Perfekte Oberflächen. Weltweit.

The Importance of

Cutting Edge Preparation

Edge Rounding and Polishing of Cutting Tools

OTEC Präzisionsfinish GmbH
Dieselstrasse 8-12
75334 Straubenhardt
GERMANY
www.otec.de

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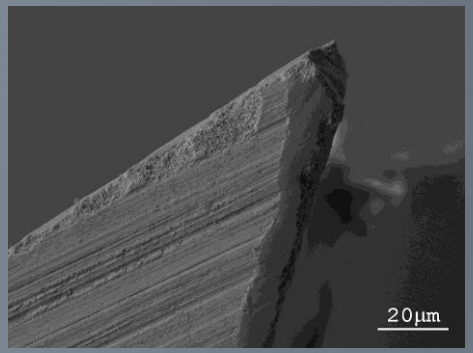
Aim of cutting edge preparation

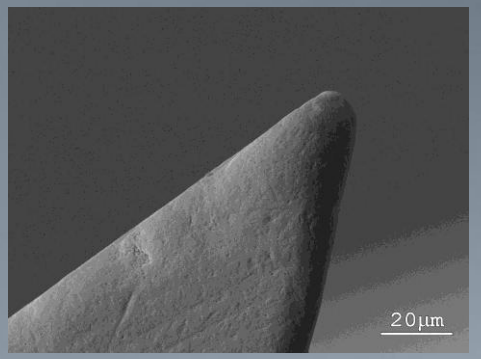


Removal of micro defects

- Less micro chipping, less jaggedness, removal of burs, surface structure improvements...

Modification of the cutting edge in terms of micro geometry

- Stabilisation 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



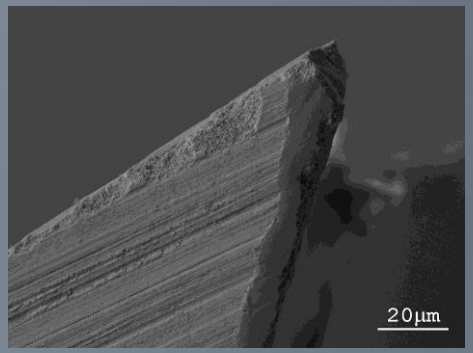
Tip of an end mill before and after edge preparation with a drag finishing process. Material: Tungsten Carbide

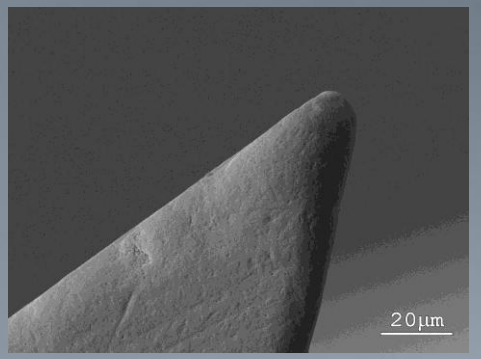
Quality characteristics for subsequent processes

- Gives better bonding for coatings
- Surface treatment (Droplets removal)

Advantages for the tool-user

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





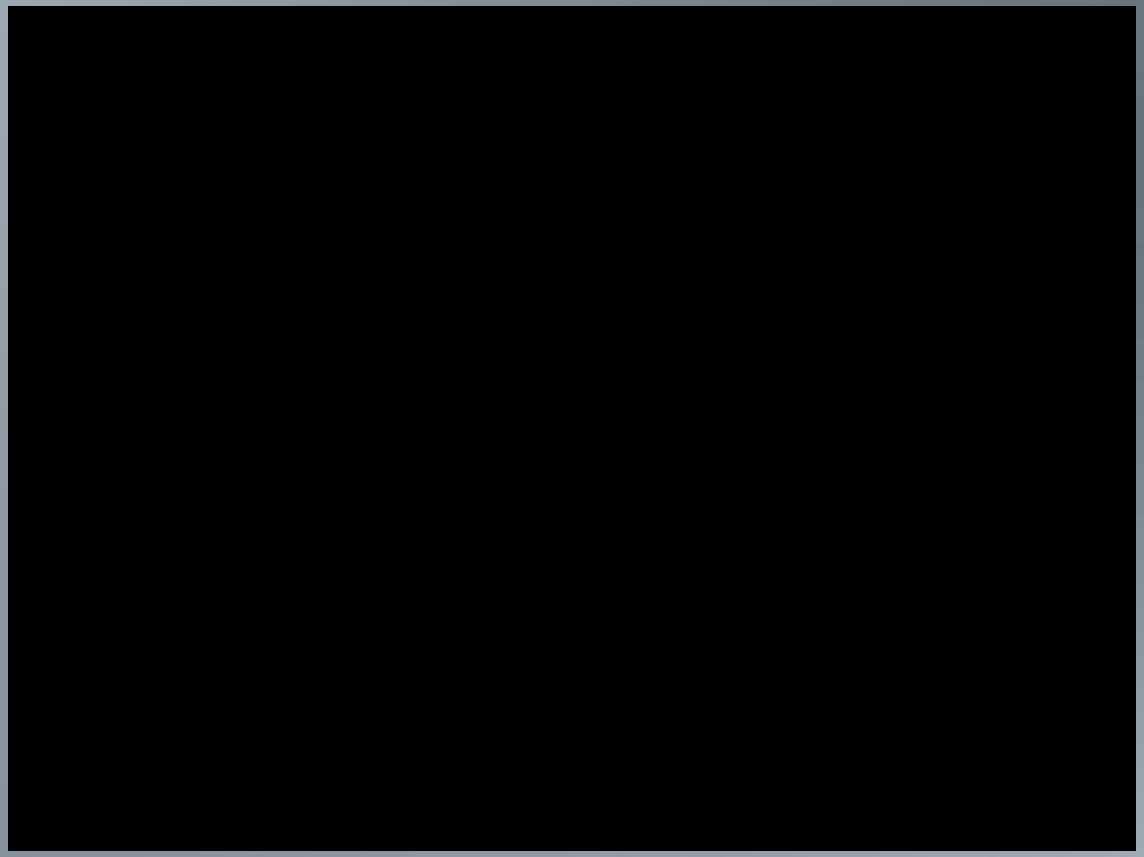
Tip of an end mill before and after edge preparation with a drag finishing process.
Material: Tungsten Carbide

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

- Drag-Grinding or
- Drag-Finishing:

- Charges up to 60 WP‘s
- Process-time: 2 min.
- up to 20 min.



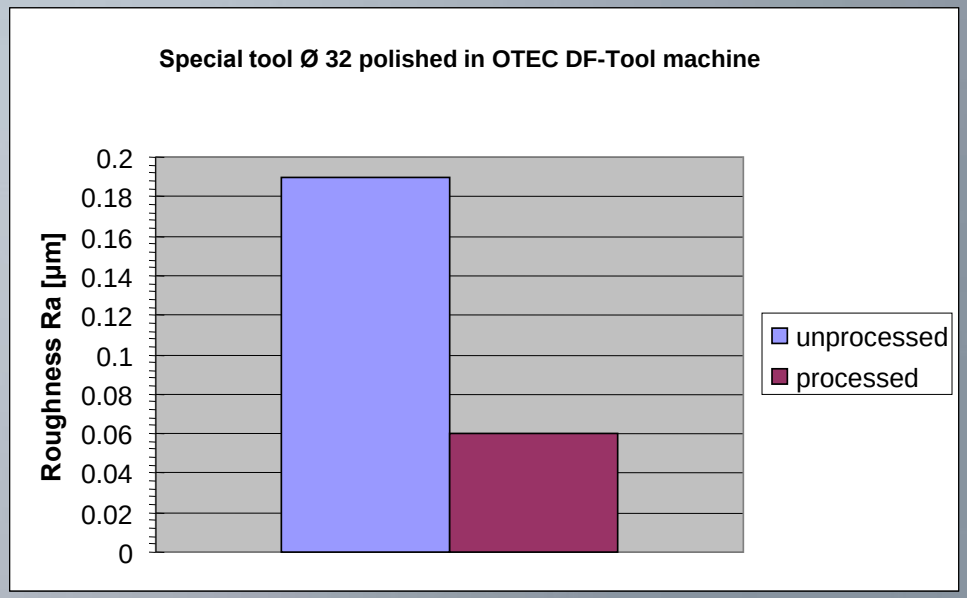
Streamfinishing:

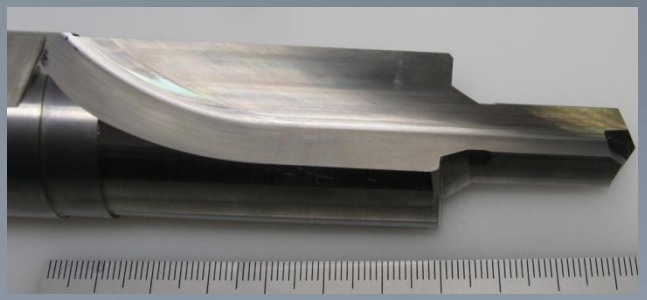
- up to 6 Workpieces
- easily integratable in automatic working lines
- very short running times: 5 sec. up to 2 min.

