FAKULTÄT FÜR MASCHINENBAU

Cryogenic Wet-Ice Blasting
- Process Conditions and Possibilities

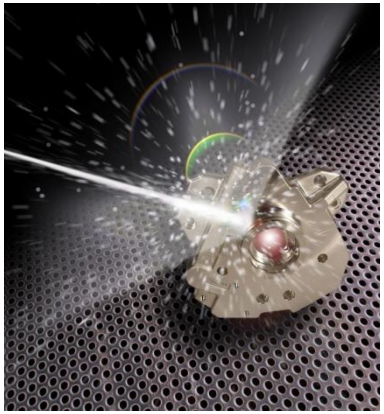
Magneto-Abrasive Machining for the Mechanical Preparation of High-Speed Steel Twist Drills

Dipl.-Ing. Florian Welzel

Institute of Manufacturing Technology and Quality Management
Chair of Cutting Technology, Prof. Dr.-Ing. habil. Prof. h.c. B. Karpuschewski

Otto-von-Guericke-University of Magdeburg/Germany
Faculty of Mechanical Engineering
Institute of Manufacturing Technology and Quality Management

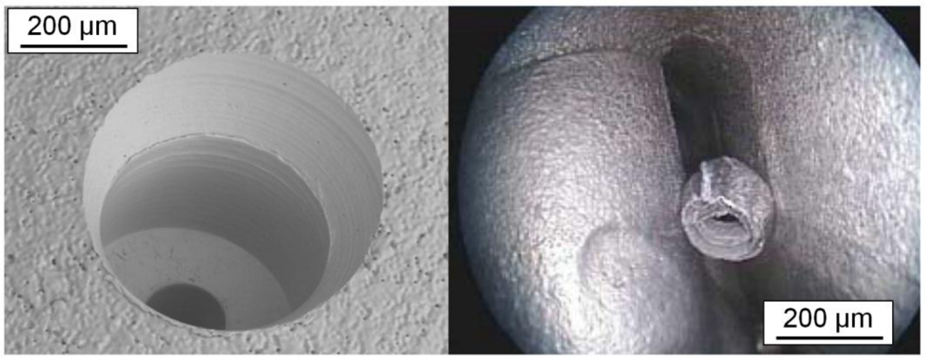
Cryogenic wet-ice blasting - process conditions and possibilities

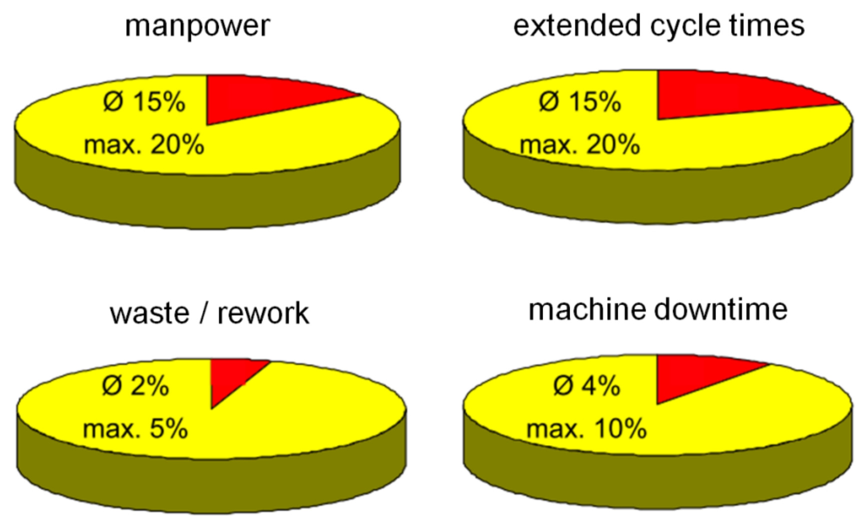


Prof. Dr.-Ing. habil. Prof. h.c. B. Karpuschewski
Dr.-Ing. K. Schmidt
Dr.-Ing. Th. Emmer
Dipl.-Ing.(FH) M. Petzel M.Sc.

Fields of application:

- Deburring
- Cleaning
- Surface treatment





Source: Ergebnisbericht Spansauber, TU Kaiserslautern, FBK, J.C. Aurich, 2006

Burr at borehole (left), chip in fluidic system (right)

Extra expenses in production due to burrs and chips

Structure:

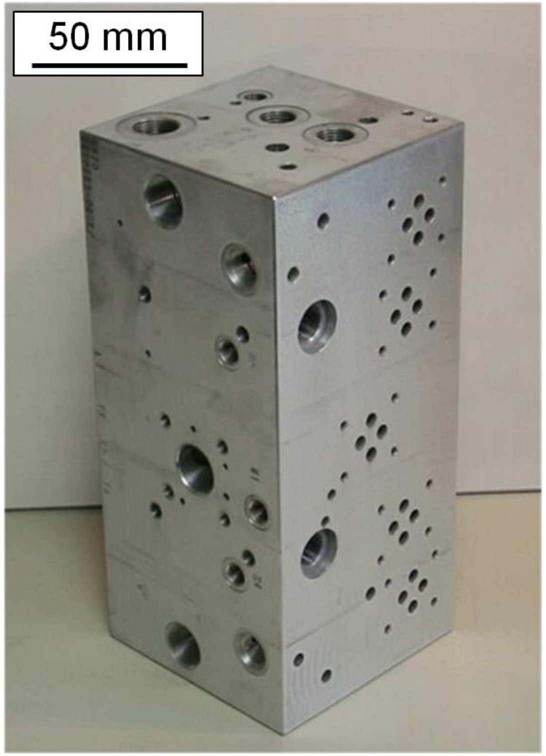
1. Goals of cryogenic wet-ice blasting (in short WIB)
2. Working Principles
3. Process description of WIB
4. Experimental Results
5. Conclusions

Ice particle production machine in the IFQ

„Cryo-Tank“ for wet-ice blasting - WIB

1. Goals of Cryogenic wet-ice blasting WIB

- Simultaneous deburring and cleaning of highly complex and highly stressed components such as control blocks and engine parts
- Deburring without solid residues and required following cleaning
- Defined blasting particle size and hardness
- Limited use of chemical additives - emulsion
- No damage at the workpiece surface
- Potential for surface smoothing
- No defined edge geometry



Source: SKL-Maschinenbau GmbH

2. Working Principles

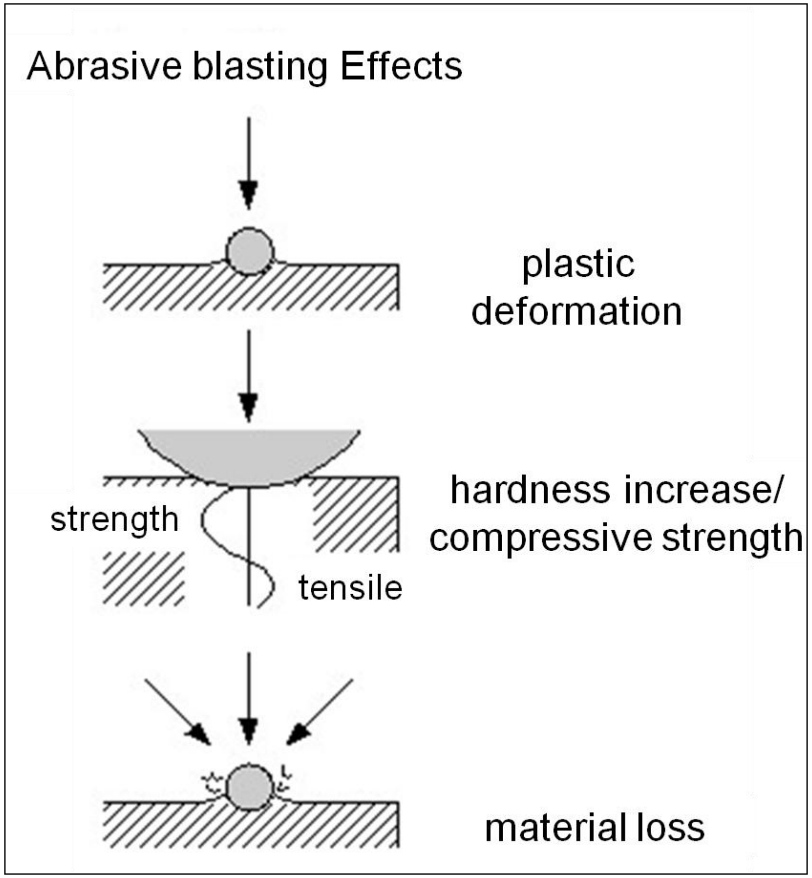
The size of the transferred energy is dependent on the:

- particle energy,
- properties such as grain shape of the abrasive, grain materials and grain hardness,
- angle of impact
- properties of the blasted surface.

The particle energy is calculated according to the basic physical formula

$$E_{kin} = ½·m·v^2$$

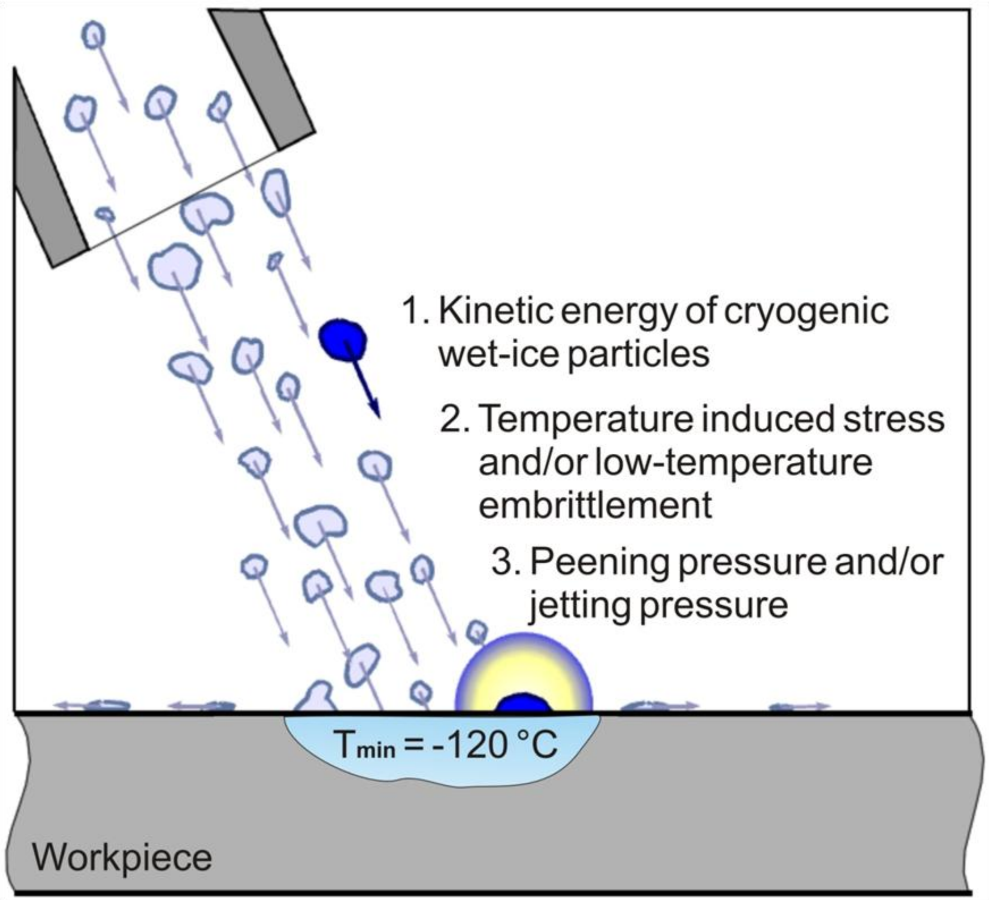
and thus grows proportionally with the particle mass and the square of the particle velocity.



Source: Sigg Strahltechnik GmbH

In case of cryogenic wet-ice blasting (WIB) there are some other effects:

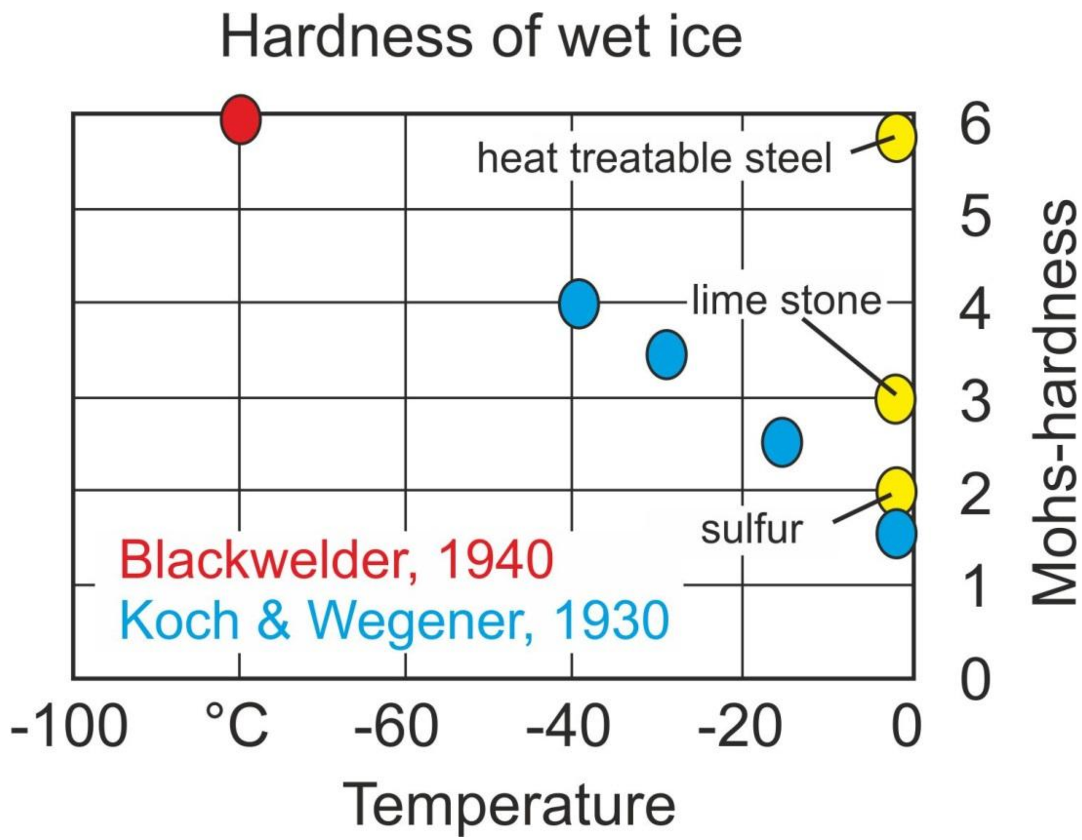
- temperature-induced stress on the surface
- low temperature embrittlement of the ground material
- Peening pressure of the multiple fluid shock waves
- Jetting pressure of the molten water on the surface



Based on: F. W. Bach, University Hannover, IW

Ice particles as a blasting abrasive

“An ideal blasting abrasive should have an edged form, has a hardness of at least 6 Mohs and disintegrates into gas at room temperature completely” [J. Haberland].

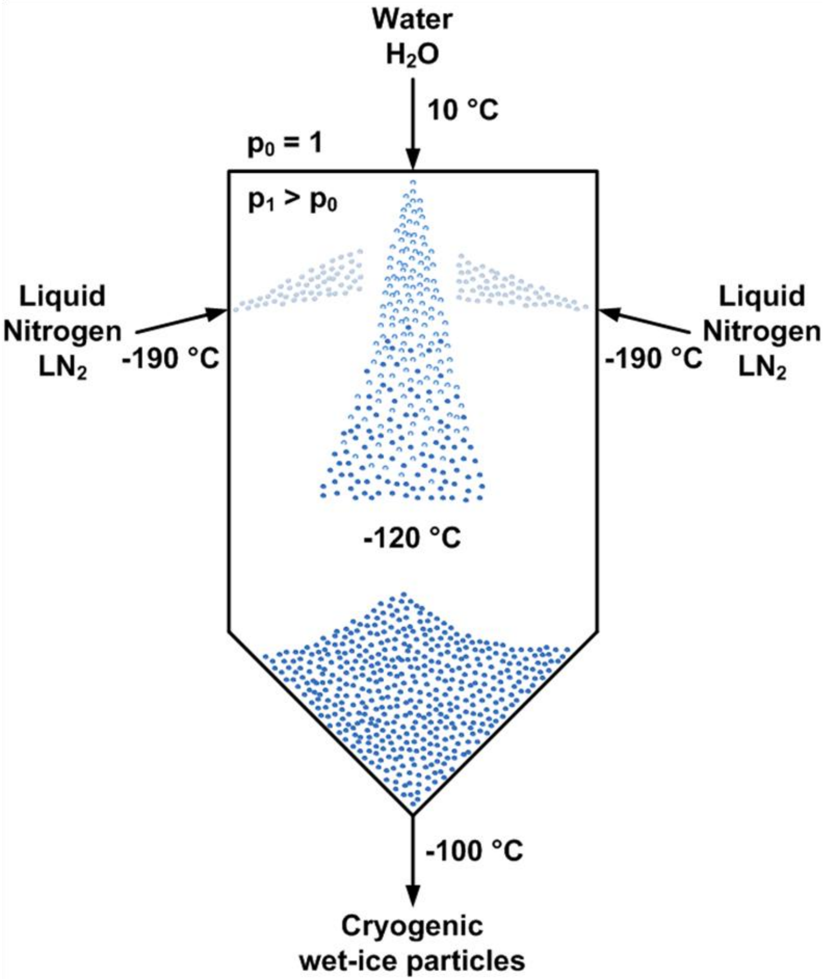


The Mohs hardness of ice was checked and confirmed experimentally

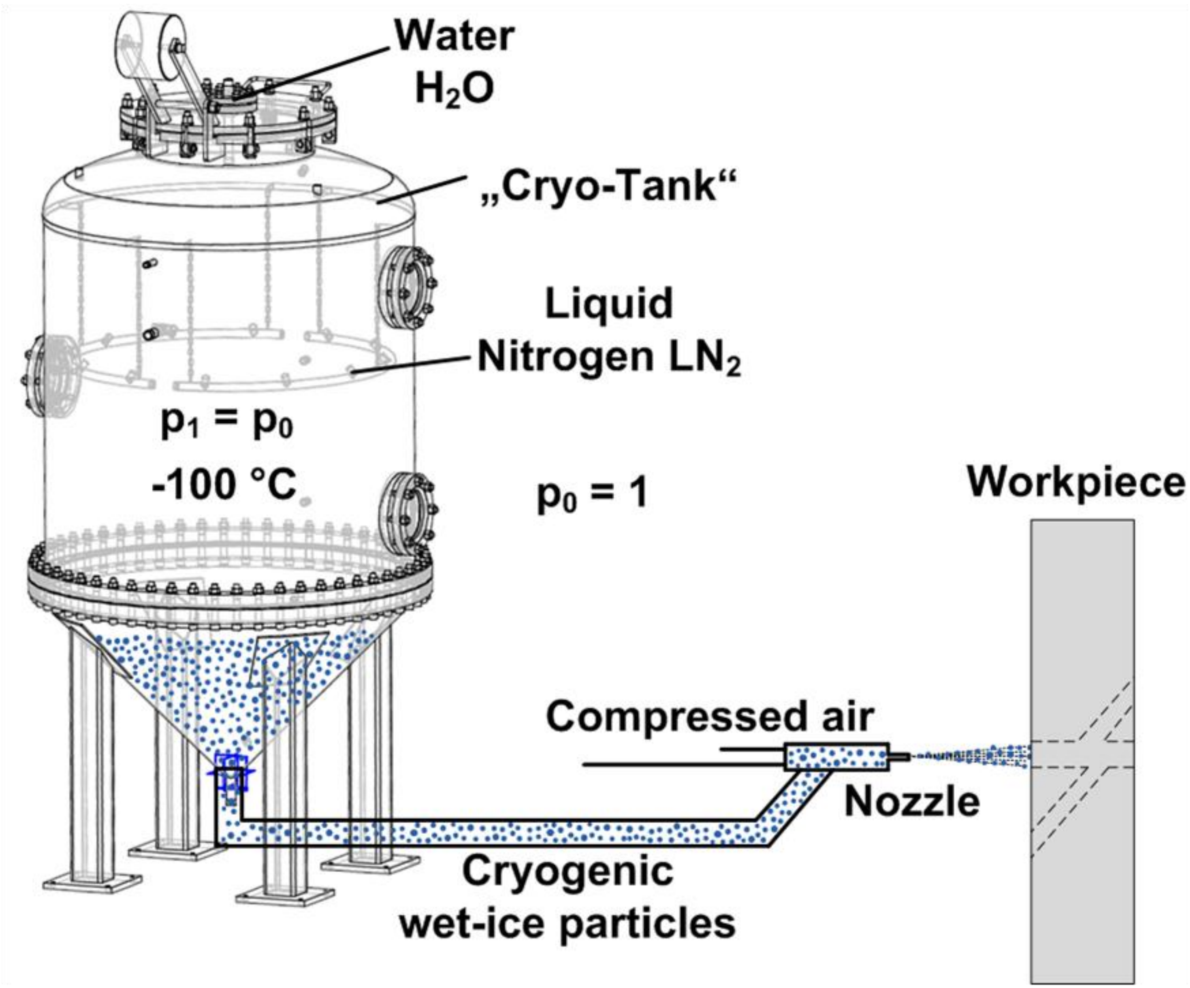
3. Process description of WIB

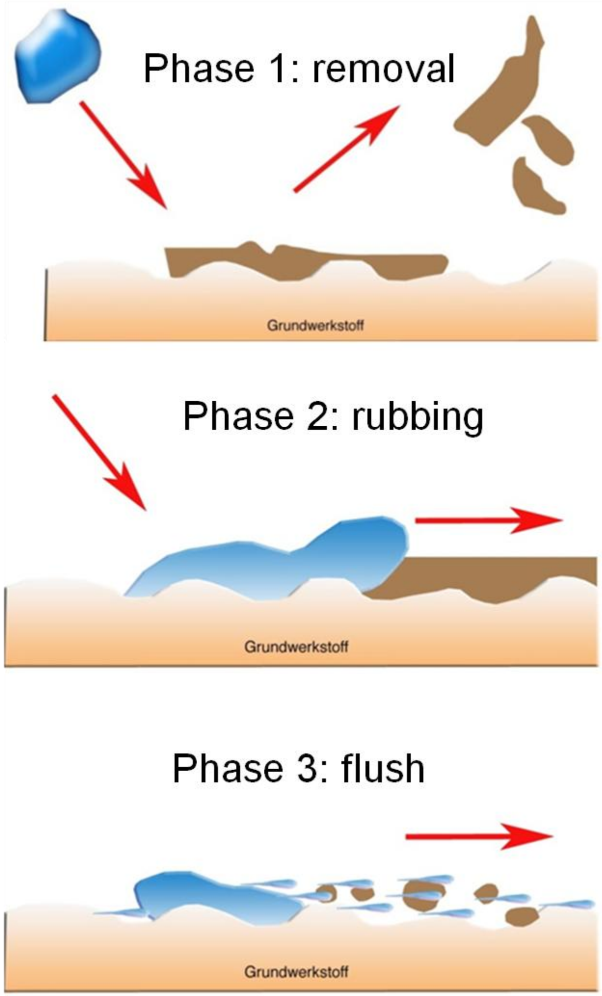
Manufacturing process of cryogenic wet-ice particles

- The “Cryo-Tank” is cooled down via a ring tube in the upper part of the system by liquid nitrogen LN_2 till at least -120 °C.
- Water atomizes over a full cone nozzle in the lid of the system and freezes in the cold atmosphere.
- Frozen ice particles accumulate in the lower part of the equipment in the hopper, that feeds them to the outlet opening.



