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Laser Touch Dressing Of Electroplated CBN Grinding Tools

J. Pfaff[a]*, M.Warhanek[a], S. Huber[b], T. Komischke[a], F. Hänni[c], K.Wegener[a,b]

[a] Institue of Machine Tools and Manufacturing (IWF)-ETH Zurich, Leonhardstrasse 21, 8092 Zurich, Switzerland
[b] inspire AG, Technoparkstrasse 1, 8005 Zurich, Switzerland
[c] Reishauer AG, Industriestrasse 36, 8304 Wallisellen, Switzerland

* Corresponding author. Tel.: +41-(0)44-633-6254; fax: +41-(0)44-633-1492. *E-mail address:* pfaff@iwf.mavt.ethz.ch

Abstract

In this paper, an alternative process for dressing electroplated cBN grinding wheels using an ultrashort pulsed laser is presented. Other than abrasive grains dressed conventionally, laser touch dressed cBN grains exhibit cutting edges that have partially defined geometric elements with a positive clearance angle. Grinding experiments, including long-term tests, are performed on hardened steel, for a comparative study on the performances of laser dressed and conventionally dressed tools. While the processing forces are slightly higher for the laser touch dressed tools, the roughness of the ground surface is improved.

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Keywords: cBN; Laser; Dressing; Grinding

1. Introduction

Single layer electroplated cBN grinding wheels are increasingly put to use by reason of their high wear resistance, grit protrusion and large chip accommodation volume [1]. Due to uneven grain shapes and protrusion, electroplated wheels have a high surface roughness, which is detrimental to the surface quality and precision of the workpiece. The roughness of the tool can be improved by removing the tips of over-protruding grains in a touch dressing process [2], [3].
In this work, a laser touch dressing (LTD) process for single layer cBN grinding wheels, producing a clearance angle on the cut grains is presented. The surface characteristics and grinding performances of the tools are analyzed.

2. State of research

Nowadays, dressing processes encompass not only mechanical processes but also thermal, chemical or a combination of the aforementioned [4]. Laser has been increasingly used for the preparation of superabrasive (cBN or diamond) grinding wheels and especially for sharpening, since Westkämper [5] first reported on the dressing of a grinding wheel by laser. It has been shown that by creatively using short and ultra-short pulsed lasers, ordered structures ablated in superabrasive material influence the grinding characteristics. Walter et al. [6] studied the influence on the grinding performance and tool wear of various micro patterns generated by laser ablation, on the surface of hybrid bonded CBN grinding pins. Butler Smith et al. [7], [8] presented a laser ablation process to create abrasive structures with defined cutting geometries in thick-film CVD diamond. These structures proved to outperform conventional diamond electroplated abrasive elements, when grinding a Ti-6Al-4V alloy, resulting in a better surface finish of the workpiece.

The positive influence of a clearance angle on the cutting efficiency of abrasive grains [9] can the exploited by the laser machining of the abrasive grains on electroplated grinding tools. Dold [10] detailed a sequential laser process where the electroplated diamond grinding wheel is first dressed to the

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desired grain protrusion, before clearance and rake faces are generated on the diamond grains. The dressing forces of such wheels were found to be significantly lower compared to conventional tools. Warhanek et al. [11] demonstrated that the LTD process itself induces positive clearance on D 426 diamond grains which leads to an important reduction of processing forces compared to conventionally dressed tools when grinding vitrified corundum samples. In this paper the authors investigate the application of the aforementioned LTD process on CBN wheels for grinding hardened steel.

3. Experimental setup

3.1. Laser touch dressing

The LTD process is applied to single layer electroplated cBN grinding wheels. The tools' specifications are listed in Table 1. For the LTD of the grinding wheels, a modified Laser Line from EWAG AG is used. The Laser Line is a compact, high-precision machine tool with an 8- axes kinematic, as illustrated in Figure 1. A solid state ultrashort pulsed laser with a pulse width $\tau_p < 12$ ps, a central wavelength $\lambda = 1064$ nm, a maximum output power of 35 W and a frequency range from 200 kHz to 8.2 MHz is used as beam source. Retardation plates placed in the laser path ensure a circular polarization. A focus shifting unit expands the raw beam before its entry into the scanner and can be used for shifting the position of the focal point along the W- axis. The scanner enables the deflection of the laser beam with a speed of up to 2000 mm/s in the working plane along the U- and V- axes aligned parallel to the X- and Y- axes. An F-Theta lens with a focal length 163 mm focusses the beam to a focal spot of 28 µm.

