Material Removal Simulation of Cut-Off Grinding Processes for an Adapted Tool Design

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Introduction – Computing Grain Pattern

Motivation:

Increase of productivity and tool life of cut-off grinding tools by means of material removal simulation of deterministic grain pattern

Approach:

Process model → Material removal simulation → Tool optimization

Calculation of different process parameters (e.g. forces) according to process models found by single bead scratch tests

Simulation of cutting conditions between cutting bead and work piece

Tool optimization by determining grain patterns
Introduction – Why use grain pattern? I

- Adapted bonding system can improve material removal and tool life
- Grid pattern lead to further improvement
## Introduction – Why use grain pattern? II

<table>
<thead>
<tr>
<th>Grinding layer with stochastic diamond distribution</th>
<th>Fracturing by mech. overloads because of too large grain distances and resulting ( h_{cu} )</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
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<tr>
<th>Geometrically defined grain distances</th>
<th>Wear by flattening and fracturing</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
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</tbody>
</table>

- Even bonding removal
- Envelope before grinding

\( h_{cu} \)
Cut-off Grinding with Wire Cutting Tools
### Geometrical parameters for the description of deterministic grain patterns

**Cutting bead:**

- **a**: distance between grains in circumferential direction
- **b**: distance between grains in axial direction
- **d**: diameter of the cutting bead
- **d<sub>g</sub>**: grain size
- **l<sub>gb</sub>**: displacement of grains
- **l<sub>s</sub>**: length of the cutting bead
- **m**: number of grains in axial direction
- **p**: number of grains in circumferential direction
Material Removal Simulation of Wire Cutting Beads

Calculation of removed material volume
Calculation of process forces
Calculation of single grain load
Simulation Results

Simulation parameter:
- Cutting speed: \( v_c = 20 \text{ m/s} \)
- Infeed speed: \( v_{ft} = 8 \text{ mm/min} \)
Cut-off Grinding with Circular Saws
Cut-off Grinding with Circular Saws

Parameter:

- **a, b, l_{gb}, m and p** equal to wire cutting bead

- **c** - distance between grains in radial direction
- **l_{ca}** - displacement of grains in radial direction
- **l_{cb}** - displacement of layers in radial direction
- **o** - number of grains in radial direction
- **d_{wz}** - tool diameter
- **l_{sg}** - segment length
- **b_{sg}** - segment width
- **h_{sg}** - segment height

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Page 10
Simulation of Cut-off Grinding Segments

- Simulation of different grain alignments possible
- Colouring of active grains
- Simulation of grain brake out

![Diagram of Workpiece and Tool in side and top views]
Influence of Grain Pattern on Radial Wear

Parameter:
- $v_c = 30 \text{ m/s}$
- $v_{ft} = 1.33 \text{ m/min}$
- $a_e = 30 \text{ mm}$
- $d_{wz} = 1000 \text{ mm}$
- $n_{seg} = 70$
- $b_{sg} = 7 \text{ mm}$

Coolant - water
Work material - granite

Specification:
- Tool 1 - $a = 3 \text{ mm}$
  - $b = 0.7 \text{ mm}$
  - $c = 1.15 \text{ mm}$
  - no displacement
- Tool 1, stoch.
  - stochastically grain distribution,
  - $n_{\text{grain}} = n_{\text{grain, Tool1}}$
- Tool 2 - $a = 1.5 \text{ mm}$
  - $b = 0.7 \text{ mm}$
  - $c = 1.15 \text{ mm}$
  - $l_{ca} = 0.55 \text{ mm}$
- Tool 2, stoch.
  - stochastically grain distribution,
  - $n_{\text{grain}} = n_{\text{grain, Tool2}}$
Influence of Grain Pattern on Process Forces

**Specification:**
- **Tool 1 -**
  - \( a = 3 \text{ mm} \)
  - \( b = 0.7 \text{ mm} \)
  - \( c = 1.15 \text{ mm} \)
  - no displacement
  - stochastically grain distribution, \( n_{\text{grain}} = n_{\text{grain}, \text{Tool1}} \)
- **Tool 2 -**
  - \( a = 1.5 \text{ mm} \)
  - \( b = 0.7 \text{ mm} \)
  - \( c = 1.15 \text{ mm} \)
  - \( l_{\text{ca}} = 0.55 \text{ mm} \)
  - stochastically grain distribution, \( n_{\text{grain}} = n_{\text{grain}, \text{Tool2}} \)

**Parameter:**
- \( v_c = 30 \text{ m/s} \)
- \( v_{\text{ft}} = 1.33 \text{ m/min} \)
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coolant - water
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Summary

Wire Cutting
- Grain pattern can increase removed material volume of cut-off grinding tools.
- Space between diamond grains in circumference and axial direction, combined with a displacement of the grains leads to the highest material removal.

Cut-off Grinding with Circular Saws
- Radial grain distance influences the wear behaviour of the cutting segments.
- Grain pattern can reduce process forces compared to stochastically grain distributions.
Acknowledgement

The results for the **wire cutting tools** were achieved in the project DE 447/82-1 “*Tool design for wire cutting tools for metal cutting by means of simulation*”.

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