Jet process





Source: Piller Entgrattechnik

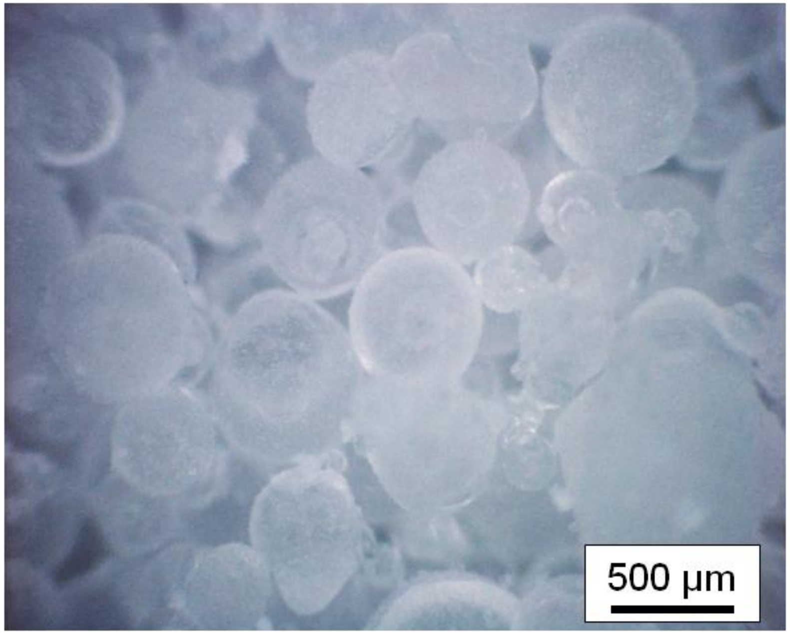
Cryogenic ice particles - „Cryo-Tank“

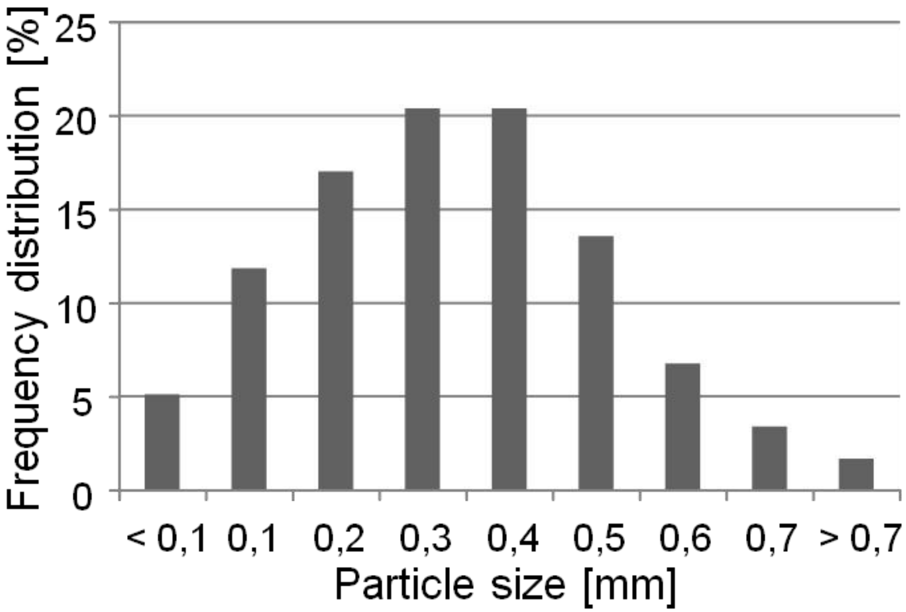
Cryogenic ice particles in the „Cryo-Tank“ (view from the top)

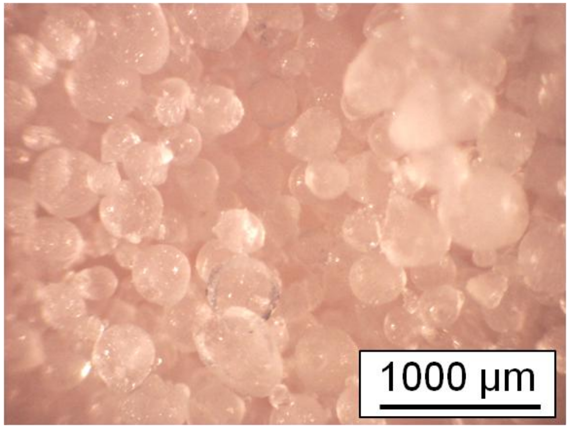
Movie

Free flowing ice particles

Cryogenic ice particles - Analysis





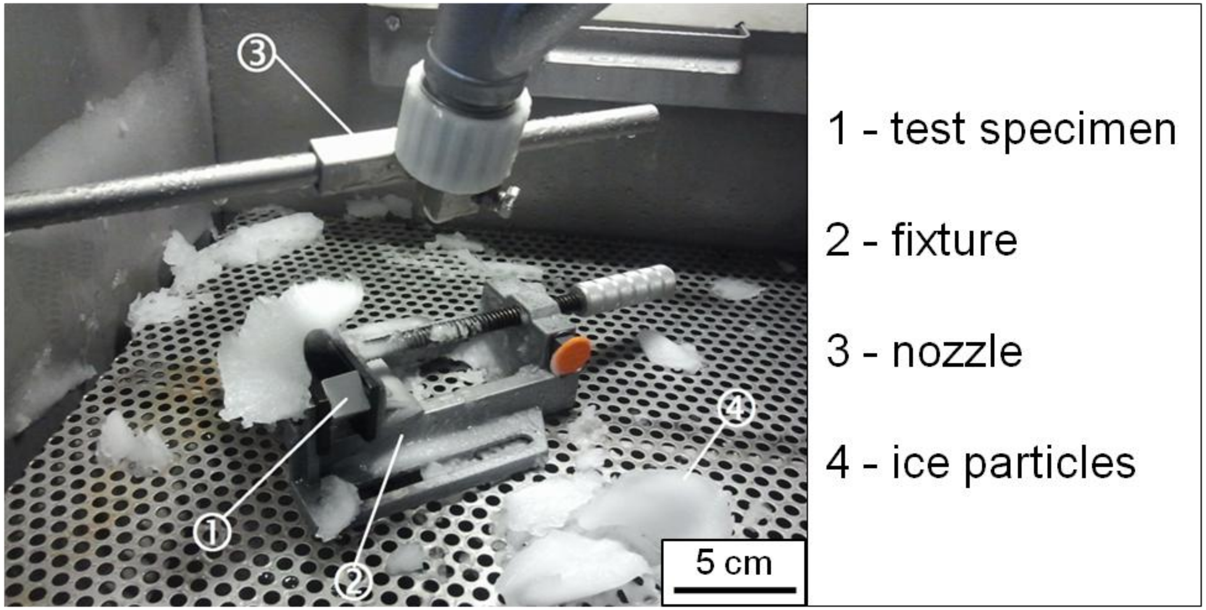


Form: spherical
Temperature: -100 °C
Mohs hardness: 6-7
Temperature resistance: stable
Free flowing properties: such as dry sand

3. Experimental Results

Analysis the abrasiveness of cryogenic ice particles - Equipment

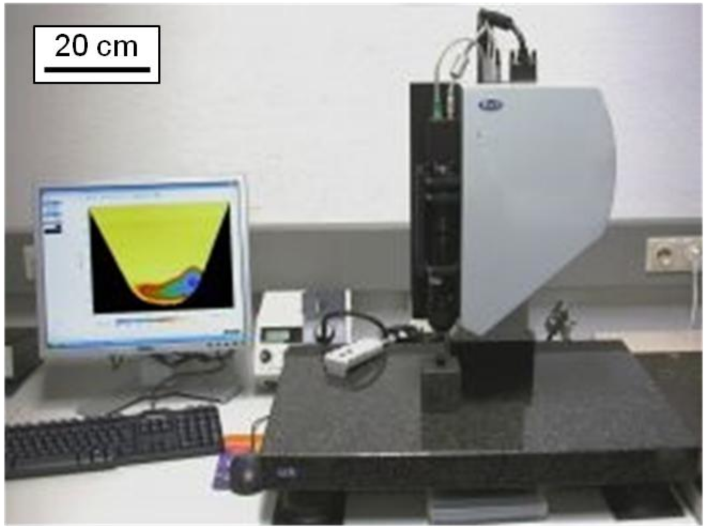
Injector blasting cubicle
for practical experiments



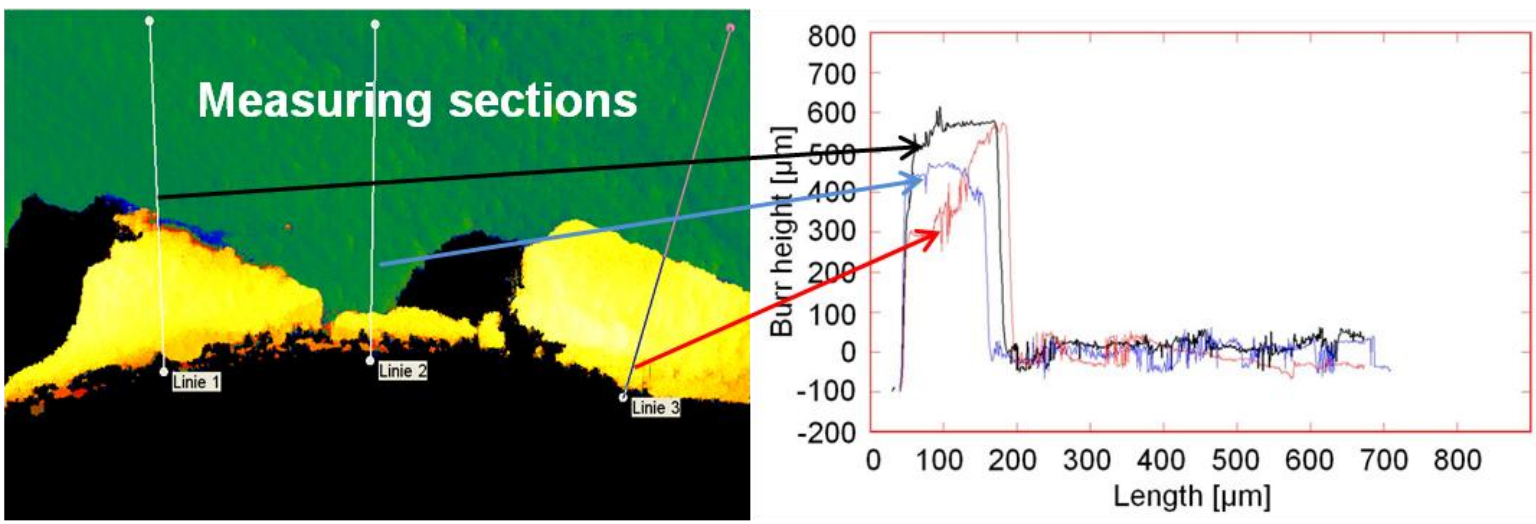
Injector blasting cubicle (view inside)

Nozzle handling with cryogenic ice particles

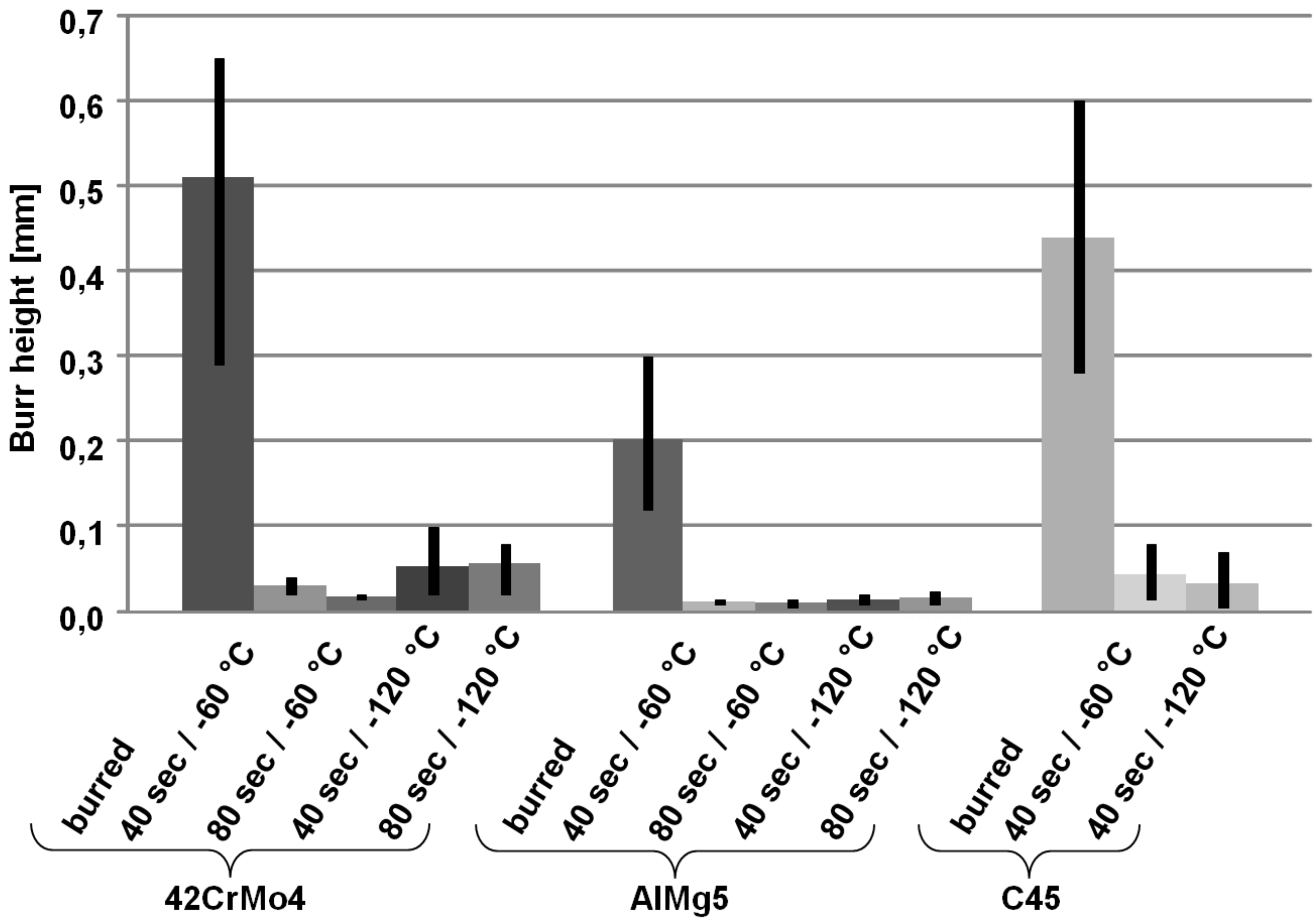
Measurement equipment for burr measuring



3D surface measurement station MikroCAD (GFMesstechnik), based on fringe projection

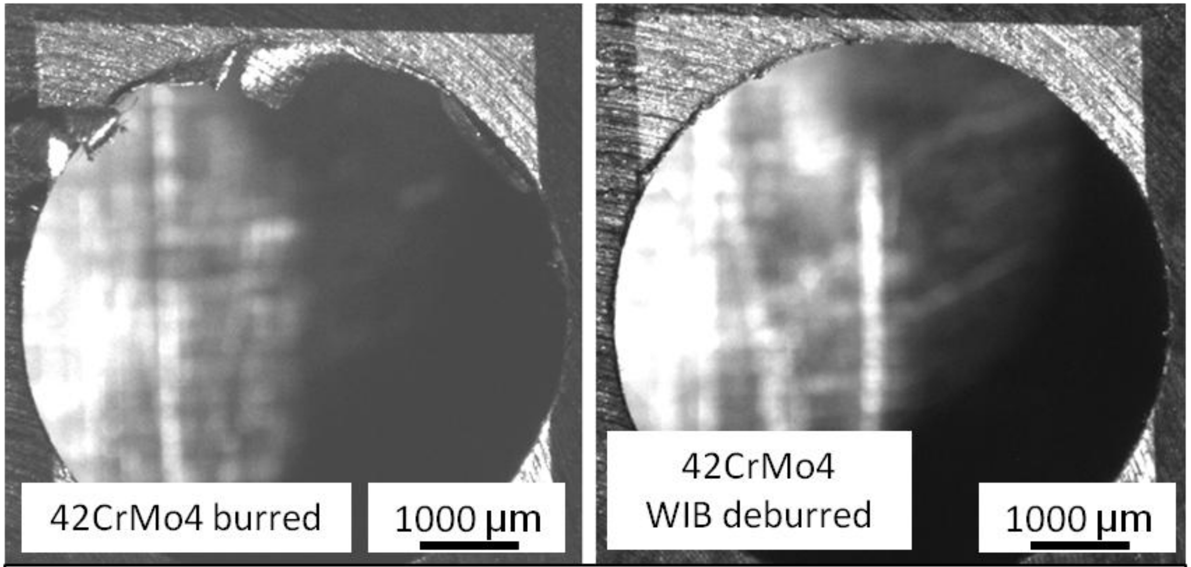


Results of deburring with cryogenic ice particles - metallic materials



Test parameters WIB of metallic materials	
Ice temperature [°C] variable	-60; -120
Jet time [sec] variable	40; 80
Jet pressure [bar]	15
Jet angle [°]	70
Jet distance [mm]	60
Ice particle size [mm]	0,1 - 0,7
Ice mass flow rate [kg/h]	50
Diameter air nozzle [mm]	4
Diameter jet nozzle [mm]	10
Ice particle speed [m/s]	140