Comparision: DF/SF

	DF	SF
Movement	Interaction of 3 rotations: Rotor, holder, workpiece-selfrotation	• container-rotation • workpiece-movement
Pressure	• immersion-depth • acceleration/decelacartion depending at the programmend speed • V max: appr. 2 m/s	• fentrifugal force 10 g • Immersion-depth • angle of attack • V max: appr. 15 m/s
	• distance of the container wall and bottom • dry or wet process	

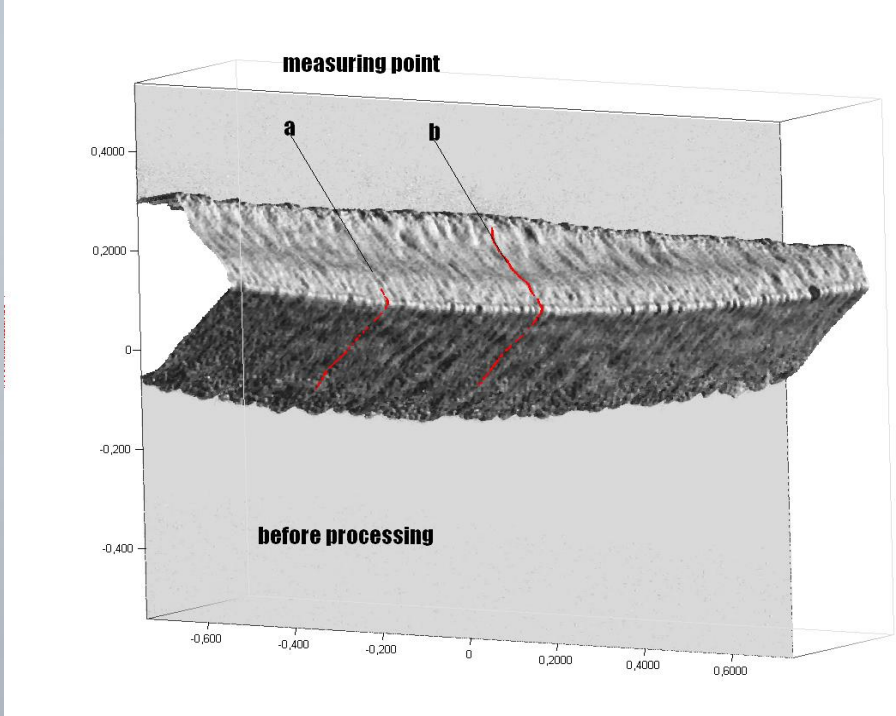
Polishing of uncoated tools

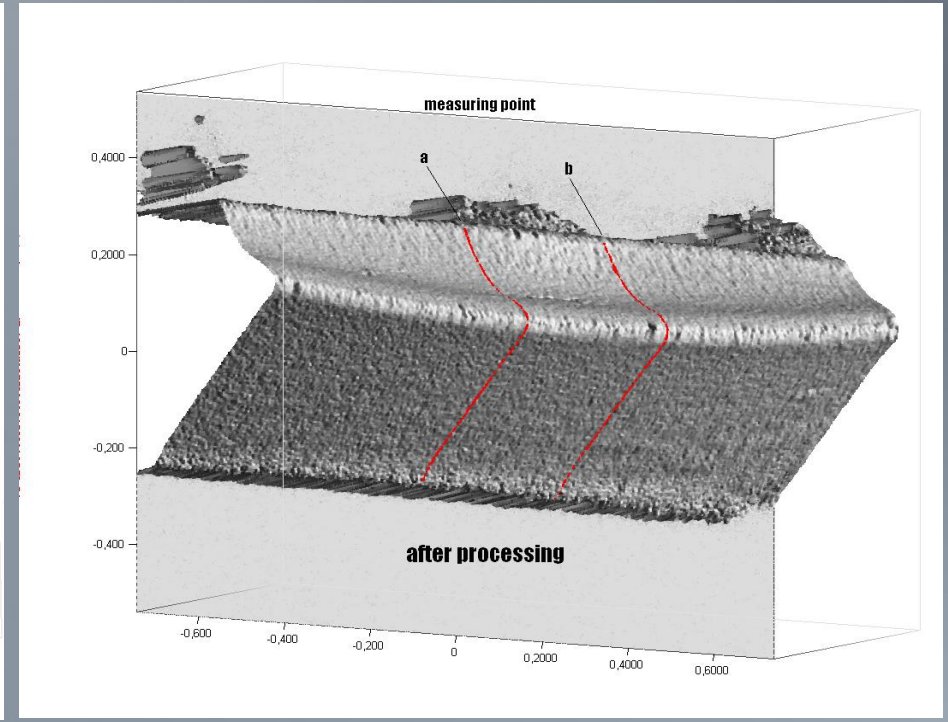




Roughness at the tool before and after polishing

Surface structure before and after polishing

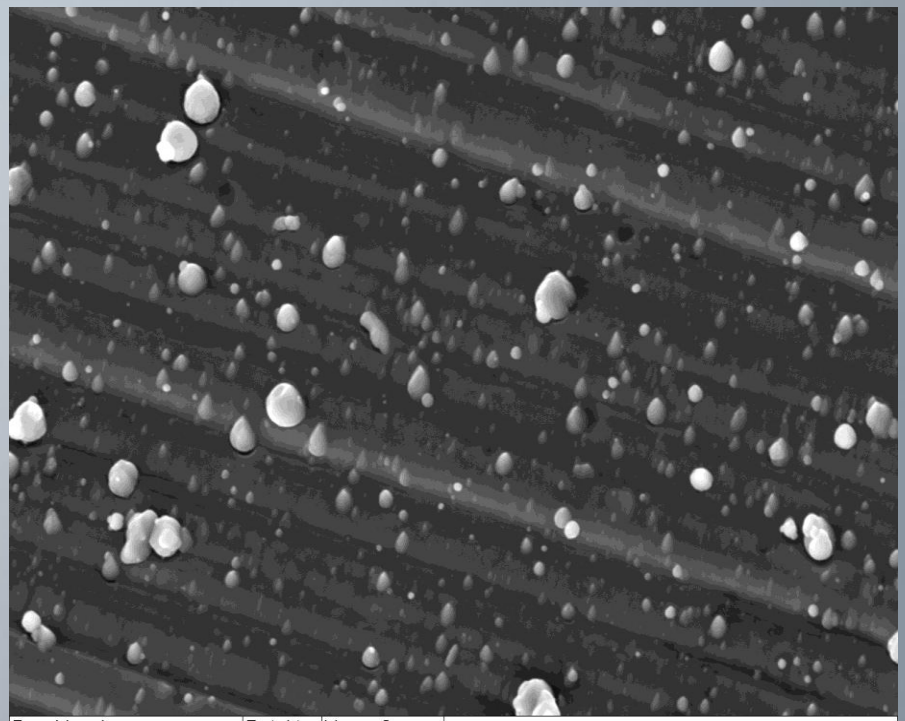


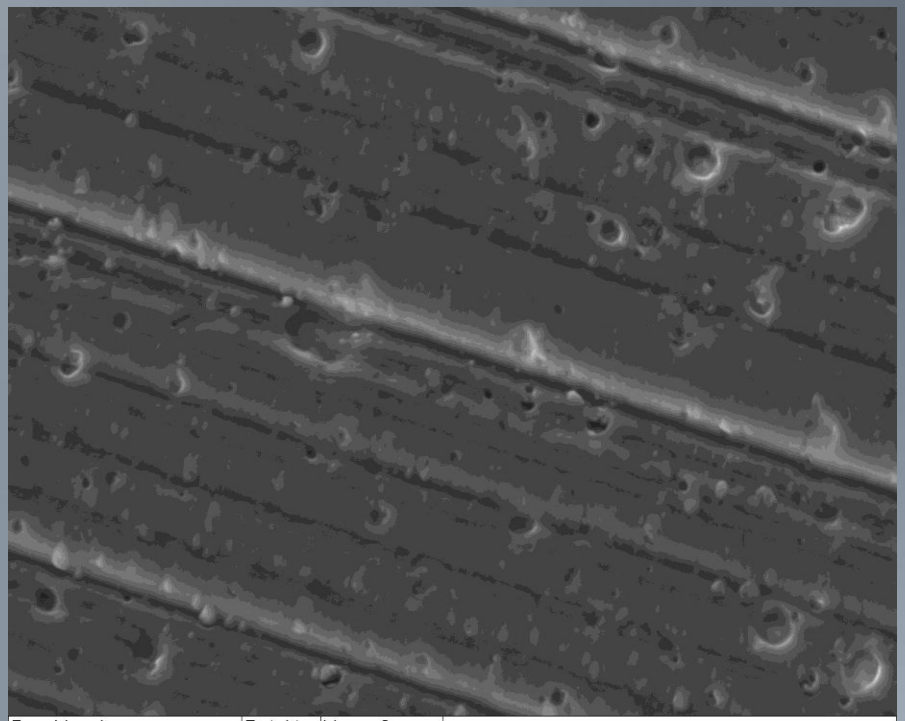


Advantages of a polished tool (Uncoated):

- 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 surface before and after droplet removal

