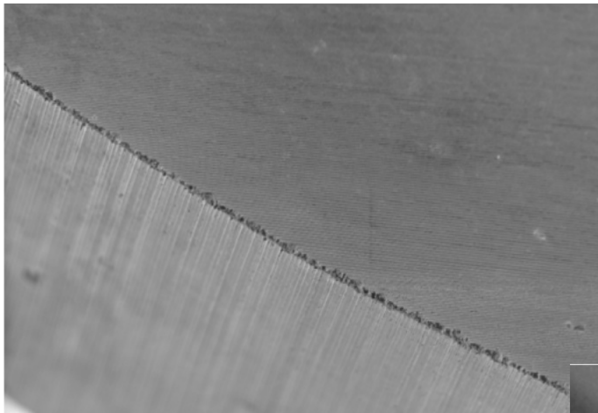
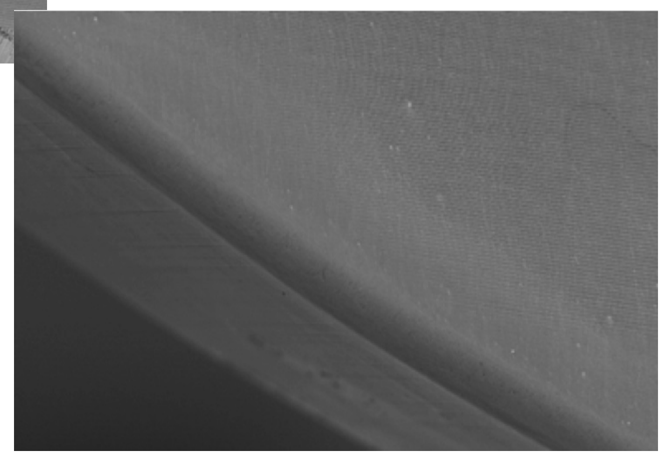
Influence of Edge Preparation on the Performance of Coated Cutting Tools



Invited talk of T. Cselle
at ICMCTF, San Diego, 25th of April, 2007



C. Buechel, O. Coddet, C. Galamand, P, Karvankova, D. Klostermann, A. Luemkemann, M. Morstein, A. Moschko,, J. Prochazka,, PLATIT, Grenchen, Switzerland
F. Barthelmae, P. Preiss, S. Reich,, GFE, Schmalkalden, Germany, M. Ruzicka, PIVOT, M. Sima, SHM, Sumperk, Czech Republic
T. Cselle, PLATIT, Grenchen, Switzerland

Influence of Edge Preparation on the Performance of Coated Cutting Tools

OUTLINE

APPLICATIONS

- Drilling
- Milling
- Turning
- Tapping
- Sawing

WHY EDGE PREPARATION?

- Form
- Surface
- Cutting material

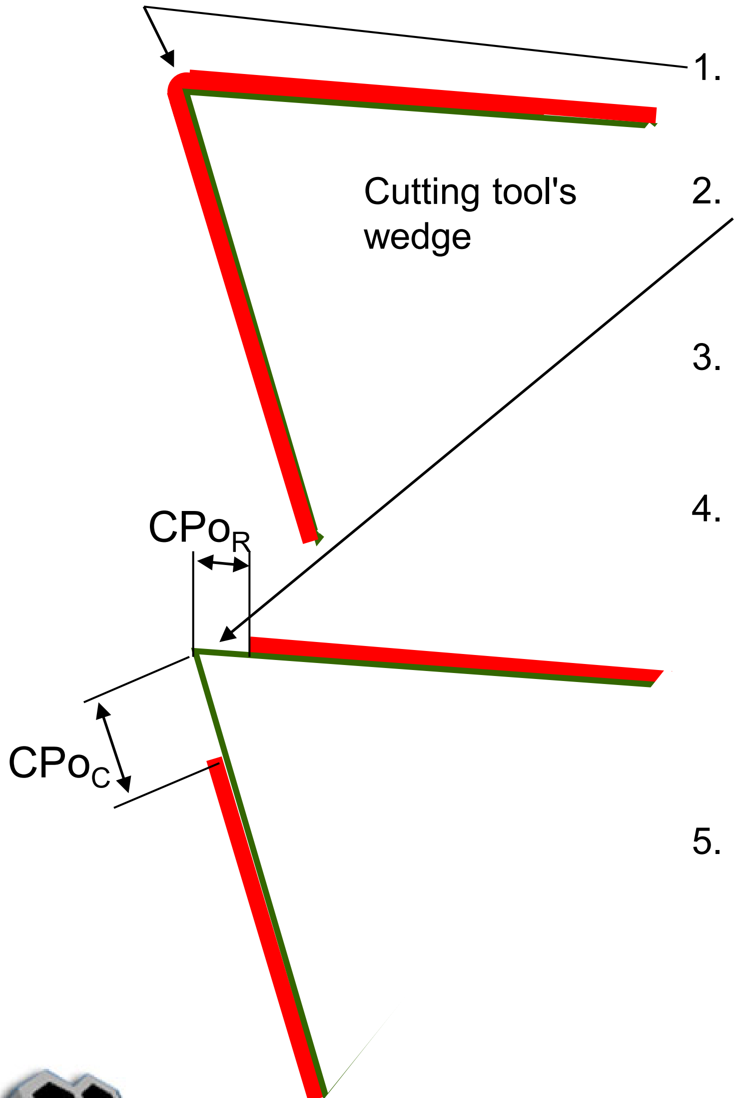
Goal of edge preparation: increase

CUTTING PERFORMANCE

TREATMENTS

- Grinding
- Brushing
- Micro Blasting
  - Dry
  - Wet
- Drag Grinding
- Magnet Finishing

Influence of Edge Preparation on the Performance of Coated Tools



The AIM of Edge Preparation:

1. Directly on sharp edge the PVD coating has a very high internal stress

2. Because of this very high internal stress the coating breaks away, peels off very shortly after starting cutting

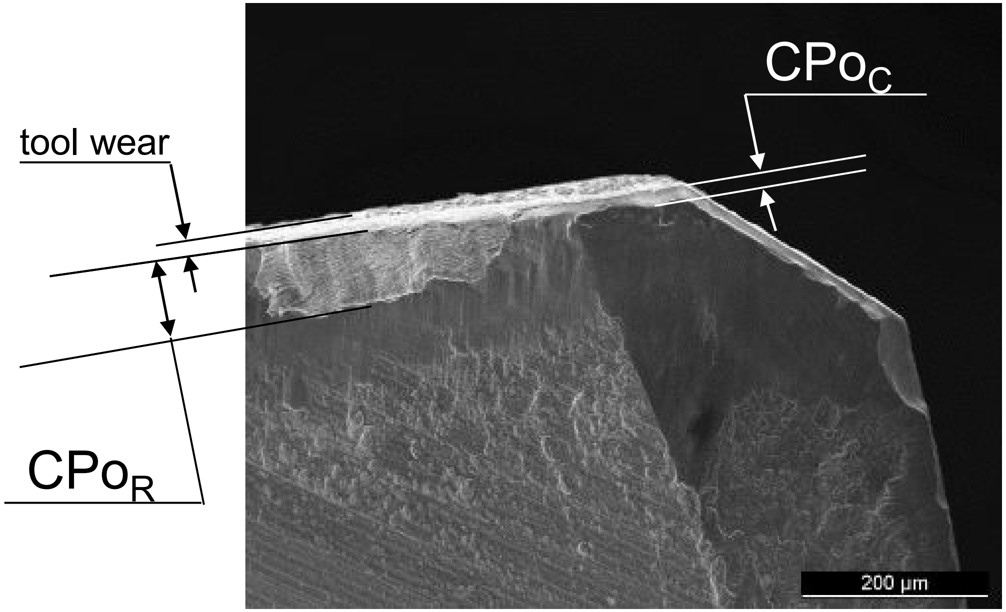
3. The tool's wear is always measured on the surface of the cutting material where the coating isn't present anymore.

4. The goodness, the quality of a coating is strongly determined by the ABILITY of the coating TO KEEP THE GROWTH OF DISTANCES CPo_R and CPO_C SLOW during the cutting process, along the tool life

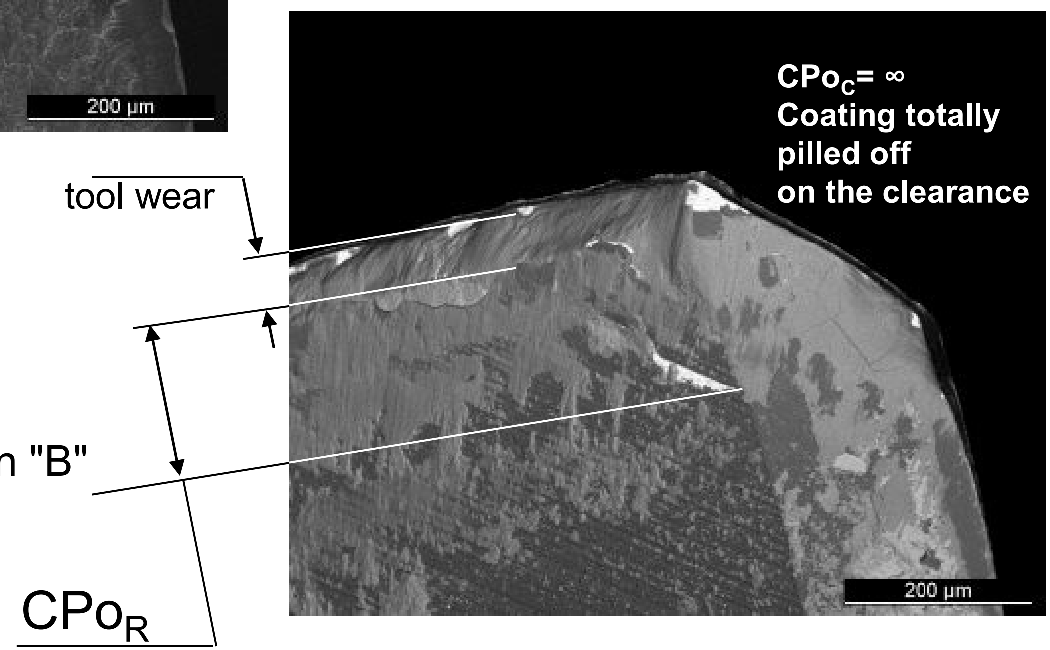
   CPo_R : coating's peeling off on the tool's rake surface
   CPo_C : coating's peeling off on the tool's clearance surface

5. The aim of a good edge preparation is;
   - to "ensharp" the cutting edges
   - to make a smooth transition of the coating possible between the tool's rake and clearance surfaces and with this
   - to reduce the internal stress of the coating
   - but without making the tool blunt

Influence of Edge Preparation on the Performance of Coated Tools



Coating's pilling off and tool wear
on the end mill with edge preparation "A"
after 40 m cutting distance



Coating's pilling off and tool wear
on the end mill with edge preparation "B"
after 40 m cutting distance

WHY Edge Preparation?

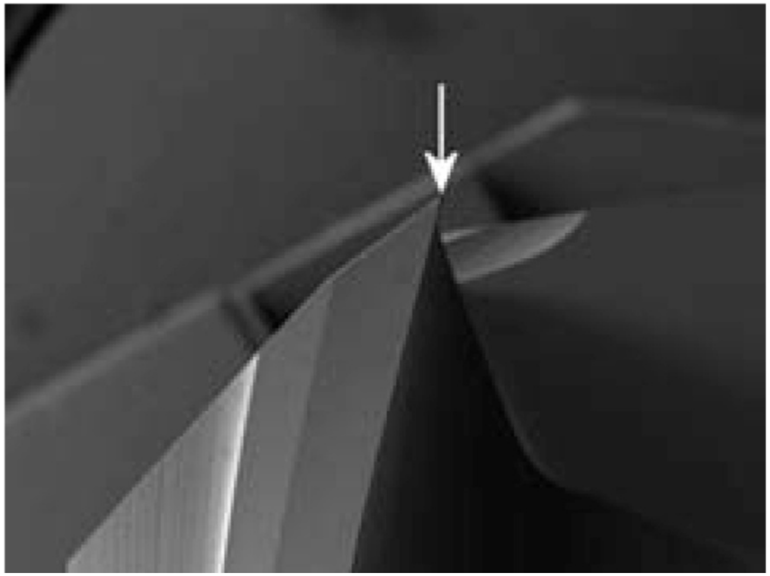
Target : EDGE STABILITY

- **Form;**
  - **(low) chipping**

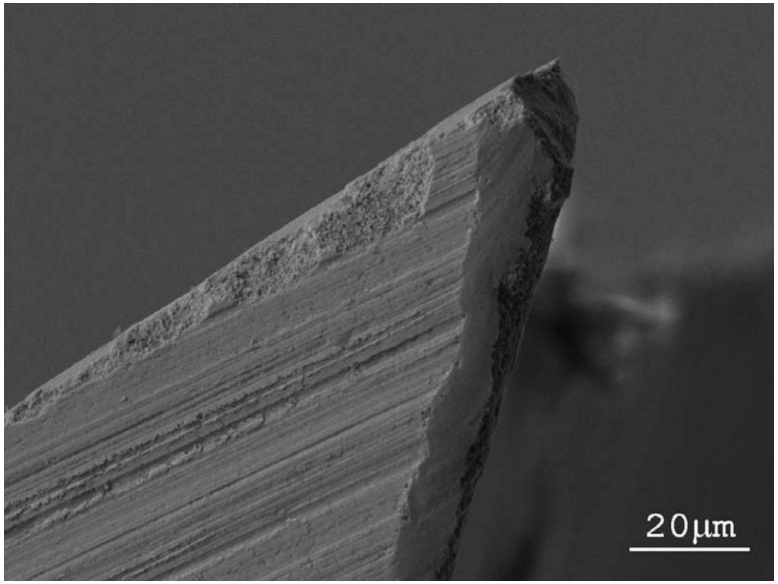
WHY Edge Preparation?

Tool Edge Images from High End Tool Manufacturers after Grinding

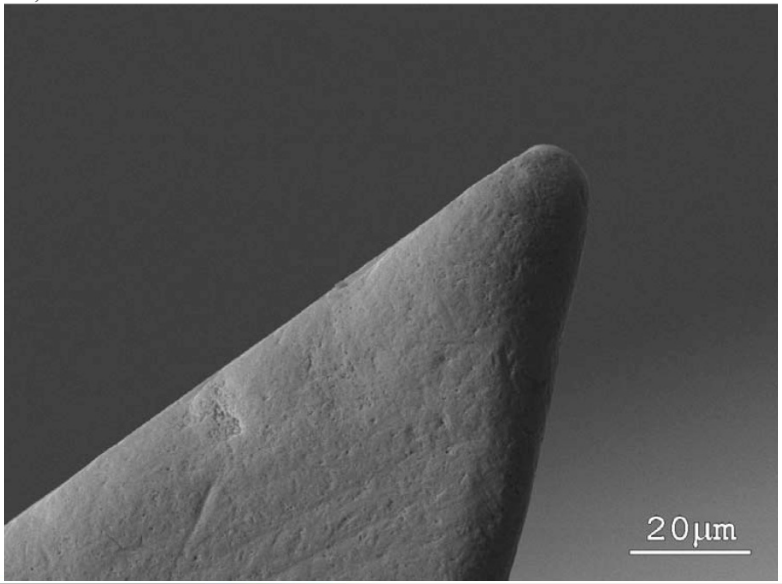
End Mill Corner:



After grinding



After edge preparation



WHY Edge Preparation?

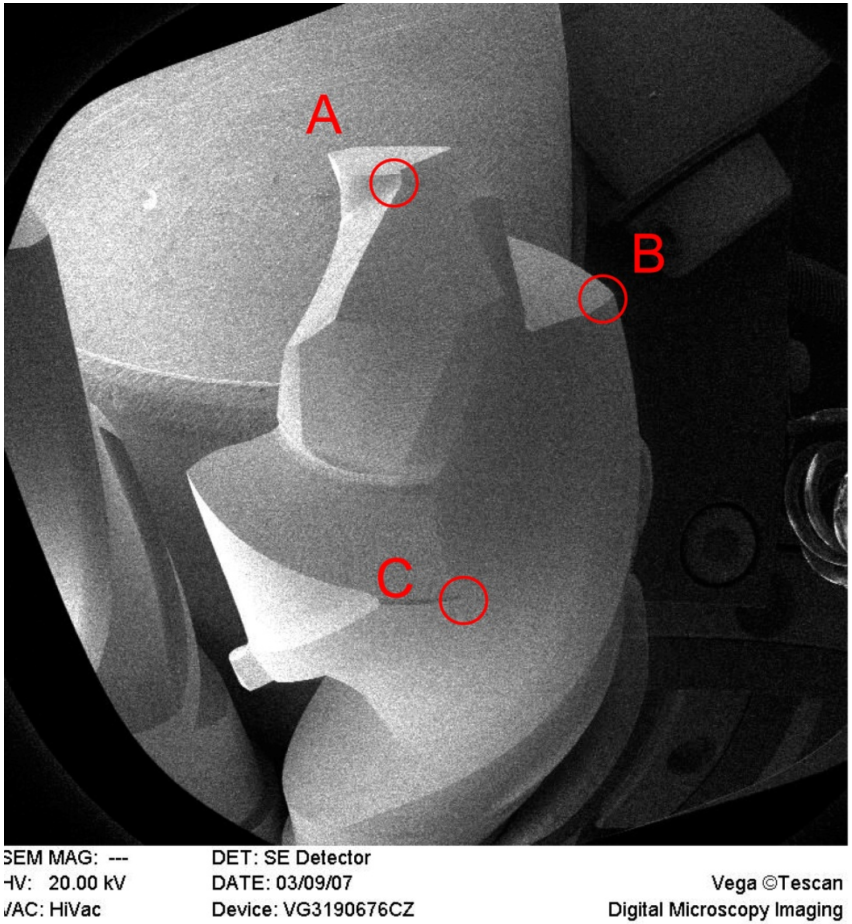
Target : EDGE PREPARATION

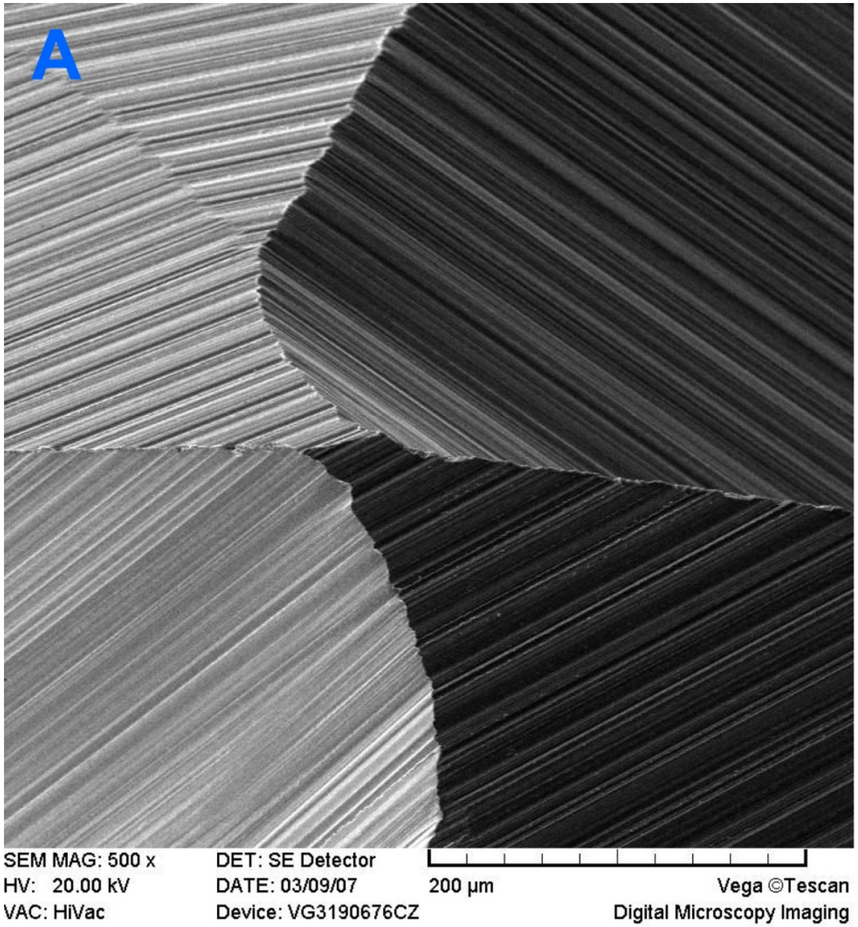
- Form;
  - (low) chipping
- **Surface;**
  - **(low) roughness**

WHY Edge Preparation?

Tool Edge Images from High End Tool Manufacturers after Grinding

Carbide Drill:





WHY Edge Preparation?

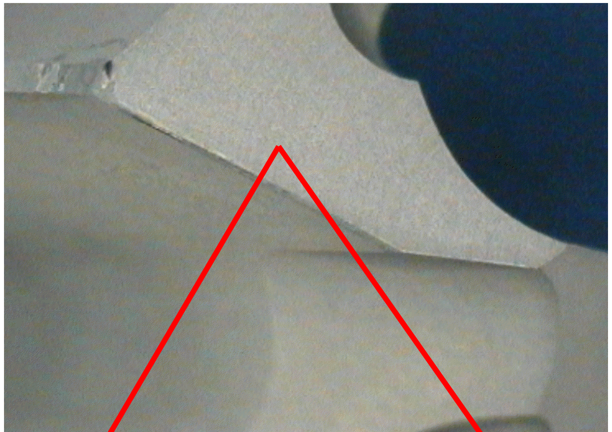
Target : EDGE PREPARATION

- Form;
  - (low) chipping
- Surface;
  - (low) roughness
- **Cutting Material;**
  - **(correct) composition**

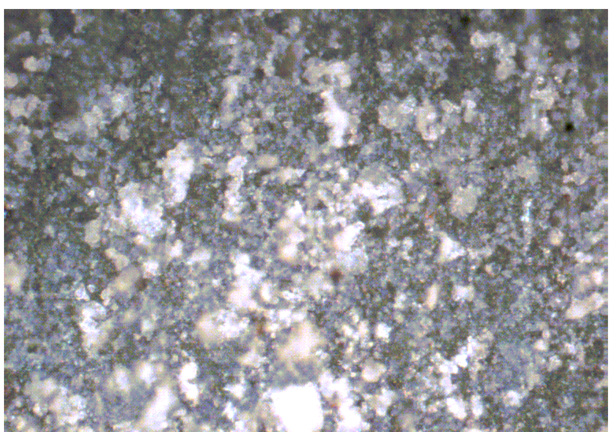
WHY Edge Preparation?