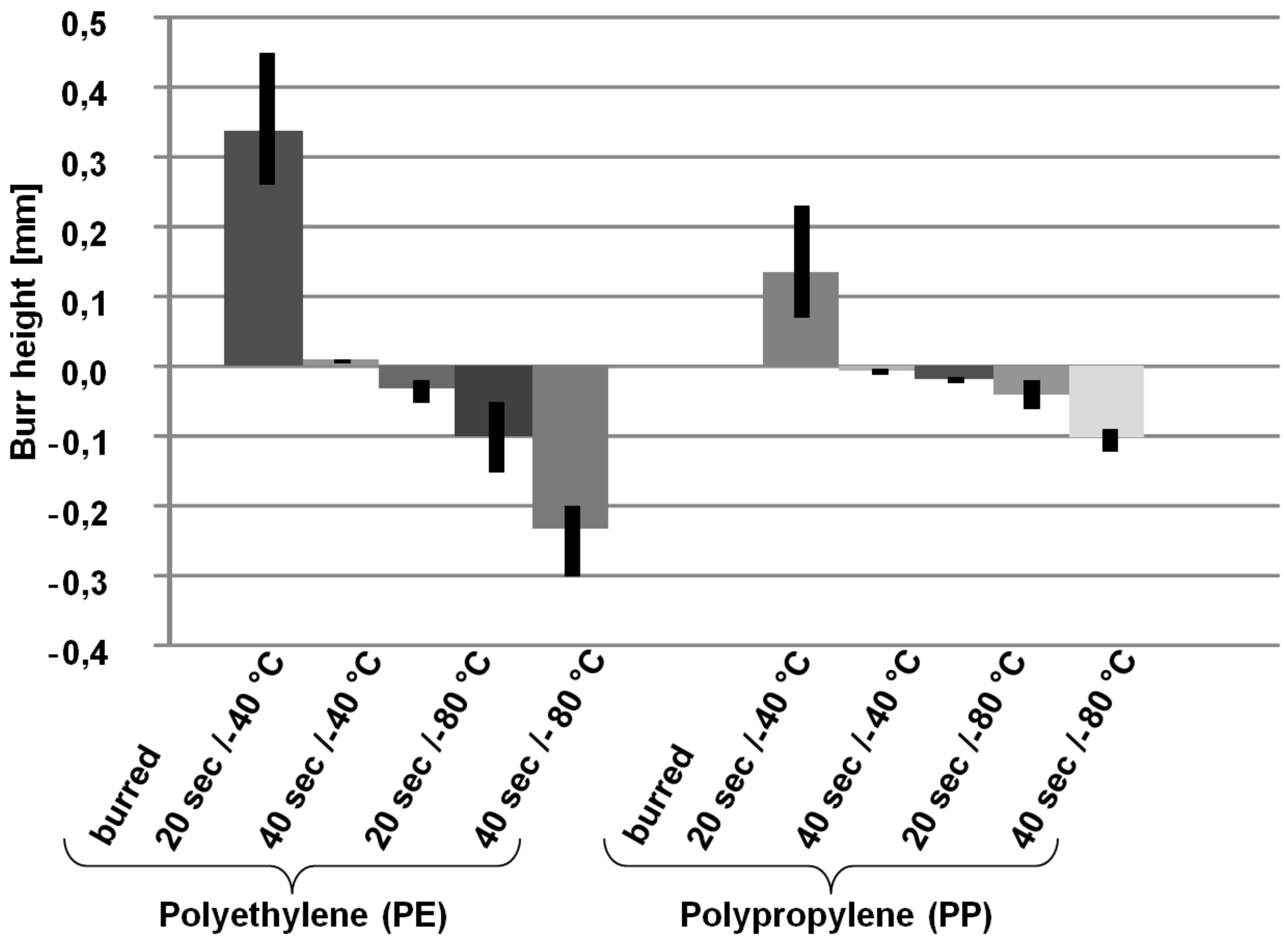
Visual analysis - metallic materials



Jet time: 40 sec, Wet-ice temperature: -60 °C, Jet angle: 70°,
Jet distance: 60 mm, Jet pressure: 15 bar, Particle speed: 140 m/s

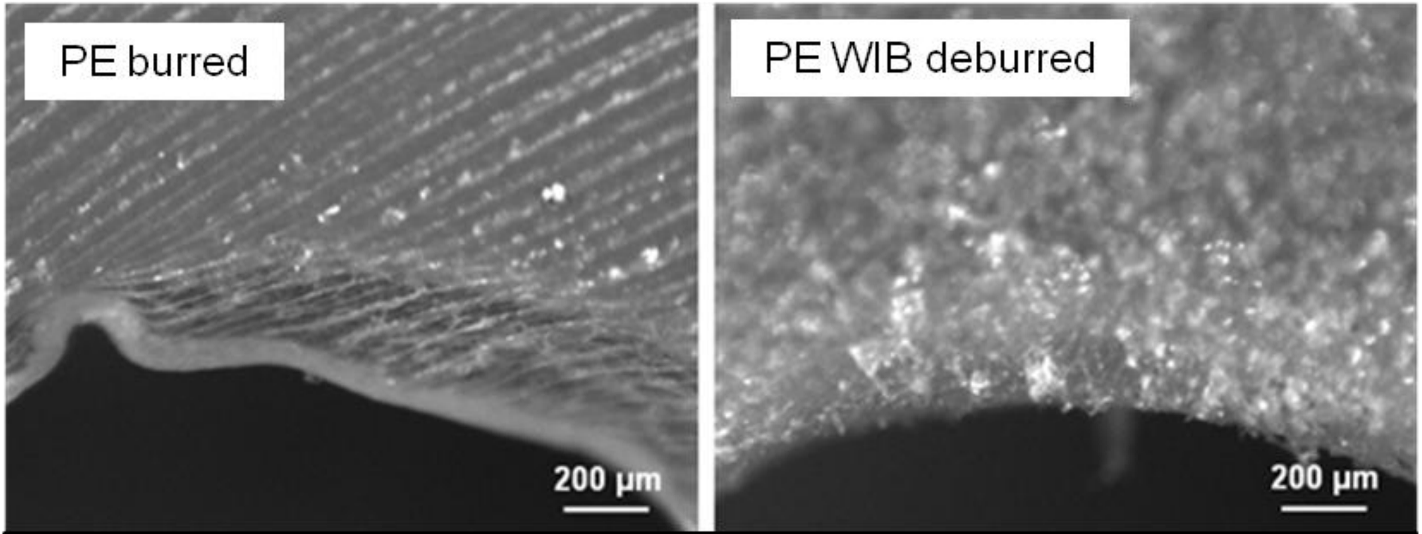
- The burr is completely removed from the borehole.
- WIB on metallic materials leaves just the burr root on the part.
- There is no more risk of loose material fractions during operation.
- The surface round the bore is not damaged.
- In case of metallic materials a large jet pressure is required.

Results of deburring with cryogenic ice particles - plastic materials



Test parameters WIB of plastic materials	
Ice temperature [°C] variable	-40; -80
Jet time [sec] variable	20; 40
Jet pressure [bar]	8
Jet angle [°]	70
Jet distance [mm]	80
Ice particle size [mm]	0,1 - 0,7
Ice mass flow rate [kg/h]	40
Diameter air nozzle [mm]	3
Diameter jet nozzle [mm]	6
Ice particle speed [m/s]	100

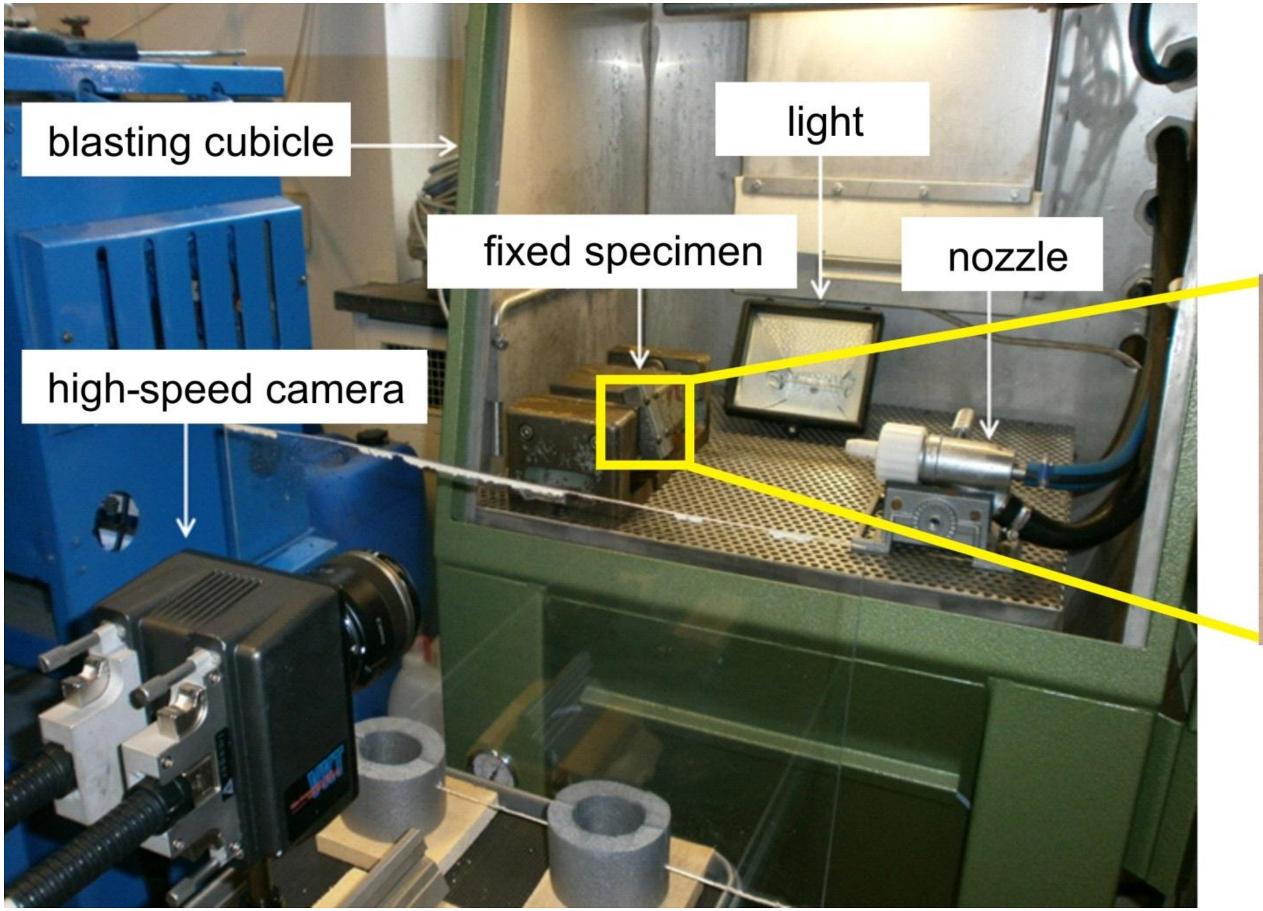
Visual analysis - plastic materials



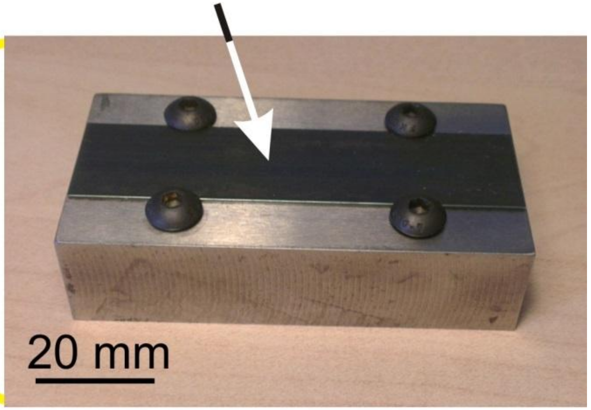
Jet time: 20 sec, Wet-ice temperature: -80 °C, Jet angle: 70°, Jet distance: 80 mm, Jet pressure: 8 bar, Particle speed: 100 m/s

- The burr is completely removed from the borehole.
- WIB on plastic materials is too abrasive and destroys the surface of parts.
- The bore and the surface round the bore is damaged.
- In case of plastic materials a small jet pressure and short machining times are required.

Impact analysis of cryogenic ice particles



fixed Almen strip for peening intensity and drop impingement measurement

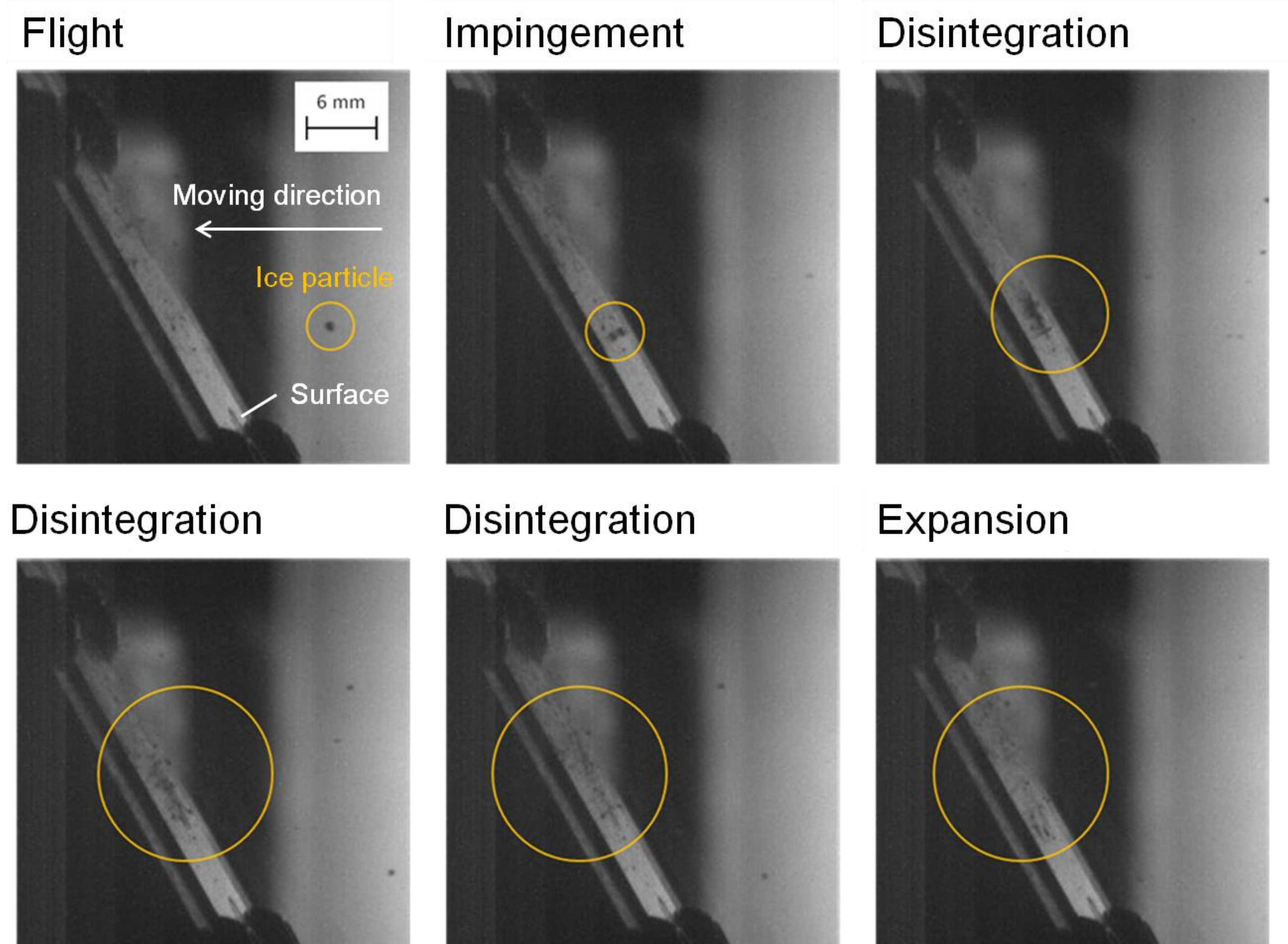


Analysis of the impact of cryogenic ice particles on a surface via High speed camera

Camera:
Photron Fastcam ultima APX

Chosen frame rate:
15.000 fps

Resolution:
256 x 256 pixel



Conclusions

- The practical studies have shown the feasibility of deep frozen wet-ice particles as an abrasive for deburring.

- With the use of deep frozen and cryogenic wet-ice as blasting abrasive the removal of burrs on multifaceted component geometries is possible.

- The temperature-dependent hardness and removal capacity of ice have been confirmed.

- The performance of the new method is promising in metallic materials and highly abrasive in softer materials.

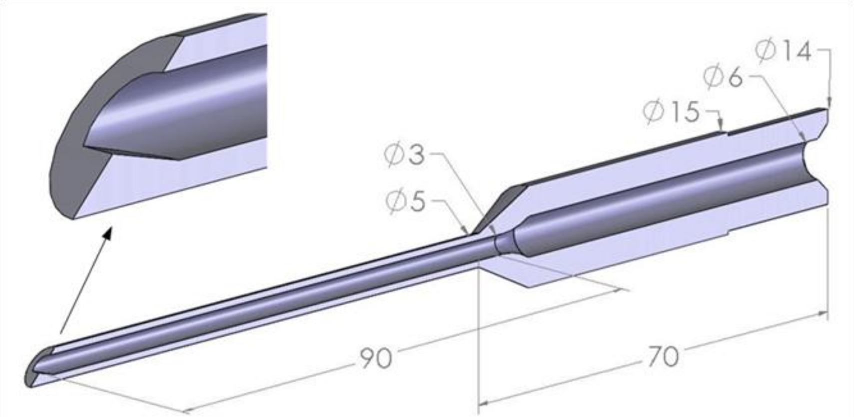
- The impact behavior of an ice particle on a surface is defined in terms of four successive phases: flight, impingement, disintegration and expansion.
  - Ice particles plastically deform and do not bounce off the surface.
  - The spread of particulate matter is generally visible in all directions.
  - The largest particle volume moves in the inclined direction of the surface and is rubbing on it.

Outlook

- The process parameters related to WIB jet processing must be adapted to other materials to be processed.

- The performance of the WIB machining will be examined for other machining tasks:
  - surface finishing and surface preparation
  - decontamination and decoating of surfaces
  - cleaning of turbines or turbine parts

- Realization of a jet lance for machining bore intersections.



Blasting lance for WIB in deep bores

Magneto-Abrasive Machining for the Mechanical Preparation of High-Speed Steel Twist Drills

B. Karpuschewski (1)[a], O. Byelyayev[a], -V.S. Maiboroda[b]

[a] Institute of Manufacturing Technology and Quality Management IFQ,
Otto-von-Guericke-University of Magdeburg
[b] Institute of Mechanical Engineering,
National Technical University of Ukraine “KPI”, Kiev