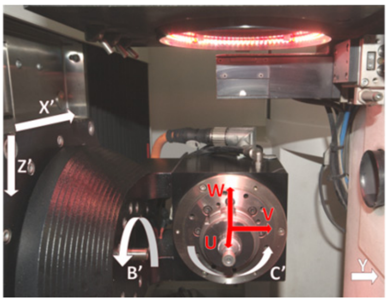

Figure 1: The Laser Line machine tool. The arrows represent schematically the 5 mechanical axes (white) and 3 optical axes (red)

The workpiece is positioned via 4 mechanical axes (X', Z', C', B'), while the Y- axis positions the scanner and is used for the radial infeed during the touch dressing process. For the LTD process, the tool is clamped on the C- axis, which is positioned parallel to the X- axis of the machine. The laser beam is deflected by the scanner in a repetitive linear motion parallel to the axis of the grinding tool. The scanner, and thus the hatch, is positioned along the Y- axis to touch the grinding tool tangentially to a set infeed. By a complete rotation of the C- axis in counter direction, the whole circumference of the tool is laser touch-dressed, ensuring that all grains are cut. The LTD parameters are summed up in Table 1. In this setup, the laser touch dressing process is completed in 22 seconds.

Table 1: specification of the grinding wheels and laser dressing parameters

Grinding wheel specifications		**LTD parameters**	
Wheel diameter	12.25 mm	Average power	29.4 W
Wheel width	10 mm	Pulse frequency	300 kHz
Grain type	ABN 300	Scanning speed	2000 mm/s
Grit size	D 251	Rotation speed	1000 °/min

3.2. Grinding experiments

The LTD tools are compared to conventionally dressed tools in a series of up-cut surface grinding experiments on hardened steel type 100Cr6 with a hardness of 60±1 HRC. The conventional dressing of the tools is done by Reishauer AG using their state of the art production process. Based on the setup used in [12], the grinding experiments are done on a modified Mikron HSM 400U five axes milling machine with a high-speed Fischer MFM-10120/11 spindle. Grinding oil, Blasogrind HC 5, at a flow rate of approximatively 50 l/min is used as coolant. Two sets of experiments are performed. The processing forces are compared for a variation of grinding parameters. This variation is done after machining a volume of 500 mm^3/mm. The long-term behavior of the tool is studied by measurements at regular intervals throughout the lifetime of the tool, up to 5000 mm^3/mm. The machining parameters are listed in Table 2.

Table 2: Machining parameters

Parameter	**Variation tests**	**Long term tests**
Feed rate, v_f [mm/min]	[1000-4000]	1000
Cutting speed [m/s]	60	60
Depth of cut, a_e [mm]	[0.025-0.1]	0.05
Width of cut, a_p [mm]	5	5

3.3. Measurements and analysis

After dressing, the tools are analyzed using SEM and optical microscopy. Raman-spectroscopy measurements are carried out on three different cBN grains processed by laser to assess the thermal damage, using a WiTec CRM 200 confocal Raman microscope with x100 magnification and a CW laser source with λ=532 nm wavelength. Grinding forces are measured on the samples, mounted on a Kistler 9256C three-axis multi-component dynamometer. Each processing force is averaged over five measurements. The effect of coolant flow is compensated. During the long term experiments, at set intervals of material removal, processing forces, as well as roughness profiles of the workpiece are measured. The roughness is measured on an Alicona Infinite Focus 3D optical microscope. Each roughness value, filtered with a cutoff length of λ_c=800 µm, is averaged over three measurements of 50 profiles each, taken along the width of cut. The abrasive covering of the tool is measured using an Alicona Infinite Focus equipped with a Real 3D rotation unit. The whole circumference of each tool is measured, over a