Tool Surface Images from High End Tool Manufacturers

Carbide Drill:

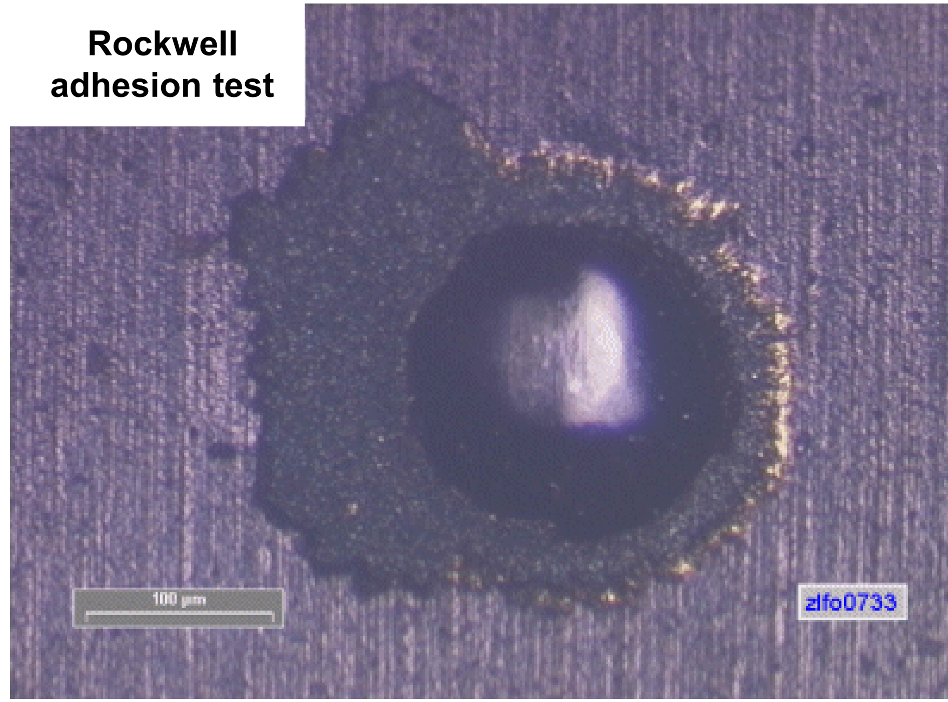


500x



Cobalt leaching

Rockwell adhesion test



Coating on cobalt leached surface
-> coating on WC layer without/with few binder (cobalt)
-> very bad adhesion

Influence of Corner Edge Preparation on the Performance of Coated Drills

APPLICATION 1

- Drilling
- Milling
- Turning
- Tapping
- Sawing

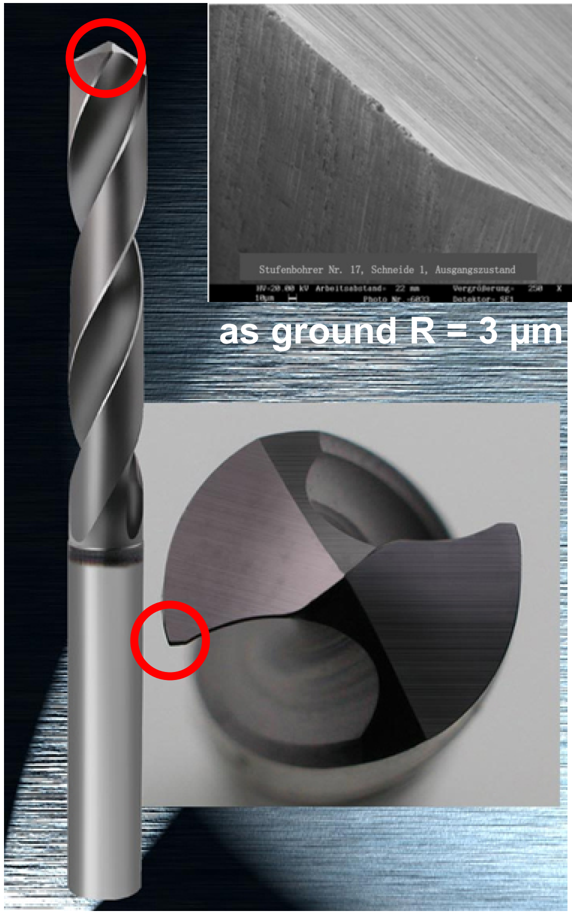
Target : **EDGE STABILITY**

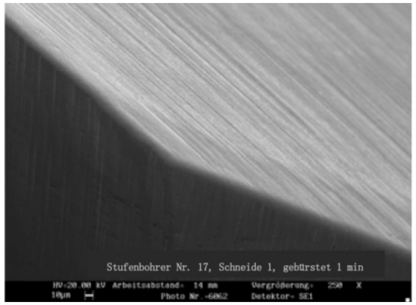
- **Form**
- Surface
- Metallurgy

TREATMENTS

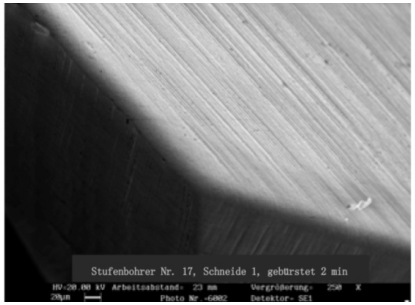
- **Grinding**
- **Brushing**
- Micro blasting
  - Dry
  - Wet
- Drag grinding
- Magnet finishing

Influence of Corner Edge Preparation on the Performance of Coated Drills

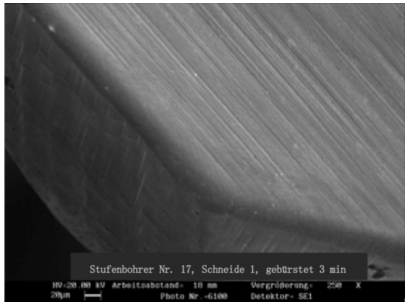




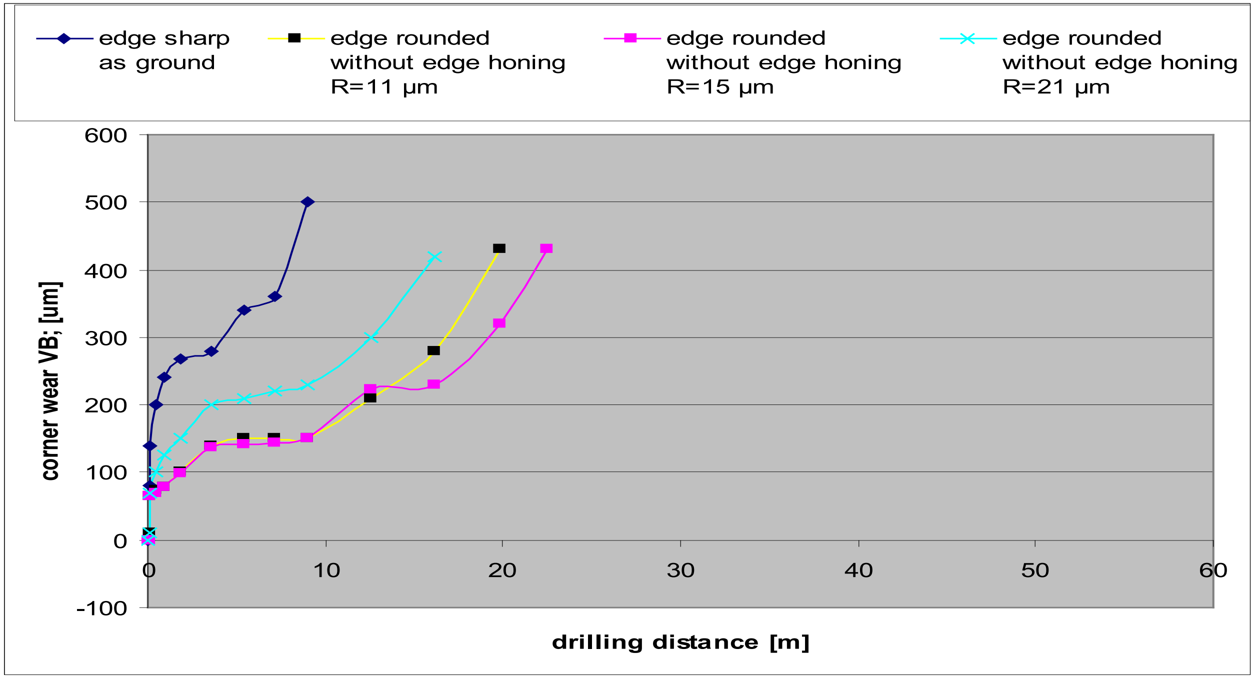
R1 = 11 µm



R2 = 15 µm

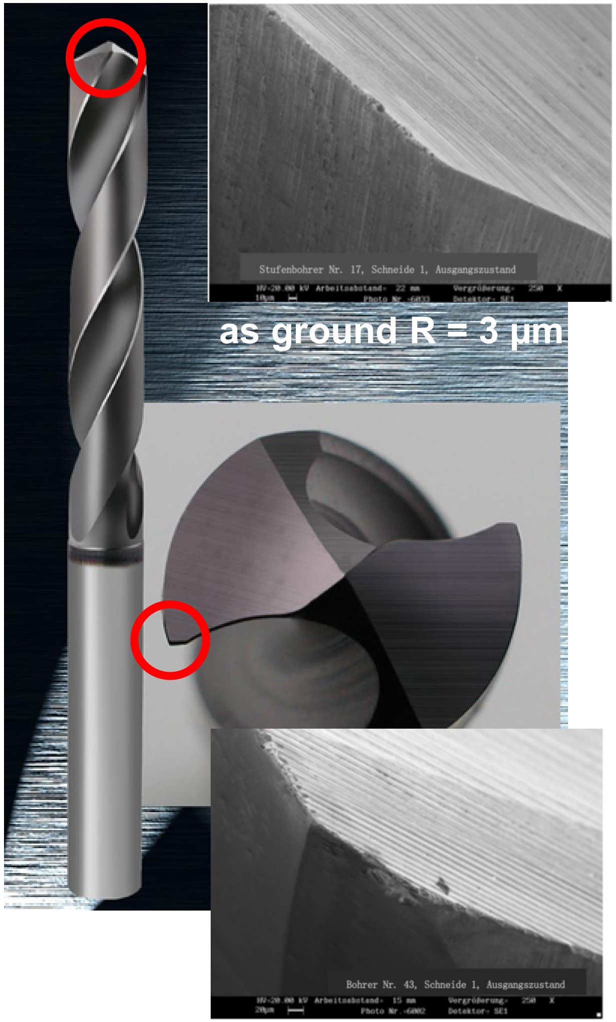


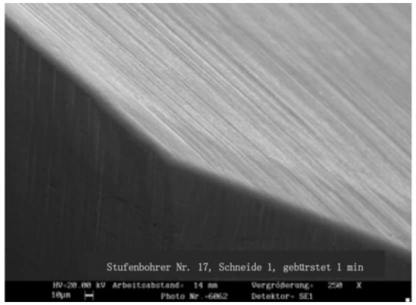
R3 = 21 µm



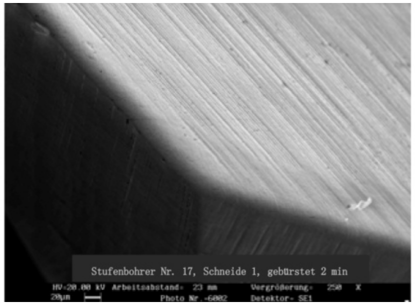
Work piece material: cold working steel - 1.2379 - X155CrVMo12-1 – HRC22 - blind holes
Solid carbide drills with nACo coating: d=5 mm, vc=75 mm/min – fz=0.15 mm/z – ap=15mm – dry air coolant

Influence of Corner Edge Preparation on the Performance of Coated Drills

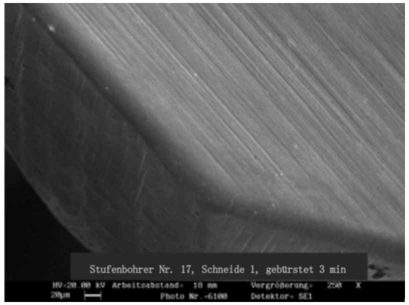




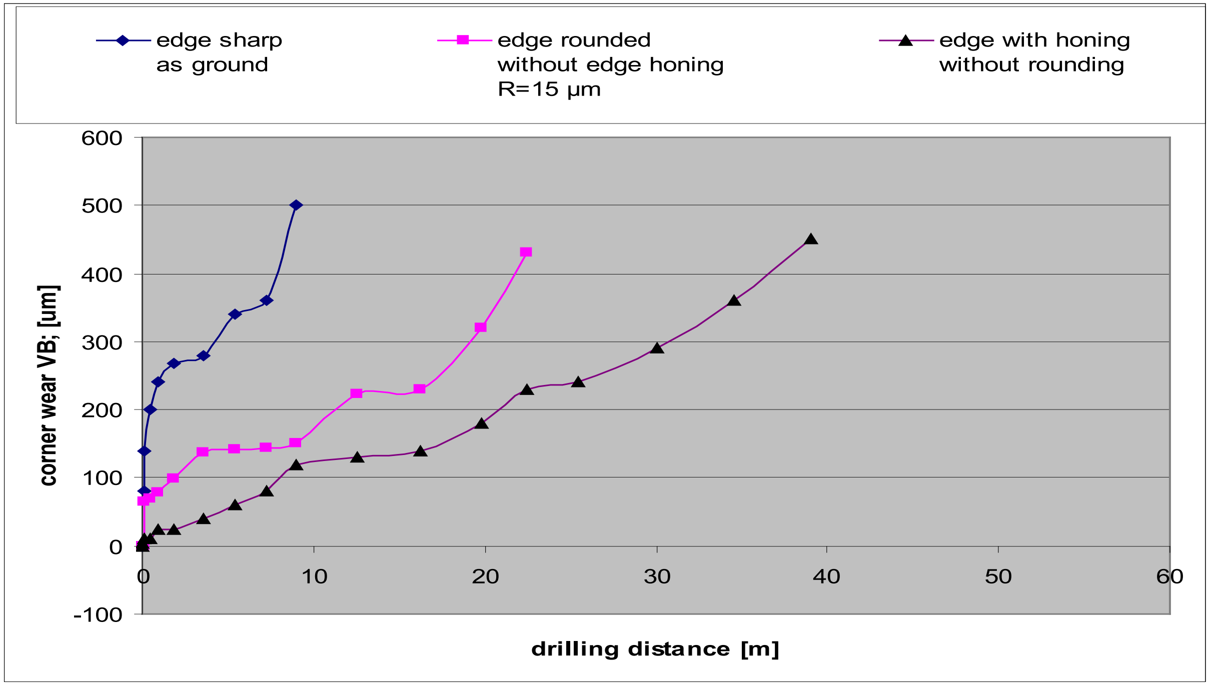
R1 = 11 µm



R2 = 15 µm

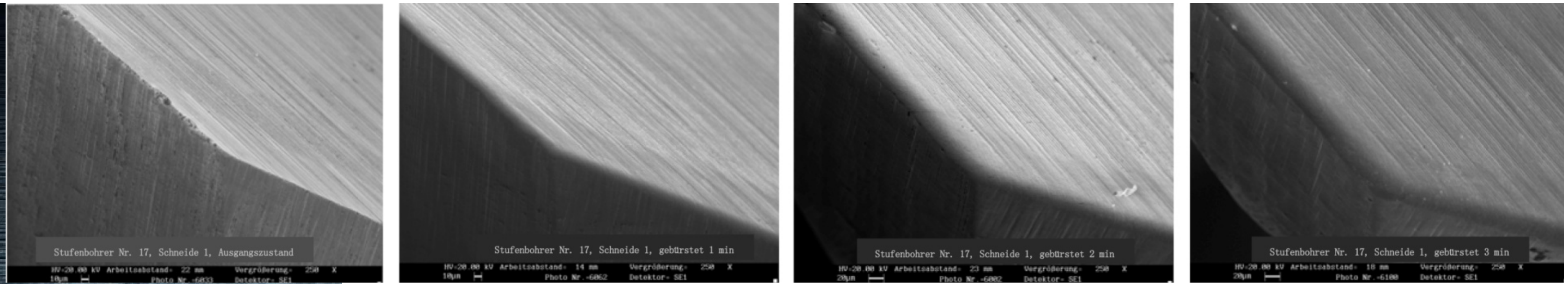


R3 = 21 µm



Work piece material: cold working steel - 1.2379 - X155CrVMo12-1 – HRC22 - blind holes
Solid carbide drills with nACo coating: d=5 mm, vc=75 mm/min – fz=0.15 mm/z – ap=15mm – dry air coolant

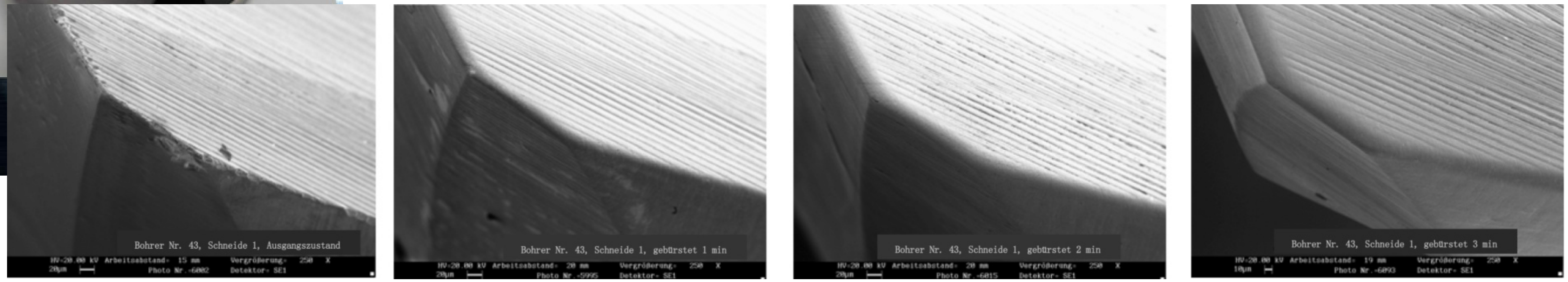
Influence of Corner Edge Preparation on the Performance of Coated Drills



as ground R = 3 µm | R1 = 11 µm | R2 = 15 µm | R3 = 21 µm

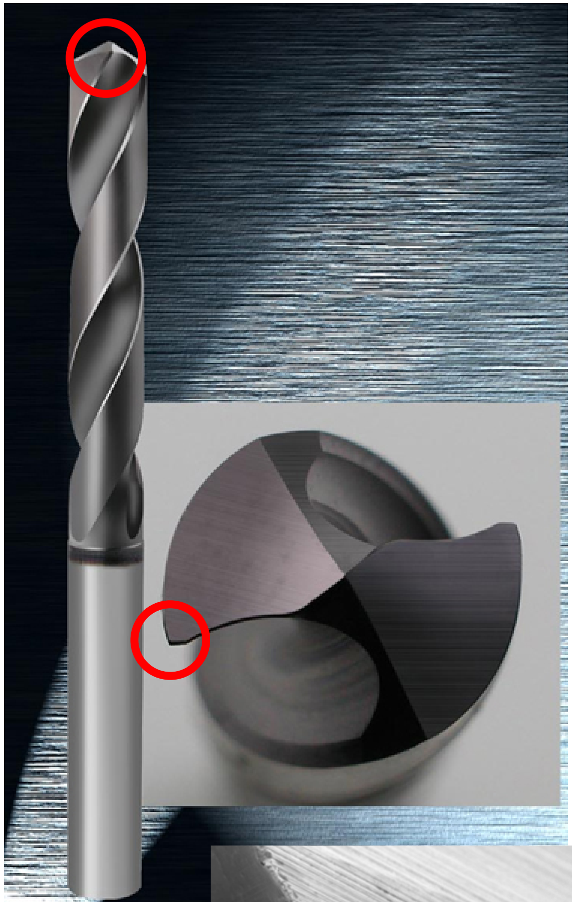
Rounded edges without corner honing

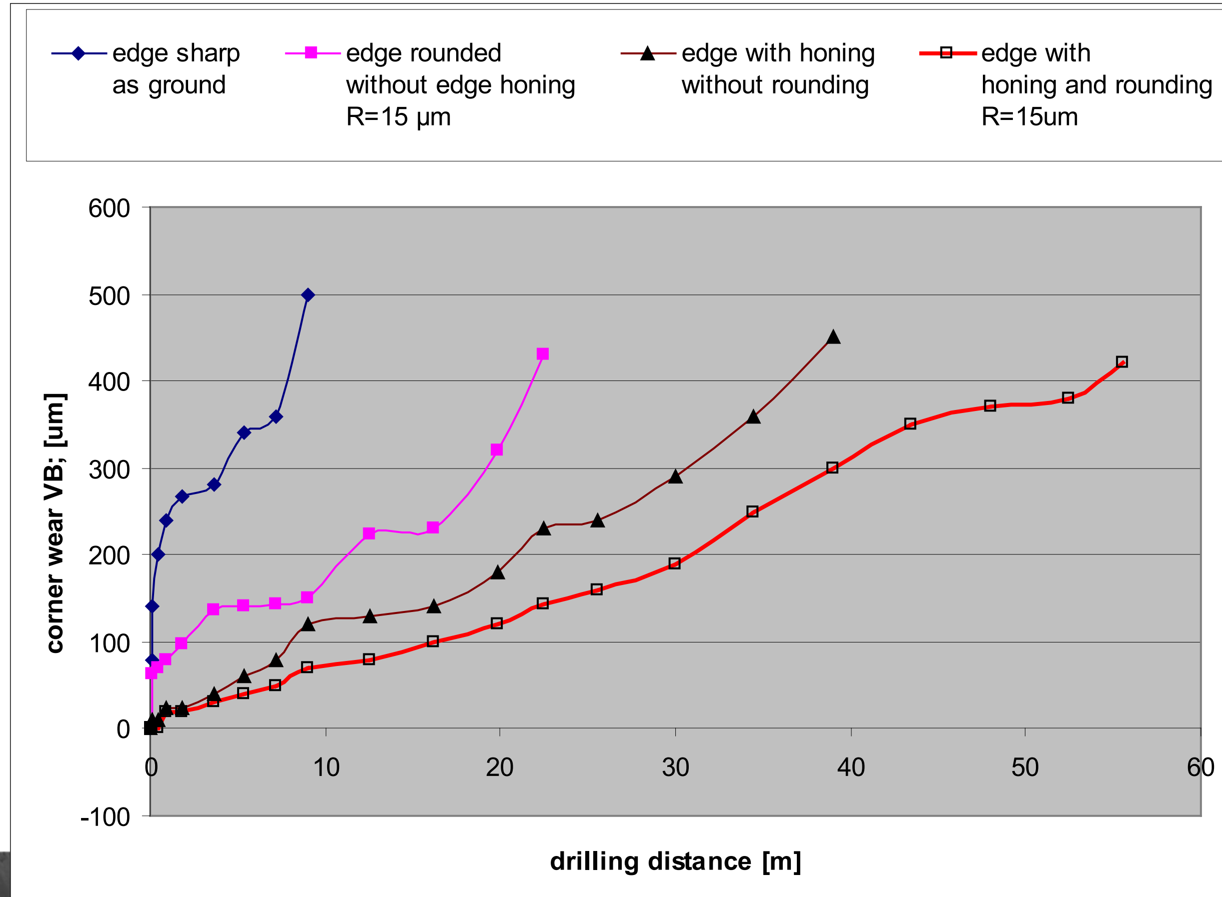
Rounded edges with corner honing

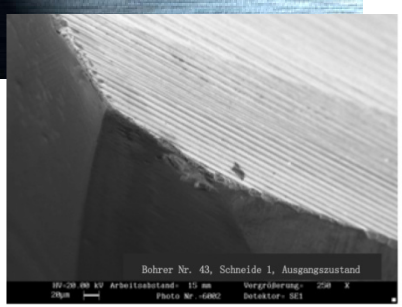


Work piece material: cold working steel - 1.2379 - X155CrVMo12-1 – HRC22 - blind holes
Solid carbide drills with nACo coating: d=5 mm, vc=75 mm/min – fz=0.15 mm/z – ap=15mm – dry air coolant

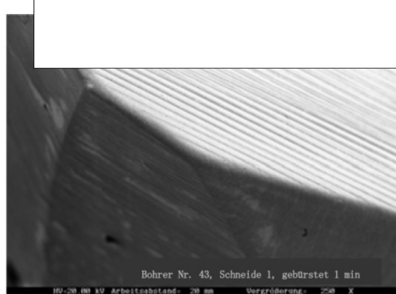
Influence of Corner Edge Preparation on the Performance of Drills



