The Importance of Cutting Edge Preparation
Edge Rounding and Polishing of Cutting Tools
Contents:

- Aim and advantages of cutting tool preparation
- OTEC’s solutions for cutting tool preparation.
- Advantages of polishing cutting tools
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- Advantages of edge rounding at drills
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- Influence of tool preparation on chip removal volume
- Influence of several radiuses at the cutting edge
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Aim of cutting edge preparation

- Removal of micro defects
  - Less micro chipping, less jaggedness, removal of burs, surface structure improvements...
- Modification of the cutting edge in terms of micro geometry
  - Stabilization of the cutting edge, improvement of friction coefficient due to improvement of the surface structure
  - Control of the chip formation and chip flow ...
  - Control of the k-factor
- Quality characteristics for subsequent processes
  - Gives better bonding for coatings
  - Surface treatment (Droplets removal)

Tip of an end mill before and after edge preparation with a drag finishing process.
Material: Tungsten Carbide
Advantages for the tool-user

- Better surfaces of the work piece
- Higher processing parameters (feed rates, speed, chipping volume)
- Extended tool life

Tip of an end mill before and after edge preparation with a drag finishing process.
Material: Tungsten Carbide
What is drag- and stream-finishing and what can it do for your tools

- Drag finishing is a reliable and reproducible method of rounding the edges with
- Simultaneous smoothing of chip flute and cutting edge, giving better chip removal, better bonding of coating and higher service life
- Affordable process, since operating costs and capital investment are low
- Can also be used for the removal of droplets after coating
- Rounding values of from appr. 5 µm to 200 µm can be achieved
What is drag- and stream-finishing and what can it do for your tools

- Increase in the service life by a factor of up to 3.5 times (in the case of steel alloys)
- Increase in the maximum feed rates by a factor of 4.5 (comparing rounded, coated, carbide drills with non-rounded, coated carbide drills)
- Low degree of surface roughness of the boreholes (made by edge rounded drills compared with non-rounded ones)
<table>
<thead>
<tr>
<th>Comparision</th>
<th>Drag finishing (DF)</th>
<th>Stream finishing (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement</td>
<td>Interaction of 3 rotations: Rotor, holder, workpiece-selfrotation</td>
<td>• container-rotation</td>
</tr>
<tr>
<td></td>
<td>• workpiece-movement</td>
<td>• workpiece-movement</td>
</tr>
<tr>
<td>Pressure</td>
<td>• immersion-depth</td>
<td>• centrifugal force 10 g</td>
</tr>
<tr>
<td></td>
<td>• acceleration/deceleration depending at the programmed speed</td>
<td>• Immersion-depth</td>
</tr>
<tr>
<td></td>
<td>• V max: appr. 2 m/s</td>
<td>• angle of attack</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• V max: appr. 15 m/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• distance of the container wall and bottom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• dry or wet process</td>
</tr>
</tbody>
</table>
Polishing of uncoated tools

Roughness at the tool before and after polishing
Surface structure before and after polishing
Advantages of a polished tool (Uncoated):

- Improved surface quality due to reduced surface roughness
- Faster chip flow
- Gives better bonding for coatings
- Reduced cutting forces needed
- Reduced tendency to cold welding
- Extended tool life
Coated end mill before and after droplet removal and after polishing
Fig. 1: Sharp tool with coating after the first borehole (Source: Kai Risse)
Fig. 2: Rounded tool with coating after the first borehole (Source: Kai Risse)
Fig. 3: Sharp tool with coating after 150 boreholes (Source: Kai Risse)
Fig. 4: Rounded tool with coating after 150 boreholes (Source: Kai Risse)
Fig. 5: Sharp tool with coating after one borehole with higher feed rate (Source: Kai Risse)
Cutting conditions

<table>
<thead>
<tr>
<th>Material</th>
<th>C45E+N</th>
<th>Cutting speed: 35 m/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting material</td>
<td>HC-K20</td>
<td>Feed rate: 601.7 mm/min</td>
</tr>
<tr>
<td>Tool diameter d:</td>
<td>1 mm</td>
<td>Dry</td>
</tr>
</tbody>
</table>

Fig. 6: Rounded tool with coating after one borehole with higher feed rate (Source: Kai Risse)
Fig. 7: Rounded tool with coating after 300 boreholes with a higher feed rate (Source: Kai Risse)
Advantages of edge rounding at end mills

- Considerable increase in the service life of carbide tools (proven by numerous studies and research projects)
- Carbide end mills: rounding of 8 – 25 µm -> increasing tool life by a factor of 2 – 3 (e.g. when machining C 45)
- Increase in tool life by factors as high as 4 – 5 in the case of high alloy steels

Therefore:
A rounding of 12 – 25 µm at the cutting edges can solve 90% of all tool life problems. At the same time, a much better bonding is achieved for PVD coating.
Influence of the Edge Preparation on Tool Life
at High Performance Torus End Mill in HIGH ALLOYED Steel

Material: 1.2379 - X15CrVMo12-1
End mill: nACRo coated - d=10mm, z=4, ae=0.25 x d – ap=1.5 x d – vc=150 m/min – fz=0.05 mm/z

Source: Platit
Even when machining aluminum alloys, an edge rounding of 8 – 10 µm can be an advantage

- It takes the sharpness off the cutting edge
- It prevents so-called chatter marks
- The milling machine runs much more quietly

Carbide end mill with a cutting edge rounding of approx. 15 µm; finished in OTEC Drag Finishing machine
How much edge rounding is required for carbide drills?