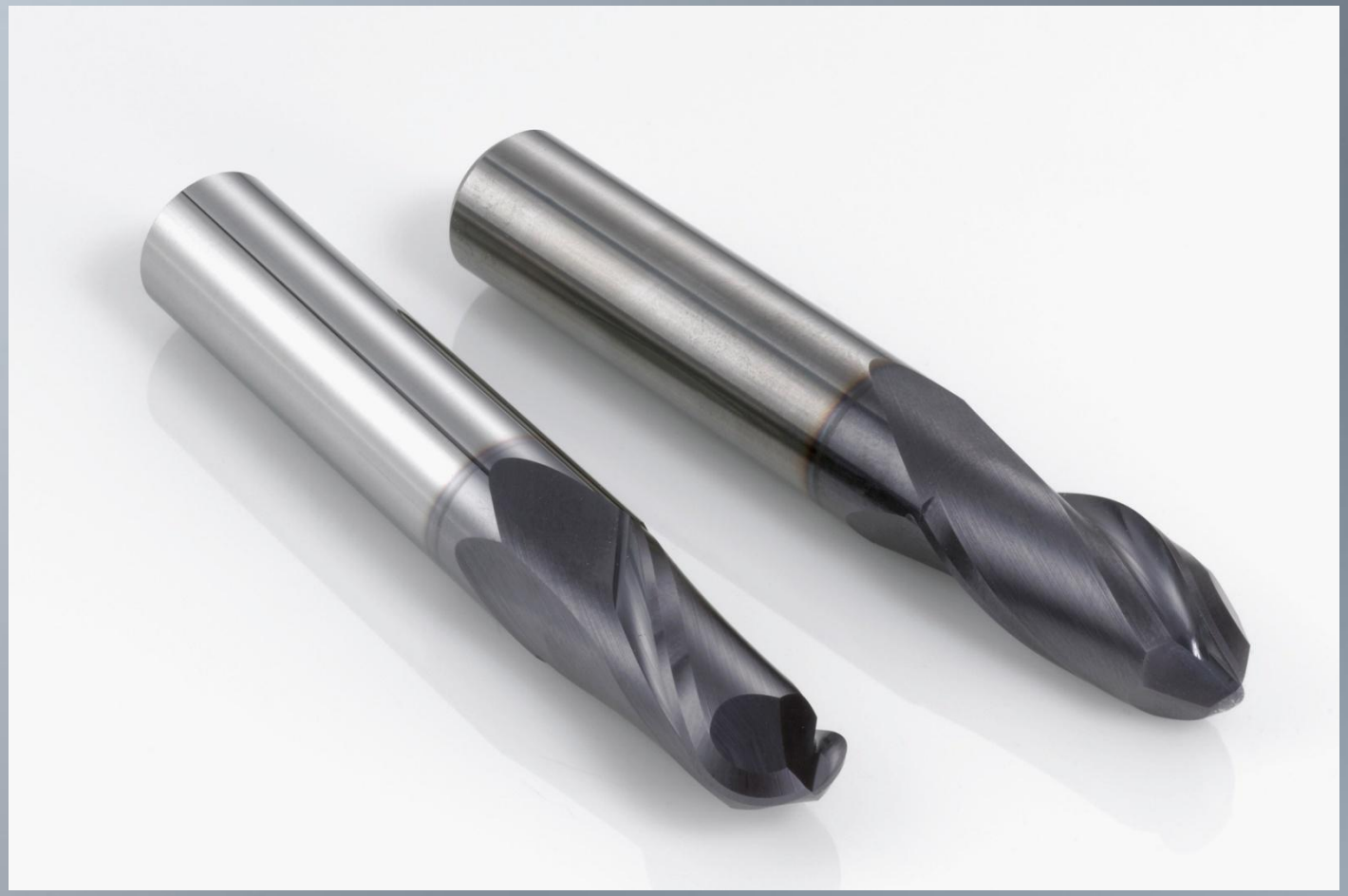




Advantages of droplet removal

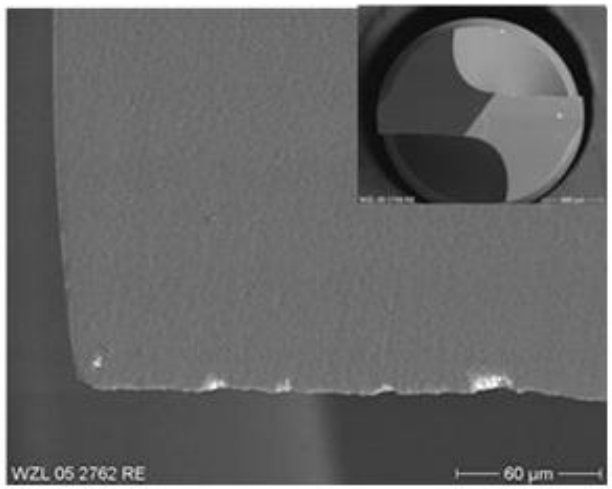
- Improved surface quality
- Reduced roughness
- Improved chip flow
- Reduced cutting forces required
- Microscopic lubricant pockets are created
- Extended tool life

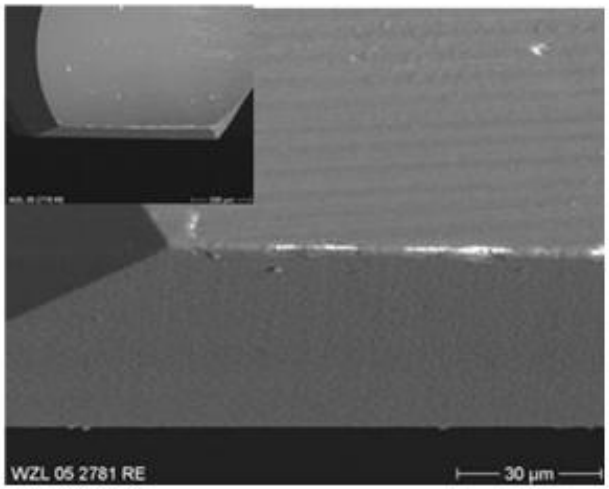
Coated end mill before and after droplet removal



Advantages of edge rounding at drills

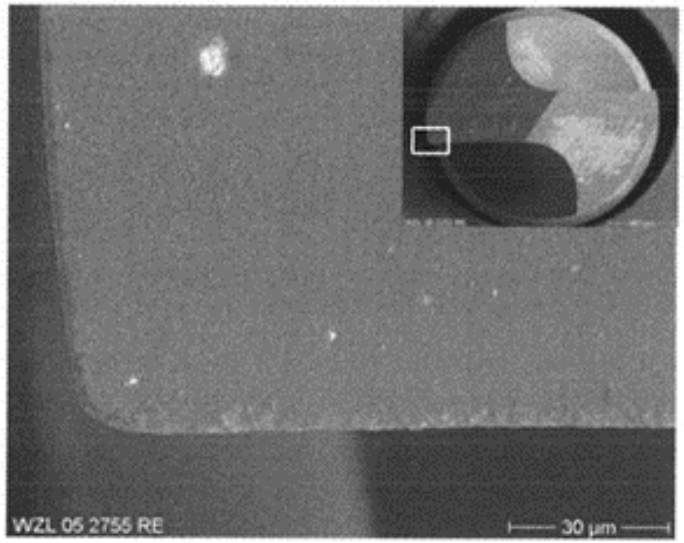
- Increase in the service life by a factor of up to 3.5 times (in the case of steel alloys)
- Increase in the maximum feed rates by a factor of 4.5 (comparing rounded, coated, carbide drills with non-rounded, coated carbide drills)
- Low degree of surface roughness of the boreholes (made by edge rounded drills compared with non-rounded ones).

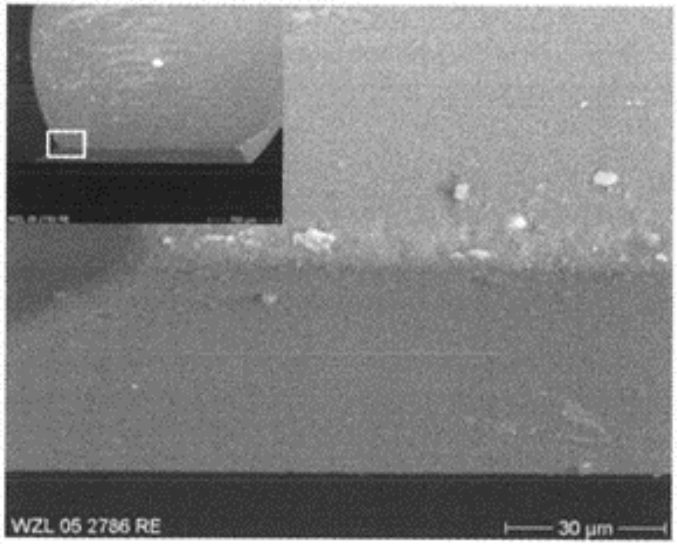




Cutting conditions			
Material:	C45E+N	Cutting speed v_c:	35 m/min
Cutting material:	HC-K20	Feed rate v_f:	133,7 mm/min
Tool diameter d:	1 mm	Dry	

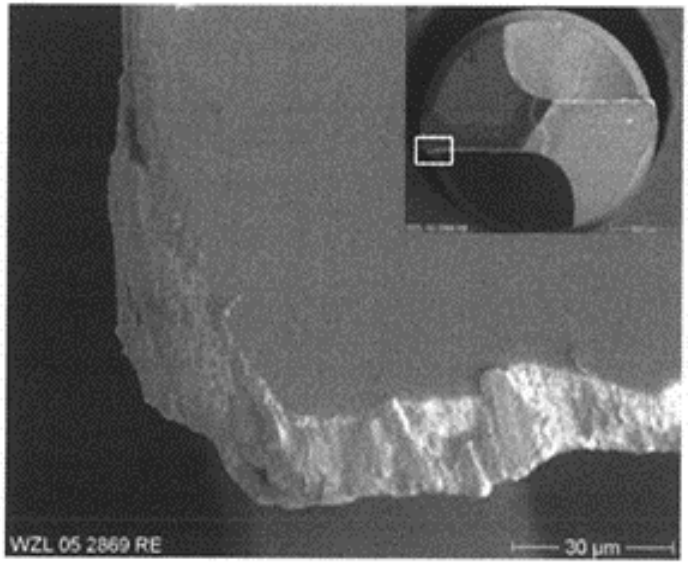
Fig. 1: Sharp tool with coating after the first borehole (Source: Kai Risse)

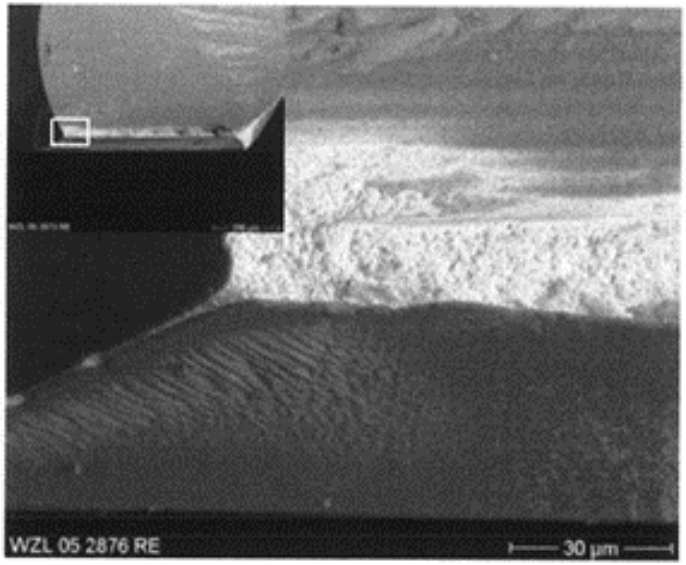




Cutting conditions			
Material:	**C45E+N**	**Cutting speed:**	**35 m/min**
Cutting material:	**HC-K20**	**Feed rate**	**133.7 mm/min**
Tool diameter d:	**1 mm**	**Dry**	