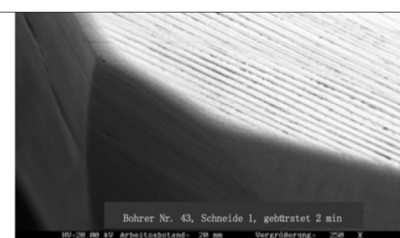




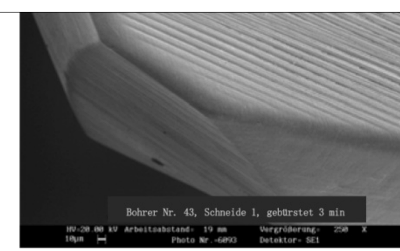
as ground R = 3 µm



R1 = 11 µm

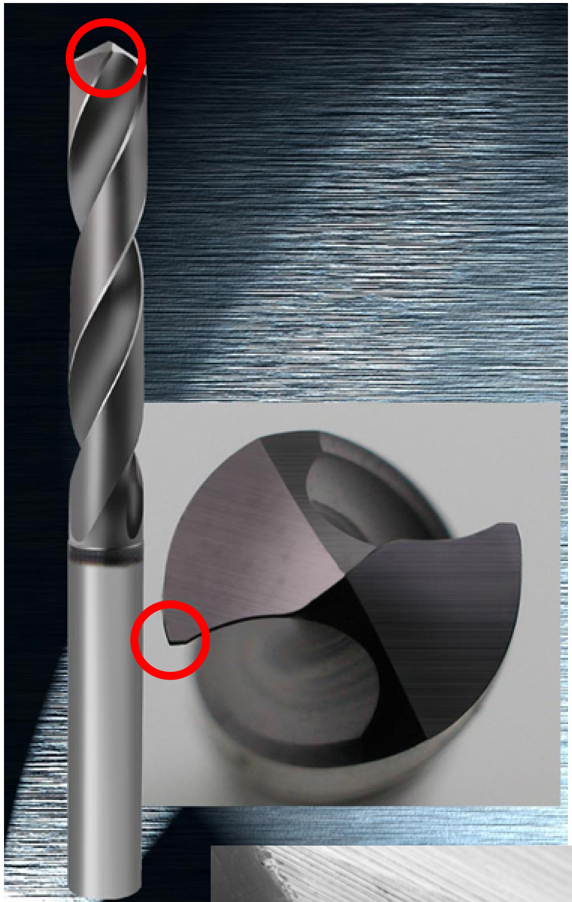


R2 = 15 µm



R3 = 21 µm

Influence of Corner Edge Preparation on the Performance of Drills

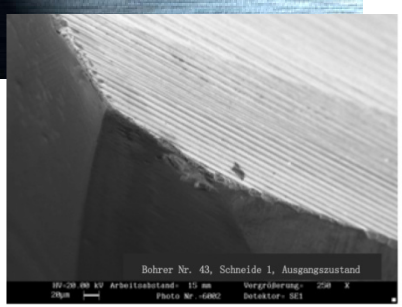


Edge brushing of inclided driven tools

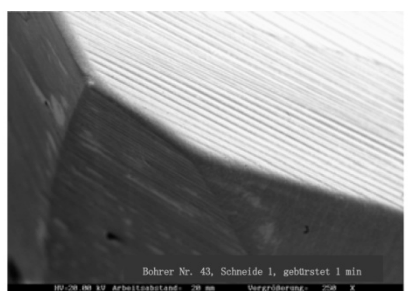
T1 = 1 min

T2 = 2 min

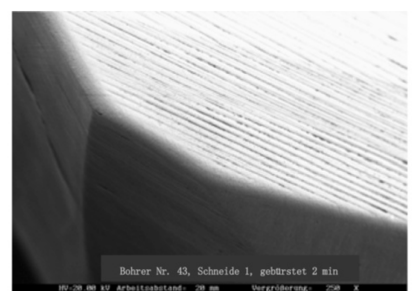
T3 = 3 min



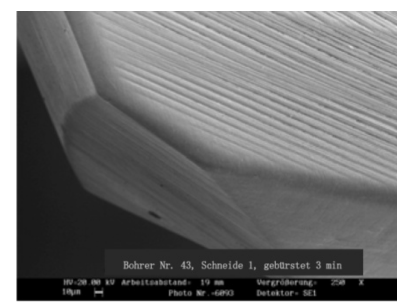
as ground R = 3 µm



R1 = 11 µm



R2 = 15 µm



R3 = 21 µm

Influence of Edge Preparation on the Performance of Coated End Mills

APPLICATION 2

- Drilling
- **Milling**
- Turning
- Tapping
- Sawing

Target : **EDGE STABILITY**

- **Form**
- Surface
- Cutting material

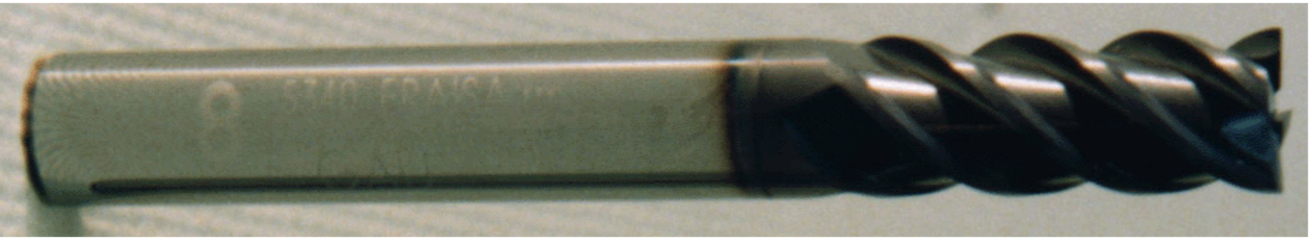
TREATMENTS

- **Grinding**
- **Brushing**
- Micro blasting
  - Dry
  - Wet
- Drag grinding
- Magnet finishing

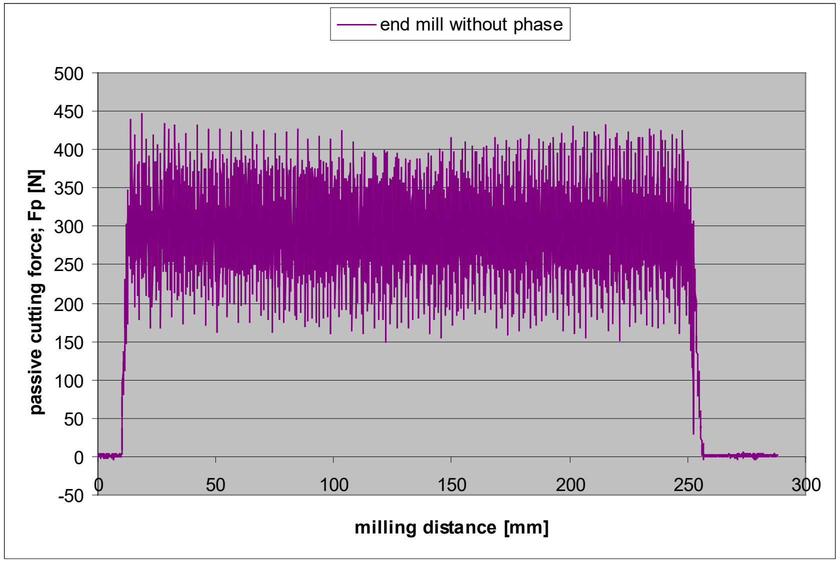
Influence of the Edge Preparation on Tool Life at Standard End Mills in Easy to Cut HEAT TREATED Steel

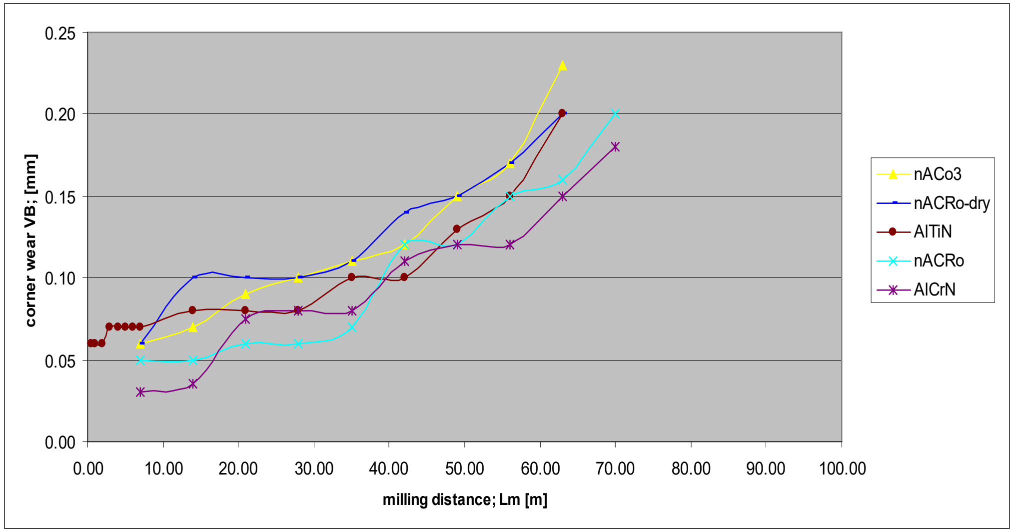
Material: 1.7225 – 42CrMo4 – 4140H – coolant; dry air
End mill: AlTiN coated - d=10mm, z=4, ae=1 mm – ap=d – vc=140 m/min – fz=0.1 mm/z

Influence of Edge Preparation on the Performance of Coated End Mills



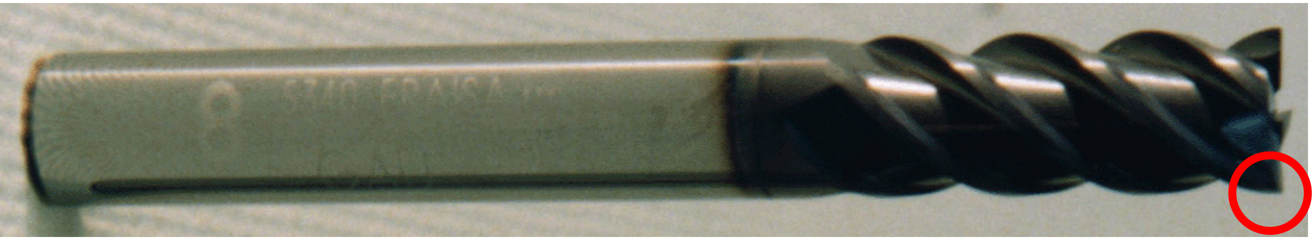
No tool life difference for different coatings because of instable chattering during milling process

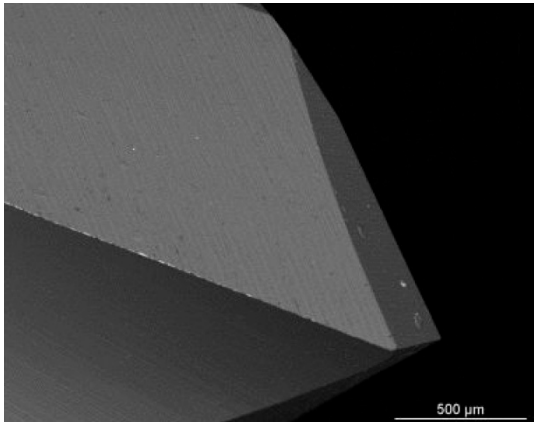




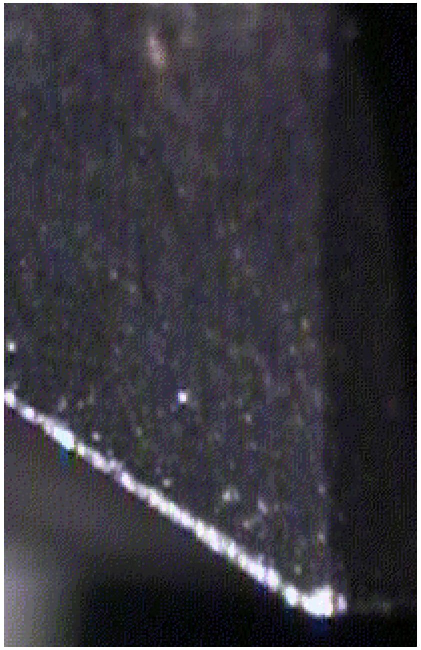
Work piece material: cold working steel - 1.2312 - 40CrMnMoS8-6 – heat treated - Rm=1000 N/mm2 - HRC32
HM end mills: d=12mm - z=4 - vc=200 mm/min – fz=0.1 mm/z – ae=ap=6mm – down cut– coolant: dry air 6 bar

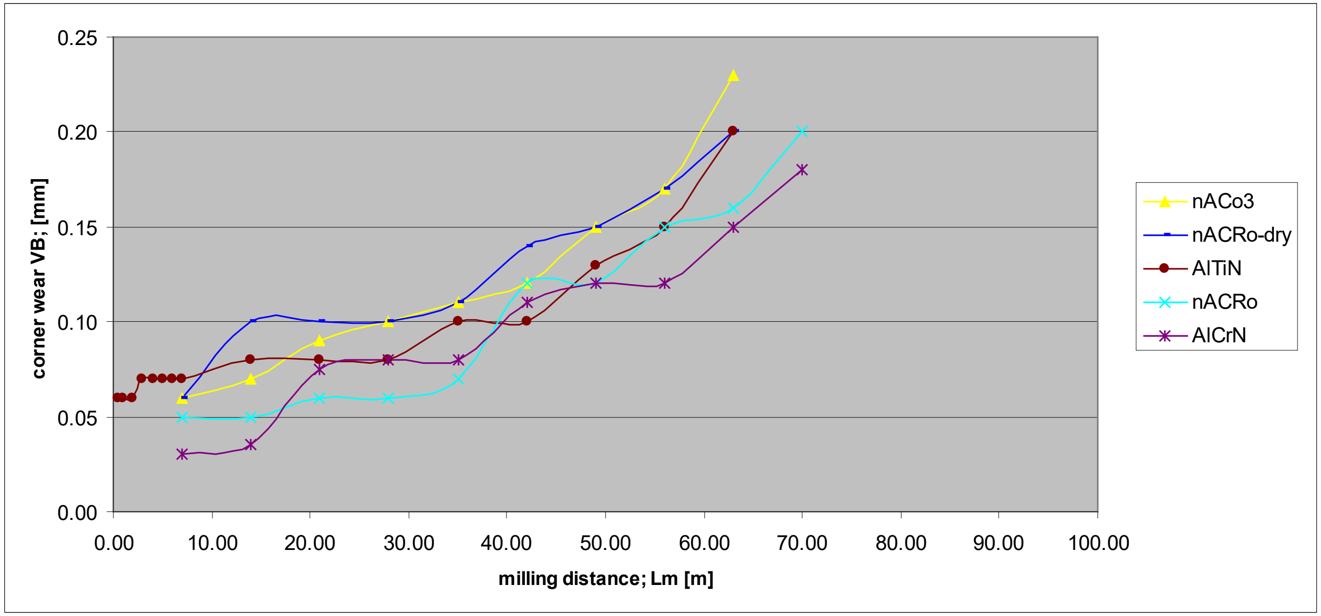
Influence of Edge Preparation on the Performance of Coated End Mills





Max. Wear is always at the corner as chipping, break out





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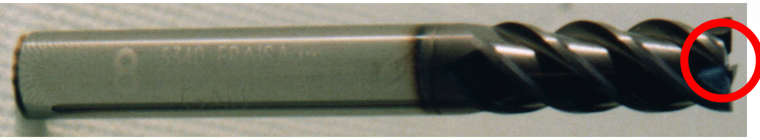
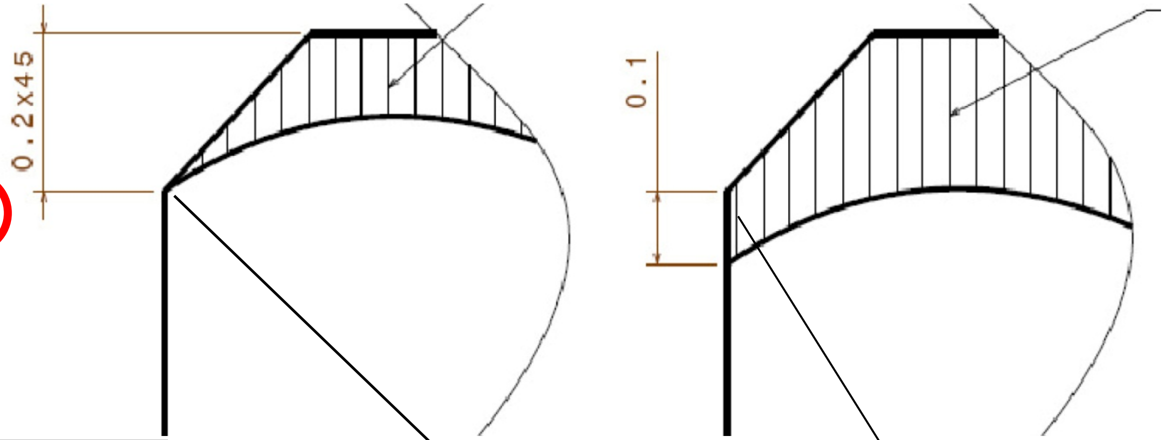
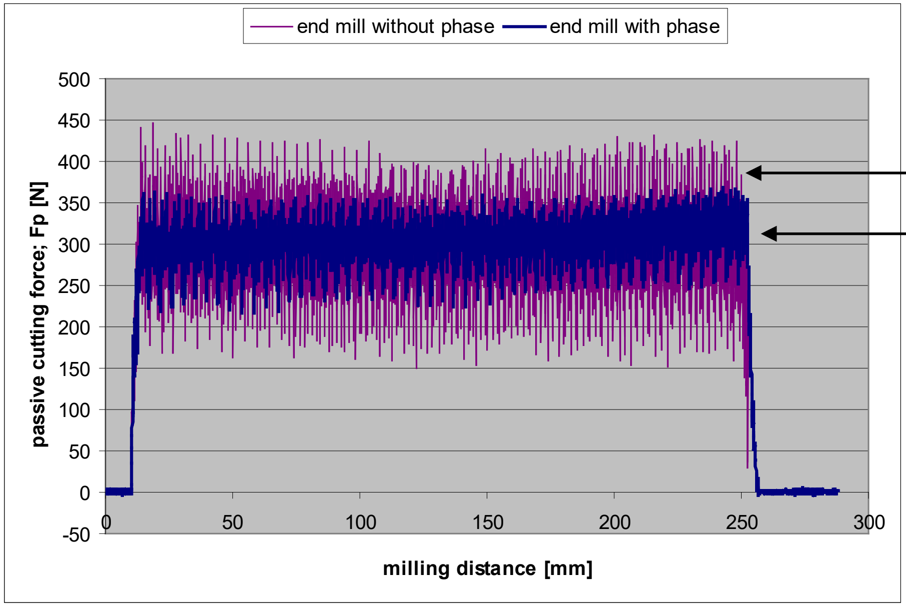
HM end mills: d=12mm - z=4 - vc=200 mm/min – fz=0.1 mm/z – ae=ap=6mm – down cut– coolant: dry air 6 bar

Influence of Edge Preparation on the Performance of Coated End Mills





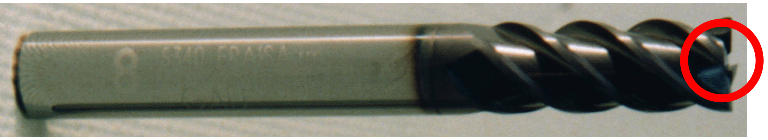


The sharp, weak edge causes chatter

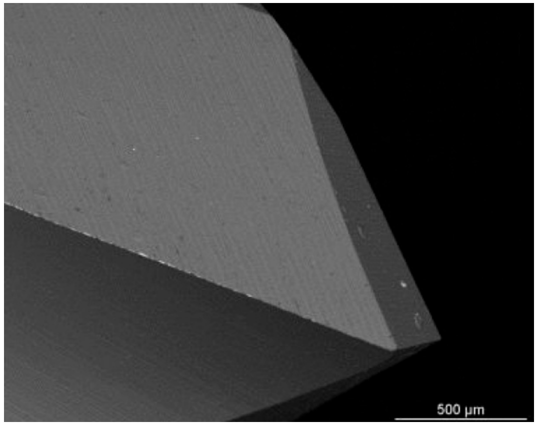
The honed, stable edge reduses chatter

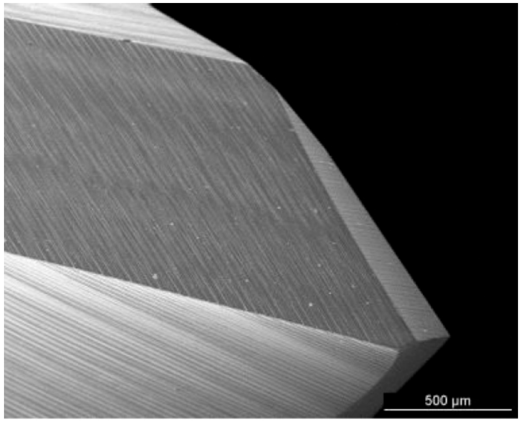
Work piece material: cold working steel - 1.2312 - 40CrMnMoS8-6 – heat treated - Rm=1000 N/mm2 - HRC32
HM end mills: d=12mm - z=4 - vc=200 mm/min – fz=0.1 mm/z – ae=ap=6mm – down cut– coolant: dry air 6 bar

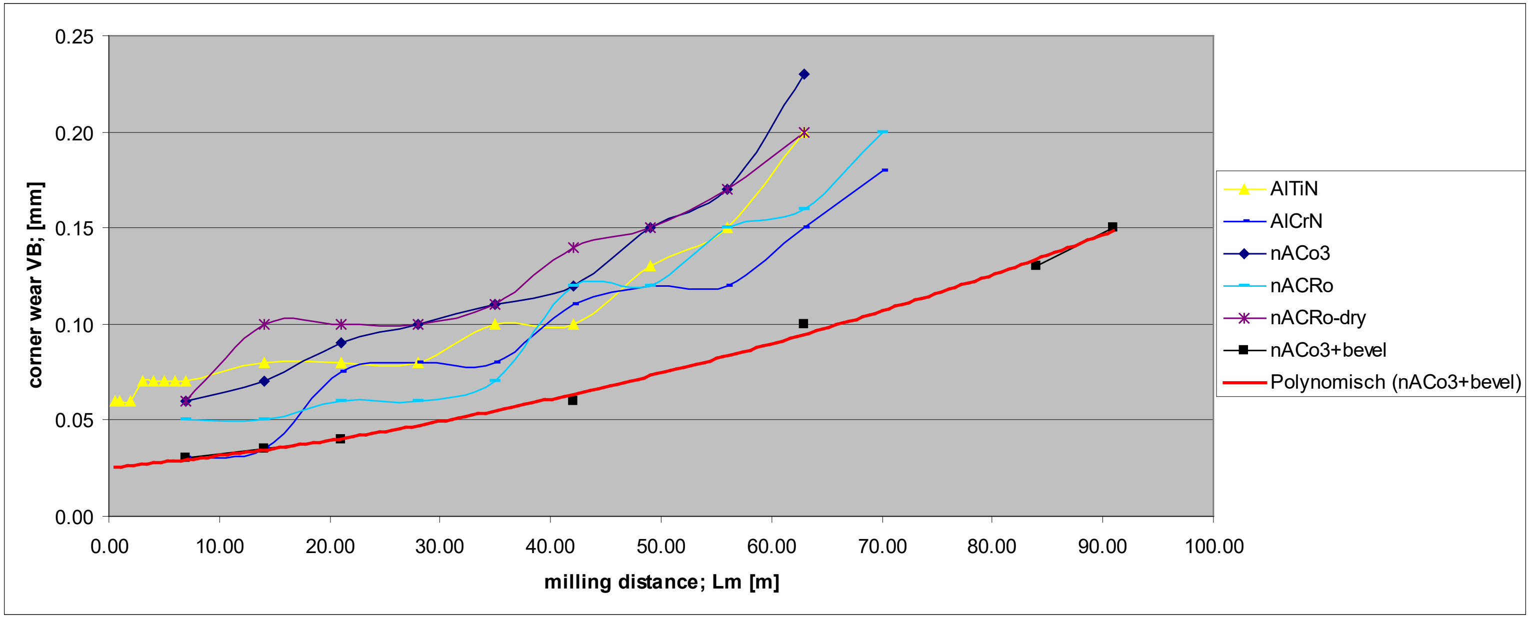
Influence of Edge Preparation on the Performance of Coated End Mills



The edge bevel increases tool life by 80%

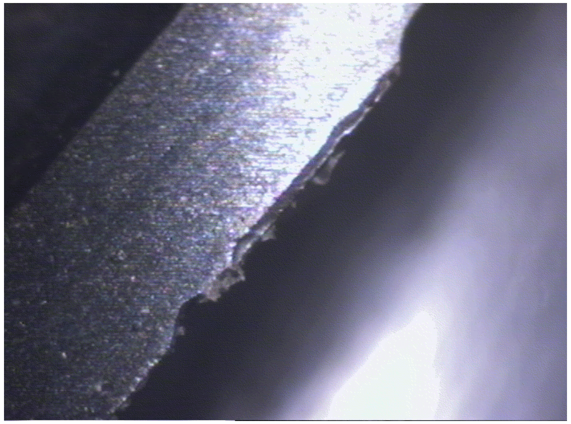




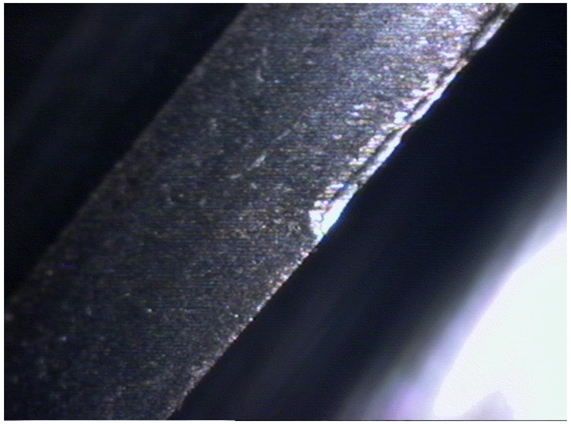


Work piece material: cold working steel - 1.2312 - 40CrMnMoS8-6 – heat treated - Rm=1000 N/mm2 - HRC32
HM end mills: d=12mm - z=4 - vc=200 mm/min – fz=0.1 mm/z – ae=ap=6mm – down cut– coolant: dry air 6 bar

