Electro-Contact-Discharge-Dressing for a more flexible use of circular saw blades

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Antalya, October 23rd, 2014
Cut-off grinding strongly depends on adequate tool, process and work piece parameters.

Cut-off grinding requires precise adaptation of stone and tool properties as well as cutting parameters.

Insufficient adaptation leads to loss of process stability and quality due to insufficient self-sharpening effect.

Additional dressing process could compensate self-sharpening insufficiencies and increase process-flexibility.
Self-sharpening effect – Adaptation of segment design to specific natural stone properties

Segment design for soft stone

- Grain protrusion = const.
- Grain wear
- Constant bonding wear
- Outer diameter before grinding
- Hard bonding

Change to hard stone

- Significant decrease of grain protrusion
- Increased grain wear (mechanically)
- Bonding wear insufficient

Segment design for hard stone

- Grain protrusion = const.
- Grain wear (splittered and flattened)
- Constant bonding wear
- Soft bonding

Change to soft stone

- Grain protrusion gains accelerated
- Strong grain wear (flattened and broken out)
- Bonding wear strongly heightened
- Soft bonding

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Bonding characteristics and consequences for flexibility-enhancement in cut-off grinding

<table>
<thead>
<tr>
<th></th>
<th>Segment design for soft stone</th>
<th>Segment design for hard stone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Grit retention force</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Wear</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Ability to set back</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

For hard stone machining with harder bonding insufficient self-sharpening effect has to be compensated

Additional dressing process is required

Harder bonding specification advantageous for serial machining of soft and hard stone
Electro contact discharge dressing (ECDD) – First experiments for application in cut-off grinding

a) chip formation and field distortion

b) arc-over resulting of field distortion

c) chip evaporation

d) removing the bonding material

High power regulated power supply:
- Limitation of current
- Regulation of voltage
- DC-isolated

Tool:
- \( d_S = 115 \text{ mm} \)
- \( w_{\text{Seg}} = 2 \text{ mm} \)
- \( d_g = 301 \text{ \( \mu \)m} \)
- Bonding: Co, Cu, Fe

Dressing:
- Electrode: Graphite
- \( U_{\text{ds0}} = 10 - 60 \text{ V} \)
- \( I_{\text{ds0}} = 1 - 3 \text{ A} \)
- \( v_c = 30 \text{ m/s} \)
- \( v_{\text{fads}} = 0.83 - 3.33 \text{ \( \mu \)m/s} \)
New ECDD device for application in stone bridge saw

**View a):**
Tool housing with ECDD-devices

- Infeed device in housing mounted on carrier plate
- Carbon brush
- Copper flange
- Electrode holder
- Graphite electrode
- Inductive distance sensors for axial vibration measurement
- Spindle

**View b):**
With mounted cutting disc

- Rotating direction

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New ECDD device on stone bridge saw – Operation test

Tool:
\[ d_S = 1000 \text{ mm} \]
\[ w_S = 5.0 \text{ mm} \]
\[ w_{\text{Seg}} = 7.0 \text{ mm} \]
\[ d_g = 301 - 601 \mu \text{m} \]
Bonding: Co, Cu, Fe

Dressing:
Electrode: Graphite
\[ U_{\text{ds0}} = 60 \text{ V} \]
\[ I_{\text{ds0}} = 3 \text{ A} \]
\[ v_c = 30 \text{ m/s} \]
\[ v_{\text{fads}} = 16.6 \mu \text{m/s} \]

Coolant:
None
Natural stone work pieces and cut-off grinding tools for experimental investigations

<table>
<thead>
<tr>
<th>Work piece specifications</th>
<th>Tool specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Granite Rosa Sardo</strong></td>
<td><strong>Tool A</strong></td>
</tr>
<tr>
<td>Material removal rate $Q'_w$ [cm$^2$/min]</td>
<td>400</td>
</tr>
<tr>
<td>Depth of cut $a_e$ [mm]</td>
<td>10</td>
</tr>
<tr>
<td>Feed velocity $v_{ft}$ [m/min]</td>
<td>4</td>
</tr>
<tr>
<td>Cutting speed $v_c$ [m/s]</td>
<td>30</td>
</tr>
<tr>
<td><strong>Sandstone Seeberger</strong></td>
<td><strong>Segment</strong></td>
</tr>
<tr>
<td>Bonding Met. composition</td>
<td>FeCo</td>
</tr>
<tr>
<td>HRC</td>
<td>35 - 40</td>
</tr>
<tr>
<td>Diamond</td>
<td>30 - 50 Mesh</td>
</tr>
</tbody>
</table>
Influence of bonding specification and electrode feed rate $v_{fads}$ on arc-over frequency

Hardness of FeCo without significant influence on arc-over frequency

Highest arc-over frequency for highly-conductive CuSn
Influence of bonding specification on process forces for ECDD-supported machining of granite

Largest effect of ECDD on highly-conductive CuSn-bonding with typical, stationary process force level
Influence of ECDD on the radial wear of different bonding specifications

- Generally higher radial wear with ECDD
- Generally lower radial wear on Sandstone

**Granite**

- Tool A
- Tool B
- Tool C

**Sandstone**

- Tool A
- Tool B
- Tool C

**Tool A, B, C:**
- $d_s = 1000 \text{ mm}$
- $b_s = 5 \text{ mm}$
- $b_{Seg} = 7 \text{ mm}$
- $n_{Seg} = 70$
- Bonding: var.
- Hardness: var.
- Diamond: 30/50 Mesh

**Dressing:**
- Electrode: Graphite
- $U_{ds0} = 90 \text{ V}$
- $I_{ds0} = 25 \text{ A}$
- $v_{fads} = 16 \mu\text{m/s}$

**Parameter:**
- Granite:
  - $v_c = 30 \text{ m/s}$
  - $v_{ft} = 4 \text{ m/min}$
  - $a_e = 10 \text{ mm}$
- Sandstone:
  - $v_c = 40 \text{ m/s}$
  - $v_{ft} = 2 \text{ m/min}$
  - $a_e = 150 \text{ mm}$

**Work piece:**
- var.

**Cooling:**
- water
## Conclusions on bonding characteristics

<table>
<thead>
<tr>
<th></th>
<th>Tool A</th>
<th>Tool B</th>
<th>Tool C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>medium hard FeCo bonding</td>
<td>hard FeCo bonding</td>
<td>medium hard SnCu bonding</td>
</tr>
<tr>
<td>Applicability for hard stone</td>
<td>o/+</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Applicability for soft stone</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Erodable with ECDD</td>
<td>o</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Process stabilization by ECDD</td>
<td>o/+</td>
<td>o</td>
<td>+</td>
</tr>
<tr>
<td>Wear in granite with ECDD</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Wear in sandstone with ECDD</td>
<td>o</td>
<td>o</td>
<td>-</td>
</tr>
</tbody>
</table>

Best compromise for ECDD-supported serial cut-off grinding of granite and sandstone offers medium-hard CuSn-bonding.
Summary

- Cut-off grinding lacks flexibility due to material-related self-sharpening behavior of the tool
- New ECDD device was developed and implemented in cut-off grinding process
- Significance of dressing variables was evaluated, best dressing parameters were identified
- New segment compositions were investigated, best universal segment design for serial machining of hard and soft stone was identified

Experimental investigations proof: New ECDD dressing strategy capable of flexibility-enhancement in serial cut-off grinding of different natural stone materials
Acknowledgement

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Enhancement of the flexibility and process stability of diamond coated cutting disks for the machining of natural stone and concrete

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