- Introduction

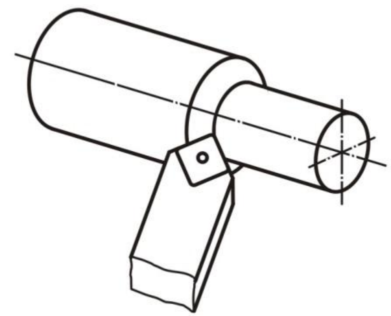
- Experimental setting

- Results

- Conclusion and outlook

Cutting process as a system

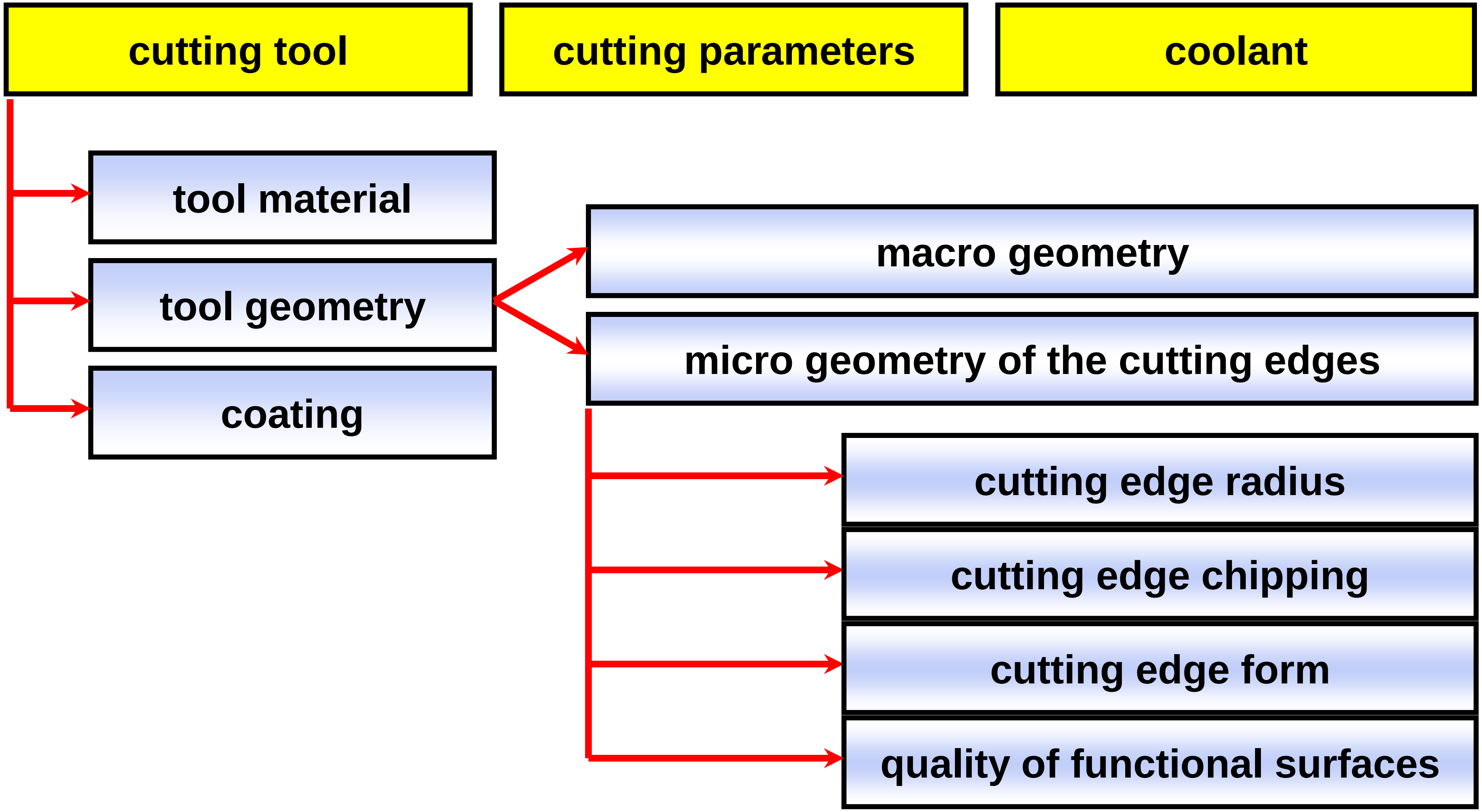
process



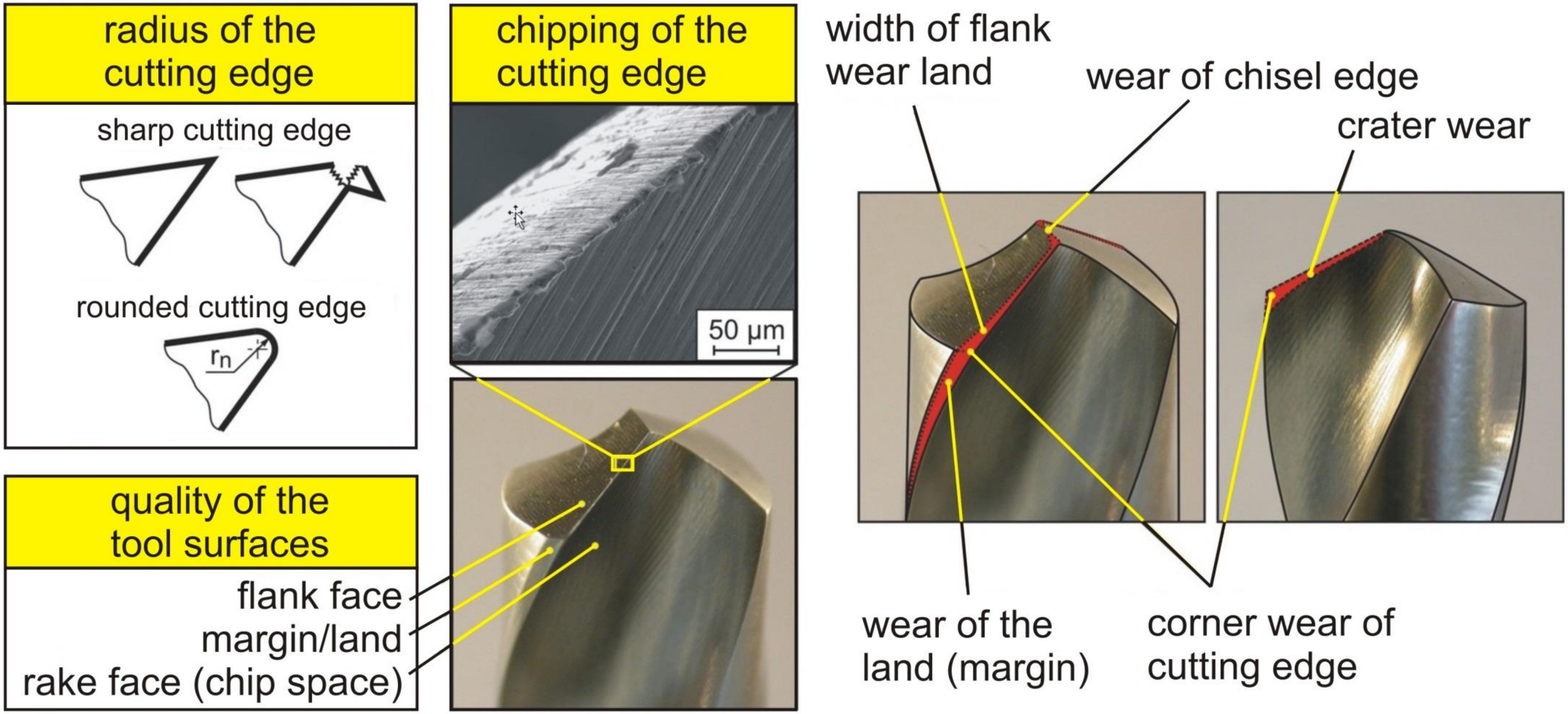
input quantities → process → output quantities

determined by	process quantities describe	describe
○ material ○ tools ○ machine setting ○ characteristics of the machine ○ supporting media	○ mechanical ○ thermal ○ chemical interactions during material removal	○ workpiece ○ tool ○ chips ○ machine ○ supporting media after material removal

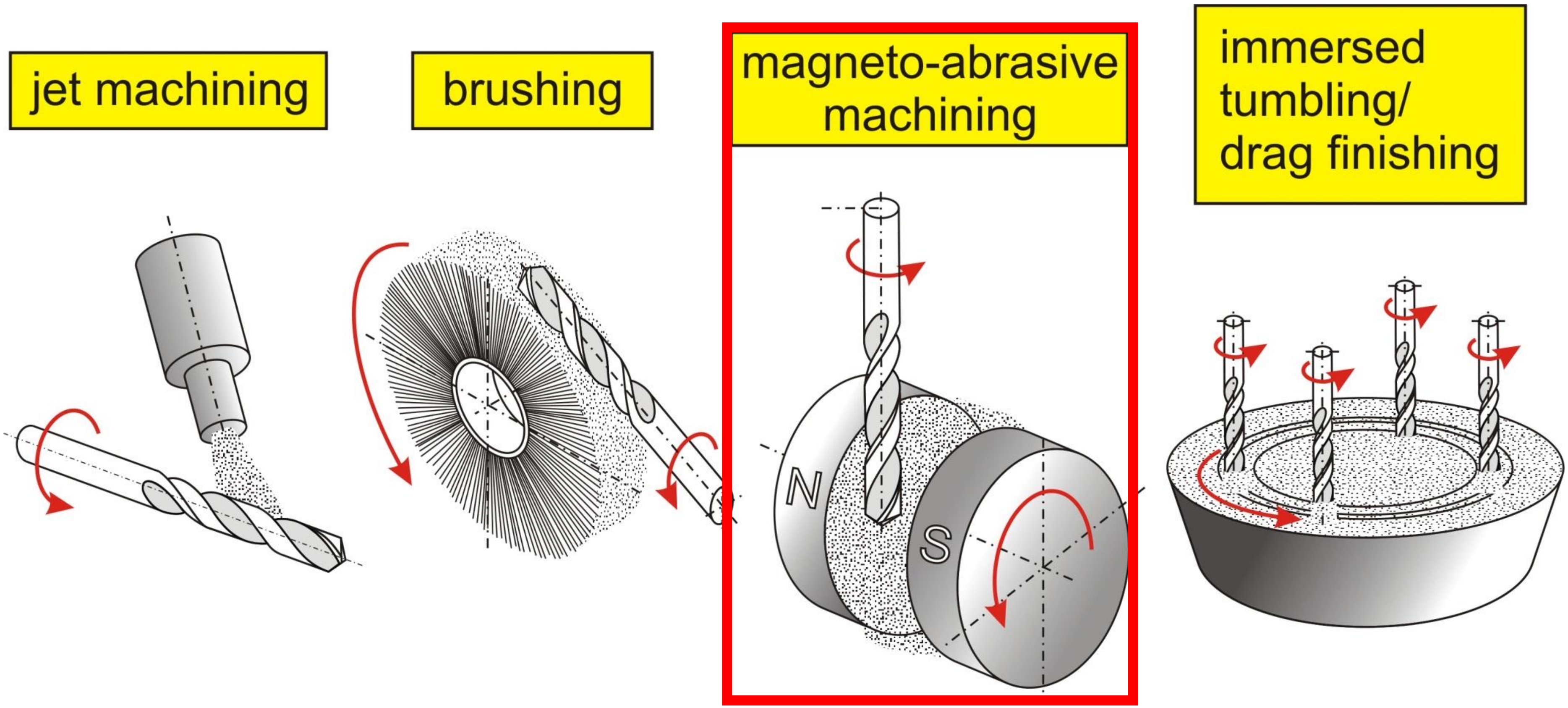
Cutting tool properties



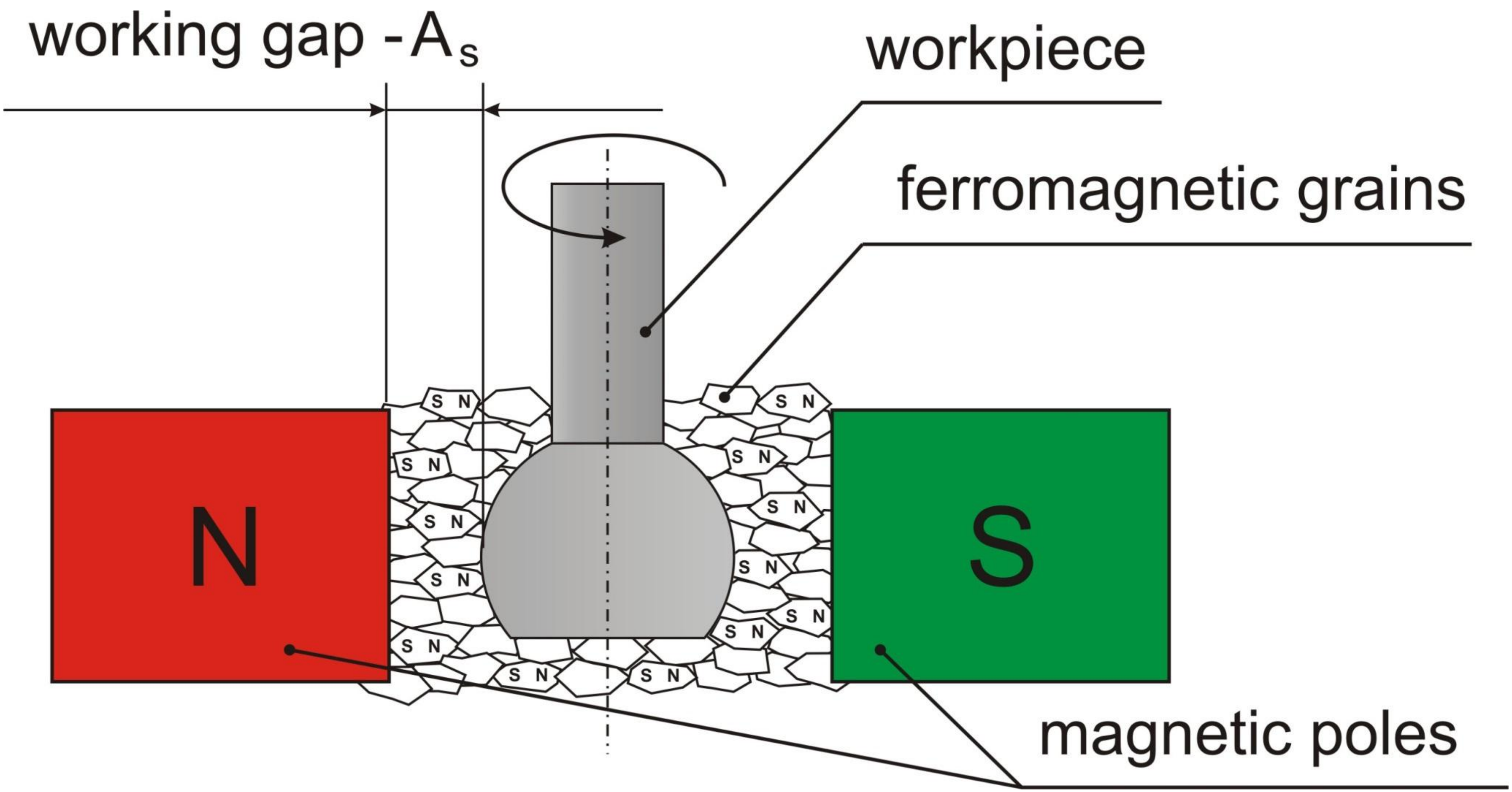
Quality characteristics of a helical drill



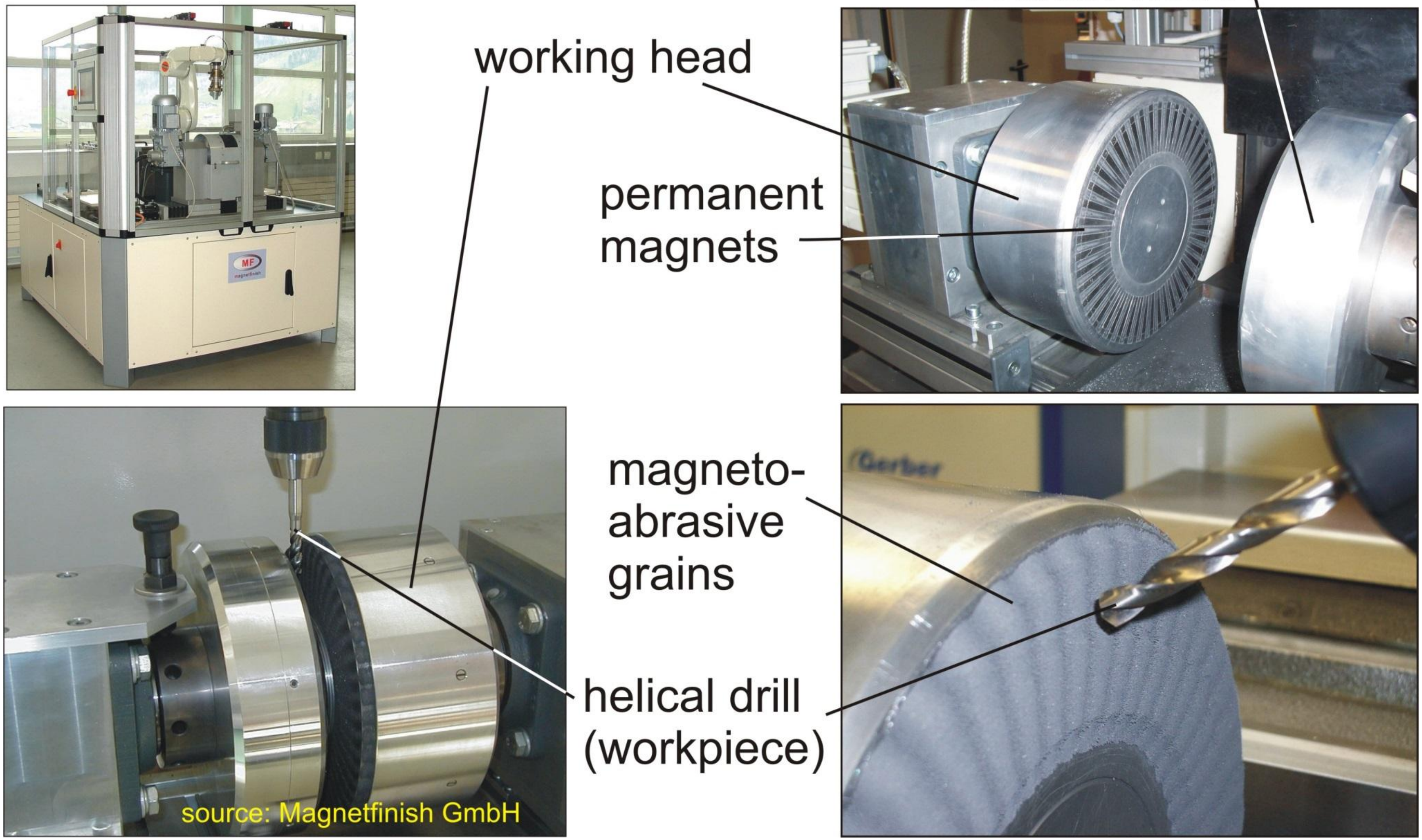
Cutting edge preparation methods



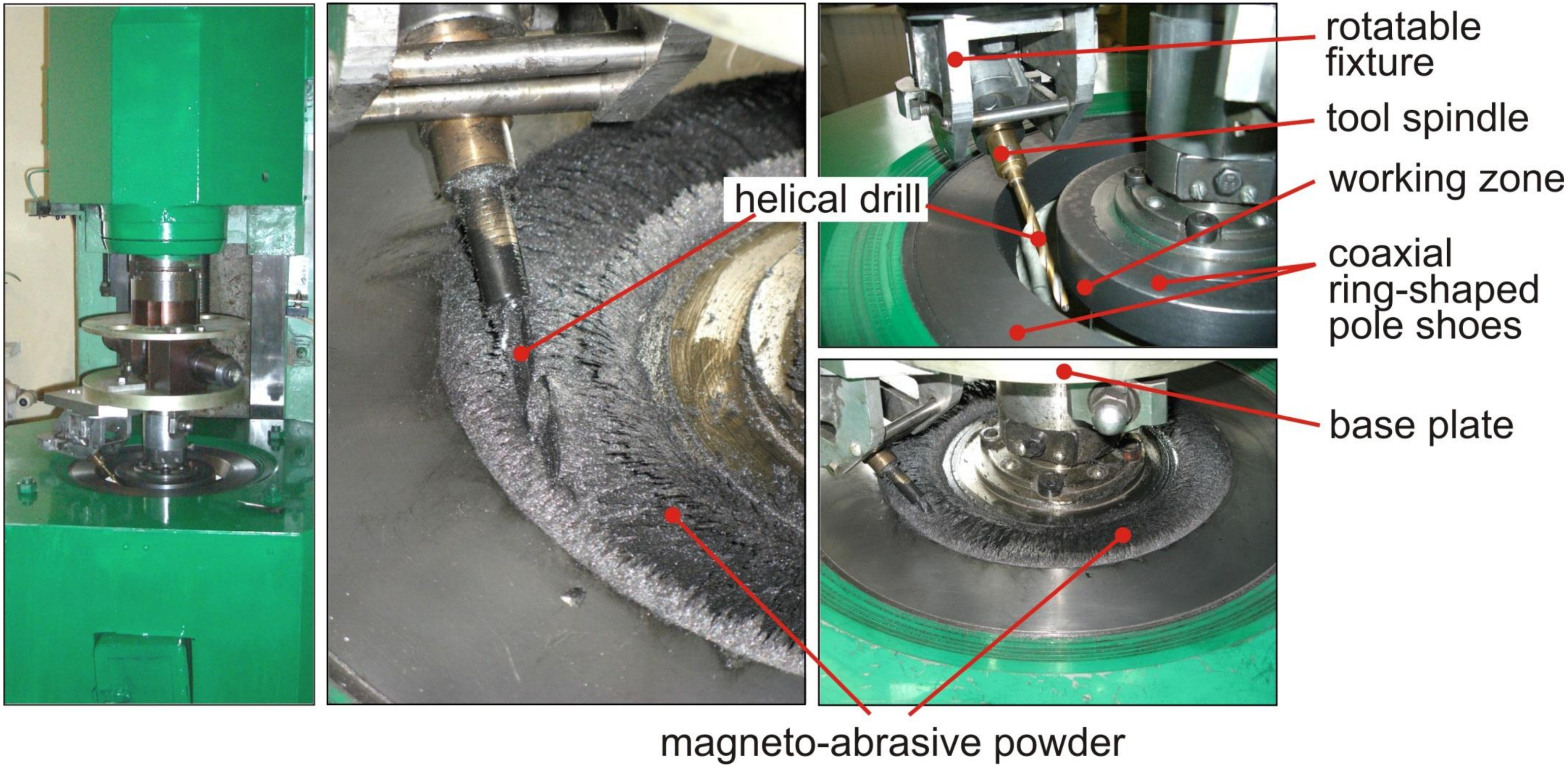
Basic principle of magneto-abrasive machining