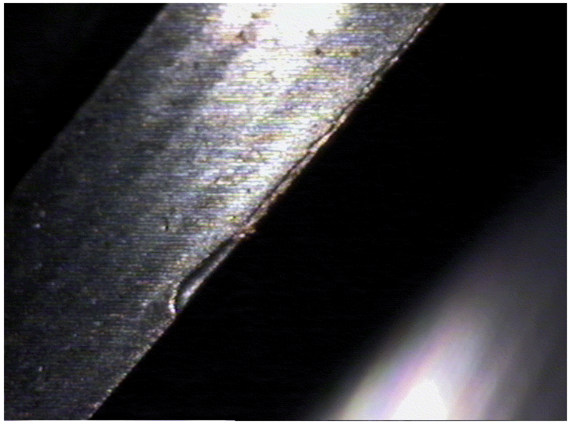
Influence of the Edge Preparation on Margin Wear after L_m=60m at Standard End Mill in HEAT TREATED Steel



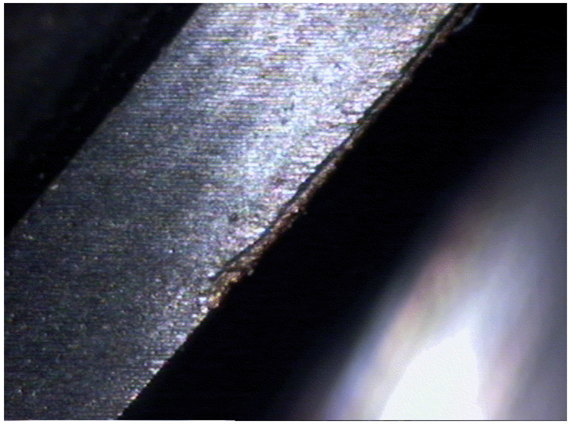
(NO) Honing = 0 um



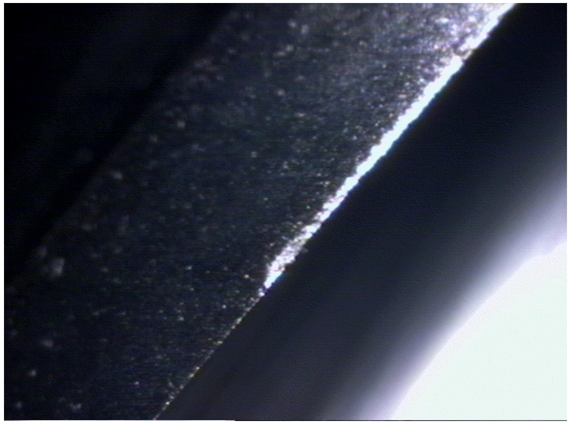
Honing = 10 um



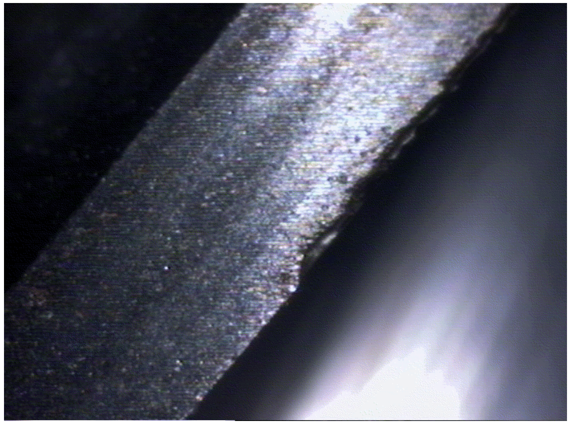
Honing = 15 um



Honing = 20 um



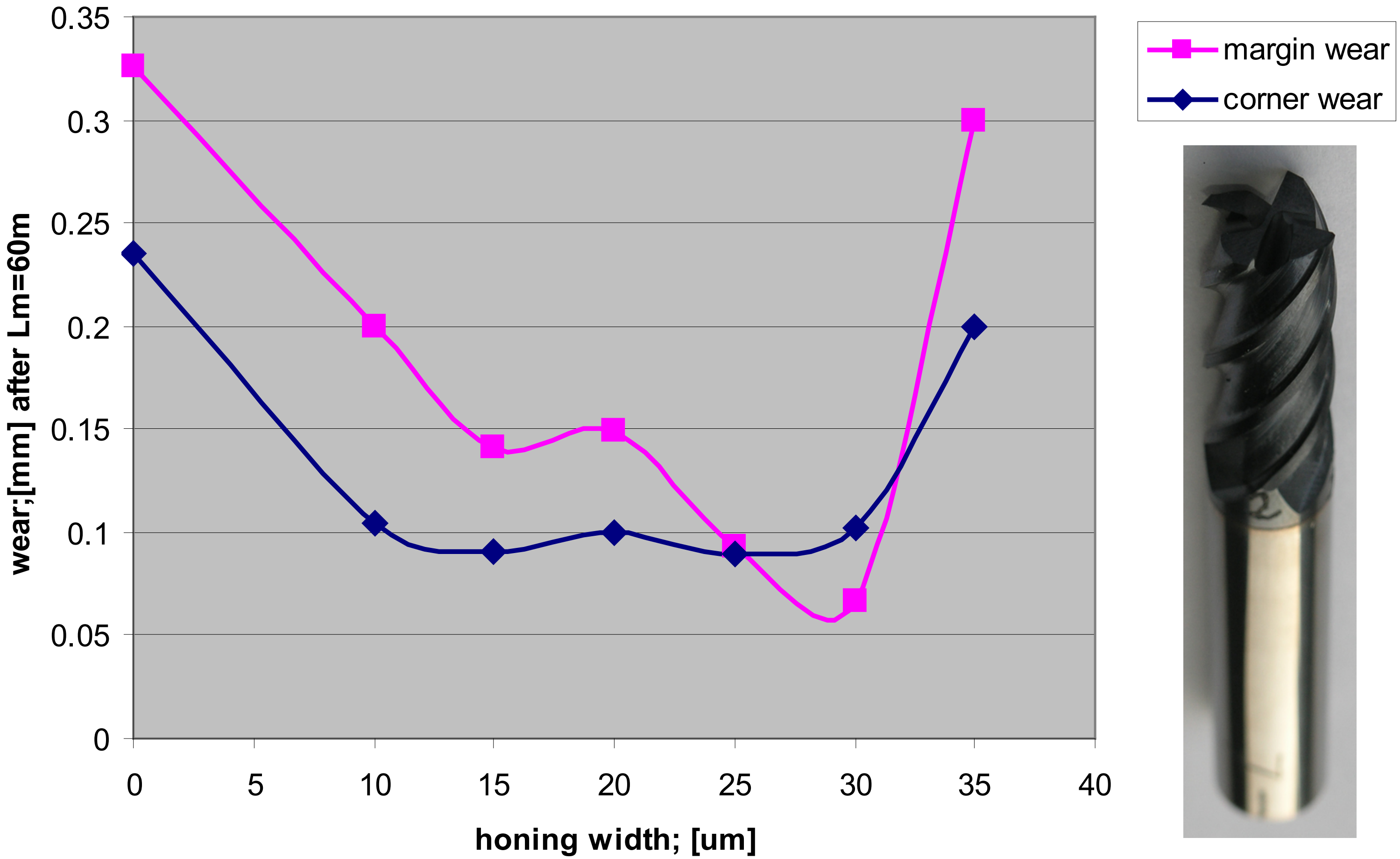
Honing = 30 um



Honing = 40 um

Material: 1.7225 – 42CrMo4 – 4140H – coolant; dry air
End mill: AlTiN coated - d=10mm, z=4, ae=1 mm – ap=d – vc=140 m/min – fz=0.1 mm/z

Influence of the Edge Preparation on Tool Life at Standard End Mill in HEAT TREATED Steel

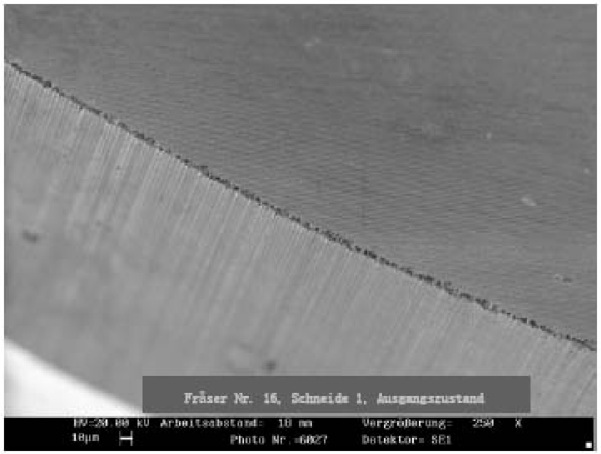


Material: 1.7225 – 42CrMo4 – 4140H – coolant; dry air
End mill: AlTiN coated - d=10mm, z=4, ae=1 mm – ap=d – vc=140 m/min – fz=0.1 mm/z

Edge Preperation for High Performance Torus End Mill

After grinding

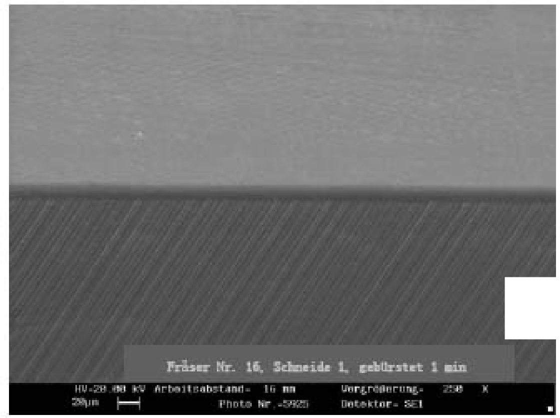
After edge prep



Umfangsschneide

r_n = 7 µm

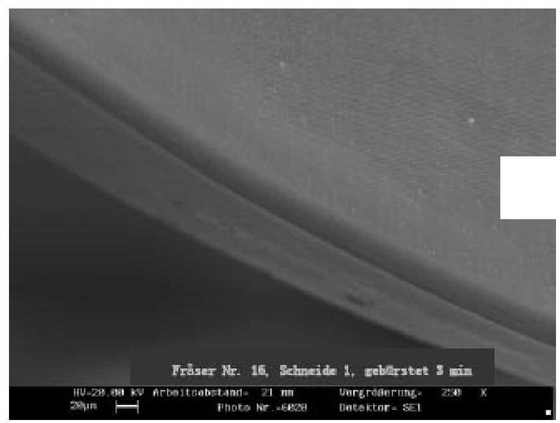
R_t = 4,5 µm



t_B = : 1 min:

r_n = 17 µm

R_t = 3,3 µm

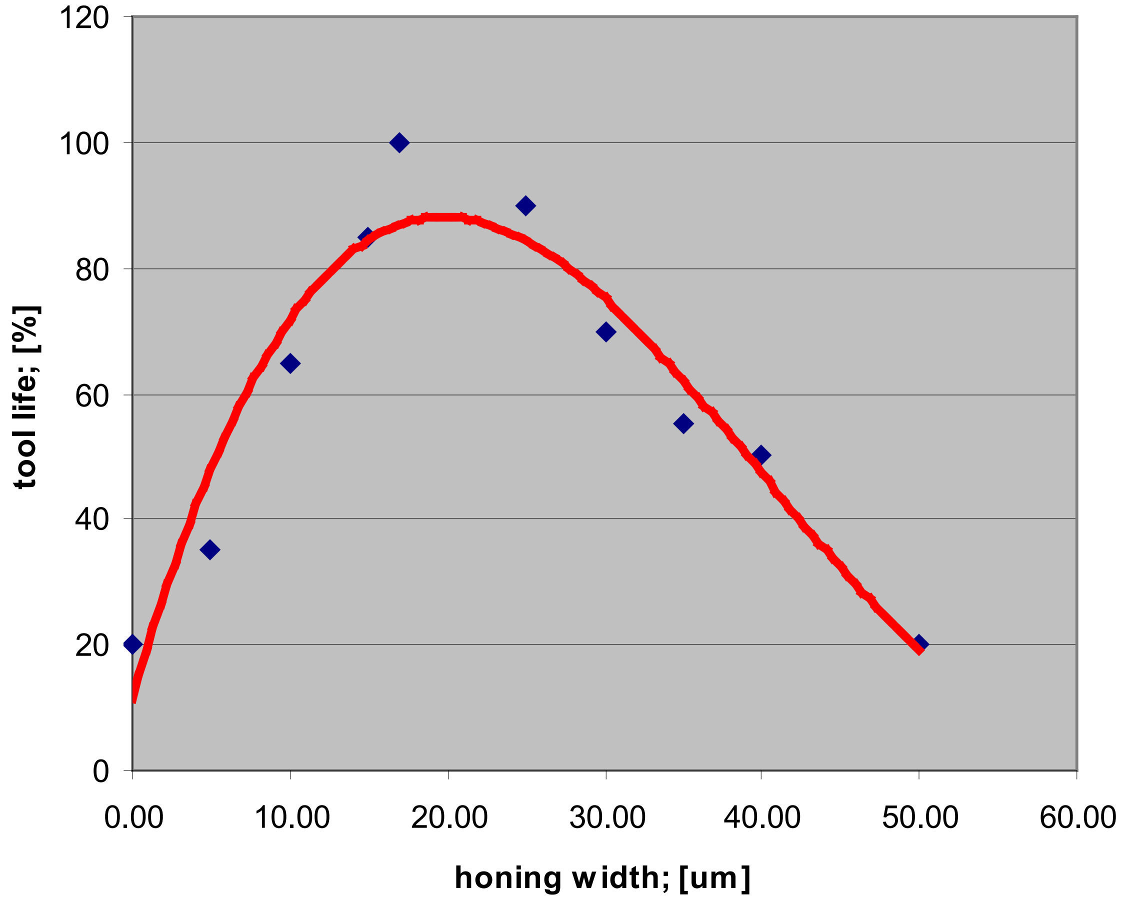


t_B = : 3 min:

r_n = 30 µm

R_t = 1,3 µm

Influence of the Edge Preperation on Tool Life at High Performance Torus End Mill in HIGH ALLOYED Steel



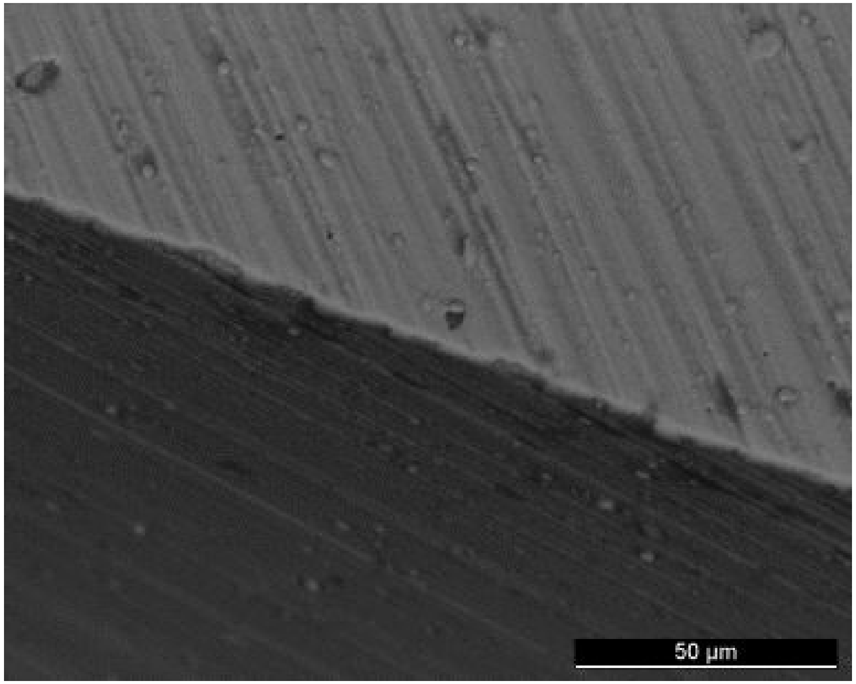
Material: 1.2379 - **X155CrVMo12-1**

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

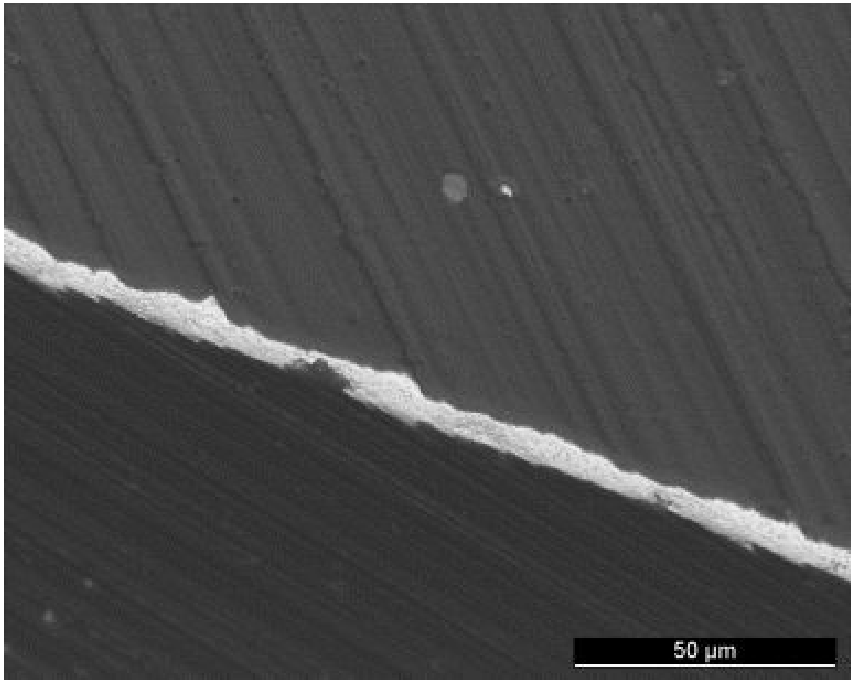
Influence of Edge Preparation on the Performance of Coated Cutting Tools

Edge Preparation after Coating

- The edges are rounded after coating
- The coating is moved away around the edge
- The edge is "set free"



The edge is covered by the coating after deposition



The edge is "set free" after coating mechanically

Influence of Edge Preparation on the Performance of Coated Cutting Tools

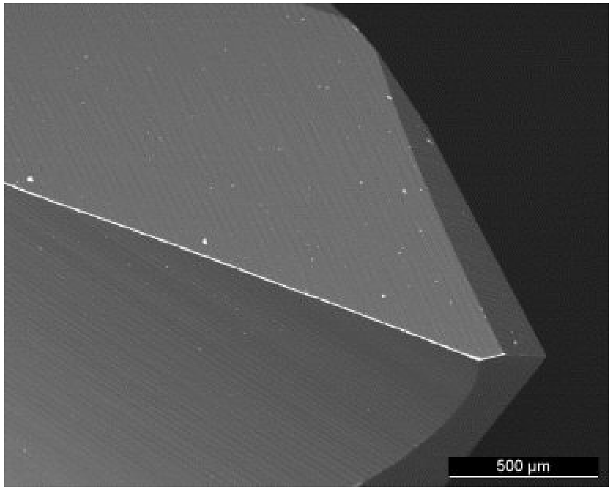
Advantages of
edge preparation after coating:

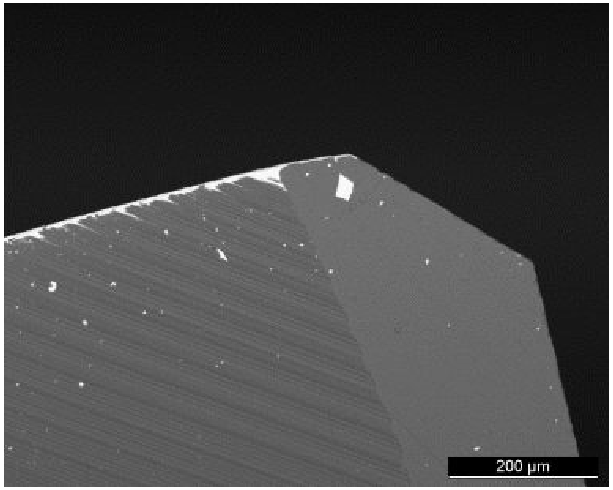
- Edge rounding &
- Droplet removing in one step
-Avoid big break outs

Disadvantages of
Edge Preparation after Coating:

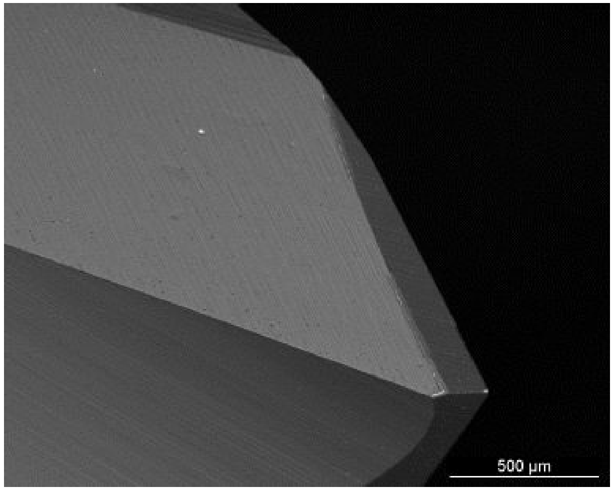
- Interruption of coating structure on long surface line
- Full and direct contact of cutting and work piece material immediately
- Lower heat and chemical insulation
- Low coating thickness near to the edge
- Full coating structure begins far away from cutting edge
- Bigger edge radius (e.g. for roughing) results larger surfaces without coating
- Impression of bad coating

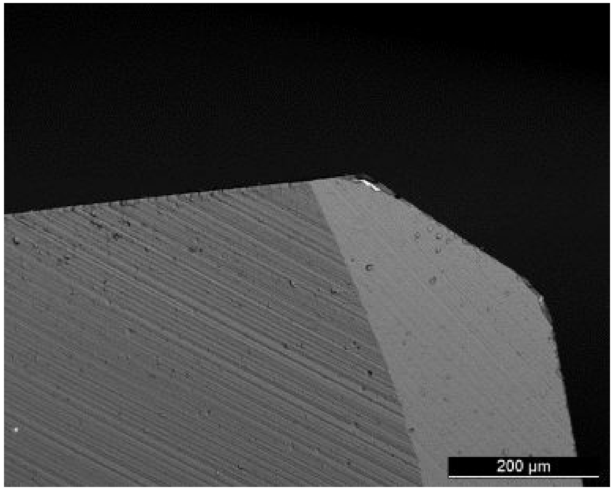
"Set free" edges





As coated





Influence of Edge Preparation on the Performance of Coated Inserts

APPLICATION 3

- Drilling
- Milling
- **Inserts for**
  - **Turning**
- Tapping
- Sawing

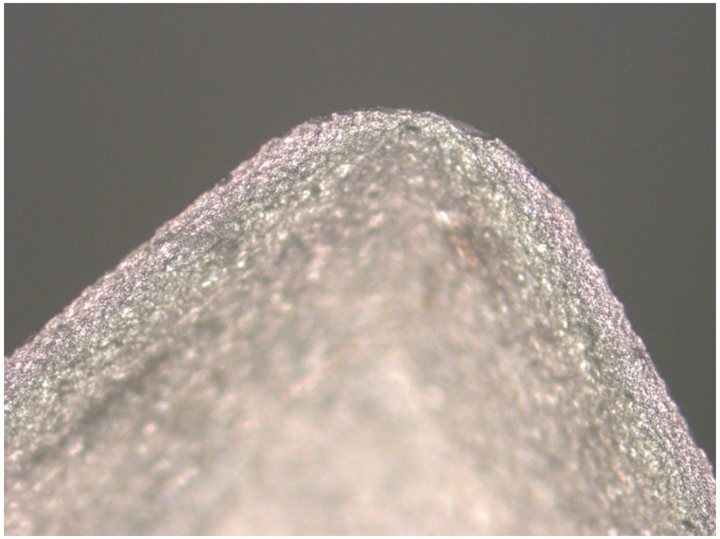
Target : **EDGE STABILITY**

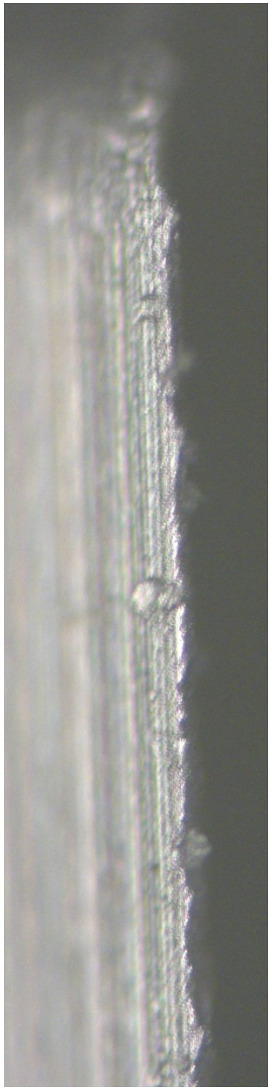
- **Form**
- **Surface**
- **Cutting material**