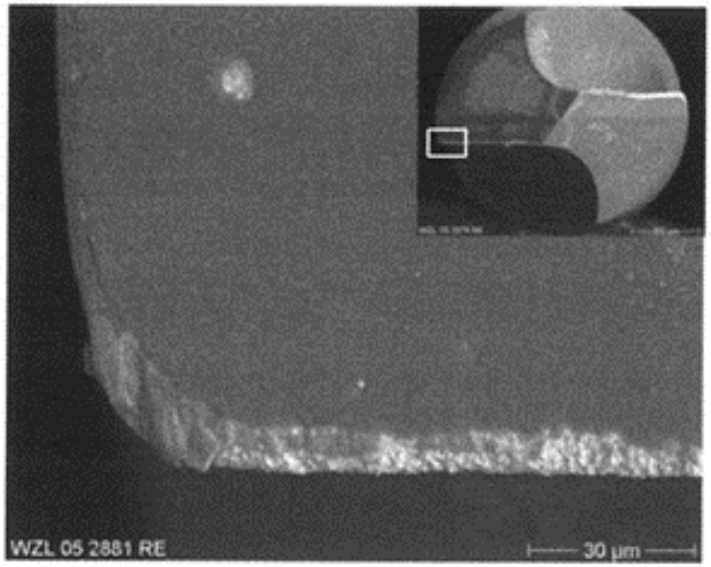
Fig. 2: Rounded tool with coating after the first borehole (Source: Kai Risse)

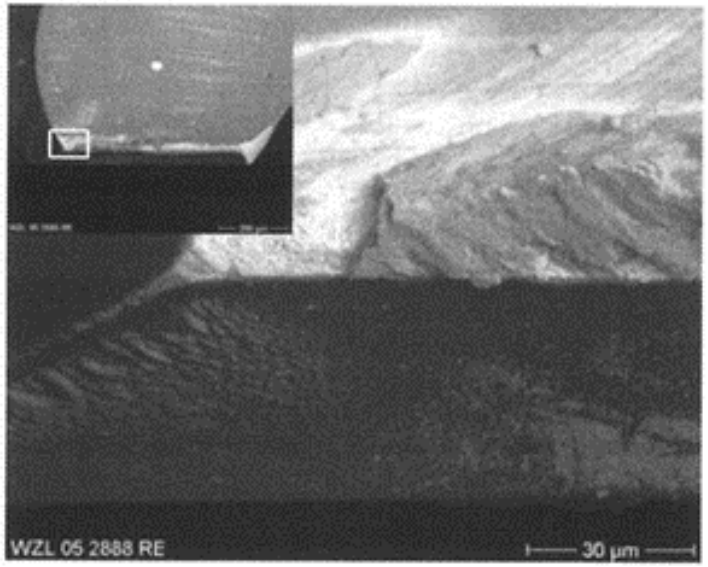




Cutting conditions			
Material:	**C45E+N**	**Cutting speed:**	**35 m/min**
Cutting material:	**HC-K20**	**Feed rate**	**133.7 mm/min**
Tool diameter d:	**1 mm**	**Dry**	

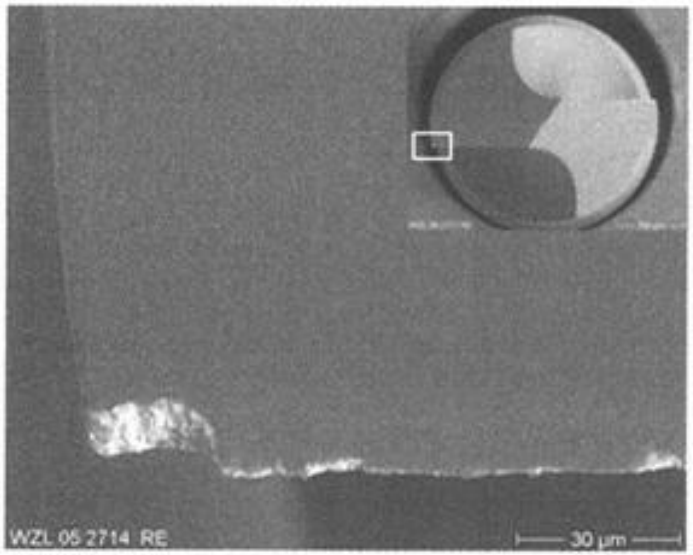
Fig. 3: Sharp tool with coating after 150 boreholes (Source: Kai Risse)

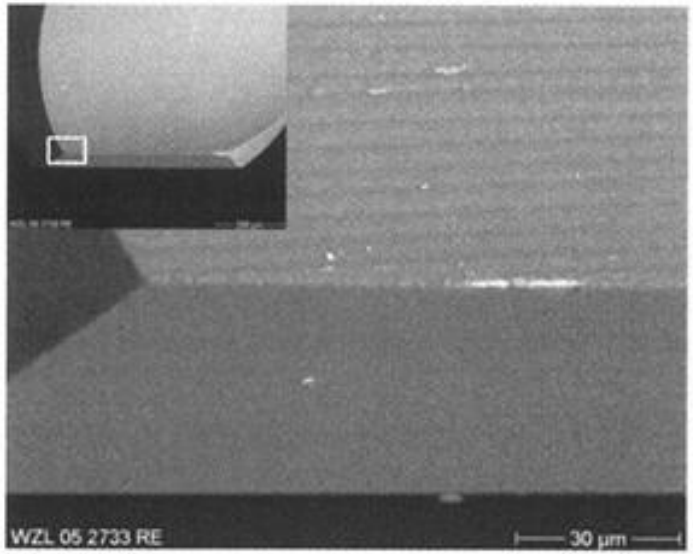




Cutting conditions			
Material:	**C45E+N**	**Cutting speed:**	**35 m/min**
Cutting material:	**HC-K20**	**Feed rate**	**133.7 mm/min**
Tool diameter d:	**1 mm**	**Dry**	

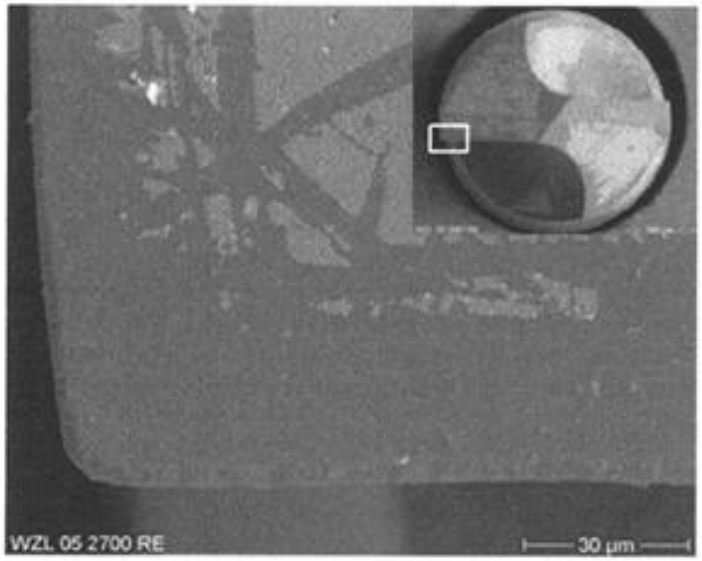
Fig. 4: Rounded tool with coating after 150 boreholes (Source: Kai Risse)

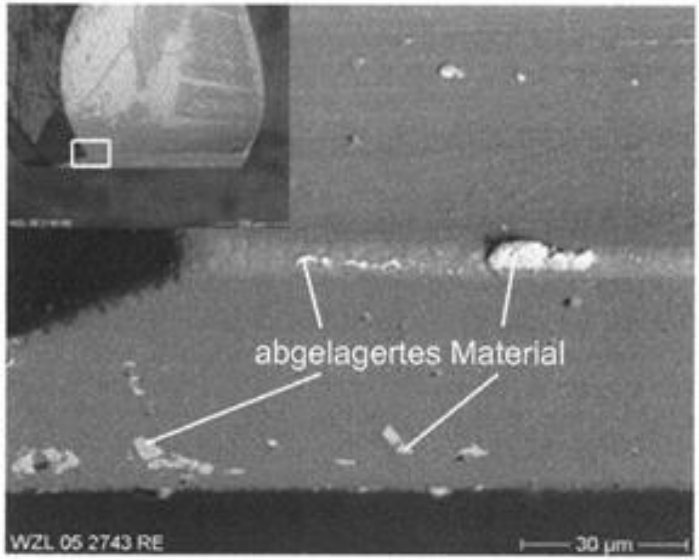




Cutting conditions			
Material:	**C45E+N**	**Cutting speed:**	**35 m/min**
Cutting material:	**HC-K20**	**Feed rate**	**601.7 mm/min**
Tool diameter d:	**1 mm**	**Dry**	

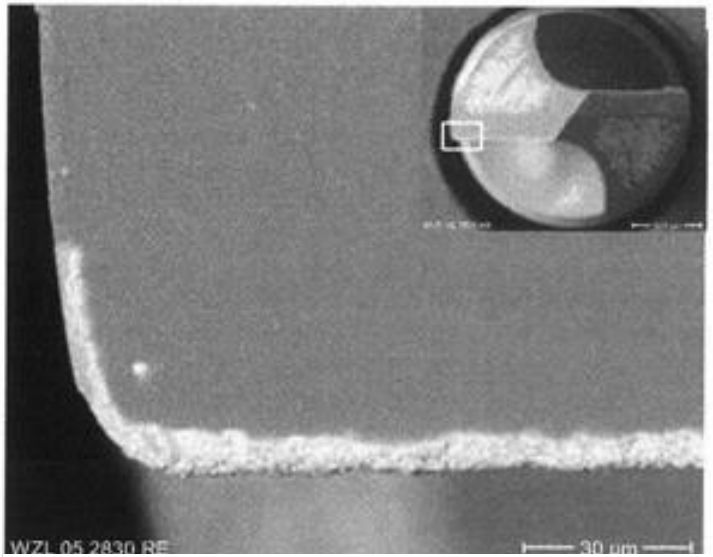
Fig. 5: Sharp tool with coating after one borehole with higher feed rate (Source: Kai Risse)

