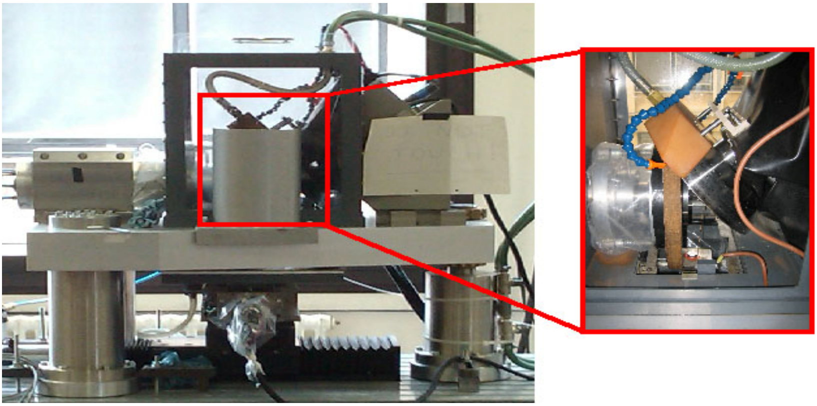

Figure 1: Experimental setup for ELID-grinding

workpiece and the wheel (and its oxide). The DOCs during grinding of ceramics and other hard materials are kept in micron range in order to obtain ductile mode grinding [3]. Less damage is caused with respect to grinding in a more brittle regime. As shown in Figure 2, the z-slide is composed of two wedges and is designed in such a way that the linear displacement of one wedge is reduced by a factor of 4 to generate the z-direction displacement of the other wedge. The smallest repeatable step obtainable in the z-direction is 0.4 µm. Another advantage of this slide is the high stiffness.

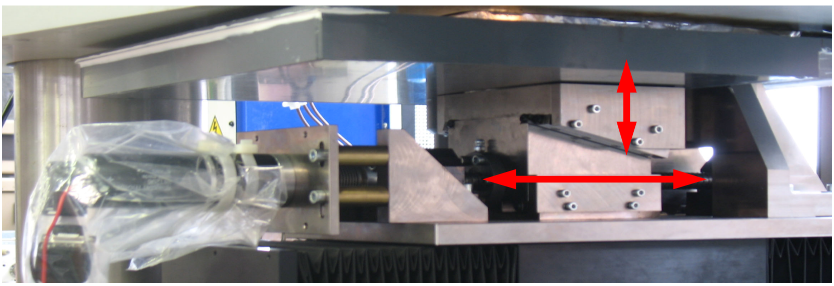

Figure 2: Z-slide composed of 2 wedges for high displacement resolution

2 ELID-process characterisation and grinding experiments

At first, the grinding wheel is trued to the desired shape. Afterwards a layer of oxide is grown on the wheel during pre-dressing. After a while the electrolytic current density goes down. The oxide is growing thicker and is less conductive than the metal. During the ELID-grinding experiments the current density slowly continues to decrease until a lower limit is reached (approximately 0.1 mA/mm^2). This is probably due to inefficient dressing. The problem is that there's too little electrolytic liquid present in the dressing gap due to the high wheel speed.

In the experiments, the DOC is set to 0.4 µm/pass, the feedrate to 400 mm/min and the cutting velocity to 19 m/s. Even without efficient dressing the wheel stays sharp for a long grinding time (~48 hours). Thanks to the low DOC, little oxide was removed during grinding. The oxide, which is actually a combination of several hydroxides in the wet environment, also acts like a sponge-like pad. In the experiments it is not as brittle as explained in the theory of Ohmori and Nakagawa [1]: in fact there is less layer breakage due to the low DOC. The electric parameters of the Fuji-Elider ED921 voltage system during ELID-grinding experiments were set to: 90 V, 20 A and 70% current duty ratio.

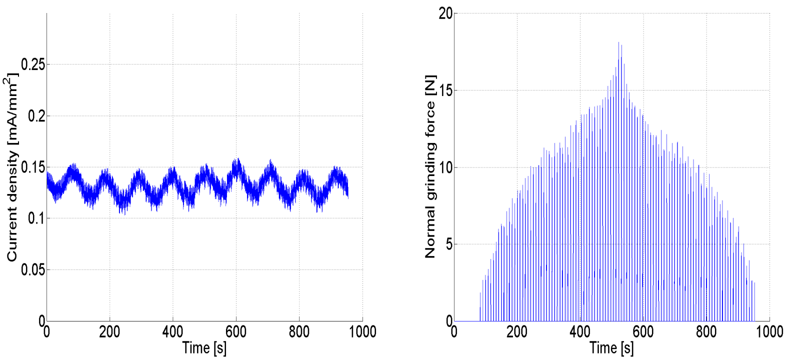

Figure 3: Current density and normal grinding force during ELID-grinding

Figure 3 gives an example of the current density and corresponding normal grinding force for a grinding experiment. The periodic fluctuations in current density are due to the rotation of the electrode. The fluctuations in the normal grinding forces are due to the imperfect alignment of the workpiece surface with the movement of the slides. The actual DOC is different throughout the width of the workpiece and this causes the higher grinding forces at certain positions. Due to this alignment error it can take a long time to grind a whole surface with this DOC.

3 Results

Experiments show that it is relatively easy to grind very smooth flat surfaces with the ELID-process on a compliant setup. Observations with a Veeco White-light Interferometer indicate that ductile mode material removal can be achieved with small depth-of-cut, and the roughness of a Si_3N_4 workpiece is measured to be approximately 3 nm Ra (Figure 4).

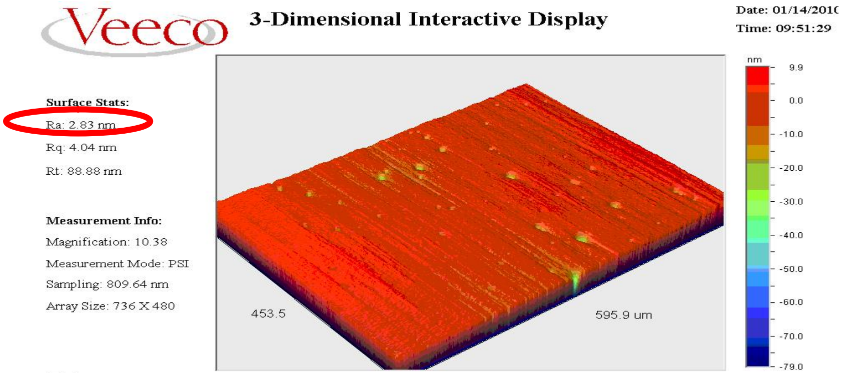

Figure 4: Measurement of surface roughness

4 Conclusions and future work

The ELID-grinding process has been successfully used to grind a flat ceramic. The obtained surface roughness is about 3 nm Ra with a DOC of 0.4 µm. However, it is not so straightforward to control the dressing mechanism. It is a challenge to obtain normal dressing efficiencies when using high wheel speeds. In the case of grinding freeforms the machine stiffness is crucial to obtain high shape accuracy. The ultimate goal of the research is to apply the ELID-process in freeform grinding of high-end engineering materials, with both good surface quality and high form accuracy.

References:

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