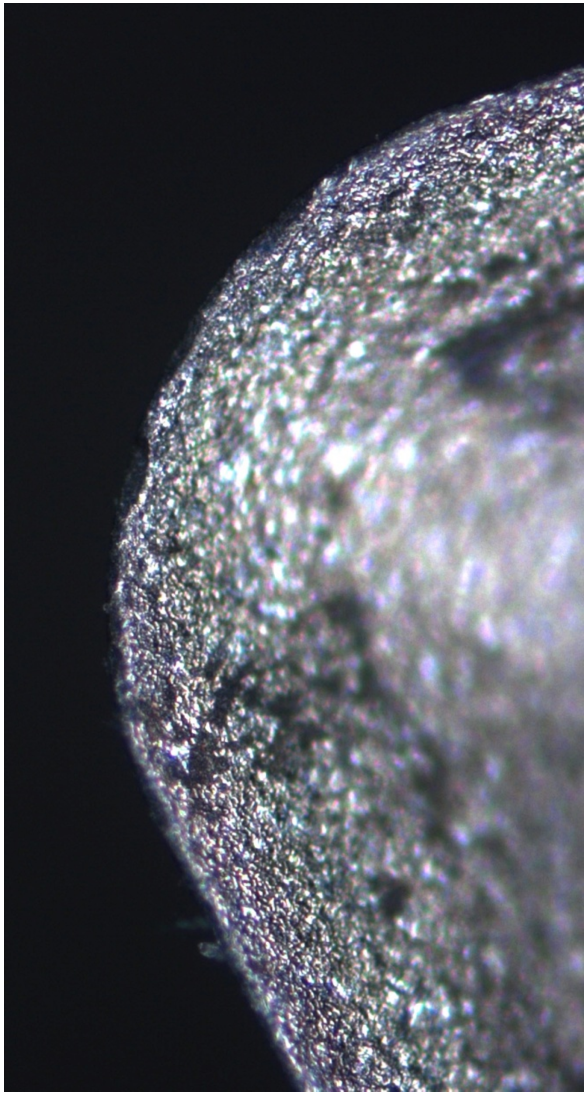
TREATMENTS

- Grinding
- Brushing
- **Micro Blasting**
  - **Dry**
  - **Wet**
- **Drag Grinding**
- Magnet Finishing

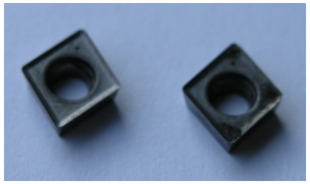
Influence of Edge Preparation on the Performance of Coated Inserts

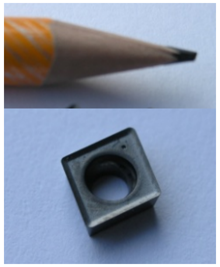




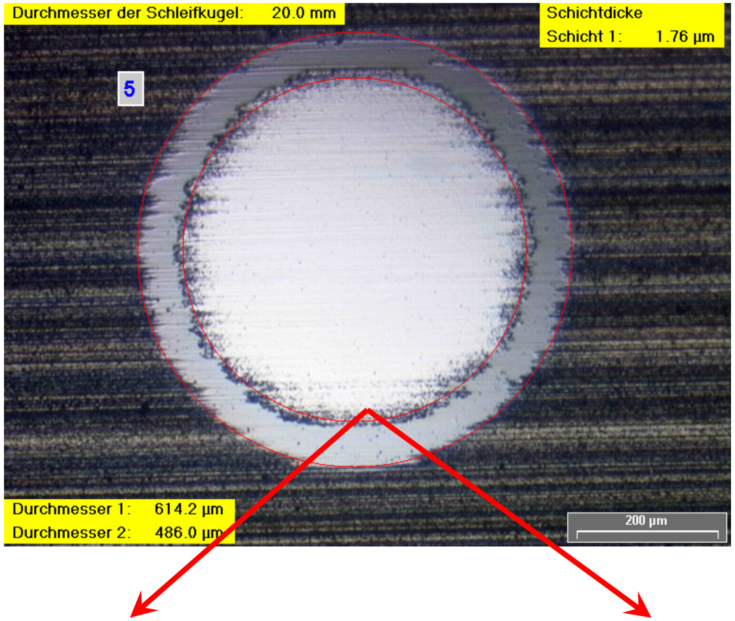


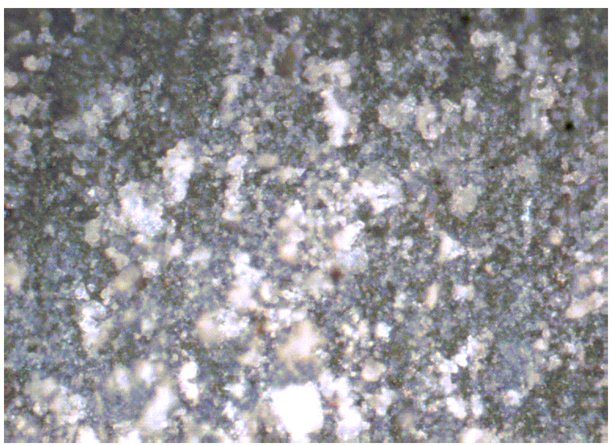
Turning inserts from the production:
- top; sintered (Co-riched)
- side; ground (Co-leached)
- blasting is a MUST!





How Much Cobalt Leaching Can Be Accepted?

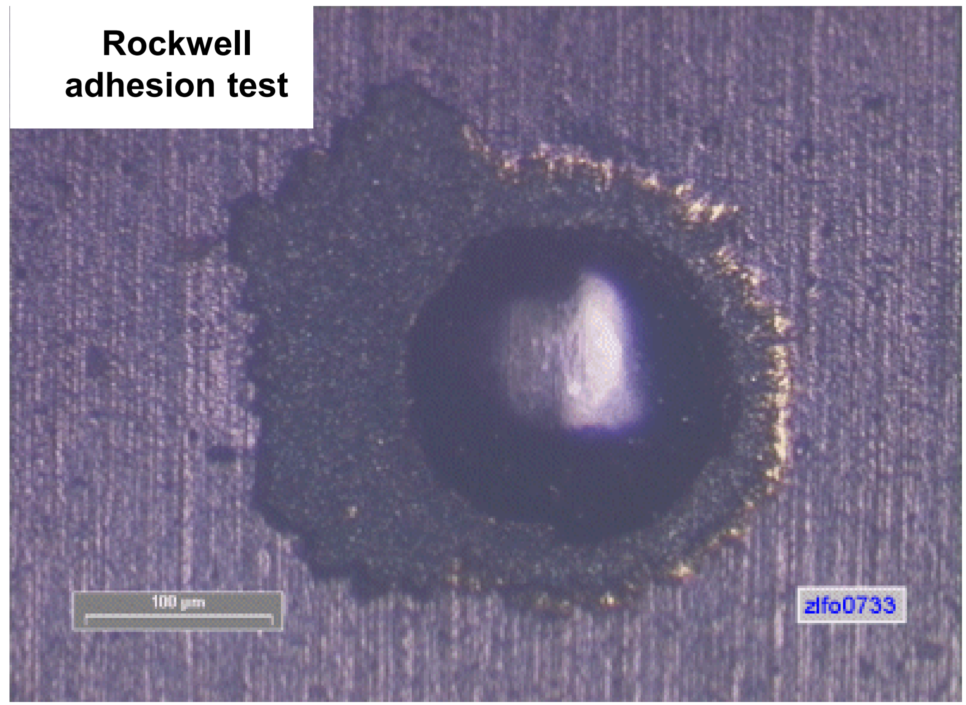




Cobalt leaching

WHY Cobalt Leaching?

- grinding with critical emulsion coolant
- grinding at too high parameters
- grinding with blunt grinding wheels
- non correct stripping



Coating on cobalt leached surface
-> coating on WC layer without/with few binder (cobalt)
-> very bad adhesion

How Much Cobalt Leaching Can Be Accepted?

Evaluation by the Rockwell test from Mercedes Benz: Characterization the goodness of coating adhesion by HF classes

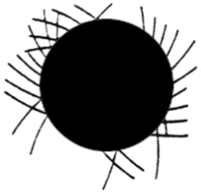

Crack pattern

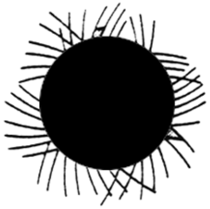

Flaking (*Substrate exposed*)

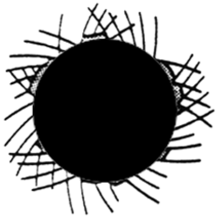
TEST PARAMETERS

Substrate Hardness:	**54 HRc** minimum
Coating Thickness:	**5 μm** maximum
Indentation:	**Rockwell C**
Visual Magnification:	**100x**

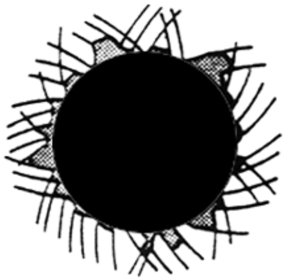
Good adhesion:


HF1


HF2

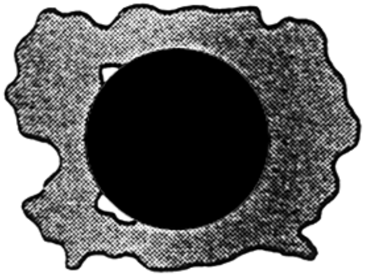

HF3

Deviant adhesion:


HF4

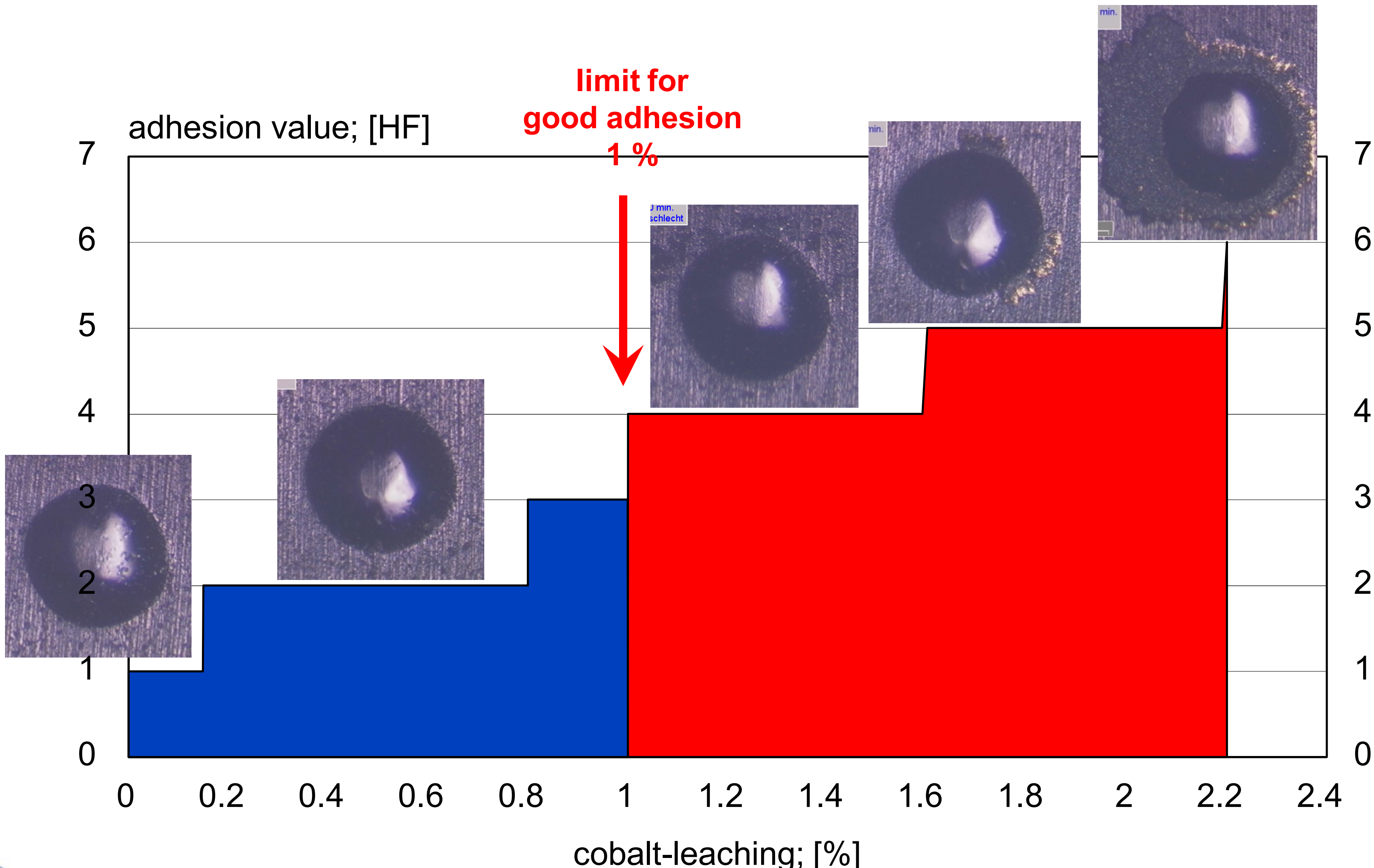
Bad adhesion:


HF5


HF6

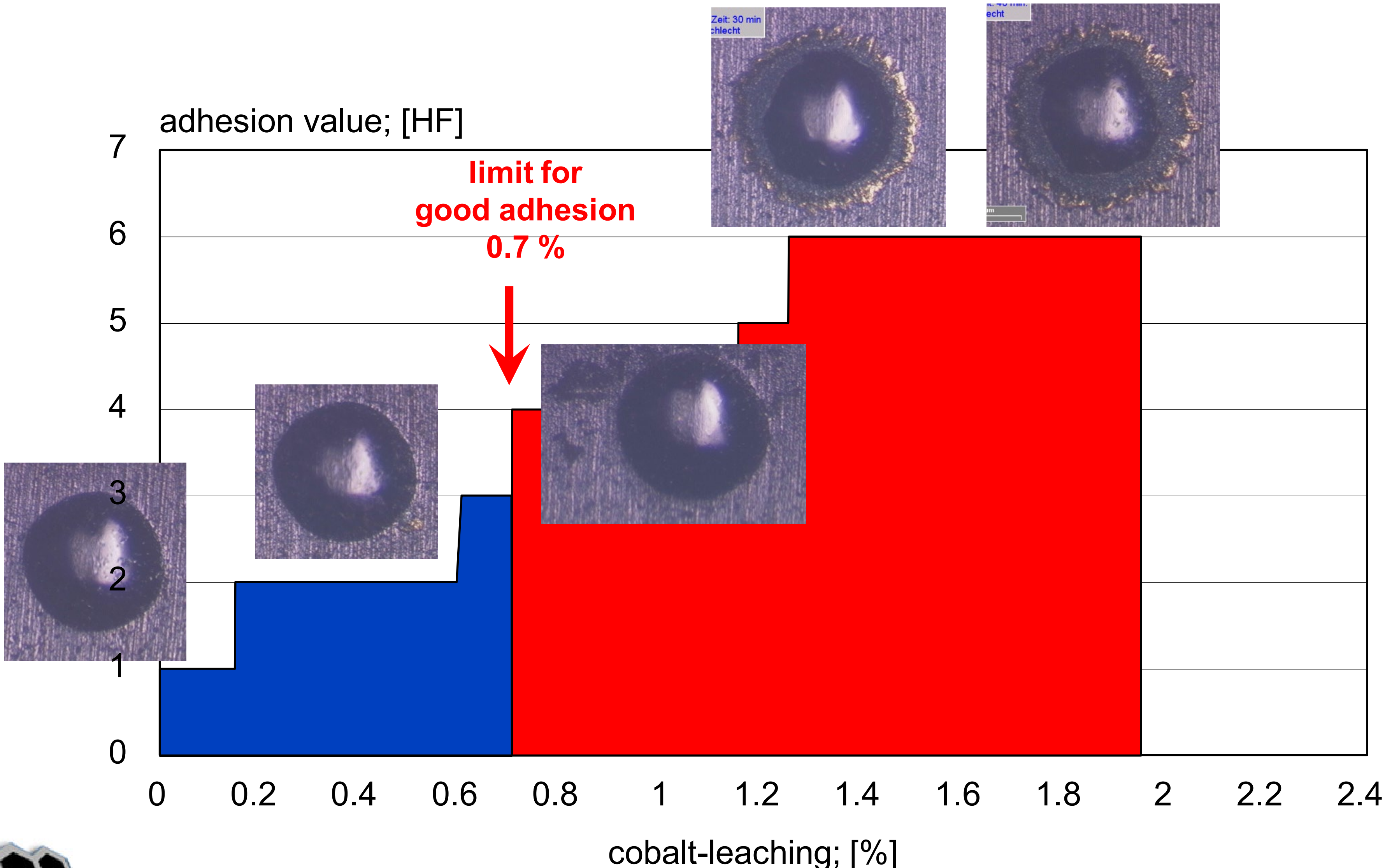
How Much Cobalt Leaching Can Be Accepted?

For good coating adhesion on K30/40 carbide with 10% cobalt



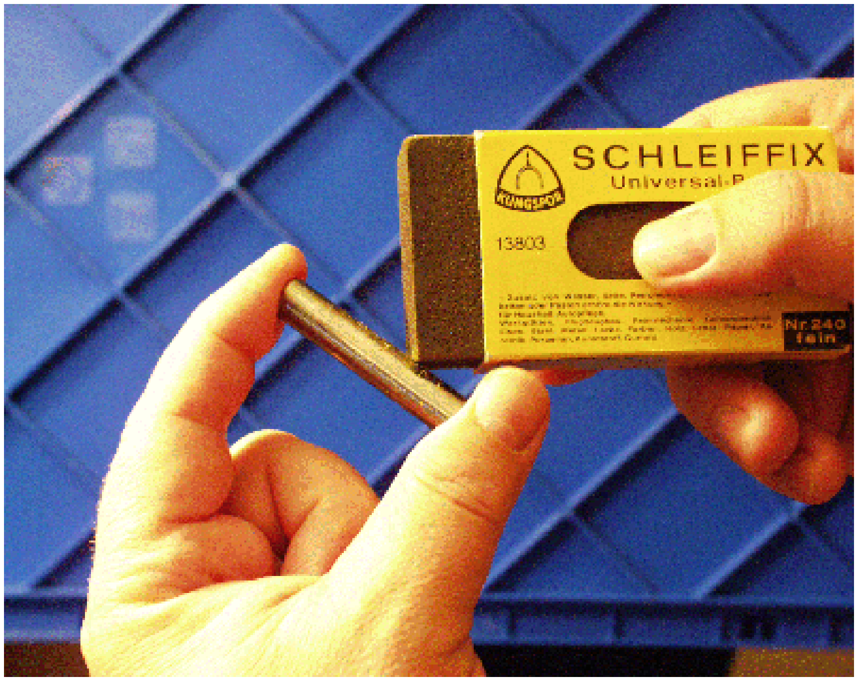
How Much Cobalt Leaching Can Be Accepted?

For good coating adhesion on K10 carbide with 6% cobalt



How to Check Cobalt-Leaching on Carbide?

Rubber Test on Carbide

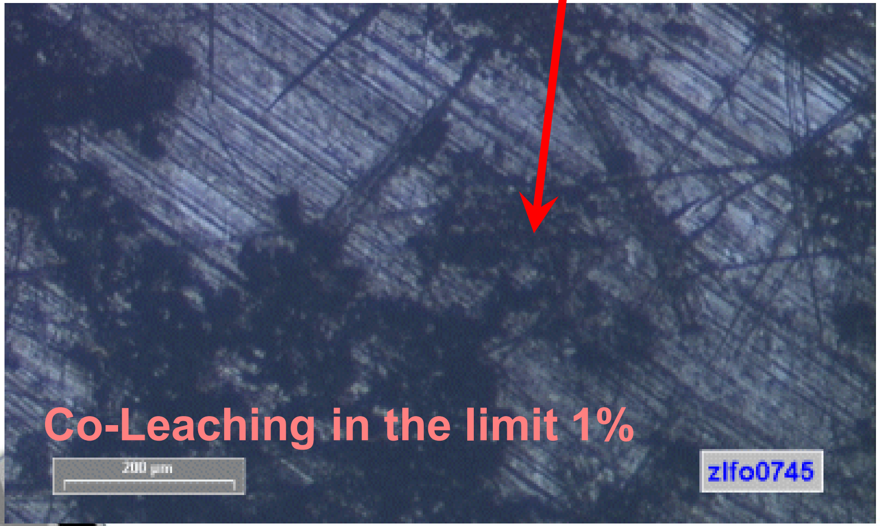


Check the carbide surface under 100x magnification

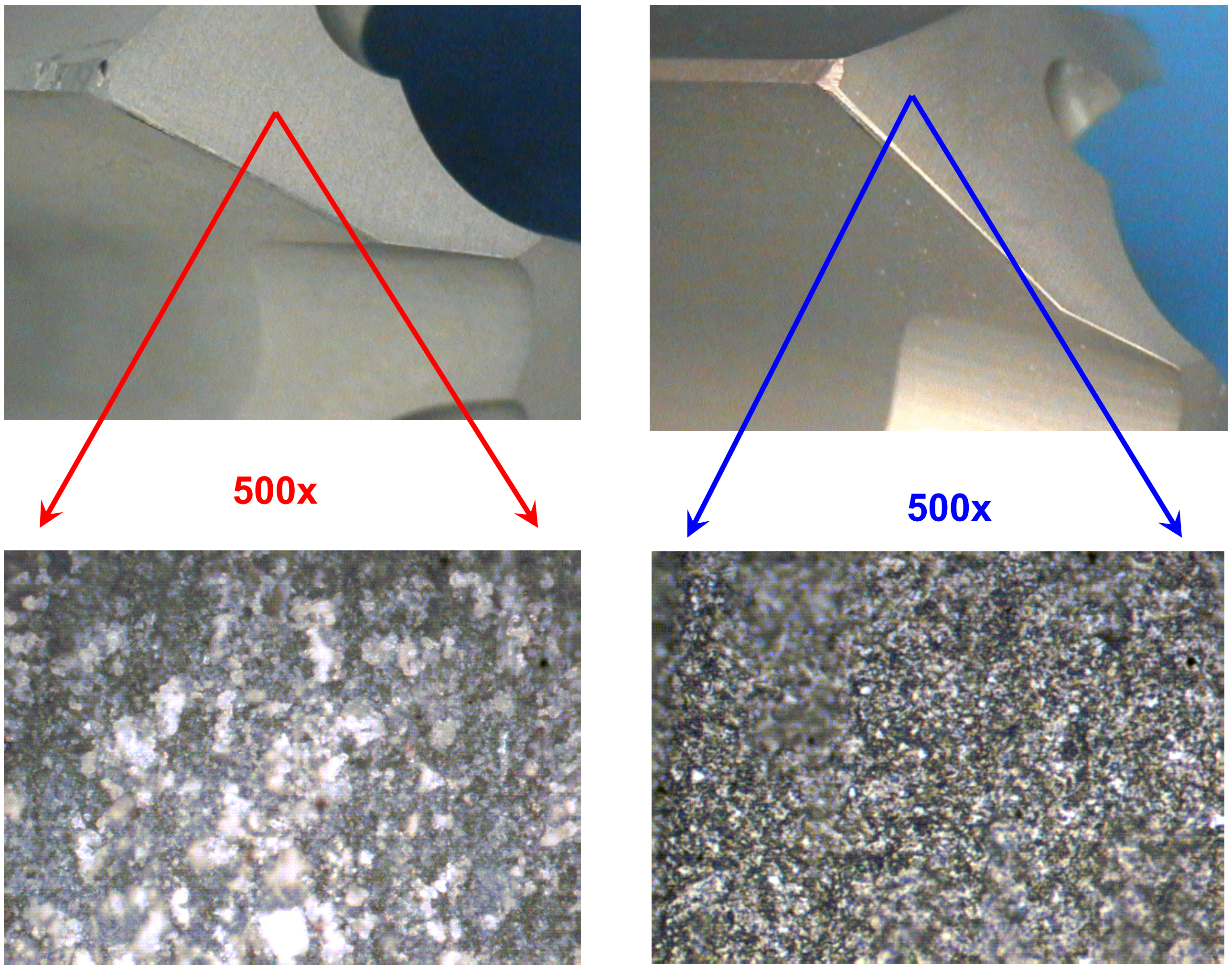
Cobalt-Leaching

How to Check Cobalt-Leaching on Carbide?

