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Publication Date:
2014

Permanent Link:
https://doi.org/10.3929/ethz-a-010277425

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A laser micro texturing technique for performance enhancement of superabrasive grinding wheels

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Keywords: grinding, laser surface texturing, ultrashort pulse ablation

Abstract
Grinding is still the process of choice when workpiece quality requirements demand high accuracy, narrow tolerances and good surface finish. Due to increasing productivity requirements in the industrial environment of high value-added manufacturing and the widespread use of advanced materials considered as difficult-to-machine, superabrasive (diamond, cubic boron nitride) grinding wheels, enabling higher cutting velocity and material removal rate, are often chosen over conventional ones. In this work an experimental setup and a laser processing strategy for texturing of grinding tool surfaces are presented. It is demonstrated that the method can be utilised to produce user-defined micro patterns on superabrasive grinding wheel surfaces. Grinding test results indicate that machining forces and thus thermal impacts on the workpiece surface can be considerably reduced with textured wheels.

1 Motivation
Utilisation of superabrasive grit materials (diamond and CBN) in combination with high strength matrix structures such as traditional metal bonds or novel hybrid bond systems [1] allows for fabrication of tools with superior grinding performance and profile holding capability. However, the introduction of these bond structures usually results in poor dressability of the corresponding tools by conventional means, which is a major limiting factor regarding their industrial application. Thus, considerable research efforts are undertaken in order to identify and develop suitable alternative conditioning methods e.g. based on electro discharge machining (EDM), laser processing and surface structuring [2]. Recently, conditioning of hybrid bonded CBN grinding tools by surface structuring, utilising ultrashort pulsed laser ablation has been proposed [3]. The present paper describes the corresponding laser texturing
method, its application for generating different tool surface patterns and grinding test results.

2 Laser texturing method

The experimental setup consists of an X-Y-Z stage, a rotary axis and a X-Y galvanometer-driven laser scanhead (Figure 1, left). In order to minimise thermal impact on the abrasive layer and enable high texturing accuracy, a solid state picosecond laser system (\(\lambda = 1064\) nm, \(t_p = 10\) ps) is utilised for these experiments. The desired surface pattern is sub-divided into equal segments, whereby the size of the segments is determined by the pattern pitch, tools diameter and the maximum tolerable focus offset in one processing step (Figure 1, right). The tool surface is processed segment by segment through a sequential operation of scanhead and rotary axis. In principle, by this method any regular pattern or texture on the surface can be produced.

![Figure 1: Experimental setup for tool texturing and schematic of the segmental laser processing strategy.](image)

3 Laser textured tools and grinding test

The laser process is applied to texture a set of small (\(d_s = 15\) mm) hybrid bonded CBN tools with different surface patterns. Figure 2 provides an overview of the produced surface patterns A to E. Before the texturing the tools are dressed by means of a SiC wheel. All patterns are designed to yield a nominal active tool surface area of approx. 62%. The generated grooves have a depth of 50 \(\mu\)m and a width of 120 \(\mu\)m at an angle of \(\pm 30^\circ\) to the tool axis. The grooves of pattern E are slightly wider (140 \(\mu\)m), asymmetric (cf. Figure 2) and oriented parallel to the tool axis, resulting in
an intermitted cutting characteristic of this tool surface. SEM micro analysis and micro-Raman spectroscopy show resonably good quality of the fabricated structures and no indication of significant thermal deterioration of the tool surface or crystallographic transformation of the CBN grits into hexagonal BN.

Figure 2: SEM micrographs of different laser textured tool surfaces and details of structured grooves

Face grinding tests of hardened steel are carried out to assess the grinding performance of the structured tools in comparison to a non-structured tool. Texturing can significantly reduce grinding forces, whereby it is found that the pattern geometry has a major influence on the forces and the resulting workpiece roughness. Figure 3 displays corresponding measurement results, showing up to 35% lower forces (pattern B) for textured tools. However, higher workpiece roughness has to be taken into account when forces are reduced (increase of $R_a$, $R_z$ by 15% to 80%). Given the fact that the textured wheels all have about the same nominal active surface area, the
considerable differences in grinding characteristics suggest that the pattern geometry has a significant influence on chip formation process on the tool surface and hence provides a possibility to optimise the grinding characteristics. First wear studies show generally a comparatively low average radial wear for all tested tools (< 3 µm at $V'_w = 10200 \text{ mm}^3/\text{mm}$). For tools C and E a radial wear of ~ 1.4 µm was measured, which is similar to the reference tool (~ 1.2 µm), while tools A, B and D revealed slightly higher values (up to 2.9 µm). However, due to the low values a sound comparison of tool performance based on these wear measurements is difficult.

Figure 3: Grinding test with textured wheels - results

4 Conclusions and Outlook
The capability of pulsed laser ablation processing for structuring of tool surfaces has been demonstrated by fabrication and test of several demonstrator tools. Grinding results show a considerable influence of the surface textures on the grinding results and the possibility to significantly reduce forces at higher MRR. Future studies are intended to address optimisation of the surface textures regarding grinding performance, workpiece surface integrity/finish and tool wear.

References: