Electrical discharge dressing of metal-bonded grinding wheels

Introduction

Metal bonded diamond wheels are generally used for grinding difficult-to-cut materials, since diamonds have key properties such as high wear resistance, high hardness, low friction and thermal expansion coefficients, and the metal bond provides properties such as high grain retention forces and high thermal conductivity. One particular application is found on grinding high performance ceramics, which are materials with several exceptional properties such as high hardness, high stiffness and good thermal and chemical stability, finding an increasing number of applications in the automotive, aerospace, medical, electronics and machine-tool industries. Apart from the above mentioned advantages, metal bonded diamond wheels are considered difficult-to-dress tools. It has no pores, so that bond material has to be removed between grains to generate chip pockets and provide sufficient grain protrusion. Thus, the main challenge when it comes to the use of metal bonded wheels concerns the conditioning process.

Metal-bonded diamond wheels are usually conditioned by conventional silicon carbide wheels. This method, however, has limitations. The high wear of the SiC wheel negatively impacts dressing accuracy, so that usually only non-complex wheel profiles are dressed by this method. In addition, SiC-dressing is very time consuming, and for this reason, metal-bonded diamond wheels are generally conditioned on independent dressing machines. In this case, however, another problem arises, since after dressing the grinding wheel has to be carefully reassembled to the grinding machine, in order to avoid clamping errors. Wire electrical discharge dressing (WEDD) is an alternative to the conventional dressing method. Given that diamonds are generally electric insulators, WEDD-dressing can generate grain protrusion in metal-bonded diamond wheels, since only electrically conductive materials can be eroded.

Technology

On-machine wire electrical discharge dressing (WEDD) of metal bonded grinding wheels is the main focus of this project. In WEDD, different wheel profiles (macro geometry) can be manufactured with the same electrode and wear compensation is guaranteed by using a continuous unwinding wire supplied from a spool. Grain protrusion (micro geometry) can be generated, since in electrical discharge machining (EDM) only electrical conductive materials can be eroded. Thus, a selective removal process takes place, i.e. the diamonds (electric insulators) are not eroded while the electric conductive metal bond is removed between the grains by consecutive electric discharges. As a result, a sharp grinding wheel with accurate macro geometry is generated. Figure 1 shows a schematic representation of the ED-dressing principle, in which the macro and micro geometry of a grinding wheel is generated in on single step.

Application

To enable the wire electrical discharge dressing (WEDD) to be carried out inside a grinding machine, a dressing device was designed and integrated into a CNC universal cylindrical grinding machine. Figure 2 illustrates the CAD design of the WEDD-device, highlighting the wire drive unit and the two axes feed system. It was mounted on the support of the internal grinding spindle, allowing for on-machine and in-process dressing experiments to be carried out.

Figure 1: Electrical discharge dressing principle

Figure 2: WED-dressing device
The feed system is equipped with roller guideways on both horizontal and vertical directions, which allows for relative displacement from wire electrode to grinding wheel in axial and radial directions respectively, making possible the erosion of different profiles. Servo feed control on both axes uses the gap voltage as sensing parameter, enabling the achievement of a stable electric discharge dressing condition. The wire drive system adjusts and maintains a constant wire feed speed, provides constant wire tension and is responsible for supplying and disposing the wire electrode. It is located on the vertical stage of the two axis NC-controlled positioning device and is basically composed of one DC servo motor and a permanent magnetic hysteresis clutch. Different torques can be precisely adjusted and constant wire tension can be generated by keeping the clutch torque constant. Figure 3 shows a diamond grinding wheel being WED-dressed by the above described WED-dressing device.

Figure 3: On-machine wire electrical discharge dressing

Results

Wire electrical discharge dressing (WEDD) enables the generation of higher grain protrusion on metal bonded diamond wheels. The grinding wheel is thus more aggressive, which is an important characteristic in such a tool. With a more open structure, less friction between bond and workpiece is likely to happen, which directly impacts the amount of heat generation during grinding. It also influences the cooling and lubricating efficiency, since more grinding fluid can be transported to the grinding zone. Furthermore, since more chip pockets are available, tool load is also less likely to occur. Lower grinding forces were achieved when using WED-dressed wheels in comparison to SiC-dressed wheels. Grinding wheel wear was also affected by the type of dressing method. Less wheel wear was measured using WED-dressed grinding wheels. The use of grinding oil for both grinding and erosion processes proved to be suitable. Erosion material removal rates up to 100 mm³/min were achieved using this dielectric (Blasogring HC5), allowing the dressing process to be carried out within a reduced time. This is an important criterion for making WEDD feasible to be economically carried out inside the grinding machine. Better dressing accuracy was achieved when smaller dressing depth of cuts were applied and constant axial wire feed speed was used. On-machine wire electrical discharge dressing using free stretched wires is not suitable. Poor dressing accuracy and low dressing material removal rates were achieved with this method. The free stretched wire can easily be deviated during dressing either by the cutting fluid/dielectric or by the air barrier which is formed around the grinding wheel. A special wire guide was designed and integrated on the WED-device, improving dressing performance.

Based on the results achieved so far, it can be stated that on-machine WEDD is suitable, flexible, effective and reliable, ensuring a significant improvement on the dressability of metal bonded diamond wheels. Finally, Figure 4 shows two different grinding wheel profiles, generated by WEDD.

Figure 4: WED-dressed diamond grinding wheels

Status

The project was reviewed and approved by the Innovation Promotion Agency (CTI), under the designation “KTI 11992.1PFIW-IW”, and has formally started on November 2010.

Partners

Studer: Grinding Machine, Thun/Switzerland
Agie: EDM, Losone/Switzerland
Blaser: Fluids, Hasle-Rüegsau/Switzerland
Diametal: Grinding Tools, Biel/Switzerland
CeramTec: Ceramics, Plochingen/Deutschland

Contacts

Eduardo Weingärtner
IWF Institut für Werkzeugmaschinen und Fertigung
ETH Zürich
CLA Tannenstrasse 3
CH-8092 Zürich
Tel +41 44 632 04 95
Fax +41 44 632 11 25
E-Mail weingaertner@iwf.mavt.ethz.ch

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