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 (of about 4 microns of average grit size) and is driven by an aerostatic spindle. The electrode is a rotating injection electrode which covers the grinding wheel. This gives a better and more uniform electrolysis on the wheel. The setup is a flatgrinder with a total machine loop stiffness of approximately 8 N/micron. Nevertheless, this relatively compliant machine generates very good results in case of surface quality of the workpiece.

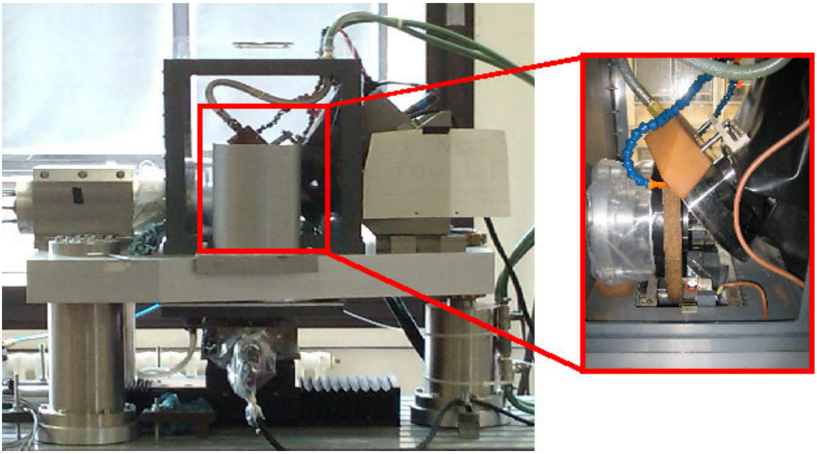

Figure 1: Experimental setup for ELID-grinding

The workpiece translates in 3 orthogonal directions. The z-axis can move with very small steps of less than 1 micron. Higher depths of cut (DOC) would cause big grinding forces and cause damage to both the 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]. This will cause less damage to the workpiece 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 micron. Another advantage of this slide is that it has a high stiffness.

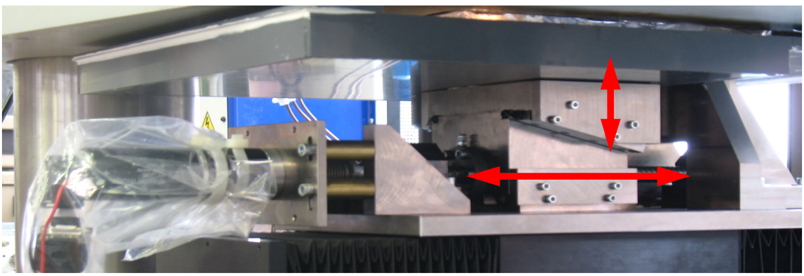

Figure 2: Z-slide composed of 2 wedges for high displacement resolution

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 the pre-dressing stage. After a while the electrolytic current density goes down. The oxide is growing thicker and due to the isolation it forms, the current drops. 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 micron/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 very 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], there is less layer breakage due to the low DOC. The pad contains Mo which reduces the friction in the contact zone and reduces the wheel wear. These are the main reasons why the grinding ratio during ELID-grinding is quite high compared to conventional grinding (about 50 times higher). 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.

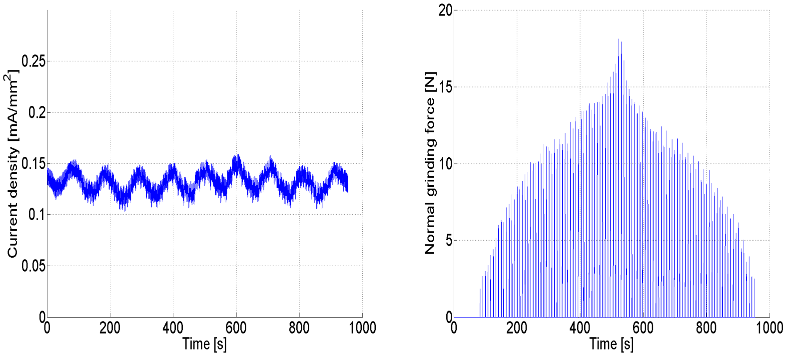

Figure 3: Current density and normal grinding force during ELID-grinding

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 slides movement. The actual DOC is different throughout the width of the workpiece and this causes the higher grinding forces at certain positions. Due to this 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 flat surfaces with very low surface roughness value with the ELID-process even on a setup without high loop stiffness. With a Veeco Whitelight Interferometer the roughness of a Si_3N_4 workpiece is measured to be approximately 3 nm Ra.

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 micron. However, it is not so straightforward to monitor and control the in-process dressing mechanism. It is a challenge to obtain normal dressing efficiencies when using high wheel speeds.
In the case of grinding freeforms, the stiffness of the machine is crucial to obtain high shape accuracy. The ultimate goal of the research is to apply the ELID-process in grinding of freeforms on high-end engineering materials, where both good surface quality and high form accuracy are required.

References:

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