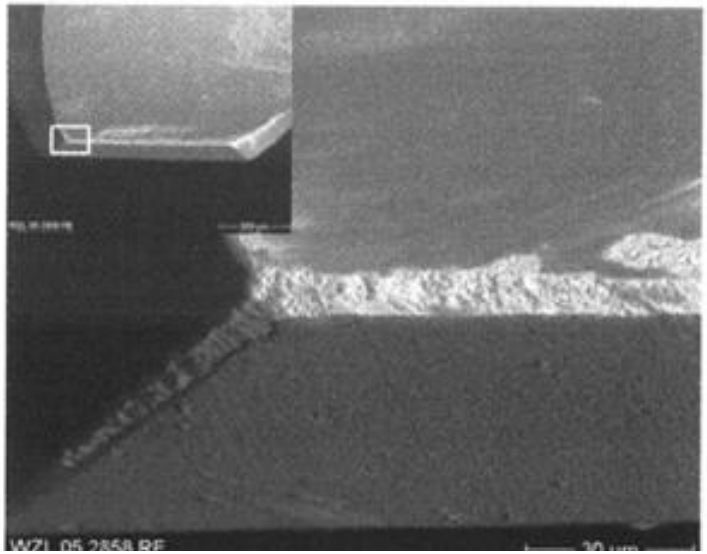




Cutting conditions			
Material:	**C45E+N**	**Cutting speed:**	**35 m/min**
Cutting material:	**HC-K20**	**Feed rate**	**601.7 mm/min**
Tool diameter d:	**1 mm**	**Dry**	

Fig. 6: Rounded tool with coating after one borehole with higher feed rate (Source: Kai Risse)





Cutting conditions			
Material:	**C45E+N**	**Cutting speed:**	**35 m/min**
Cutting material:	**HC-K20**	**Feed rate**	**601.7 mm/min**
Tool diameter d:	**1 mm**	**Dry**	

Fig. 7: Rounded tool with coating after 300 boreholes with a higher feed rate (Source: Kai Risse)

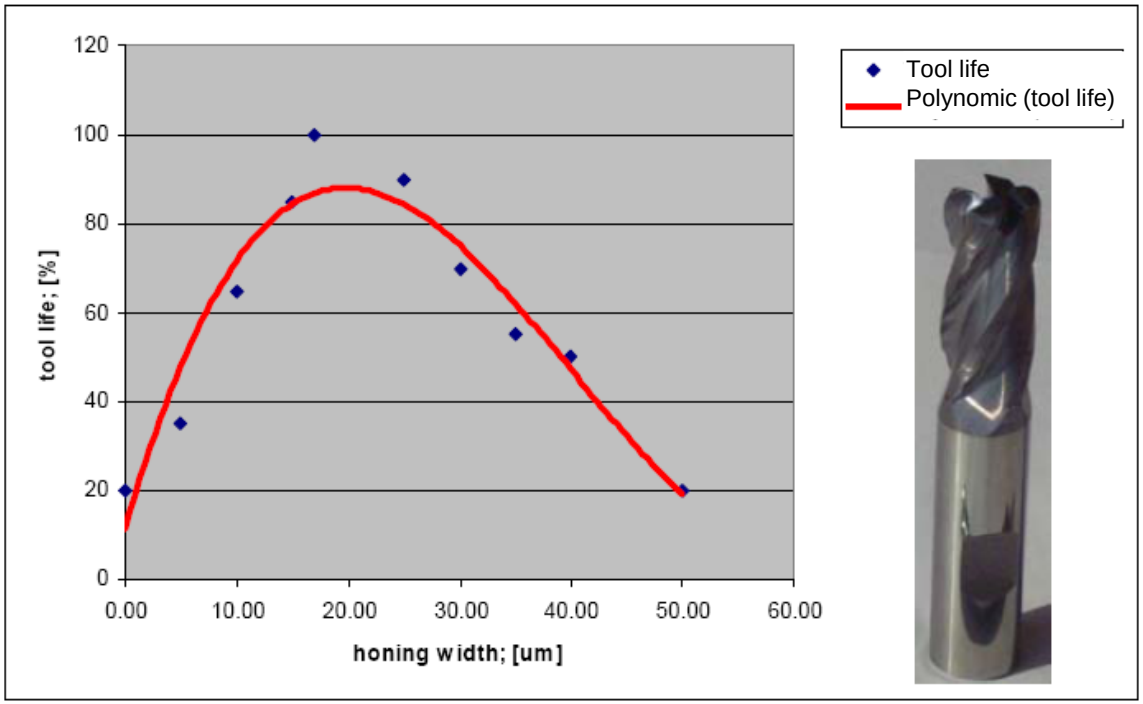
Advantages of edge rounding at end mills

- 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:

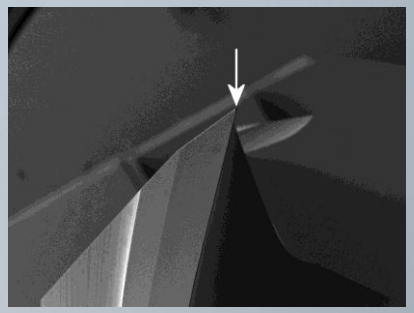
A rounding of 12 – 25 µm at the cutting edges can solve 90% of all tool life problems. At the same time, a much better bonding is achieved for PVD coating.

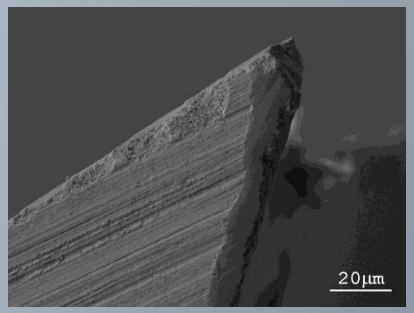
Effect of Edge Preparation on the Tool Life of a Torus End Mill in HIGH ALLOY steel

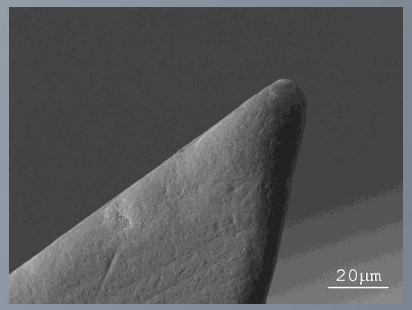


Material: 1.2379 - X155CrVMo12-1
End mill: nACRo coated - d=10mm, z=4, ae=0.25 x d – ap=1.5 x d – vc=150 m/min – fz=0.05 mm/z

Source: Platit







Carbide end mill with a cutting edge rounding of approx. 15 µm; finished in OTEC Drag Finishing machine

Even when machining aluminium 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.

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 aluminium 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.

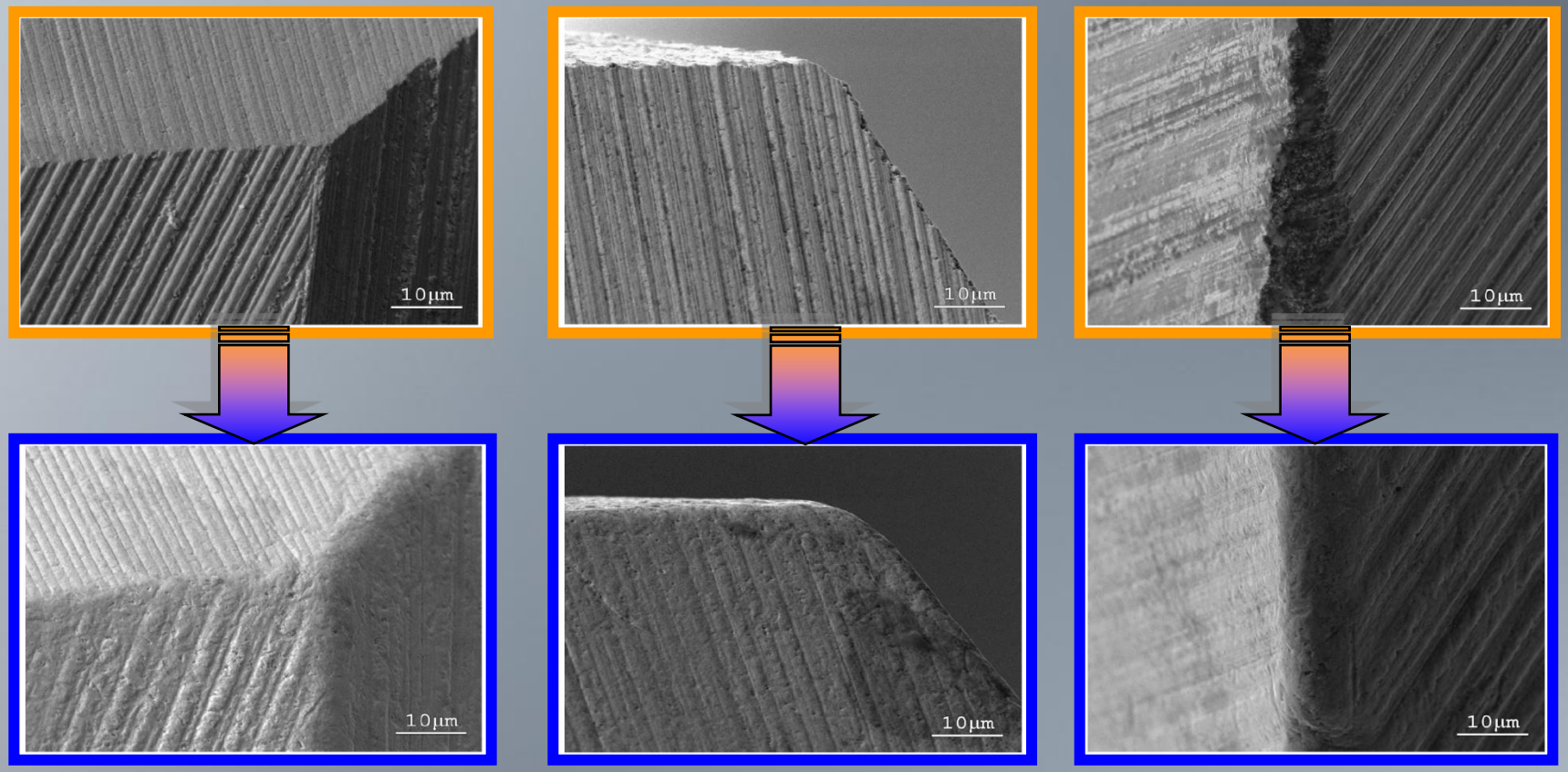
Recommended rounding values for end mills

For end mills, the following edge rounding values are recommended:

- Wood processing: 6-8 µm
- Aluminium 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.