Cobalt-Leaching showed by rubbering on K40 carbide with 10% Cobalt



Improvement of the Surface Density and Coatability by Micro Blasting

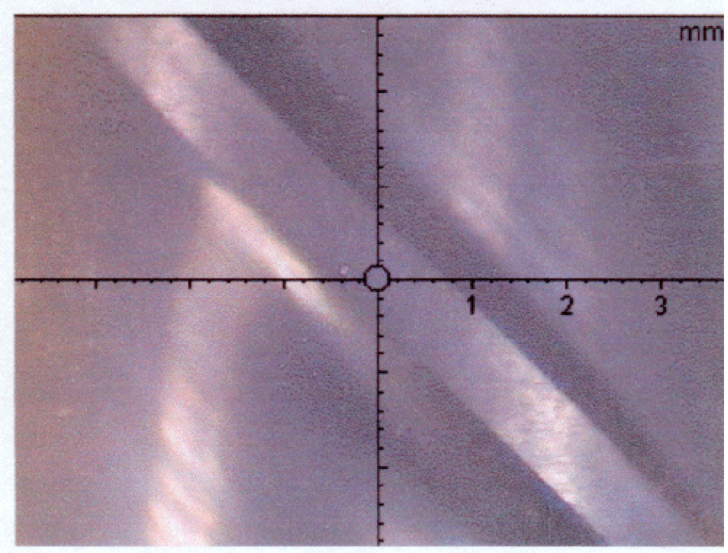


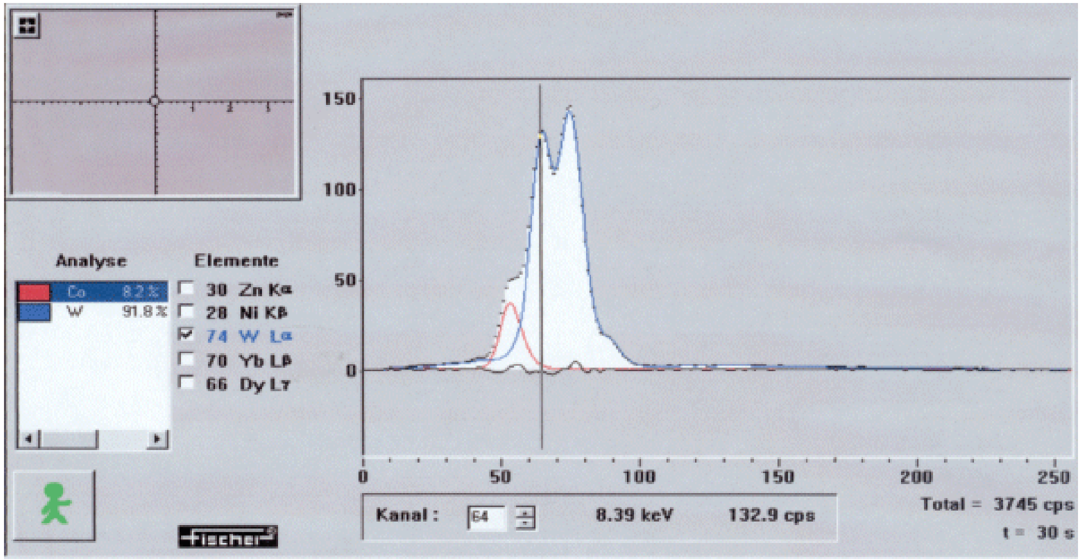
Tool surface with cobalt-leaching

Tool surface after micro blasting Without cobalt-leaching

Improvement of the Surface Density and Coatability by Micro Blasting

Measuring Cobalt Leaching by X-Ray



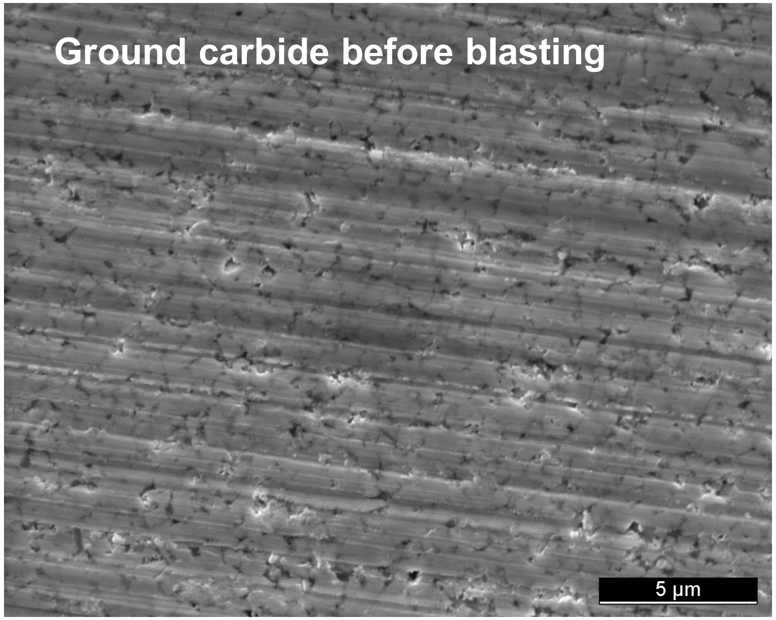


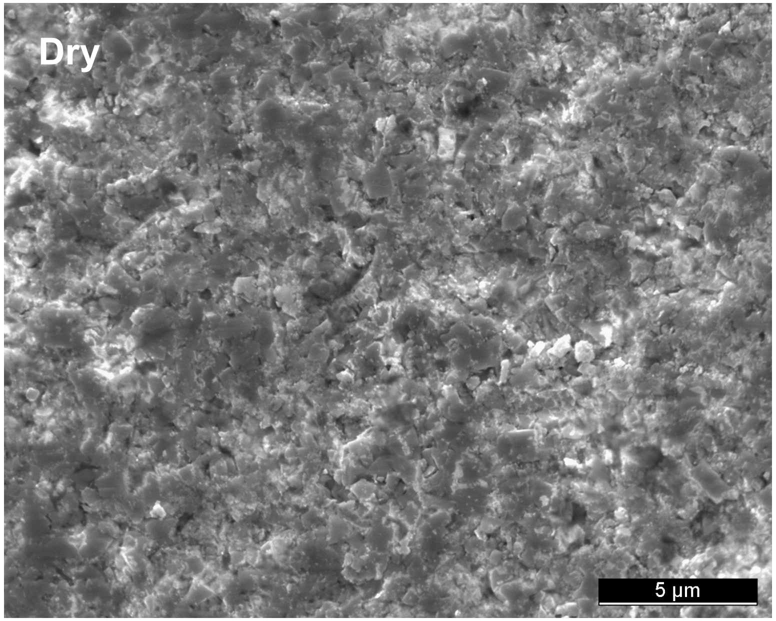
Focusing
on the margin of the tool

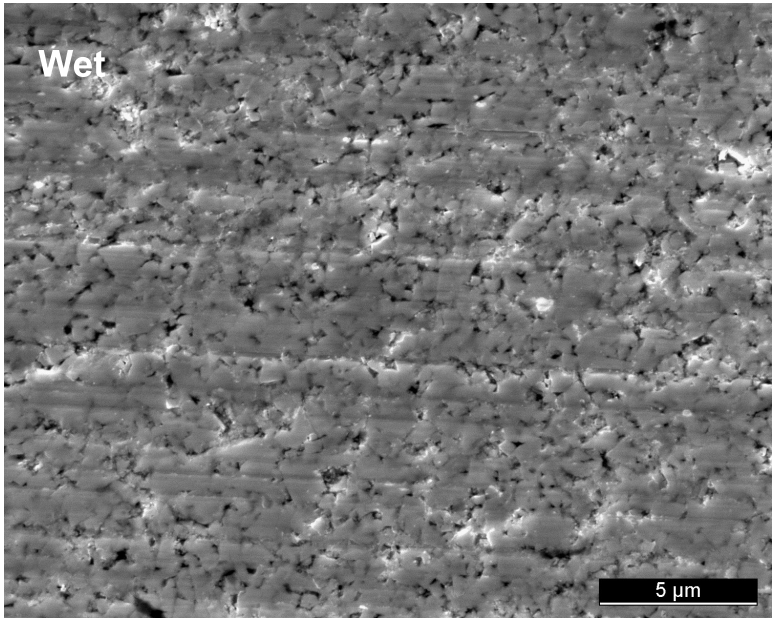
Spectrum with Co and W

Improvement of the Surface Density and Coatability by Micro Blasting

Dry or Wet by Micro Blasting? Comparison of Achievable Surface Structure

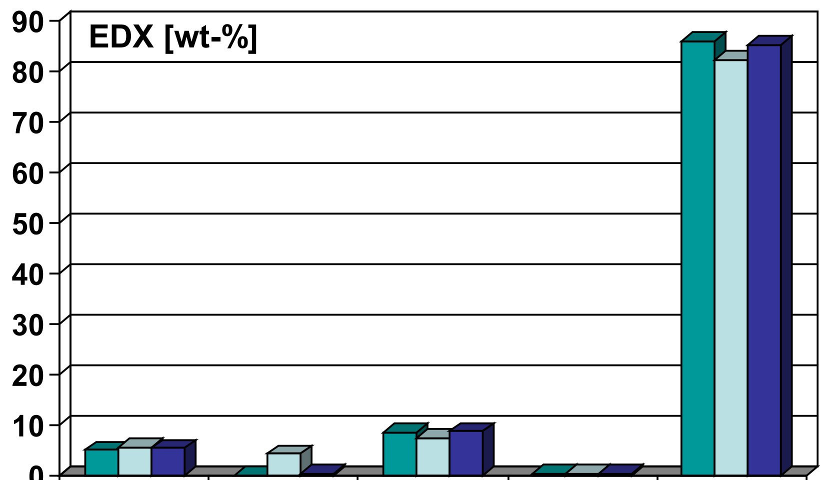




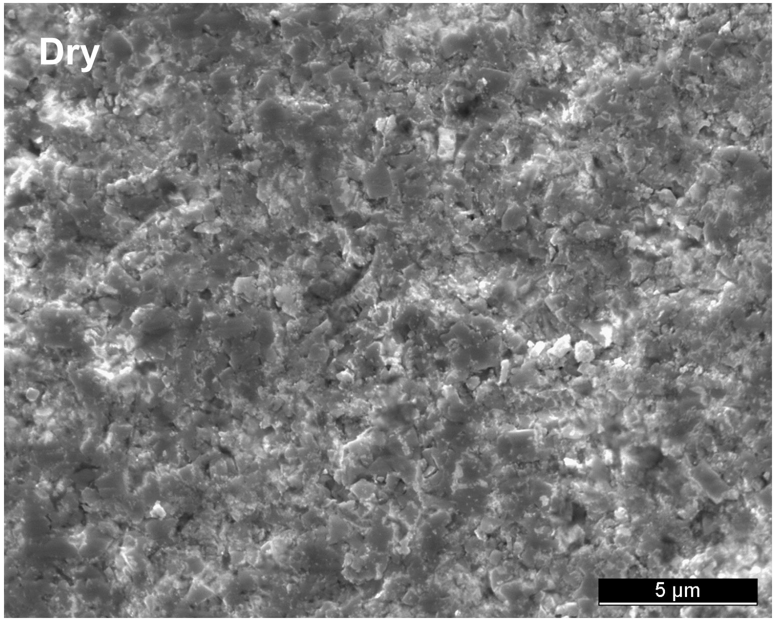


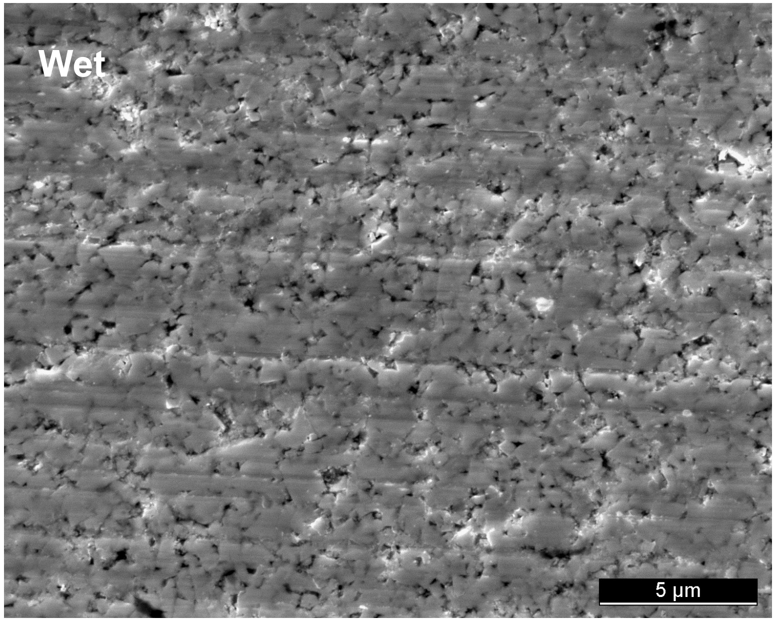
Improvement of the Surface Density and Coatability by Micro Blasting

Dry or Wet by Micro Blasting? Comparison of Achievable Surface Structure



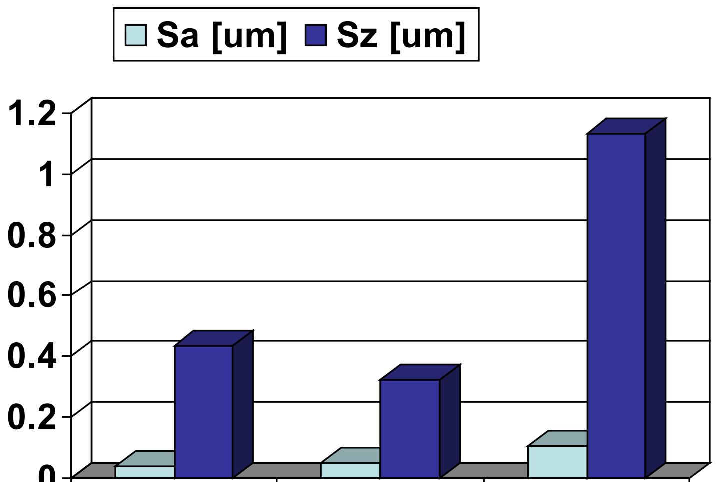
	C	O	Co	Cr	W
Ground carbide	5.1	0	8.6	0.4	85.9
Dry	5.7	4.3	7.5	0.4	82.1
Wet	5.4	0.4	8.7	0.4	85.1



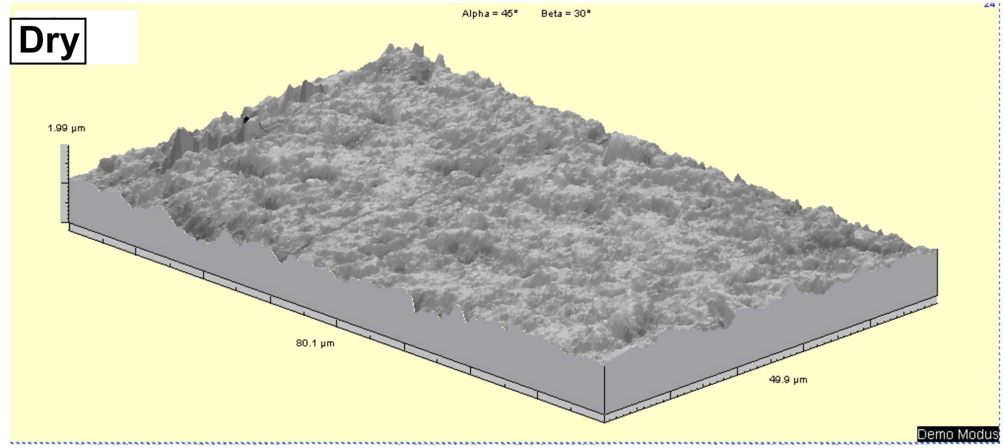


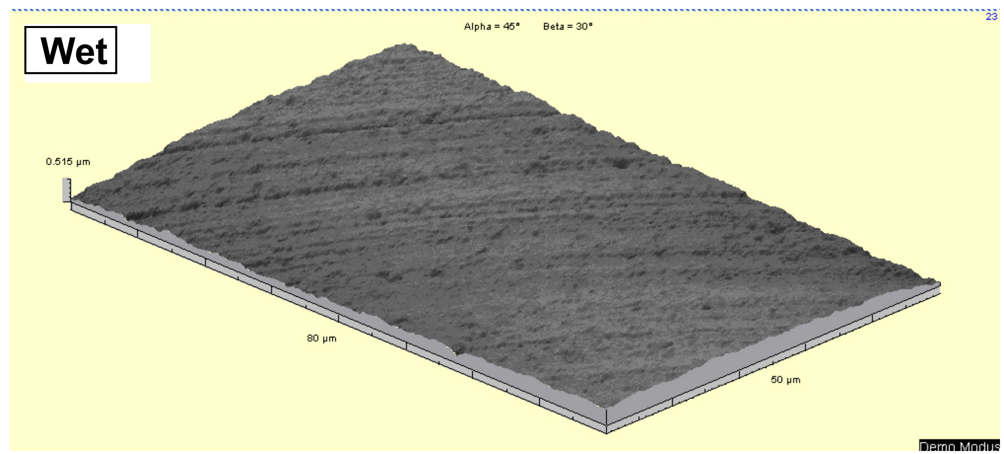
Improvement of the Surface Density and Coatability by Micro Blasting

Dry or Wet by Micro Blasting?
Comparison of Achievable Surface Roughness (AFM)



	Ground carbide	Wet	Dry
Sa [um]	0.0388	0.053	0.106
Sz [um]	0.4376	0.3264	1.1338





Improvement of the Surface Density and Coatability by Micro Blasting

Dry or Wet by Micro Blasting?

Comparison Example: Al2O3, 2 bar 320Mesh, 44 um grain size	DRY	WET
Surface roughness Example: 2 bar 320Mesh, 44 um grain size	Sa=0.11 um Sz=1.14 um	Sa=0.05 um Sz=0.32 um
Rest material after blasting	Smearing of residual material	Danger of cobalt leaching because of water
Coating adhesion	HF1	HF1
Edge rounding	"Filling" required	Better to control
Main features	- No drying needed after blasting - Easy handling at interrupted work - Lower price	- Drying after blasting needed - Difficult cleaning at interrupted work - Higher price

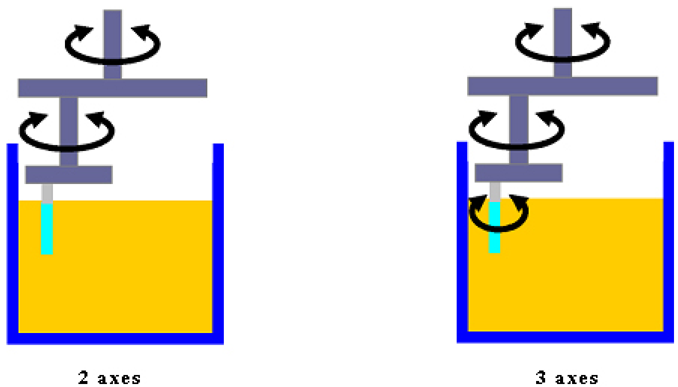
Influence of Edge Preparation on the Performance of Coated Inserts

