Conditioning of Hard Tools by Ultra Short Pulsed Lasers

EPMT – Genève 2013

C. Dold, Chr. Walter, G. Eberle, U. Maradia, J. Stirnimann
Topics

- Laser touching of dressing wheels
- Laser machining of PCD-tools
- Laser ablation of diamonds
- Laser conditioning of grinding wheels
- Laser structuring of cutting inserts
- Laser process simulation
- Conclusions
Comparison of conventional- & laser-dressing process:

- **Conventional grinding machining:**
  - Machining sequence: Dressing tool → dressing wheel → grinding wheel
  - Diamond to diamond machining
  - Material removal by micro cracks and grain break out

- **Laser machining:**
  - Machining sequence: Laser beam → dressing wheel → grinding wheel
  - Laser beam tangential to the dressing wheel
  - Diamond grains are precisely cut (no cracking!)
  - Goals:
    - Adjusting a defined contact area → cutting of grain tips
    - Machining of a defined topography on the outer surface
    - Remove negative flank angles from the grain
Laser touching of dressing wheels

Evaluation of touch dressed wheels:

- Cylinder roll / material:
  - Industry diamond Type IIa
  - Grain size D181
  - Nickel bonded

- Tangential laser machining:
  - Cutting of the grain protrusion
  - The bonding layer is not touched
  - Used wavelength: $\lambda = 343, 1030$ nm

- Dressing of a grinding wheel:
  - Grinding machine: Studer S31
  - Dressing a SiC-grinding wheel
  - Force measurements by a rotating Dynamometer
Laser touching of dressing wheels

Results of the evaluation:

- Selective machining of the area:
  - Problem-free machining by laser
  - All grains are machined with positive flank angle & without micro cracks
  - Process speed > 2 – 5 x higher than conventional dressing
  - No thermal nor mechanical damage of bonding layer

- Analysis of surface roughness:
  - Laser machined dressing tools shows slightly better results

- Process forces:
  - Tangential forces: Laser < Mechanical dressing
  - Normal forces: Laser << Mechanical dressing
Laser machining of PCD-tools

- High performance tools often shielded / coated by PCD, CVD, cBN

- Advantages of laser machining of PCD tools & inserts:
  - Individual adaptation to defined process → unlimited variety
  - Cutting geometry in 2D & 3D possible
  - Complex chip surface & chip breaking area in 3D-machining
  - Mostly single stage process compared to conventional process

- Sequence of laser machining an insert:
  1. Removing of overlaying contour
  2. Machining of the cutting edge geometry:
     - Flank face
     - Rounding of the cutting edge
  3. Machining of optional geometry elements:
     - Rake face
     - Chip breaker
     - Chamfer radius
Laser machining of PCD-tools

Validation & comparison of laser- & conventional-machined PCD tools:

- Comparison of grinded & lasered inserts
- Validation by means of turning CRP material with 3 different fiber orientations
- Evaluating of:
  - cutting forces
  - cutting edges
  - machining time
Laser machining of PCD-tools

Results of the validation:

- **New grinded cutting edges:**
  - Grain breakout → size of ½ grain

- **New lasered cutting edges:**
  - No grain breakout
  - Good chipping of the cutting edge

- **Worn cutting edges:**
  - Similar for grinded & lasered inserts:
    - Flank-wear land width
    - Wear behavior
    - At a cutting depth of 1 grain size → identical wear

- Identical machining time for grinding and lasering an insert
Laser ablation of diamonds

Enabling advanced functionalities of Diamond and other ultra-hard materials by Integrated Pulsed Laser Ablation Technologies

www.fp7-diplat.eu

Coordinator contact: Christian Walter
walter@iwf.mavt.ethz.ch

FP7-2012-NMP-ICT-FoF
FoF.NMP.2012-7 - New technologies for casting, material removing and forming processes
Laser conditioning of grinding wheels

- **Goal:** Generate a cBN grinding wheel topography by laser machining

**Principle:**
- Laser conditioning
- Sharpening
- Profiling

**Laser source:**
- Short puls fiber laser: Rofin Lasag QFS 50
- $P = 50 \text{ W}, \tau_P = 150 – 200 \text{ ns}$
- $e_P = 1 \text{ mJ} @ 50 \text{ Hz}$

**Cutting head:**
- Fixed focal length with process gas
- $f = 150 \text{ mm}, dfoc = 50 \mu\text{m}$
- Process gas: Pressured air (5 bar)
Example: Laser conditioning of a cBN grinding pin

Tool geometry:

Tool & Workpiece after machining:

Details of the lasered tool:
Radius < 20 µm
Radius 1 mm
Laser conditioning of grinding wheels

Results of laser conditioning process:

- Tangential- and normal forces (F_t, F_n)
  - Clearly lower compared to conventional process
  - Identical difference to conventional force curves even at high material removal rates
  - Slightly higher wear due to higher grain protrusion

- Stable grinding conditions after run in
- Compact surface due to tangential profiling
- No grain damage in consequence of laser machining
Laser structuring of cutting inserts

- **Goal:** Minimizing of chip friction on cutting inserts
  - Wear reduction
  - Better chip flow
  - Better surface quality

- **Task:** Structuring of the chip surface to build lubricant pockets
Laser structuring of cutting inserts

**Laser machine TRUMPF VC5**
- **Hardware specification**
  - $\lambda$: 355 nm
  - Laser type: Nd: YVO4
  - $f$: 160 mm
  - Focus dia.: $\sim$25 $\mu$m
- **Software**
  - Marking software
  - CAD editor
  - Laser parameter administration

**Optical measurement**
- Alicona Infinite focus

**Tasks for structuring optimisation**
- Focal plane and beam diameter:
  - Ellipticity
  - Energy density
- Optimization of laser parameters:
  - Power
  - Velocity
  - Frequency
  - Pulse width and number of pulses
  - Internal laser parameter
  - Precision
  - Hatching
- Multiple marking and controlling depth
- Change of optics
Laser structuring of cutting inserts

Results of cutting experiments:
- Relation between fill density, pattern structure & friction coefficient

![Image of 3D bar chart showing the relation between fill density, pattern structure, and friction coefficient. The chart compares different patterns labeled A, B, C, D, E, AC, BC, and N. The x-axis represents fill density percentage, the y-axis represents pattern structure, and the z-axis represents friction coefficient μ. The chart includes images of the pattern structures for each label.](image-url)
Simulation of USP-Laser Processes

Pulse time dependent ablation characteristic:

Two-temperature modell

Classical heat conduction equation

Simulation result of a 10 ps-laser process:
Conclusions

- Conclusions for laser ultra short pulse machining of ultra hard surfaces:
  - The process is convenient for grain and insert geometries
  - Smallest cutting edge radii accessible:
    - Single grain type IIa \( r_K > 4 \, \mu m \)
    - PCD, CVD-D \( r_K > 2 \, \mu m \)
  - Surface roughness \( Ra < 0.2 \, \mu m \)
  - No thermal damage of the machined material \( \rightarrow \) best cutting edge quality

- Trends for laser process development:
  - From tool inserts to highly complex 3D geometries
  - Laser beam guidance:
    - Higher scanning velocities
    - Accuracy of tool center point (TCP)
    - Synchronisation (time) with CNC axes
Thanks to …

Many thanks to …

… for supporting us!
Thank you for your attention!