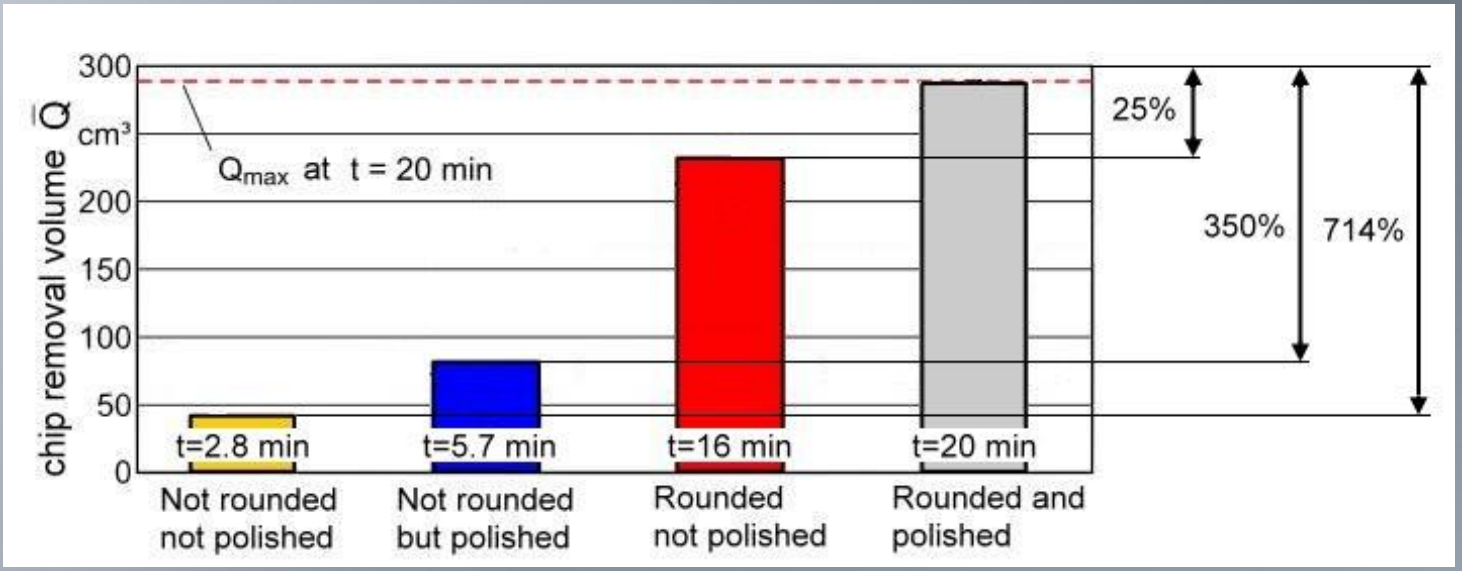
Surfaces Before and After Edge Honing



Milling

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

Tool: DHC Inox end mill



=>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.

2. Projekttreffen

16. Februar 2010
Mapal Dr. Kress KG, Aalen

Preparation of complex cutting tools

Prof. Dr.-Ing. D. Biermann
Institut für Spanende Fertigung, Technische Universität Dortmund

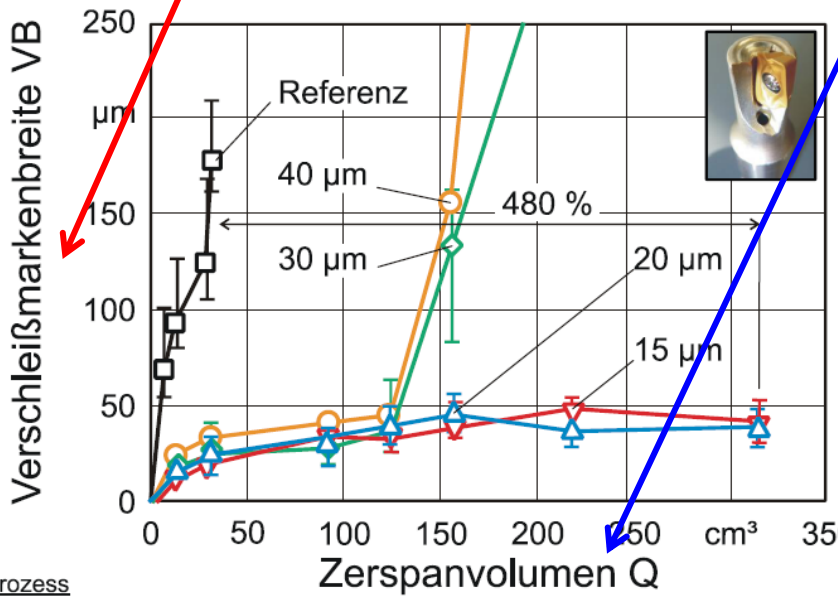
Prof. Dr.-Ing. B. Denkena
Institut für Fertigungstechnik und Werkzeugmaschinen, Leibniz Universität Hannover

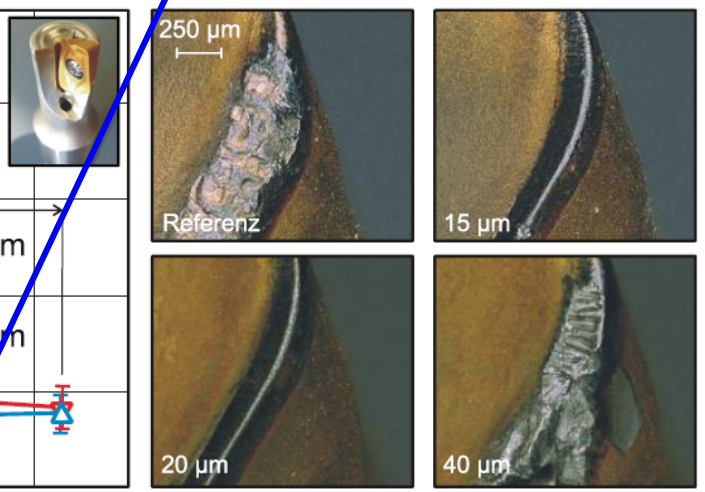
Komplettpräparation von komplexen Zerspanungswerkzeugen II

The tools have been edge honed and several radiuses have been created:

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

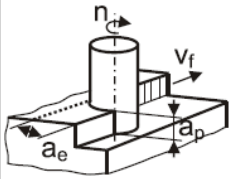
Influence of the edge radius to the tool wear/ amount of removed material – 42CrMo4





Verschleißbilder

Prozess



Eingriffsgrößen:			Spannsystem	Hydrdehnspannfutter	Werkstoff:
Schnittgeschw.	v_c	= 200 m/min	Kühlung	Adrana 5%	42CrMo4
Schnitttiefe	a_p	= 2 mm	Werkzeug		Verschleißmessung
Eingriffsbreite	a_e	= 8 mm	Hersteller:	Ceratizit GmbH & Co KG	Keyence VHX600
Zahnvorschub	f_z	= 0,1 mm	Typ:	XDKT 11T308SR-M50	Fa. KEYENCE GmbH
Durchmesser	D	= 12 mm	Substrat:	Hartmetall	
Zähnezahl	z	= 1	Beschichtung:	TiAlN-TiN (PVD)	

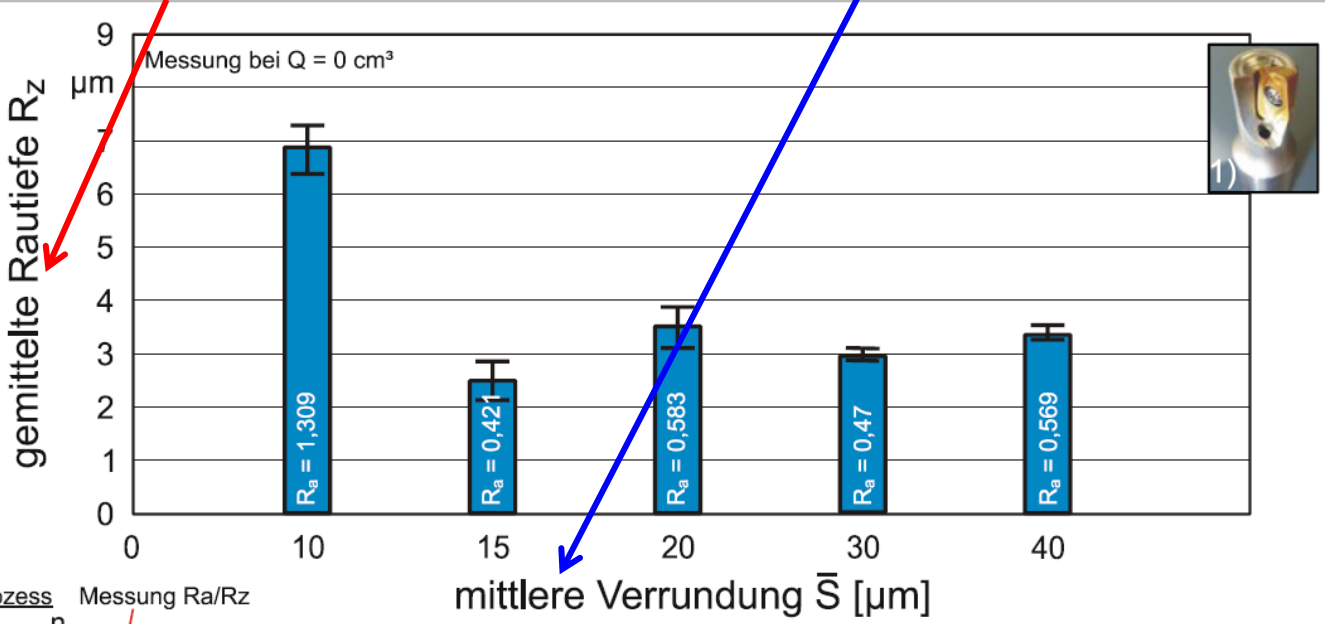
Re/63316 © IFW

Komplettpräparation von komplexen Zerspanungswerkzeugen II

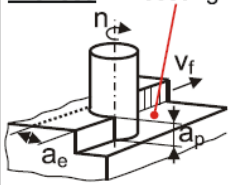
The tools have been edge honed and several radiuses have been created:

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



Prozess Messung Ra/Rz



Eingriffsgrößen:			Spannsystem:	Hydrodehnspannfutter	Werkstoff:
Schnittgeschw.	v_c	= 200 m/min	Kühlung:	Shell / Adrana 5%	42CrMo4
Schnitttiefe	a_p	= 2 mm	Werkzeug:		Rauheitsmessung:
Eingriffsbreite	a_e	= 8 mm	Hersteller:	Ceratizit GmbH & Co KG	Perthometer Concept Rauheit
Zahnvorschub	f_z	= 0,1 mm	Typ:	XDKT 11T308SR-M50	Fa. Mahr
Durchmesser	D	= 12 mm	Substrat:	Hartmetall	(DIN 4768)
Zähnezahl	z	= 1	Beschichtung:	TiAlN-TiN (PVD)	

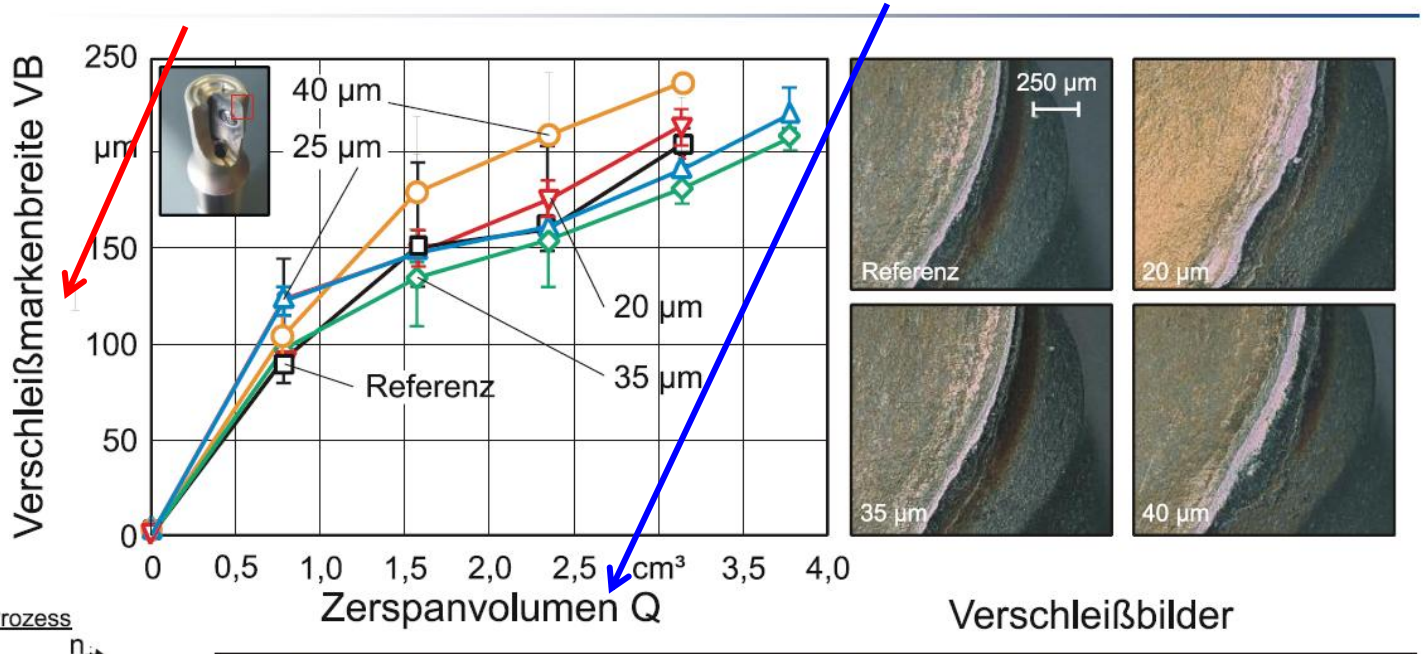
Re/63319 © IFW

Komplettpräparation von komplexen Zerspanungswerkzeugen II

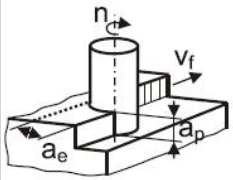
The tools have been edge honed and several radiuses have been created:

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



Prozess



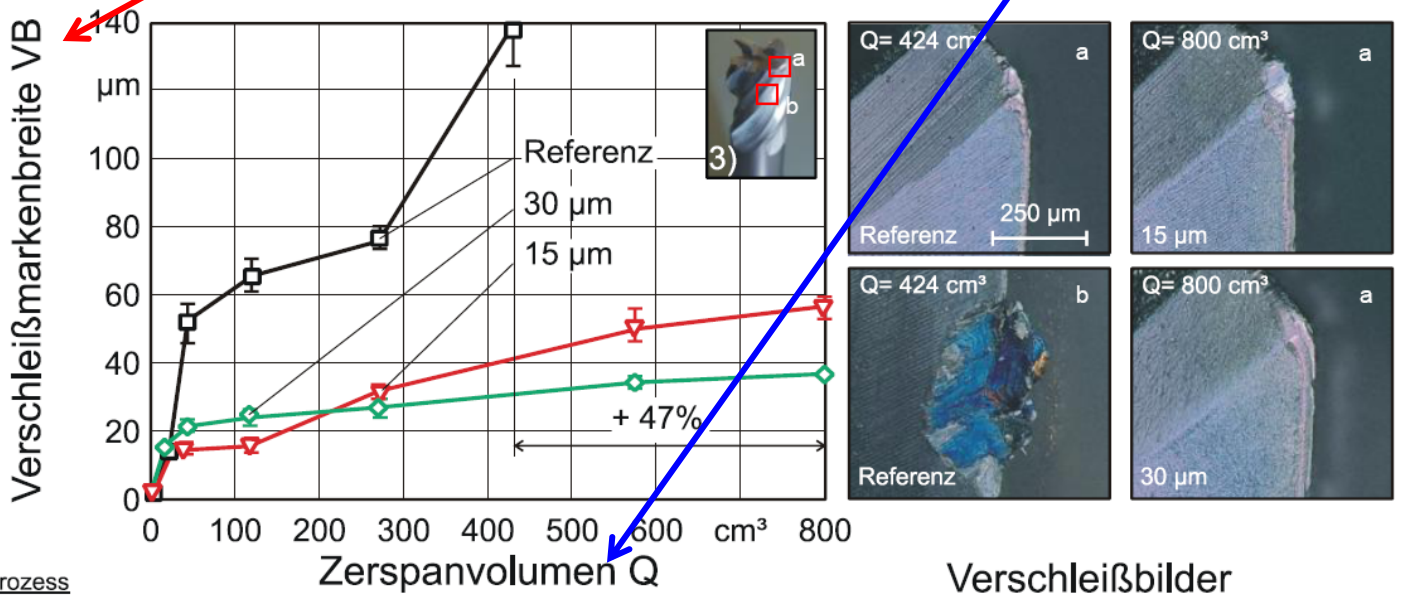
Eingriffsgrößen:			Spannsystem	Hydrdehnspannfutter	Werkstoff:
Schnittgeschw.	v_c	= 30 m/min	Kühlung	Adrana 5%	Inconel
Schnitttiefe	a_p	= 2 mm	Werkzeug		Verschleißmessung
Eingriffsbreite	a_e	= 8 mm	Hersteller:	Ceratizit GmbH & Co KG	Keyence VHX600
Zahnvorschub	f_z	= 0,08 mm	Typ:	XDKT 11T308ER-F40	Fa. KEYENCE GmbH
Durchmesser	D	= 12 mm	Substrat:	Hartmetall	
Zähnezahl	z	= 1	Beschichtung:	TiCN-Al_2O_3-TiN (CVD)	

Komplettpräparation von komplexen Zerspanungswerkzeugen II

The tools have been edge honed and several radiuses have been created:

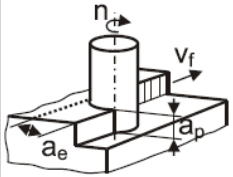
No radius
420 cm³
15µm radius
47% more removal capacity, but wear is larger than:
30µm radius
47% more removal capacity – best result

Test to increase the amount of removed material each tool before it wears too much – 42CrMo4



Verschleißbilder

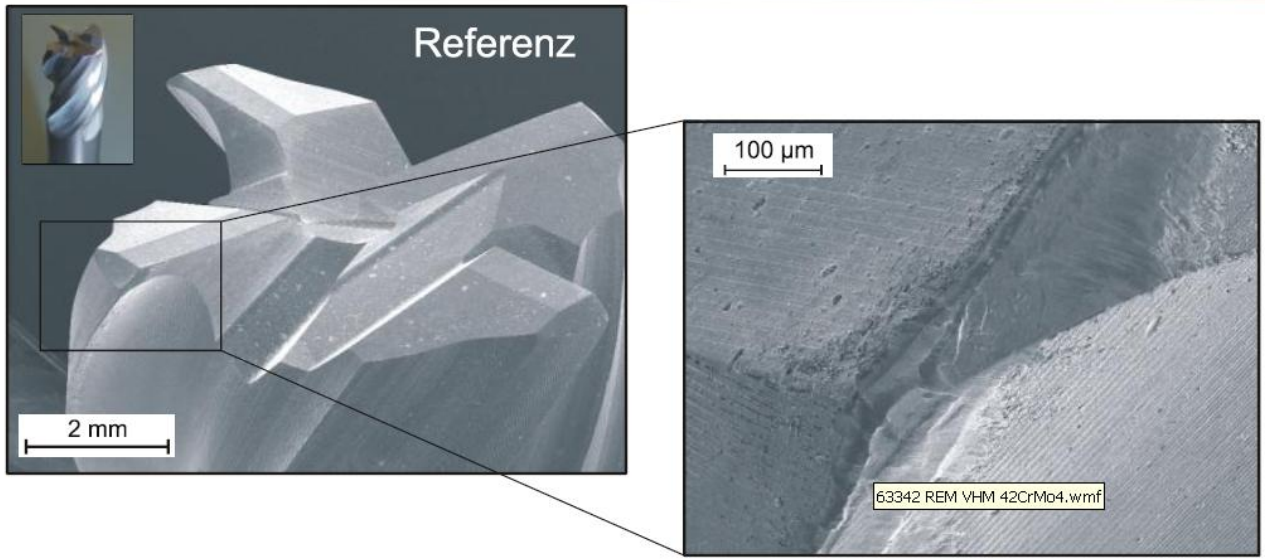
Prozess



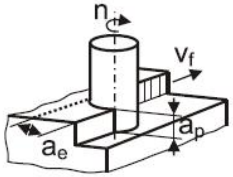
Eingriffsgrößen:			Spannsystem:	Hydrodehnspannfutter	Werkstoff:
Schnittgeschw.	v_c	= 160 m/min	Kühlung:	ohne	42CrMo4
Schnitttiefe	a_p	= 4 mm	Werkzeug:		Verschleißmessung:
Eingriffsbreite	a_e	= 5 mm	Hersteller:	Fette GmbH	Keyence VHX600
Zahnvorschub	f_z	= 0,09 mm	Typ:	DHC	Fa. KEYENCE GmbH
Durchmesser	D	= 8 mm	Substrat:	Hartmetall	
Zähnezahl	z	= 4	Beschichtung:	TiAlN (PVD, Fa. Gühring)	