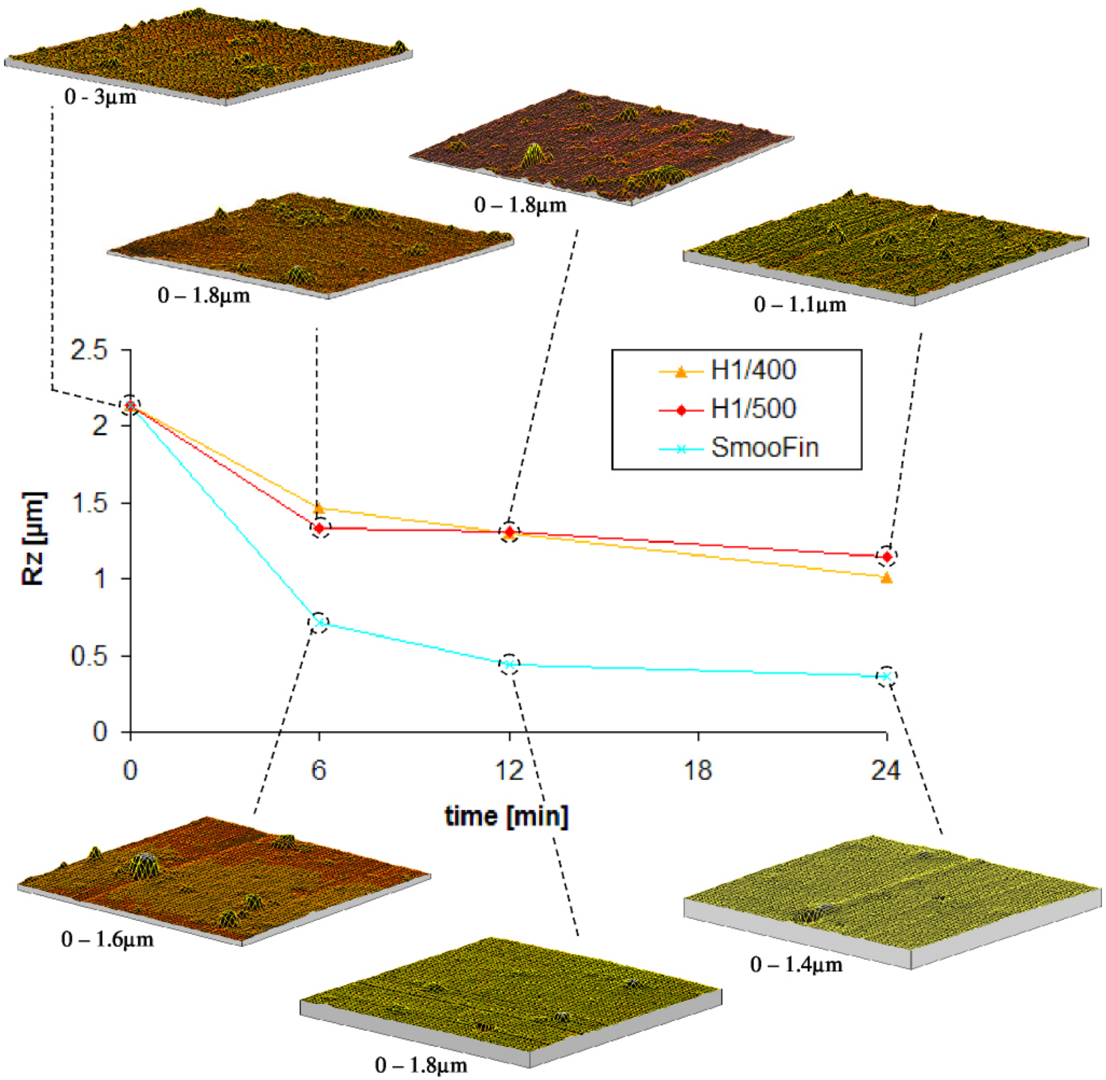
Drag Finishing in Polishing Machine by Special Powder

with 2 driven axes

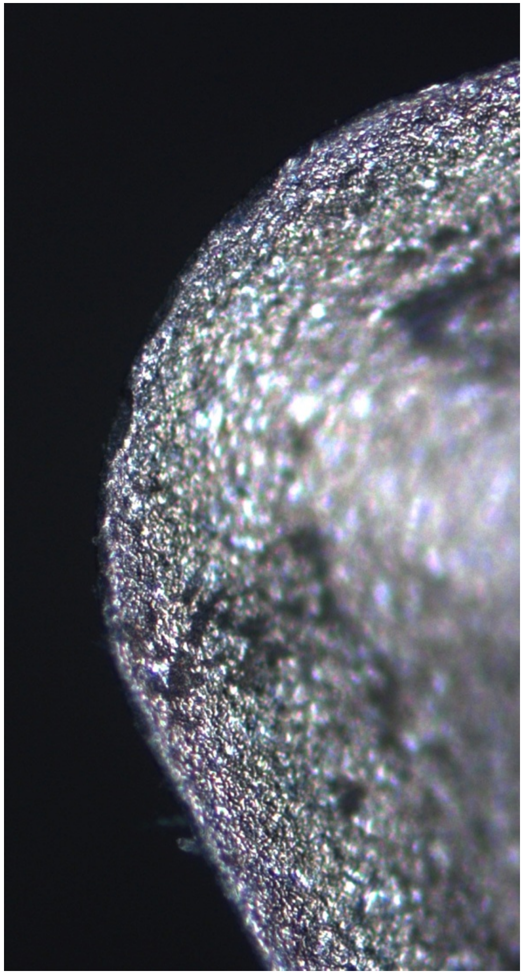
with 3 driven axes

Influence of Edge Preparation on the Performance of Coated Inserts

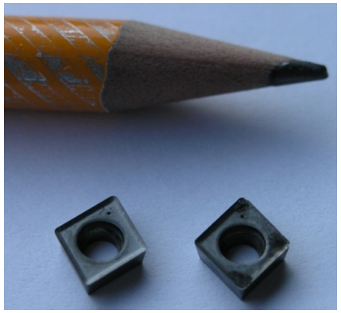


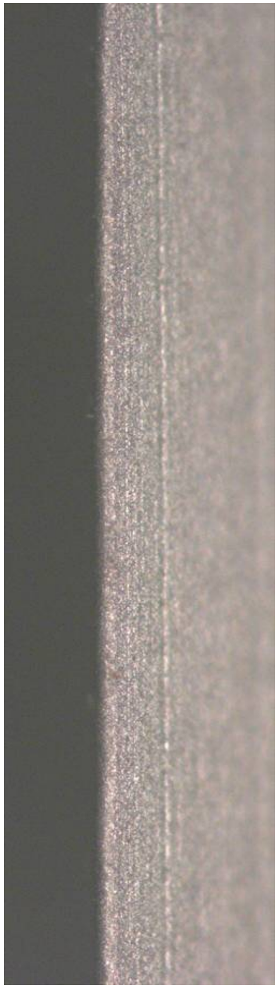


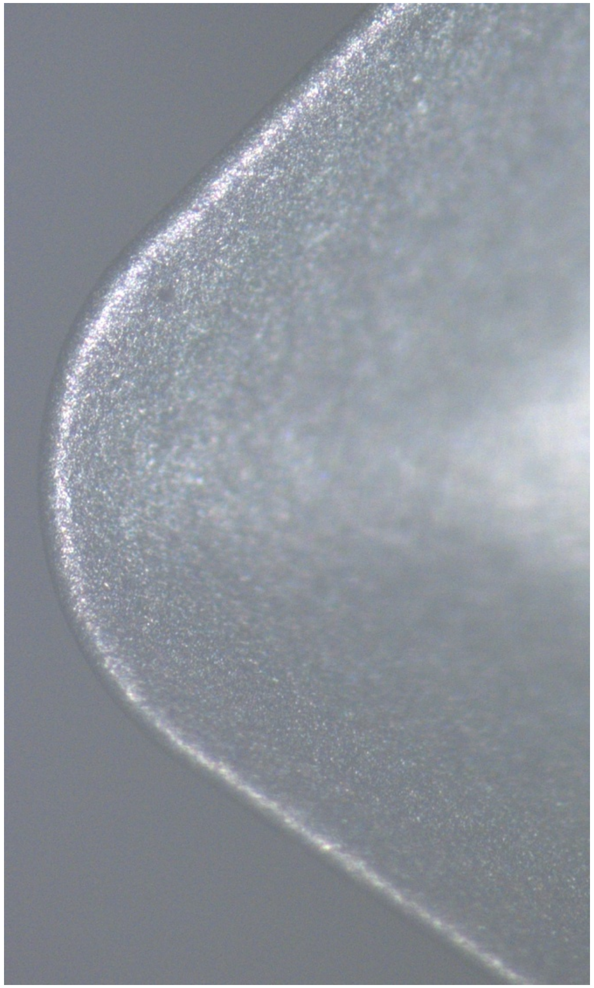
Influence of Edge Preparation on the Performance of Coated Inserts



Before

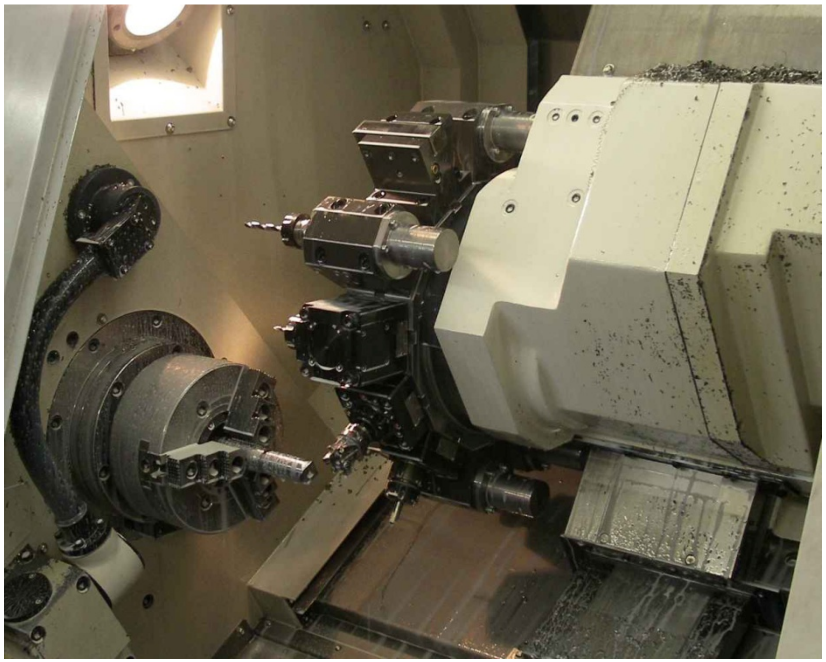


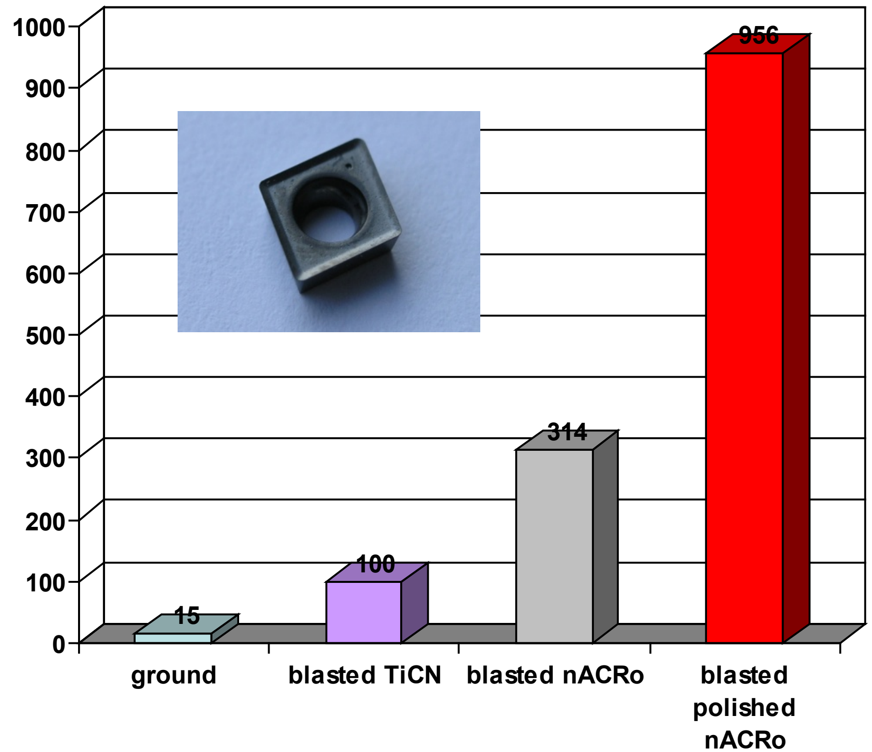




After blasting with Alox and polishing by drag finishing

Influence of Edge Preparation on the Performance of Coated Inserts





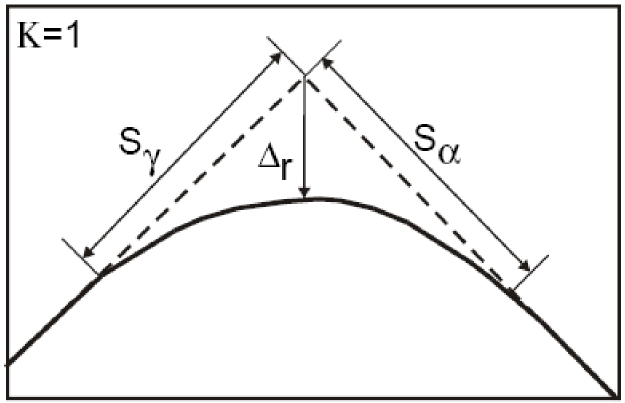
R1=30 um
Rz=2.1 um

R2=30 um
Rz=2.1 um

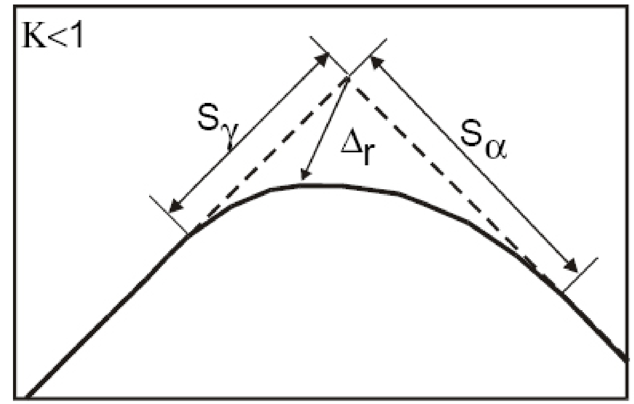
R3=38 um
Rz=0.5 um

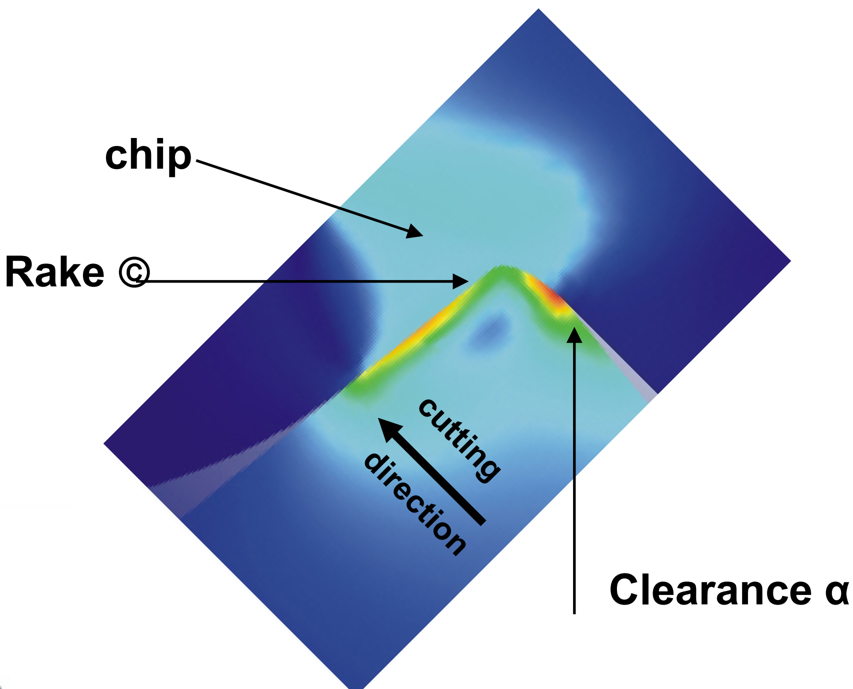
Work piece material: sintered PM steeel - Rm=1000 N/mm2 – Insert: CPGT 05T104 FN20 DS10
vc=200 mm/min – f=0.11-0.13 mm/rev – ap=0.6mm – Source: Deni, Switzerland

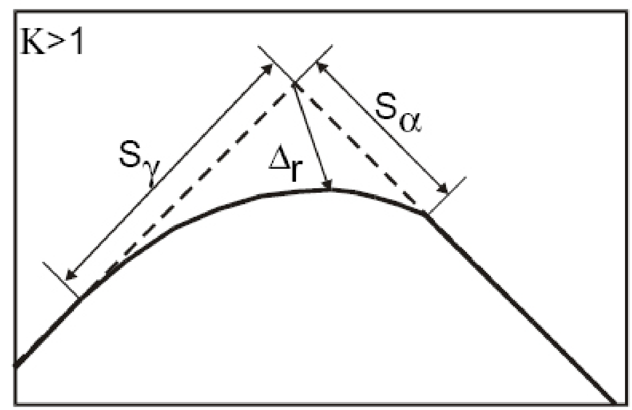
Influence of Prepared Edge Shape on the Performance of Coated Inserts



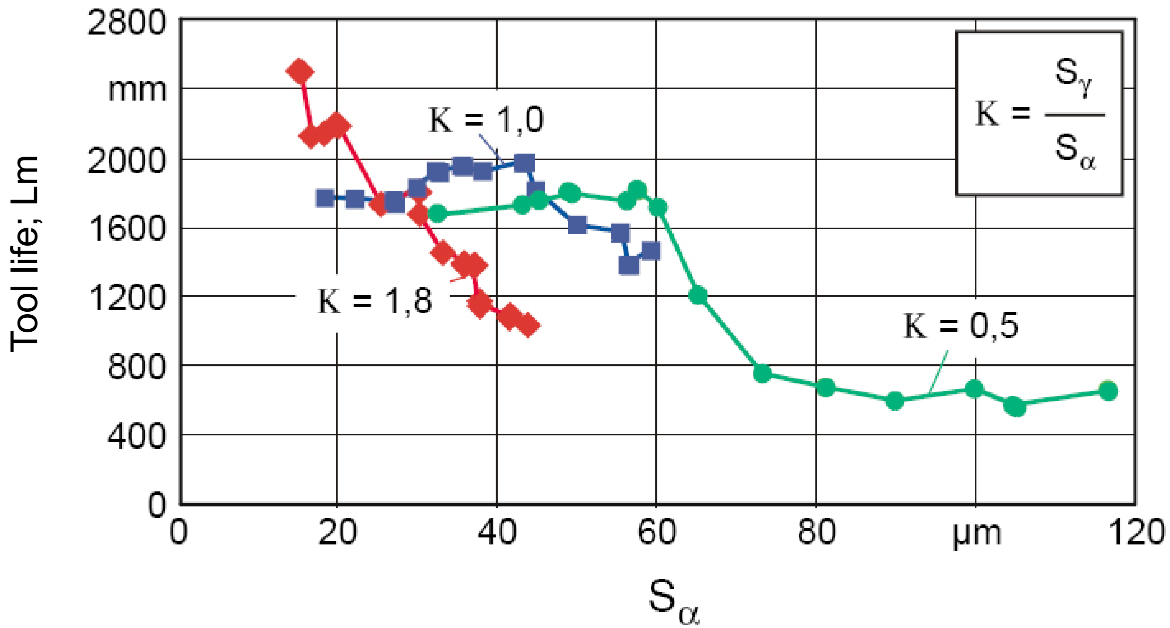
$$K = \frac{S_\gamma}{S_\alpha}$$

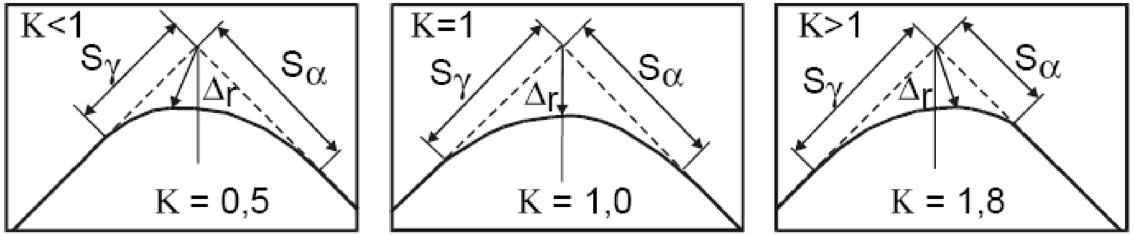


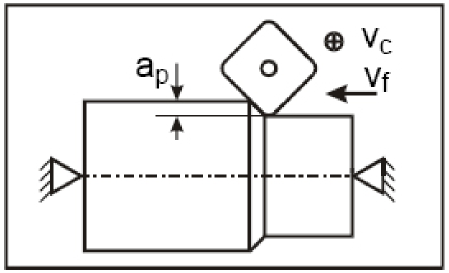




Influence of Edge Preparation on the Performance of Coated Inserts







Source: iwf University Hannover, Germany - Material: carbon steel - Ck45N - dry
HM insert: SNGA 120408 – KMF – TiAlN – vc=200 m/min – f=0.25mm/rev – ap=1.5mm

Influence of Edge Preparation on the Performance of Coated Taps

APPLICATION 4

- Milling
- Drilling
- Turning
- **Tapping**
- Sawing

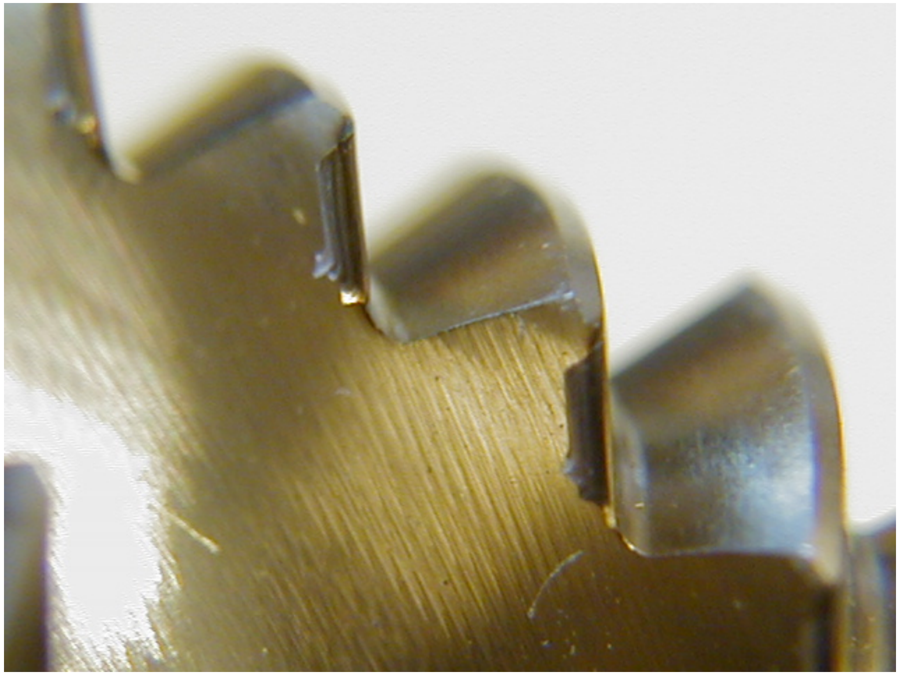
Target : **EDGE STABILITY**

- **Form**
- **Surface**
- Metallurgy

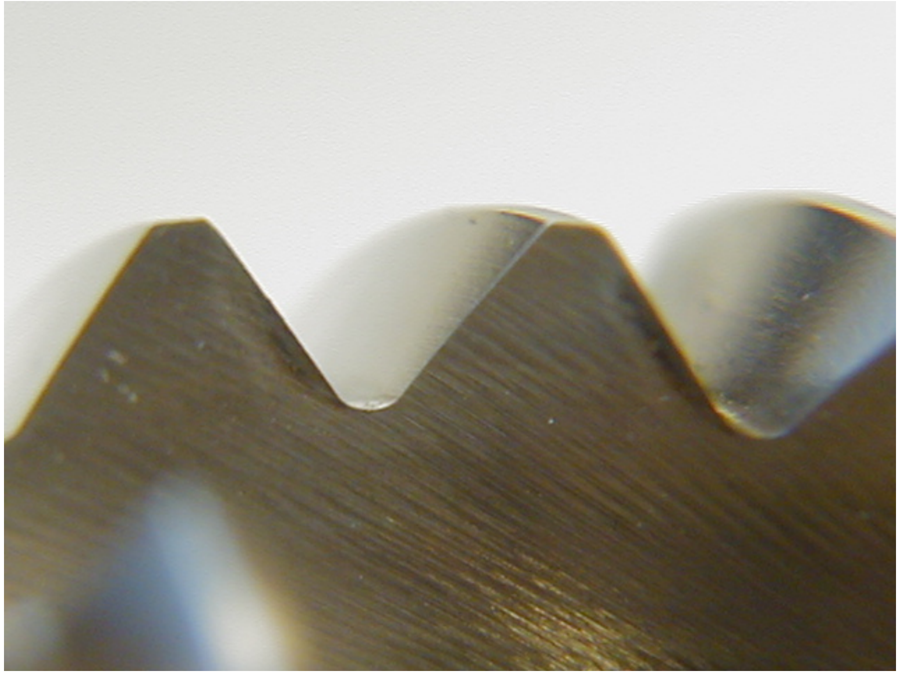
TREATMENTS

- Grinding
- Brushing
- Micro Blasting
  - Dry
  - Wet
- Drag Grinding
- **Magnet Finishing**

Influence of Edge Preparation on the Performance of Coated Taps



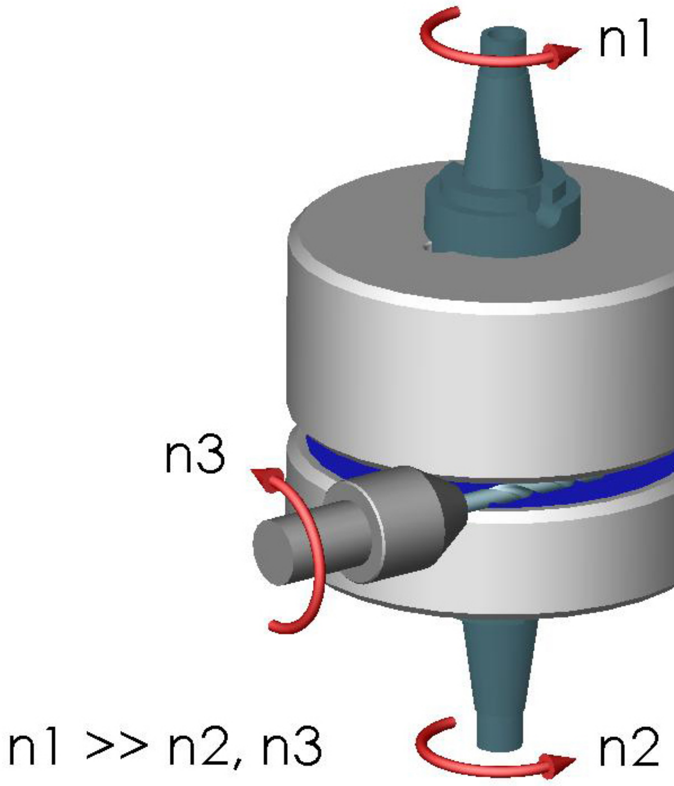
Without polishing



After polishing

Edge Preparation with Magnetic Powder with Robot Manipulation for Large Scale Tool Production