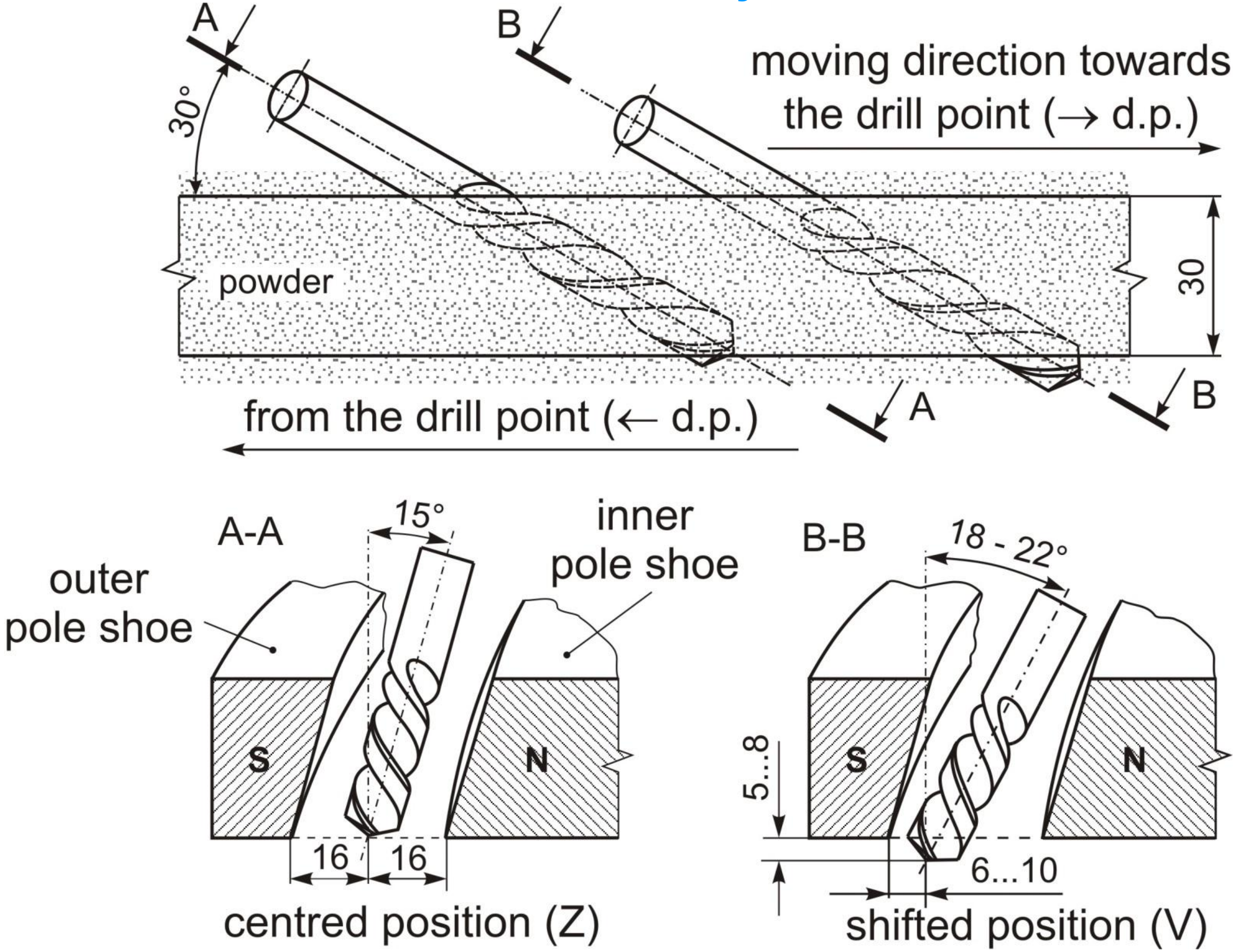
Commercial magneto-finishing system



Test system for magneto-abrasive machining with a ring-shaped configuration



Orientation of the drill in the MAM-system

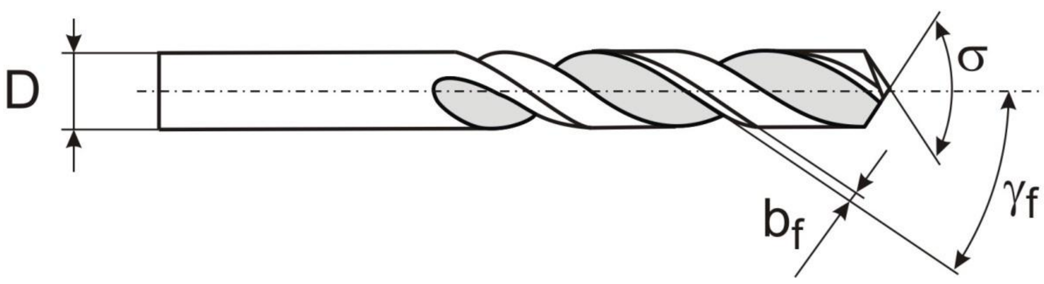


Drill properties

twist drill type	N (normal)
diameter D	6.8 mm
number of cutting edges	2
drill-point angle σ	118°
side rake angle γ_f	30°
diminution	standard
land width b_f	0.7 mm

material composition HSS

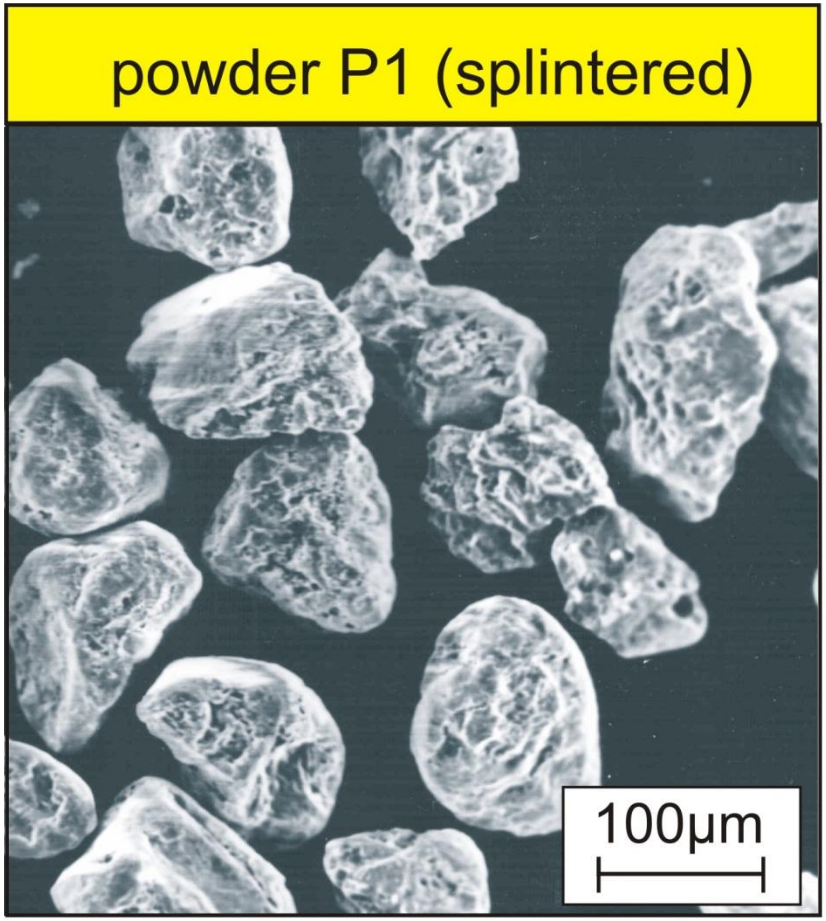
C	0.828
Si	0.312
Mn	0.283
P	0.001
Cr	3.86
Mo	4.56
W	5.70
V	1.64



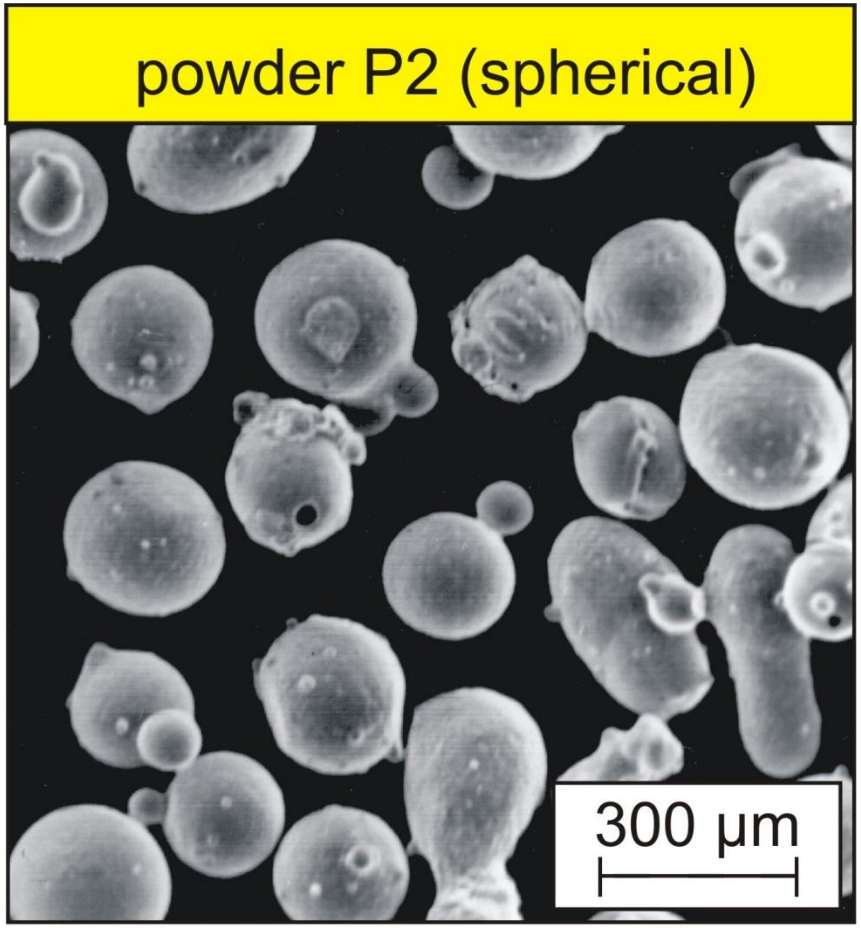
Varied process parameters

drill group	machining time [s]		drill position	powder type/ particle size [μm]
	→ d.p.	← d.p.		
1	untreated drills			
2	4x15	4x30	Z	P1 (splintered) 160/100
3	4x15	4x15		
4	-	4x15		
5	4x10	4x20	V	
6	4x15	4x30	Z	P2 (spherical) 315/200
7	4x10	4x20	V	
8	4x15	4x15	Z	powder mixture P2 ≅ 95% P1 ≅ 5%
9	-	4x15		

Powder characteristics 1

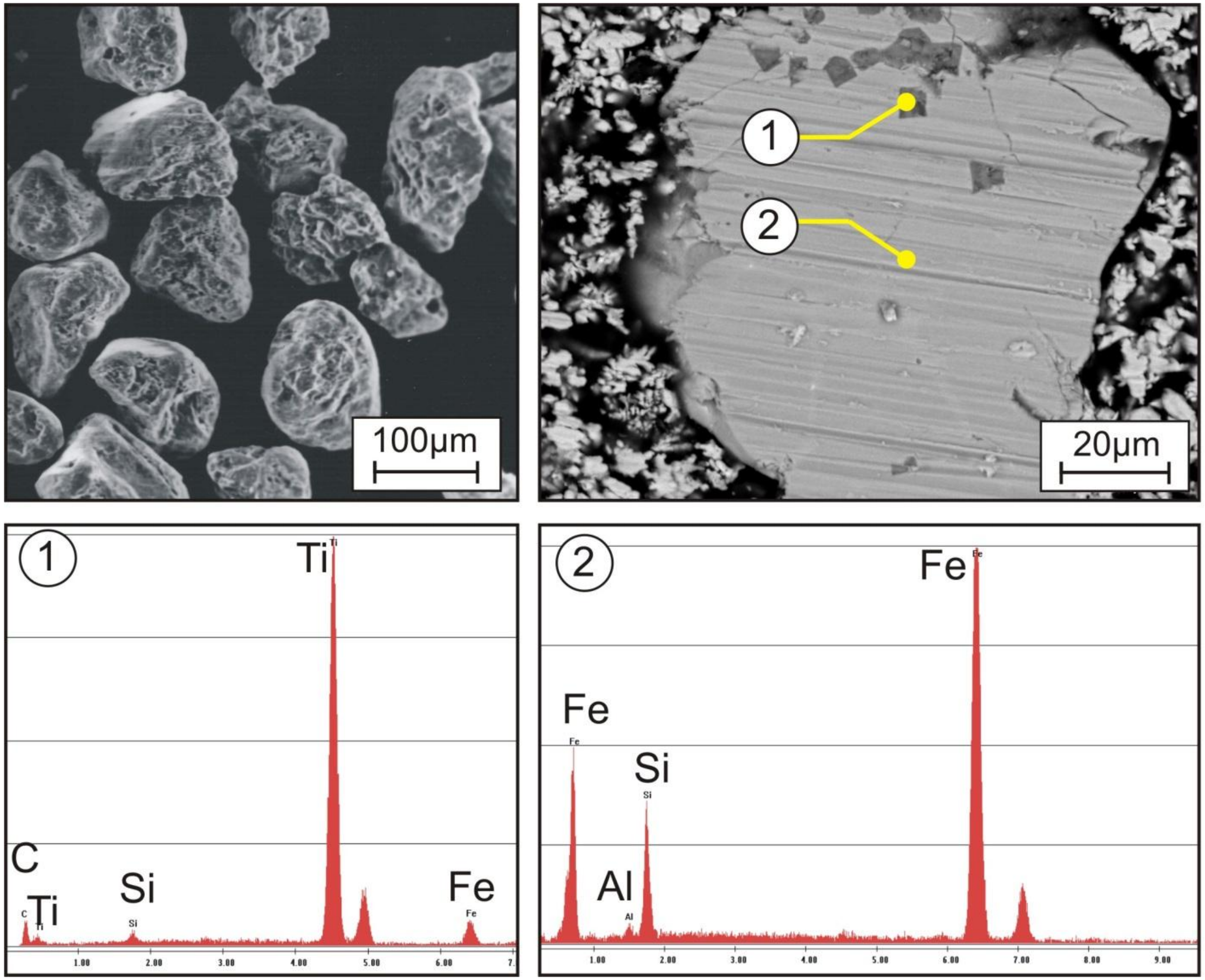


grain size: 160/100 µm



grain size: 315/200 µm

Powder characteristics 2



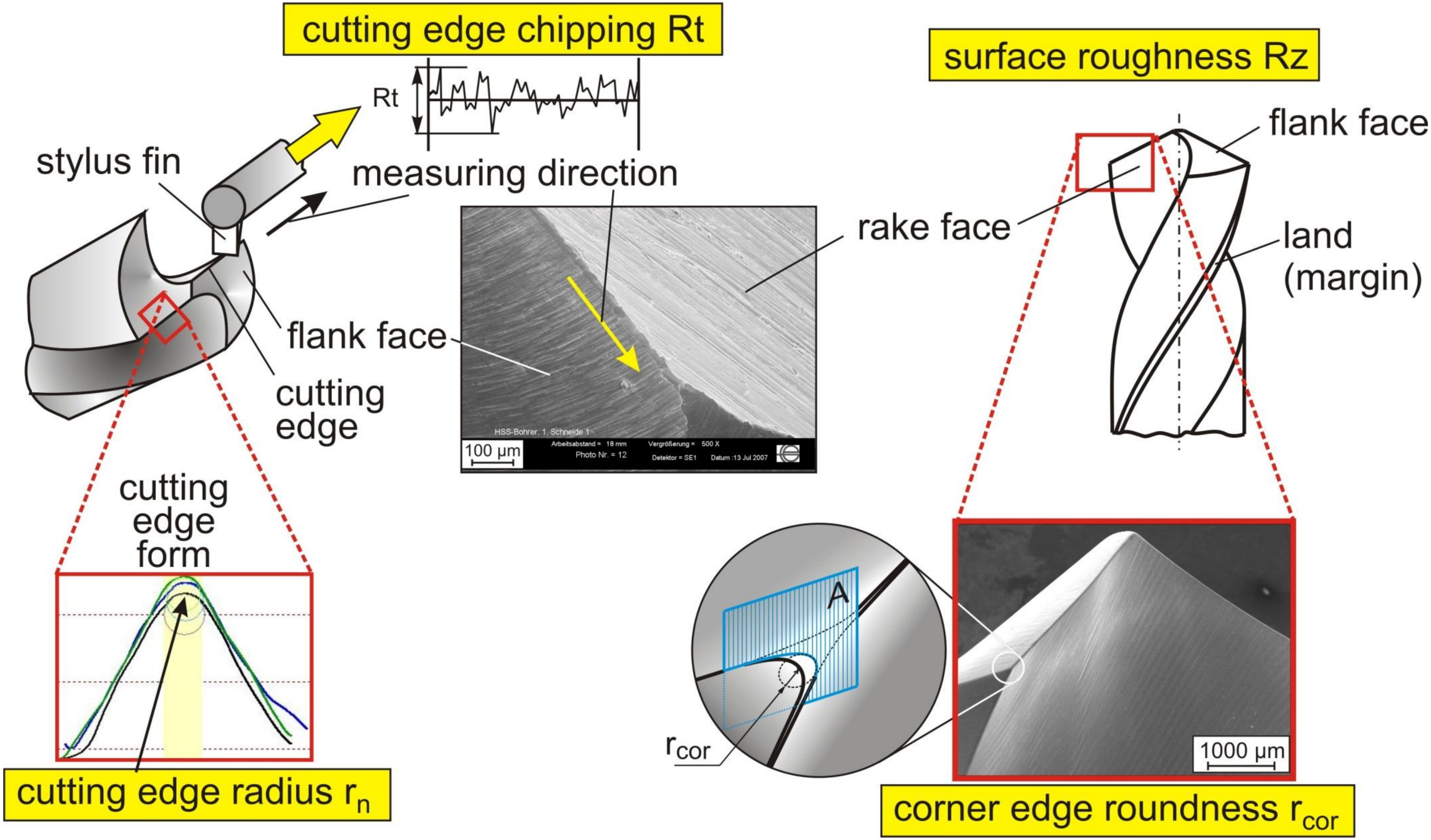
powder P1
(splintered)

grain size: 160/100 µm

“pseudo alloy”
resulting from
spray melting

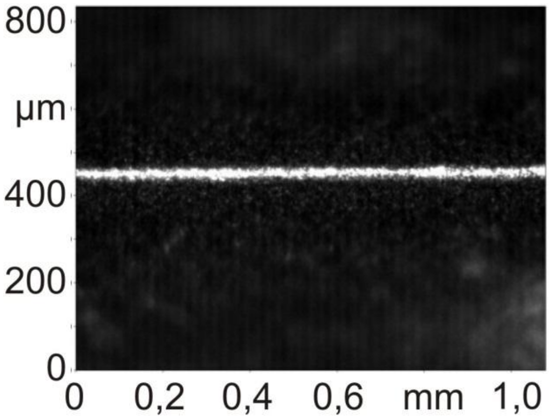
ferromagnetic matrix
Fe-Si (②) with
embedded carbide
abrasive particles
TiC (①)

Geometry measurements at the drill

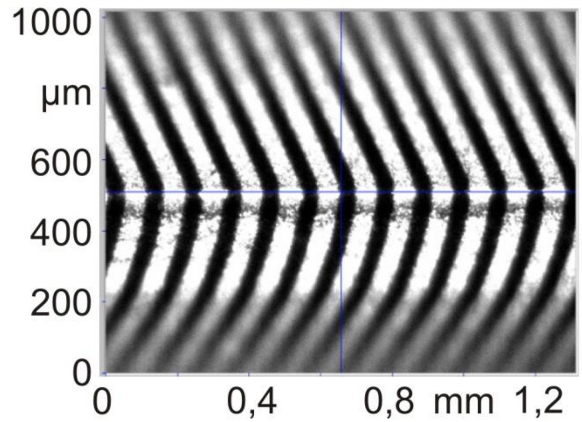


Optical cutting edge measurement

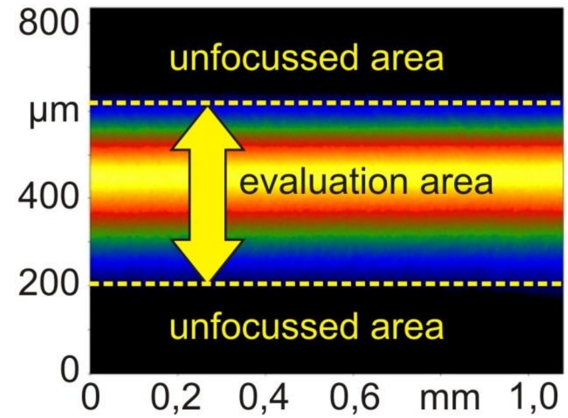
camera view of a cutting edge



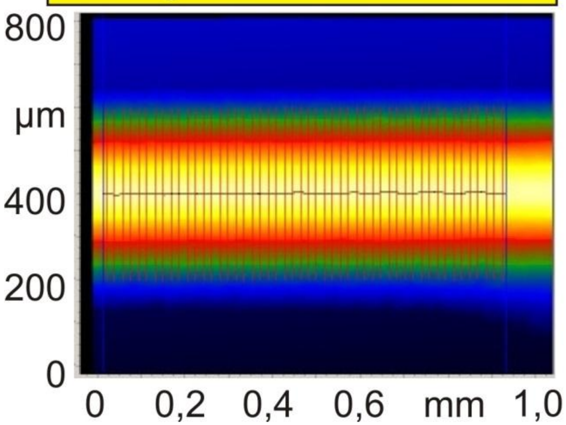
cutting edge with micro fringe projection



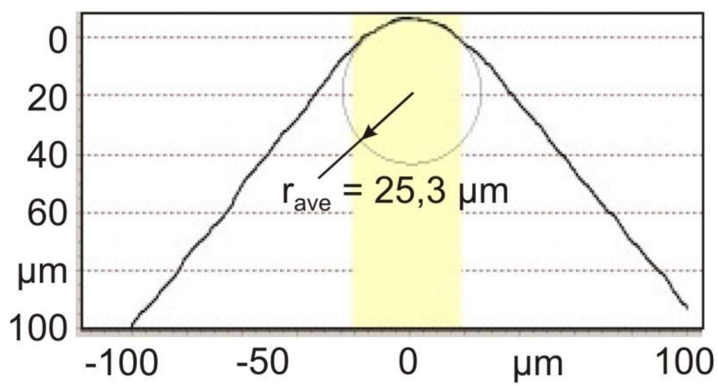
colour coded height image of the cutting edge



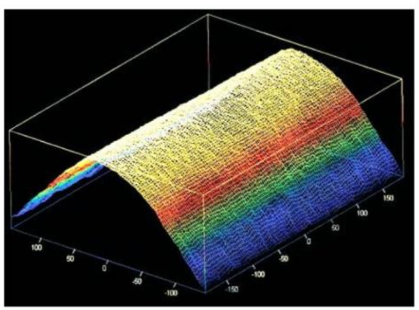
height image with inserted cutting lines



single cutting line presentation with radius determination

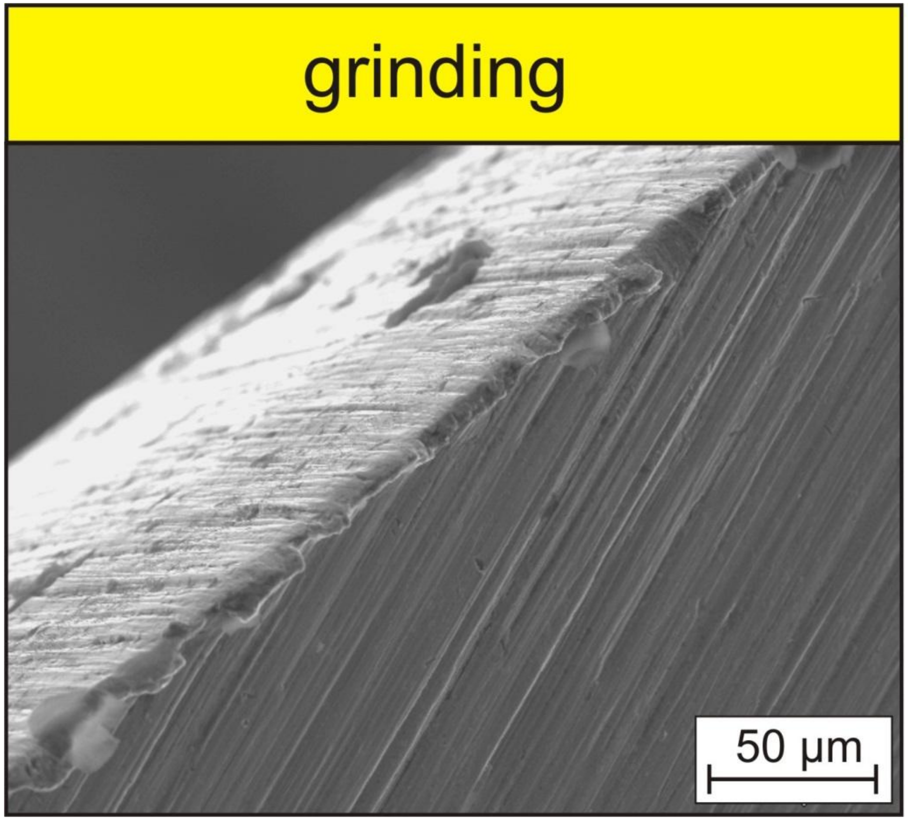


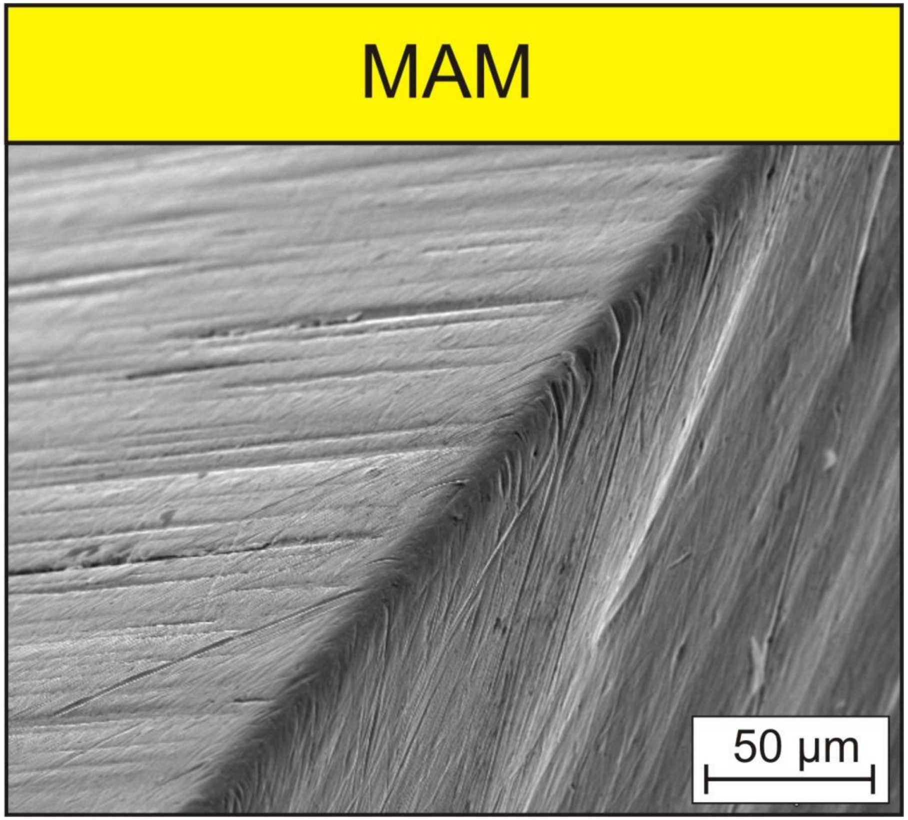
3D-contour of the cutting edge



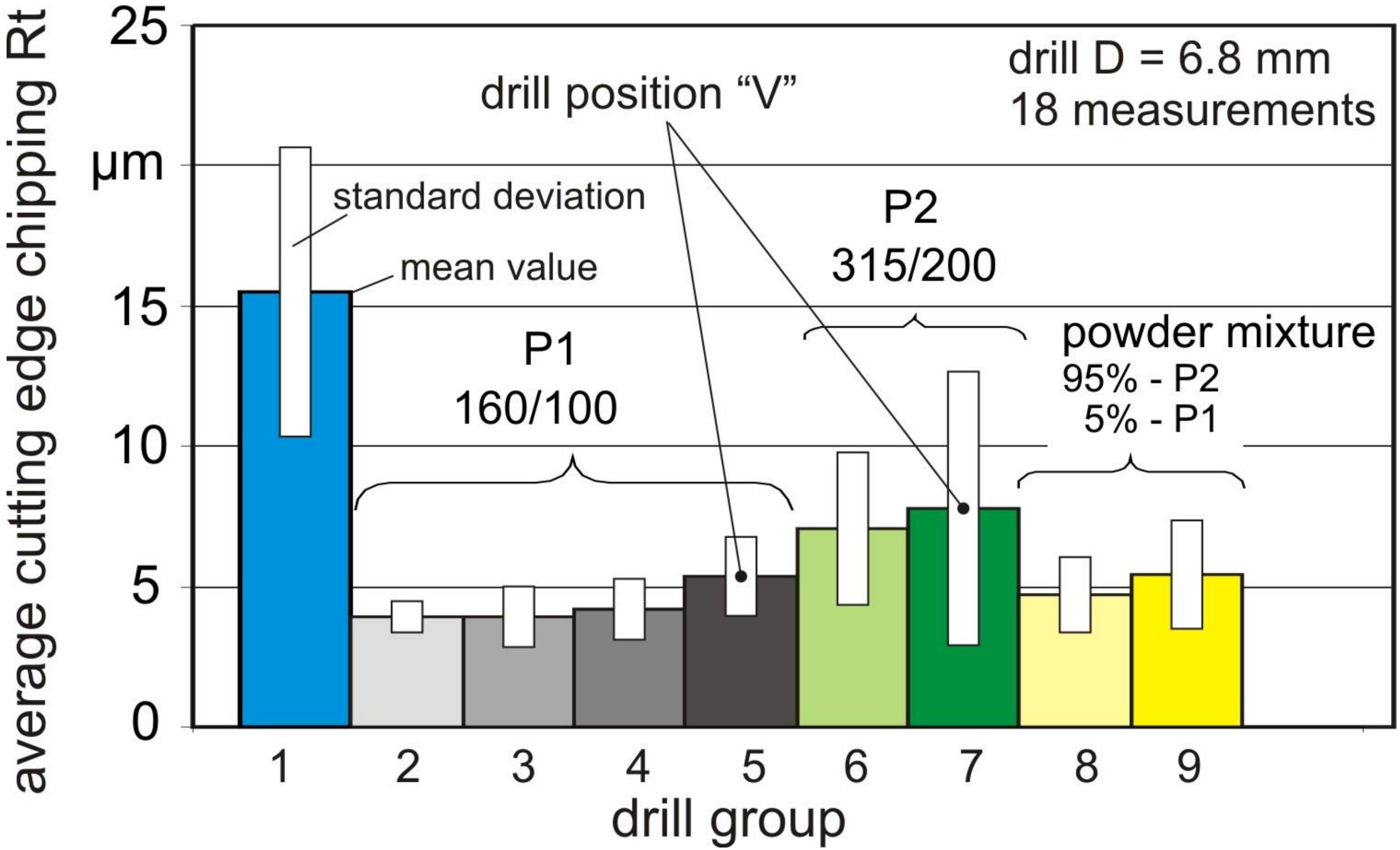
source: GFM

Cutting edge of a helical drill before and after MAM

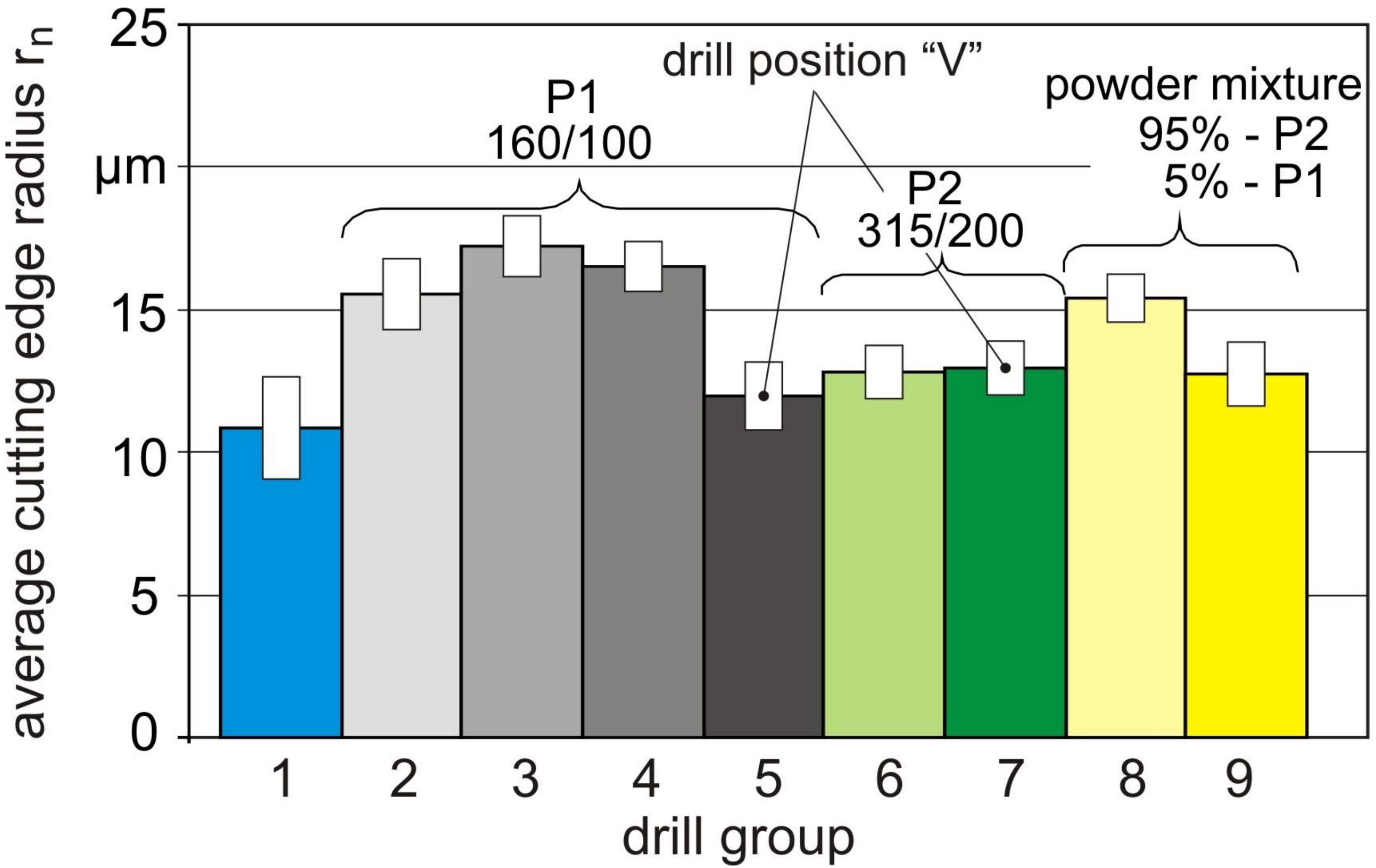




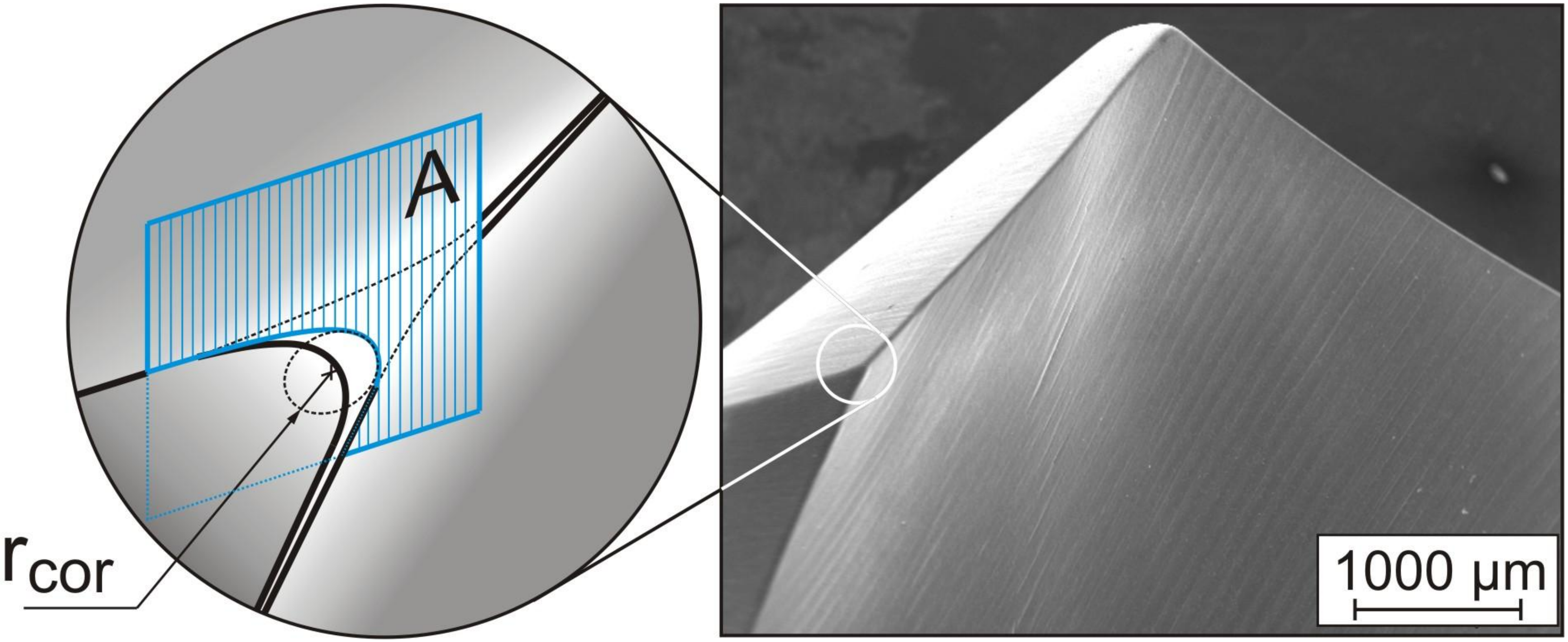
Cutting edge chipping for different drill groups



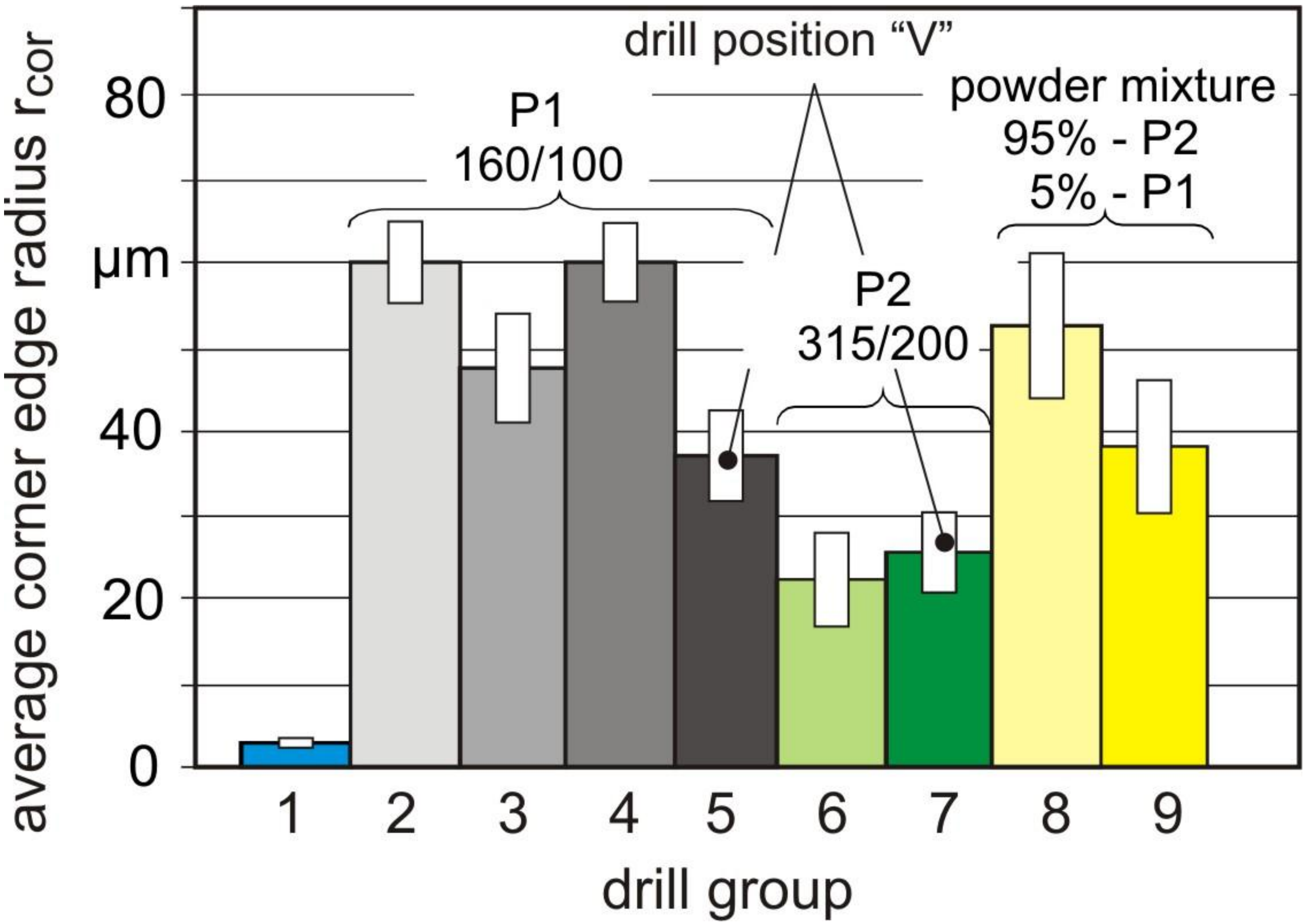
Cutting edge radii for different drill groups