Komplettpräparation von komplexen Zerspanungswerkzeugen II

SEM picture of the worn out tool



Prozess



Eingriffsgrößen:			Spannsystem:	Hydrodehnspannfutter	Werkstoff:
Schnittgeschw.	v_c	= 160 m/min	Kühlung:	ohne	42CrMo4
Schnitttiefe	a_p	= 4 mm	Werkzeug:		Analytik:
Eingriffsbreite	a_e	= 5 mm	Hersteller:	Fette GmbH	Rasterelektronenmikroskop
Zahnvorschub	f_z	**= 0,09 mm**	Typ:	DHC	Fa. Zeiss
Durchmesser	D	= 8 mm	Substrat:	Hartmetall	
Zähnezahl	z	= 4	Beschichtung:	TiAlN (PVD, Fa. Gühring)	

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Komplettpräparation von komplexen Zerspanungswerkzeugen II

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.

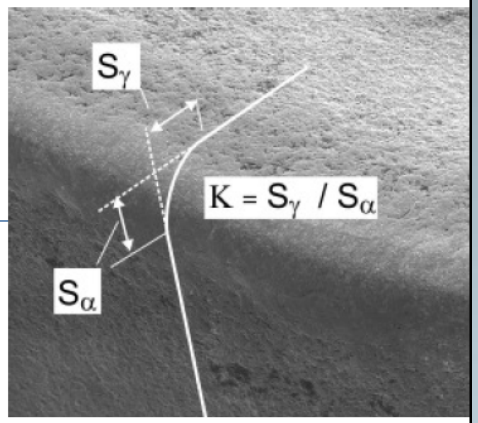
Perfekte Oberflächen. Weltweit.

Leibniz Universität Hannover
Institut für Fertigungstechnik und Werkzeugmaschinen

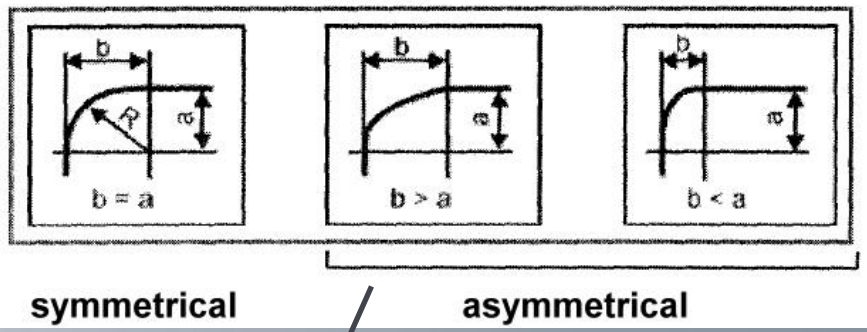
Effects of the cutting edge micro geometry on tool wear and its thermo mechanical load

Prof. B. Denkena, E. Bassett

Garbsen, 09. März 2011

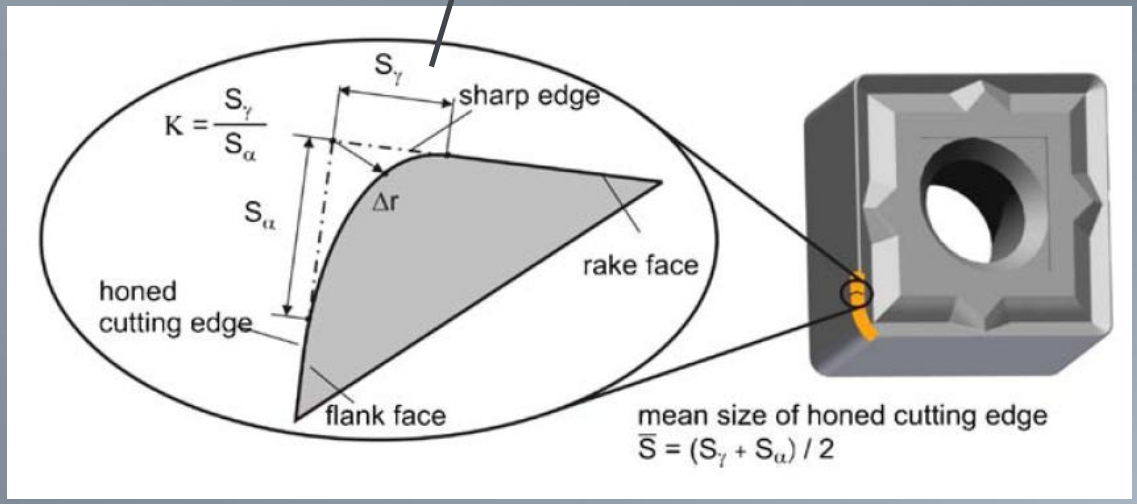


Versions of edge roundings



Tendency to crater wear at the rake face at inserts

Tendency to flank wear at inserts



Remember:

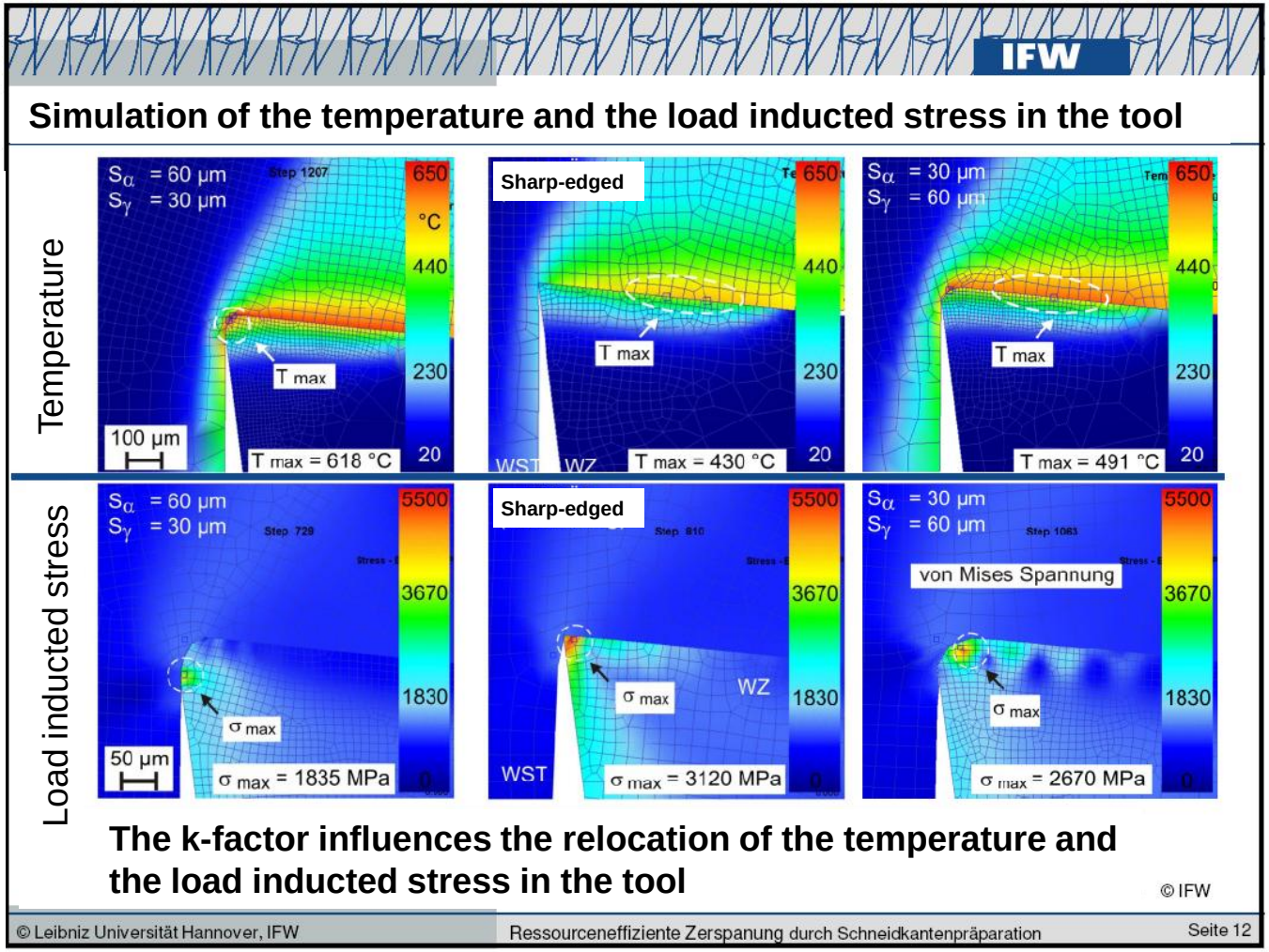
$K = S_\gamma / S_\alpha$

Temperature in the tool:

K=0,5	618°C
Sharp edge	430°C
K=2	491°C

Load inducted stress in the tool:

K=0,5	1835 MPa
Sharp edge	3120 MPa
K=2	2670 MPa



Quelle: IFW-11

Conclusion:

- 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

Bibliography

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- ISF – 11: ISF Dortmund, IFW Hannover – Komplettpräparation von komplexen Zerspanungswerkzeugen
- 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 !