- For steel alloys, the rule of thumb is:
  - 4 µm x diameter of the drill
  - For a carbide drill with a diameter of 10 mm, this means an edge rounding of approx. 40 µm (according to Kai Risse)
- For steel casting alloys, the rule of thumb is:
  - 5 µm x diameter of the drill
  - For aluminum alloys, the following value can be assumed:
    - 2 µm x diameter
- For the edge rounding of carbide drills, it is important to ensure that the cutting edge corner is not rounded significantly more than the cutting edge.
- In order to prevent tapered drill holes, both cutting edges must be rounded equally.
Recommended rounding values for end mills

- For end mills, the following edge rounding values are recommended:
  - Wood processing: 6-8 µm
  - Aluminum alloys: 8-10 µm
  - Steel, high alloyed steels, heavy finishing: 12-25 µm
  - Titanium nickel alloys: 30-40 µm

- As a rule, we can say:
  - If the cutting edge of an end mill is rounded by 10-25 µm an increase in tool life of 3-4 times can be achieved.
Surfaces Before and After Edge Honing
Milling

- Influence of rounding of the cutting edges and polishing of the coating on chip removal volume

=> Very significant increase of chip removal volume (more than 7 times higher) due to rounding of the cutting edge and polishing of the coating in comparison of not processed tools.

Tool: DHC Inox end mill
2. Projektreffen

16. Februar 2010
Mapal Dr. Kress KG, Aalen

Komplettpräparation von komple xen Zerspanungswerkzeugen

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Prof. Dr.-Ing. B. Denkena
Institut für Fertigungstechnik und Werkzeugmaschinen, Leibniz Universität Hannover
The tools have been edge honed and several radiuses have been created:

- No radius
- 40µm radius
- 30µm radius
- 20µm radius
- 15µm radius

Influence of the edge radius to the tool wear/ amount of removed material – 42CrMo4
The tools have been edge honed and several radiuses have been created:

After the radius is more than 10µm, the surface gets better. This means that a tool needs to be processed at least some time to improve also the surface quality.

Influence of the edge radius to the roughness Rz – 42CrMo4
The tools have been edge honed and several radiuses have been created:

- No radius
- 40µm radius
- 35µm radius
- 25µm radius
- 20µm radius

Influence of the edge radius to the tool wear/ amount of removed material – Inconel 718
The tools have been edge honed and several radiuses have been created:

No radius
420 cm³
15µm radius
47% more removal capacity, but wear is larger than:
30µm radius
47% more removal capacity – best result

Test to increase the amount of removed material each tool before it wears too much – 42CrMo4
SEM picture of the worn out tool
Conclusion:
- For carbide drills cutting 42CrMo4, a rounding of the cutting edge of 20…25µm leads to a more wear resistant cutting corner and a higher quality of the tool
- Inserts for drill shanks: The inner insert should have a rounding of 15…18µm, the outer insert should have 10…15µm
- Carbide reamers with several flutes should be rounded to 10…20µm for better performance, less wear and better surface quality of the hole.
- Basically you can say, that an adapted shape/form/design of the cutting edges, improves the quality of the tool and its lifetime. The ideal rounding should increase with faster feed rates.
Effects of the cutting edge micro geometry on tool wear and its thermo mechanical load

Prof. B. Denkena, E. Bassett
Garbsen, 09. März 2011
Tendency to crater wear at the rake face at inserts

Versions of edge roundings

100% radius

"Trompet" form radius

"Waterfall" radius

symmetrical

asymmetrical

Tendency to flank wear at inserts

mean size of honed cutting edge

\[ S = \frac{(S_1 + S_2)}{2} \]
Remember:
\[ K = \frac{S_r}{S_a} \]

**Temperature in the tool:**
- \( K=0.5 \) 618°C
- Sharp edge 430°C
- \( K=2 \) 491°C

**Load induced stress in the tool:**
- \( K=0.5 \) 1835 MPa
- Sharp edge 3120 MPa
- \( K=2 \) 2670 MPa

![Simulation der Temperatur und der Lastspannung im Werkzeug](image)
Recommended rounding values for end mills

- The K-factor influences the lifetime of inserts significantly. By choosing the correct K-factor, the lifetime can often be more than doubled!
- The K-factor should be set to a range of 0.5 to 2. So far there is no machine on the market which can do that. At least with inserts, OTEC-SF-machines are able to reach these results
- The K-factor depends on:
  - kind of tool
  - kind of material of the tool
  - discontinuous/continuous cut
- The K-factor has influence on maximum temperature and stress in the tool
- Increasing of the mechanical stability due to well-directed preparation of the cutting edges
- Improvement of the tool’s wear rate
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- IFW – 11: Denkena, Prof. B., Bassett, E., - Einfluss der Schneidkantengeometrie auf die thermo-mechanische Werkzeugbelastung bei der Drehbearbeitung
- Leibniz Universität Hannover, IFW
- Kai Risse
- Fa. Platit
- DFG Deutsche Forschungsgemeinschaft
- Bundesministerium für Forschung und Bildung
- And many others…
Thank you for your attention!