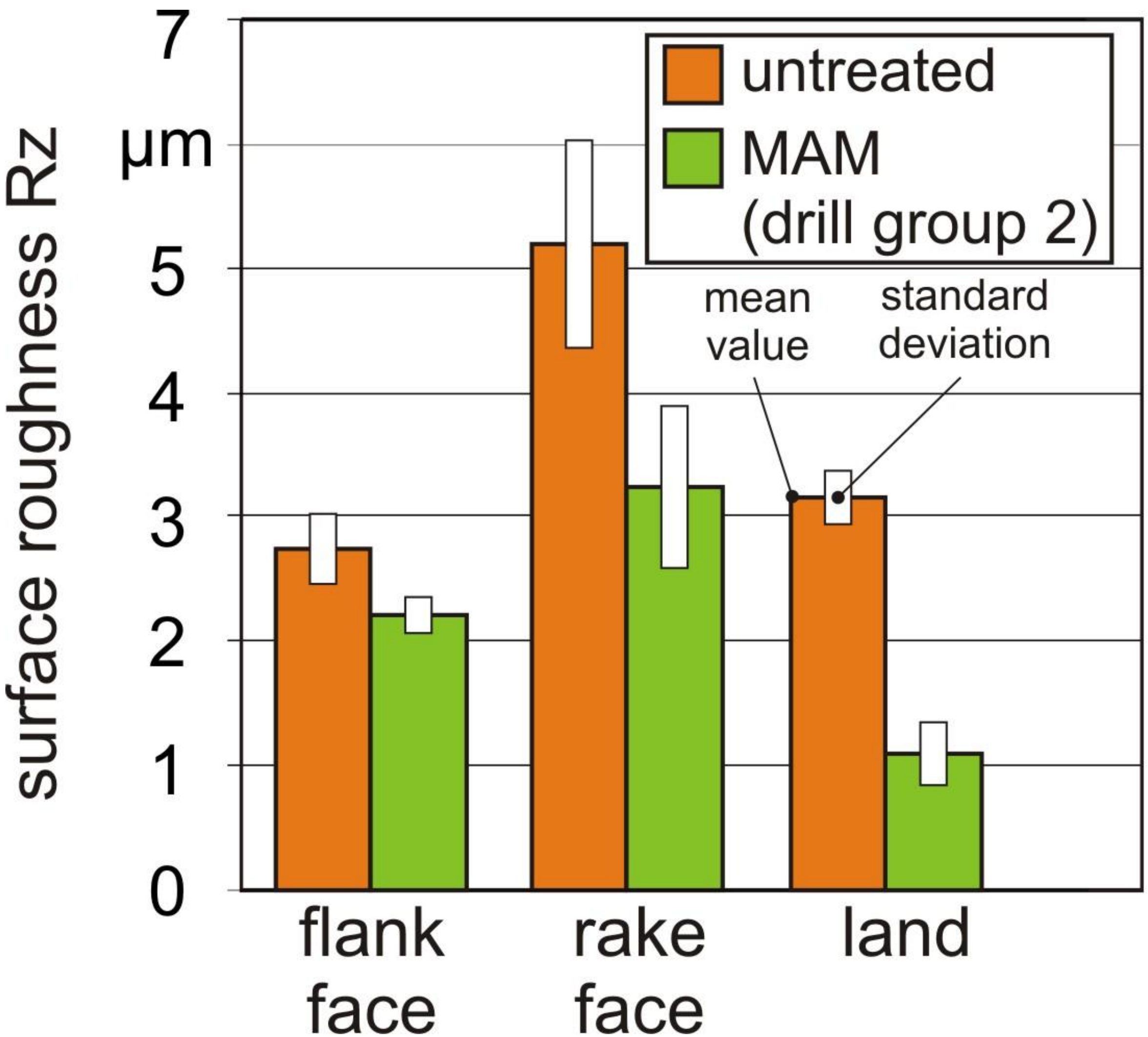
Determination of the corner edge rounding

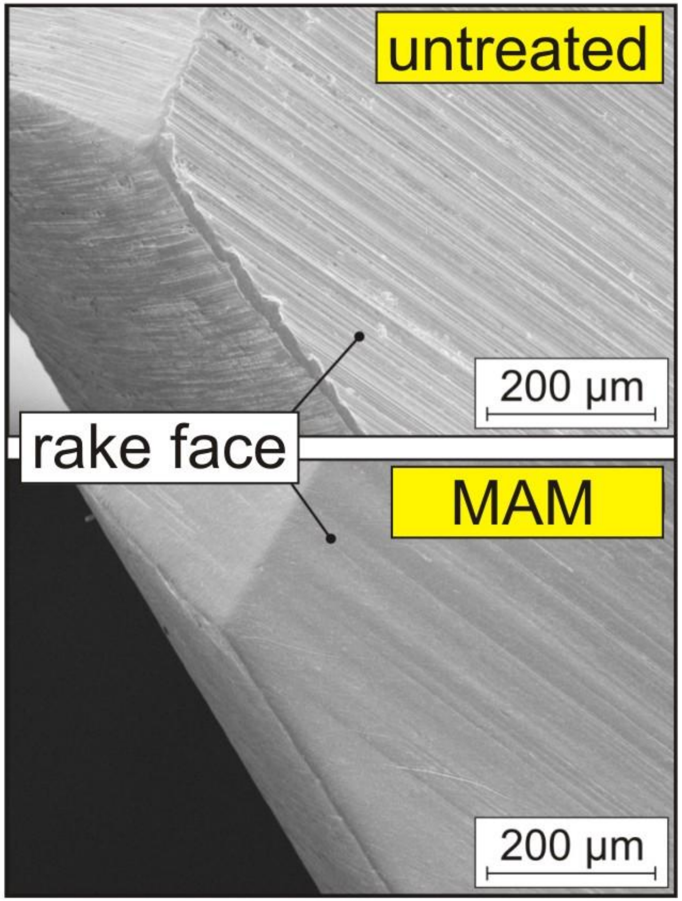


Corner edge roundness for different drill groups

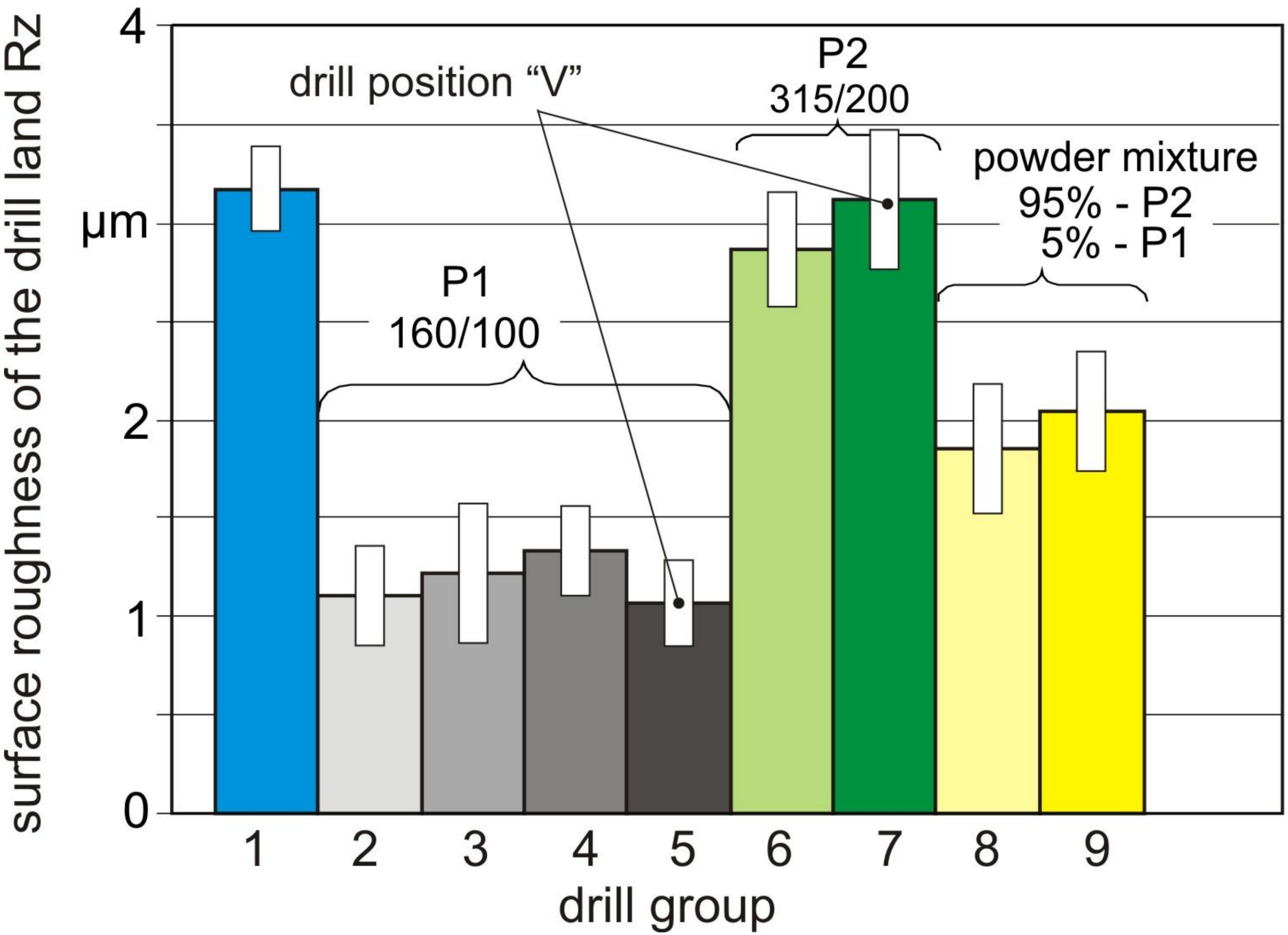


Influence of MAM on drill surface roughness

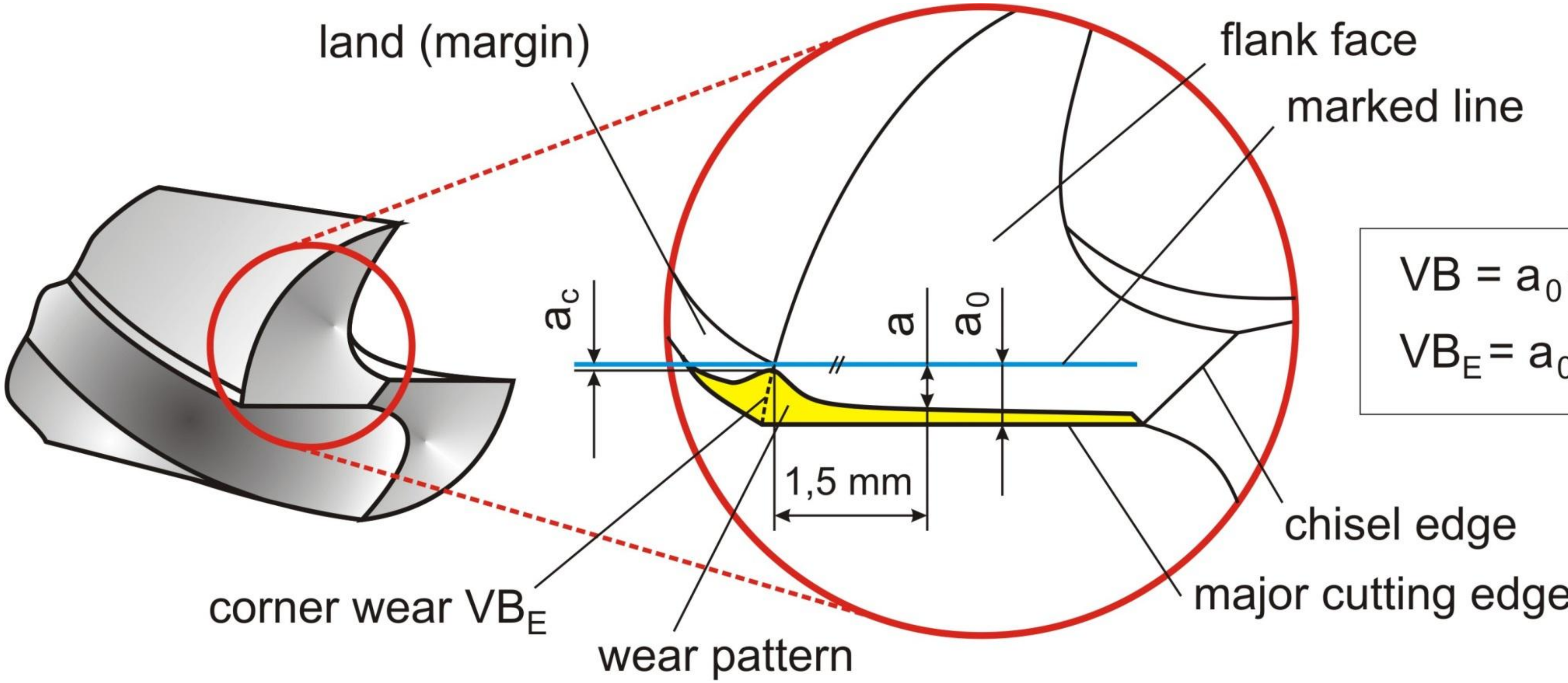




Drill land roughness for different drill groups



Drill wear measurement

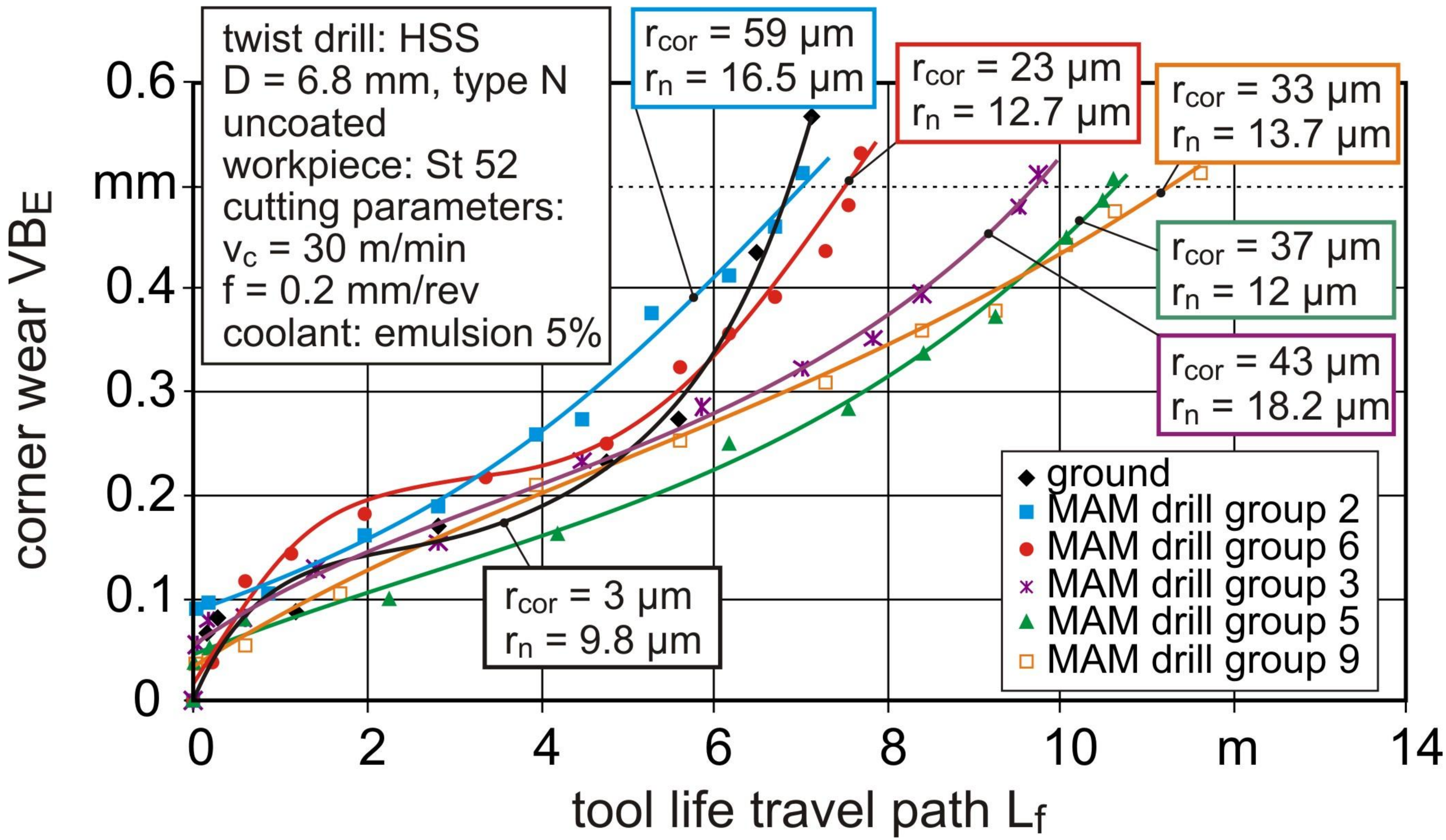


$VB = a_0 - a$

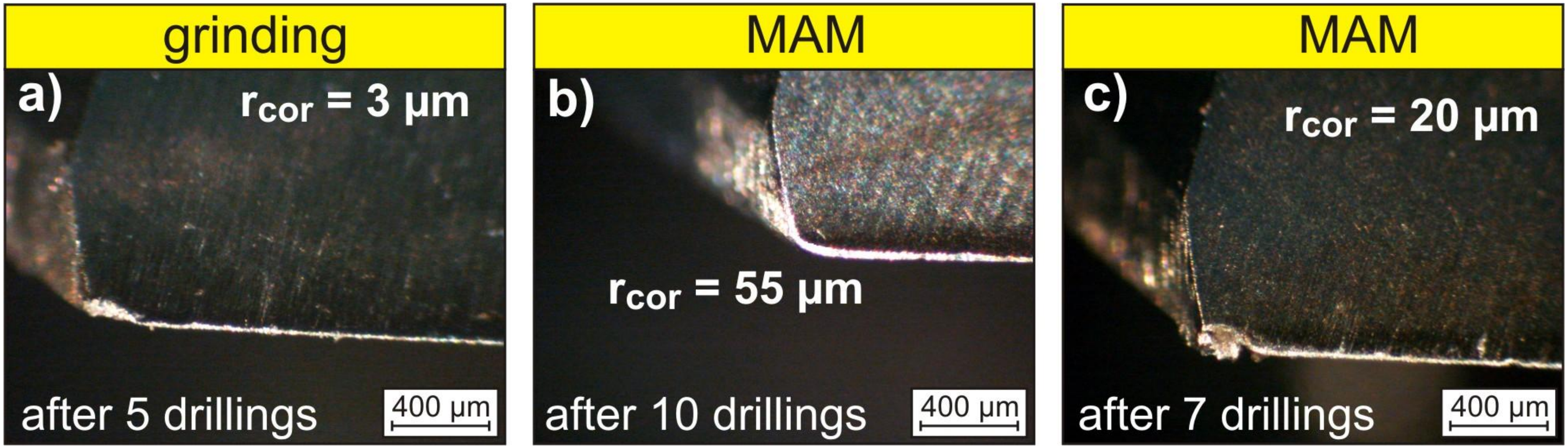
$VB_E = a_0 - a_c$

a_0 - distance between marked line and cutting edge in unworn condition

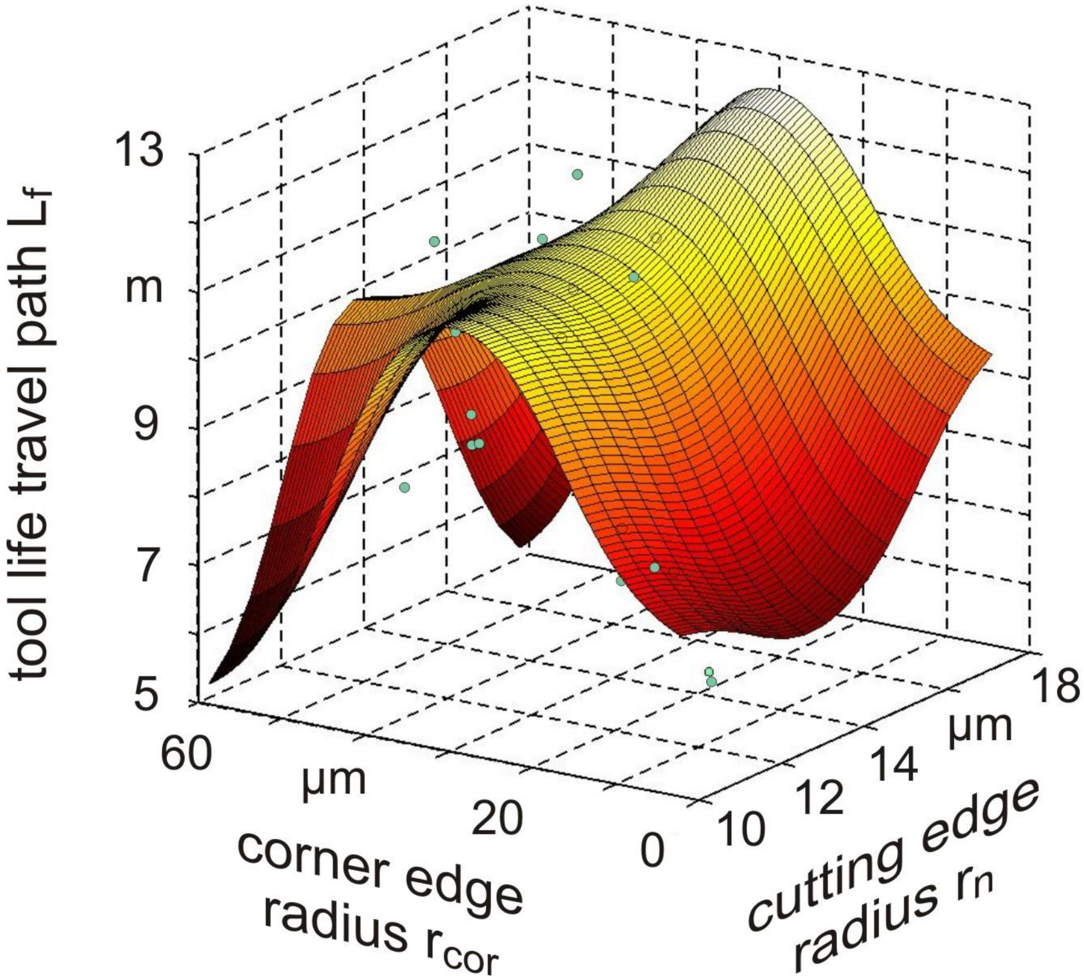
Corner wear depending on varying cutting edge geometry