MF
magnetfinish

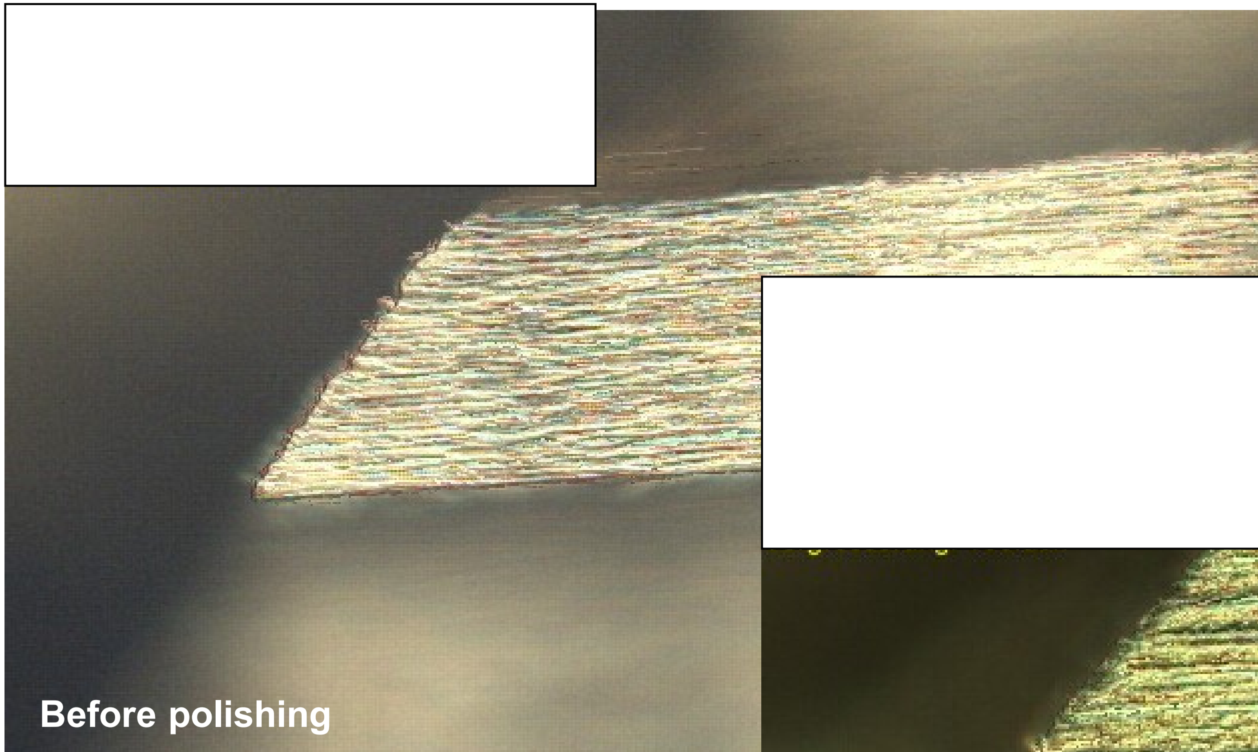


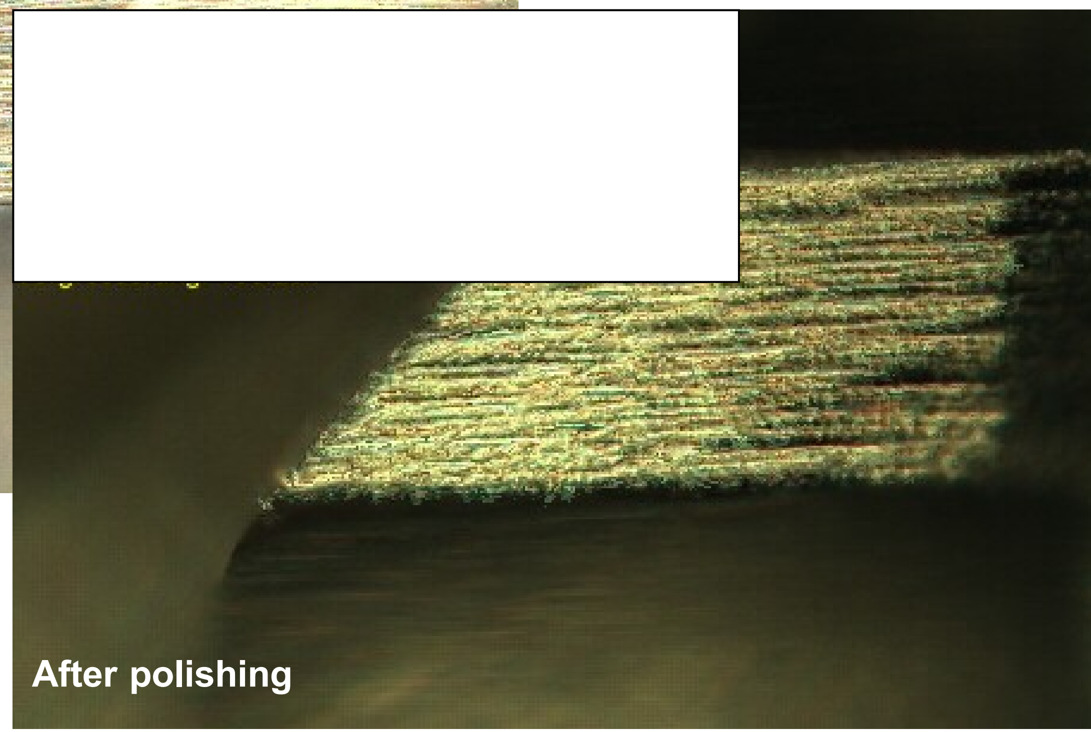
Edge Preparation of Small Tools (d>1mm) with Magnetic Powder Head as a "Grinding Wheel"

Source: MF & Schütte

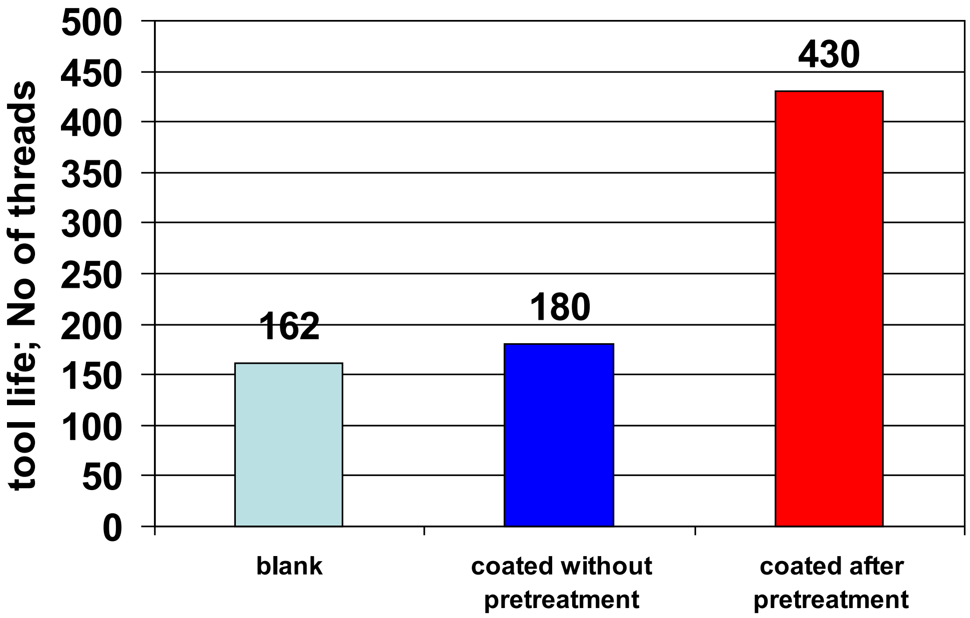
Influence of Edge Preparation on the Performance of Coated Taps

Magnification: 100x





Influence of Edge Preparation on the Performance of Coated Taps



Work piece Material: carbon steel - C45K – Coolant: emulsion 7%
Tools: rigid taps - M3 – a=1.5xd – blind holes - vc=10 m/min

Influence of Edge Preparation on the Performance of Coated at Wood Cutting

APPLICATION 5

- Drilling
- Milling
- Turning
- Tapping
- **Sawing**

Target : EDGE STABILITY

- **Form**
- Surface
- Metallurgy

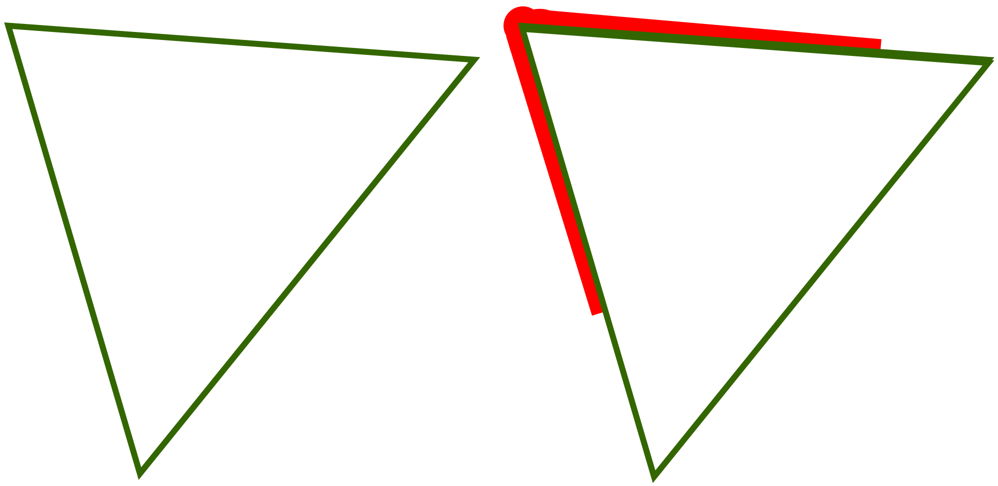
TREATMENTS

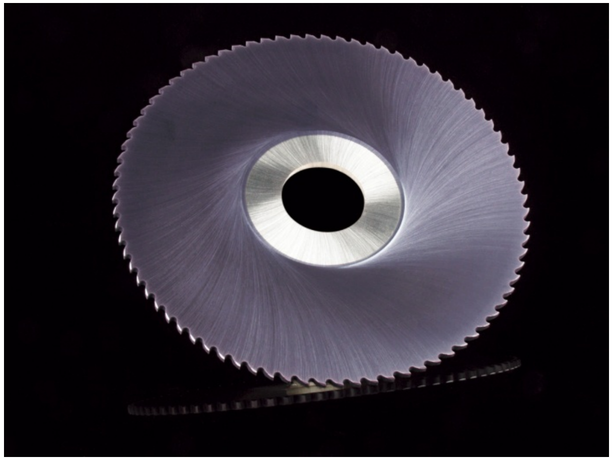
- **Grinding**
- **Brushing**
- Micro Blasting
  - Dry
  - Wet
- Drag Grinding
- Magnet Finishing

Influence of Edge Preparation
on the Performance of Coated at Wood Cutting

Expert's opinion:
The Cutting Edge Must Be Sharp! ?

Therefore coating hardly used in wood cutting;





Only 2% wood cutting tools are coated!

Influence of Edge Preparation
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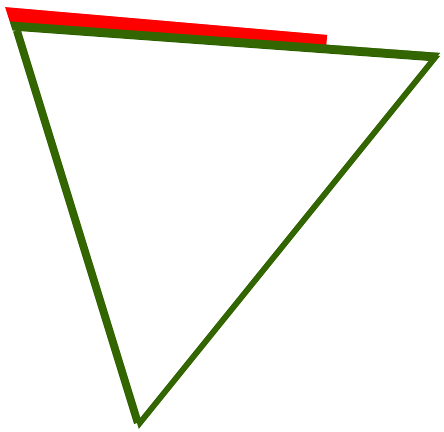
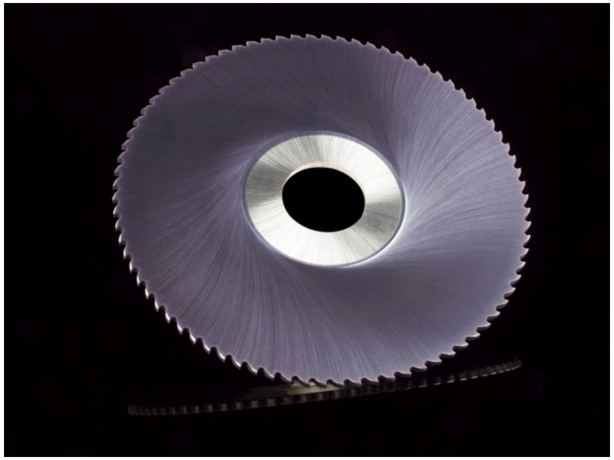
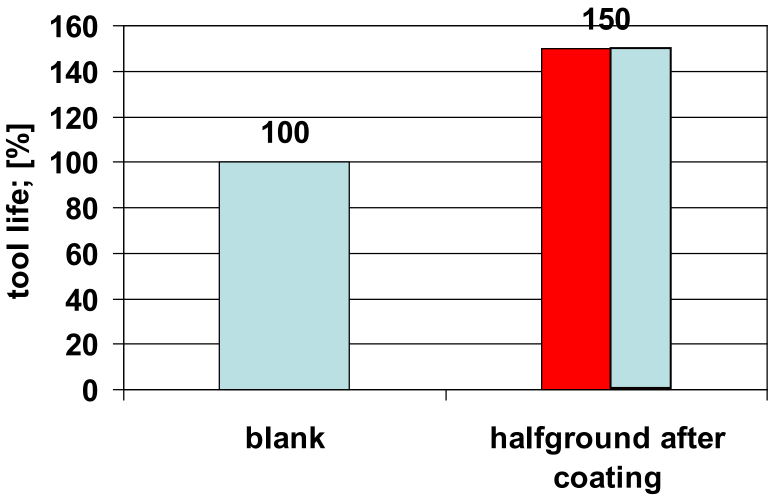
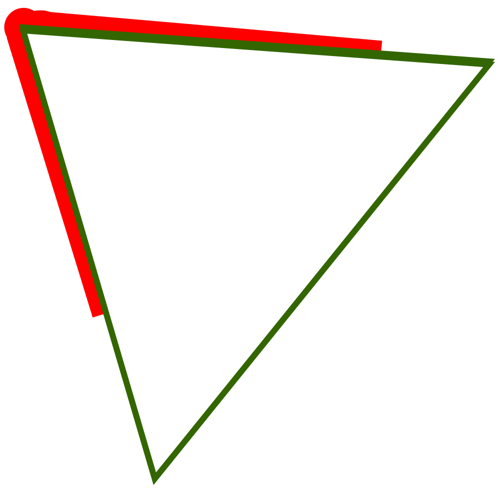


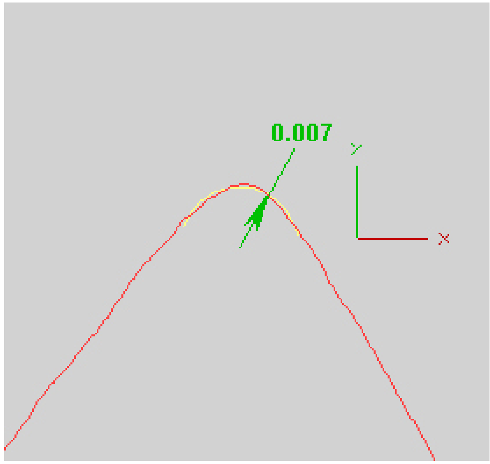


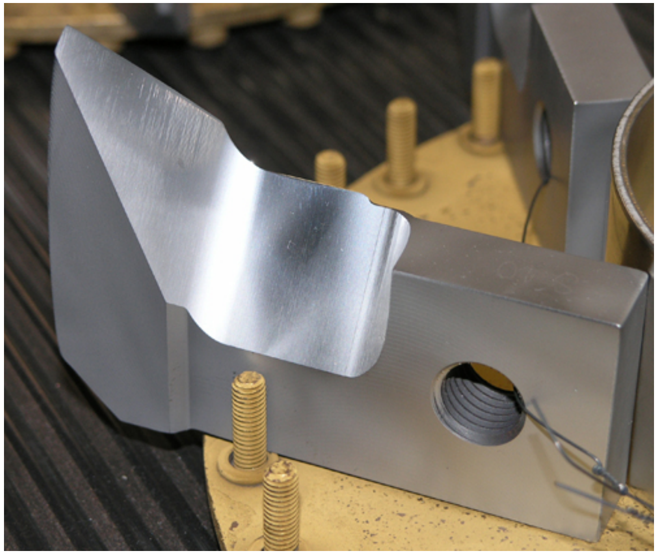
When coated the edge will be resharpened immediately after coating
Performance increase is not impressing!



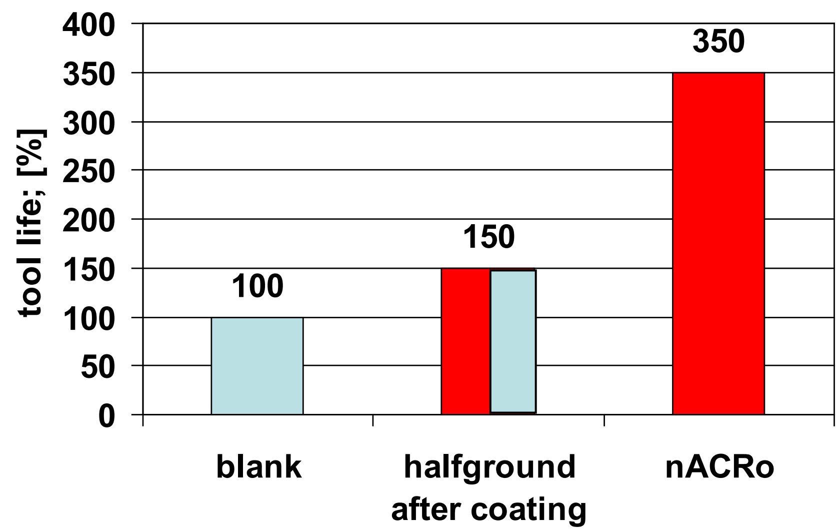
Influence of Edge Preparation on the Performance of Coated at Wood Cutting







Full coating after very fine edge rounding increases tool performance significantly even for WOOD CUTTERS



Influence of Edge Preparation on the Performance of Coated Cutting Tools

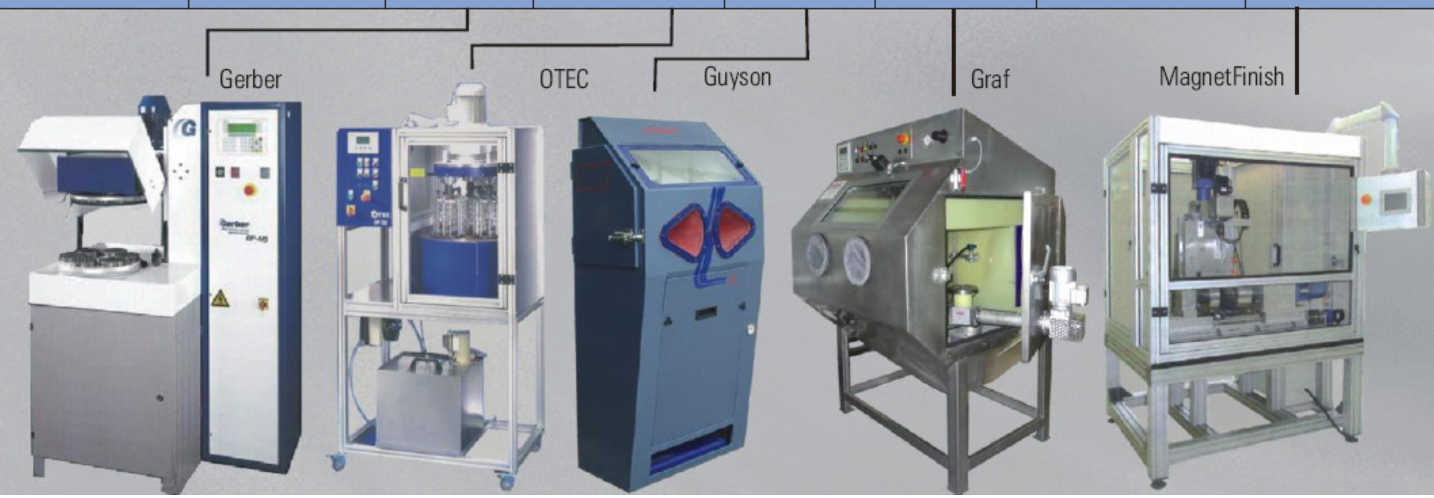
Summary: Comparison of Treatment's Features

Treatment	Typical time / shank tool	Flexibility	Costs / Tool
Brushing	2 min / 6 = 20 sec	good	medium
Drag grinding	12 min / 24 = 30 sec	medium	medium to high
Dry blasting	20 sec	medium	medium
Wet blasting	10 sec.	medium to high	low
Magnet finishing	20 sec	medium	medium to high

Influence of Edge Preparation on the Performance of Coated Cutting Tools

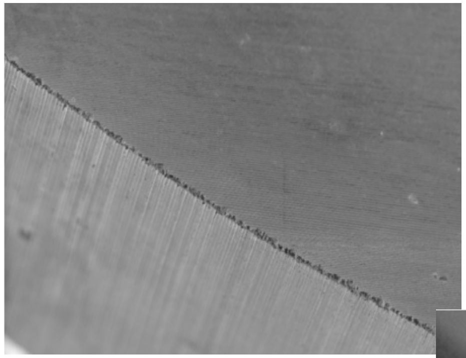
Edge Treatment Methods

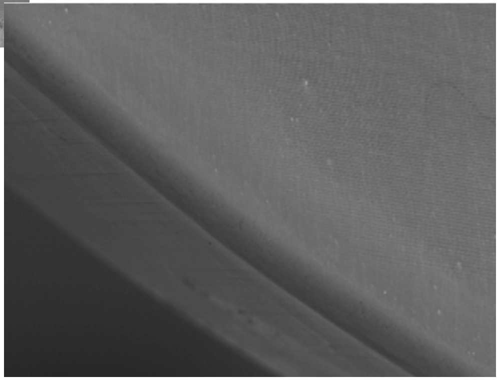
Criteria / Features	Honing by Hand with diamond file	Brushing	Drag Grinding (Polishing)	Micro Blasting Dry	Micro Blasting Wet	Water Beam	Magnet Finishing
Quality	⊕⊕ best	⊕ good	⊕ good	○ medium	⊕ good	⊕ good	⊕ good
Constancy	depending on person	⊕ good	⊕ good	○ medium	⊕ good	⊕ good	⊕ good
Flexibility	⬆⬆ very high	⬆ high	○ medium	○ medium	⬆ high	○ medium	⬆ high
Productivity	⬇ low	○ medium	○ medium	○ medium	⬆ high	⊕⊕ very high	○ medium
Price	salary only	⬆ high	○ medium	⬇ low	○ medium	⬆⬆ very high	⬆ high
Standard machines available		✓ yes	✓ yes	✓ yes	✓ yes		✓ yes
Flute polishing possible		✓ yes	✓ yes	✓ yes	✓ yes		○ limited in depth
Droplet removal possible		✓ yes	✓ yes	✓ yes	✓ yes		✓ yes
Special features	typical for small regrinders	commonly used for end mills, difficult for taps	droplet removal difficult for small diameters	residual materials on the surface	no residual mat. after blasting high air consumption	only for large scale production, corrosion protection needed	demagnetizing necessary



Influence of Edge Preparation on the Performance of Coated Cutting Tools

Summary





- Without edge preparation
  - low performance

- Different work piece materials to be cut
  - **need different edge preparation**

- Over the optimum edge preparation
  - performance drops down abruptly

- Optimum edge preparation
  - increases performance enormously

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T. Cselle, PLATIT, Grenchen, Switzerland