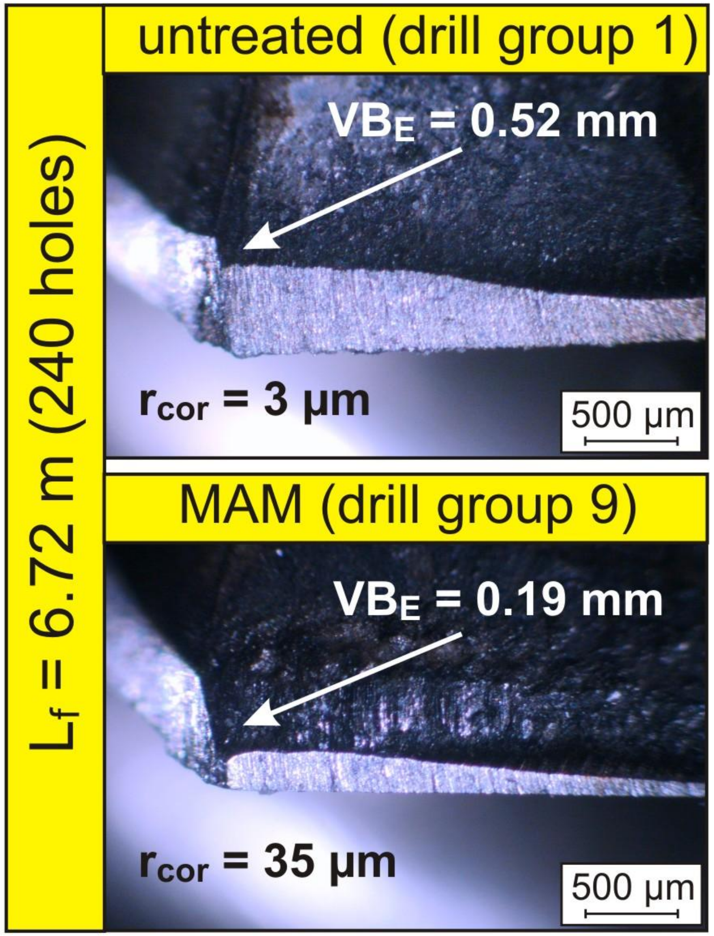


Modifications of initially sharp cutting edges

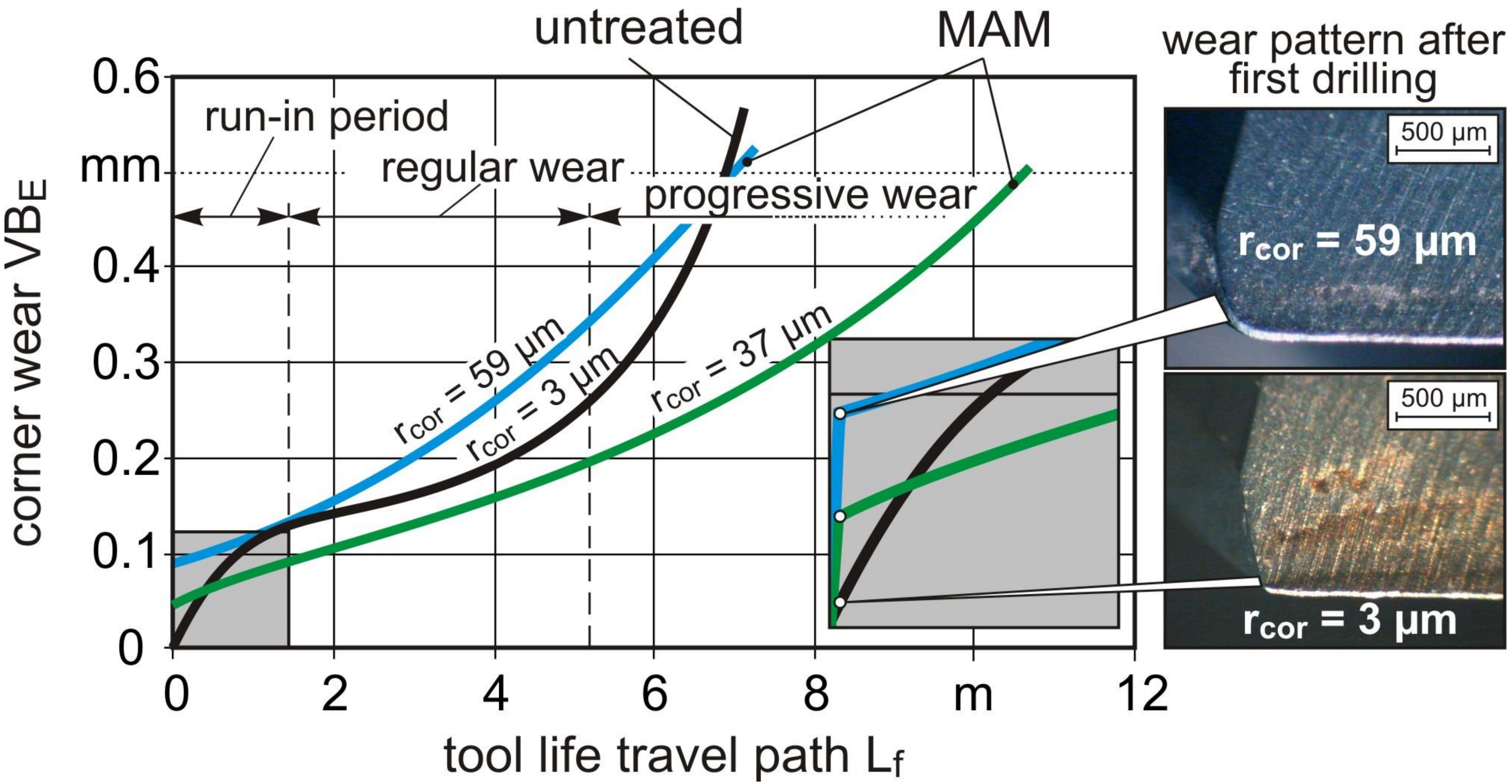


Approximation of experimentally determined tool life

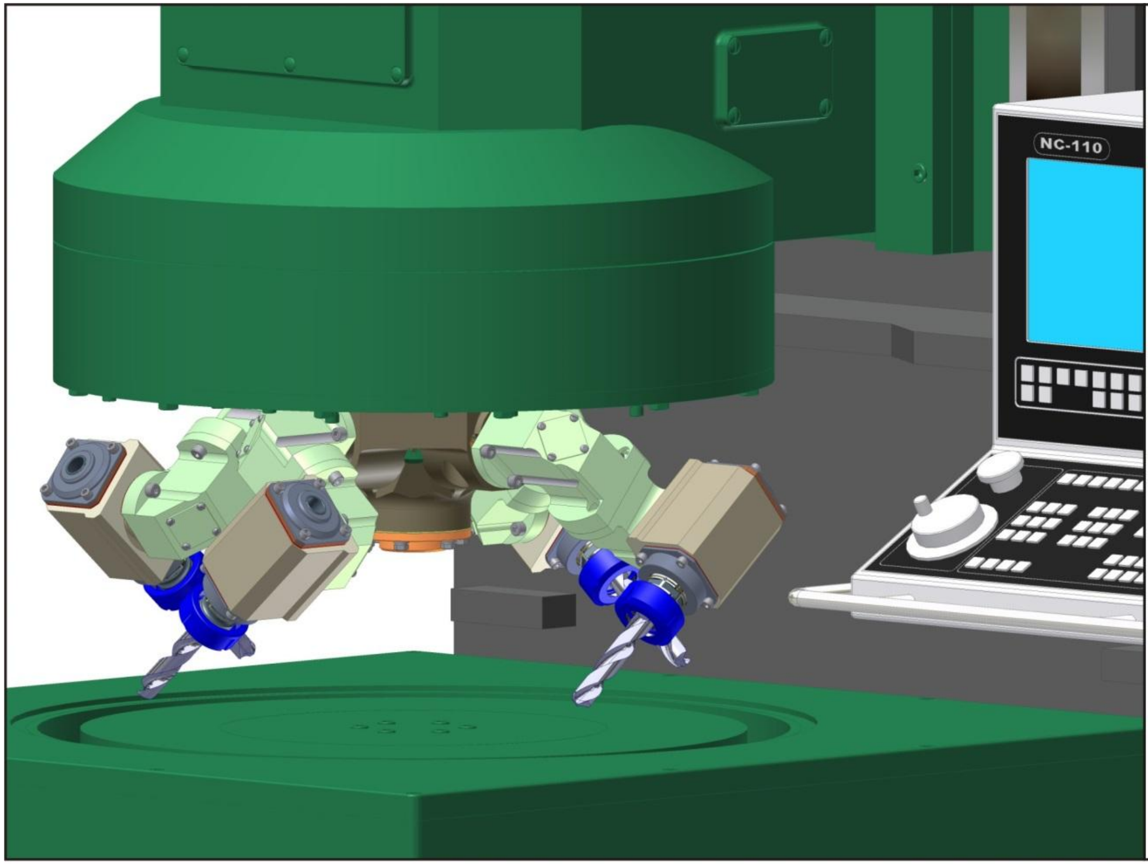


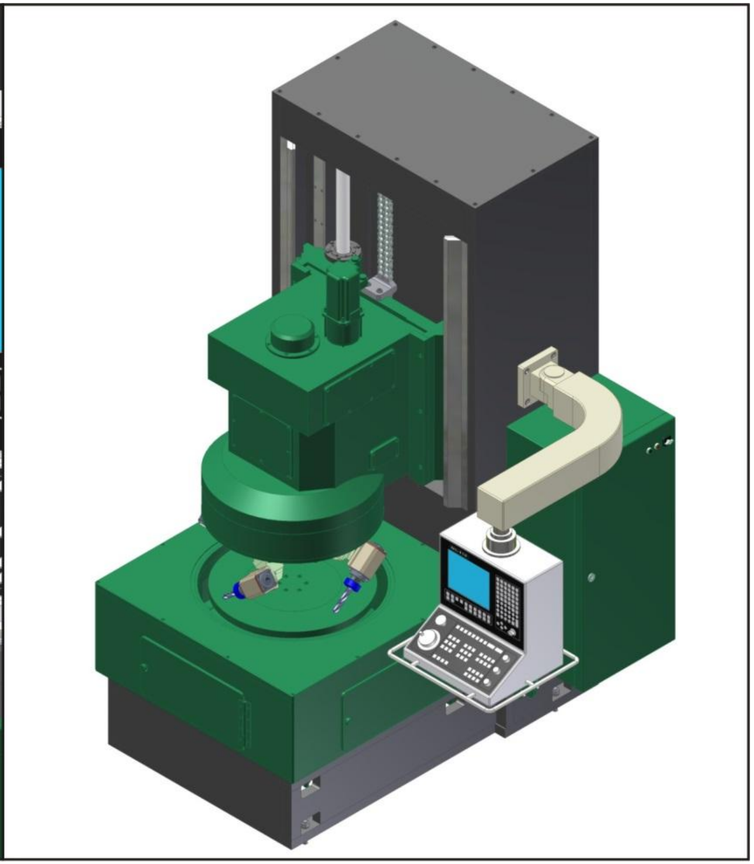


Avoidance of the run-in period of drill wear by means of MAM



Concept of a new MAM system

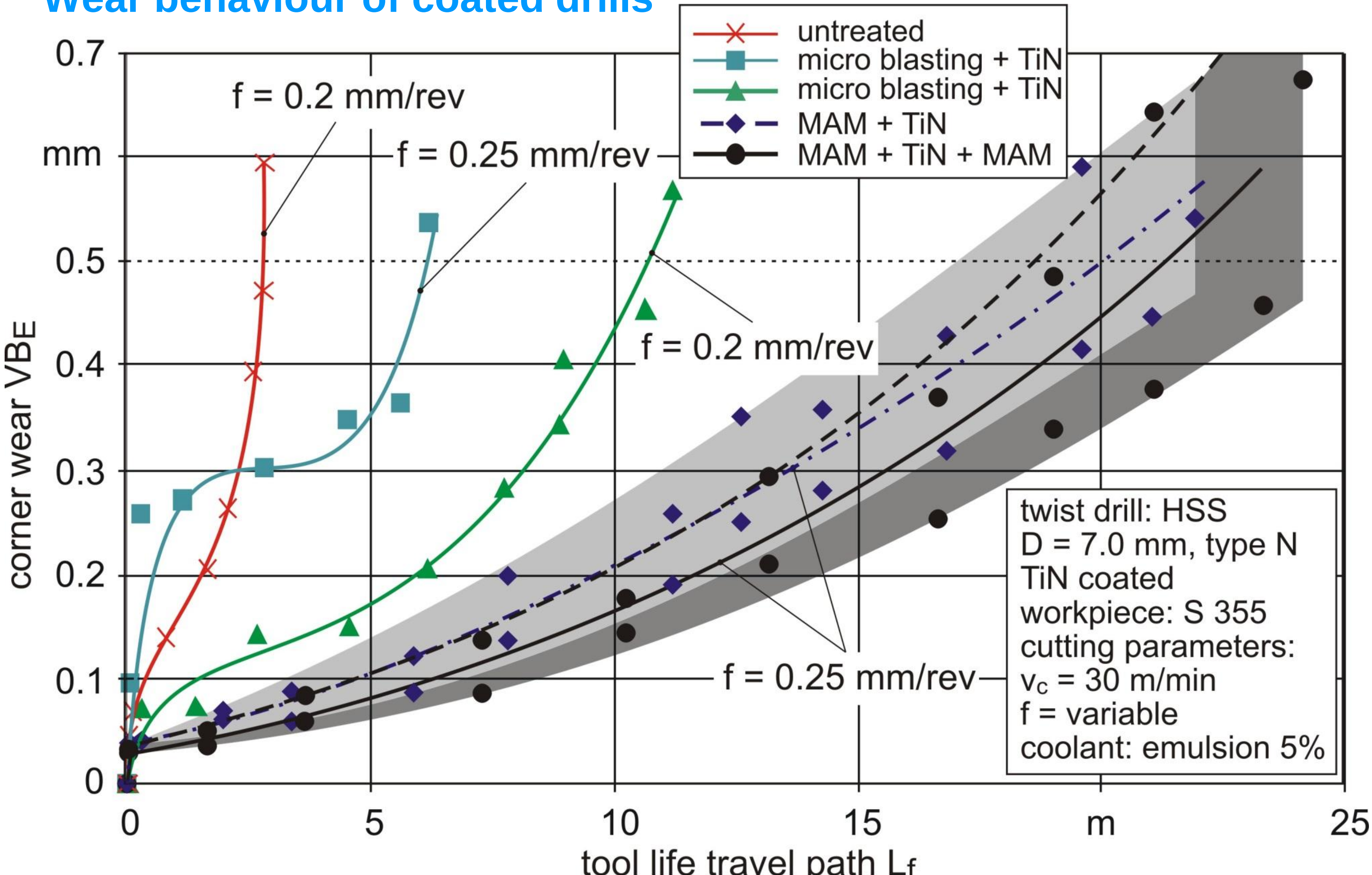




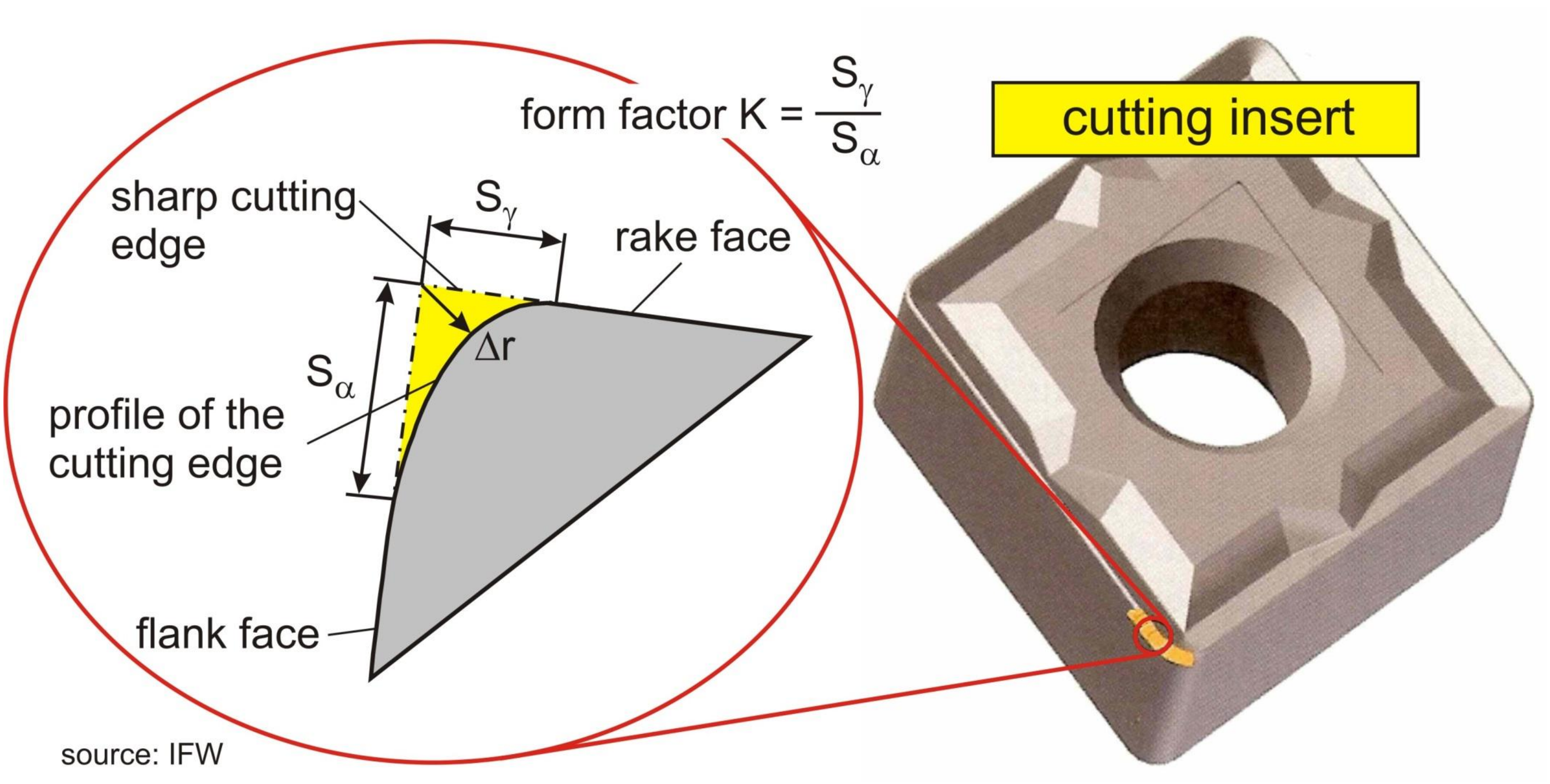
Conclusion

- improvement of the quality of drill cutting edges and all surfaces
- reproducible generation of adapted cutting edge micro geometries
- realisation of cutting edge micro structuring and surface improvement in one process step
- increase of cutting edge and corner stability
- avoidance of the run-in period of drills
- increase of tool life of uncoated drills up 87%
- (2 times increase of the tool life of coated drills)

Wear behaviour of coated drills

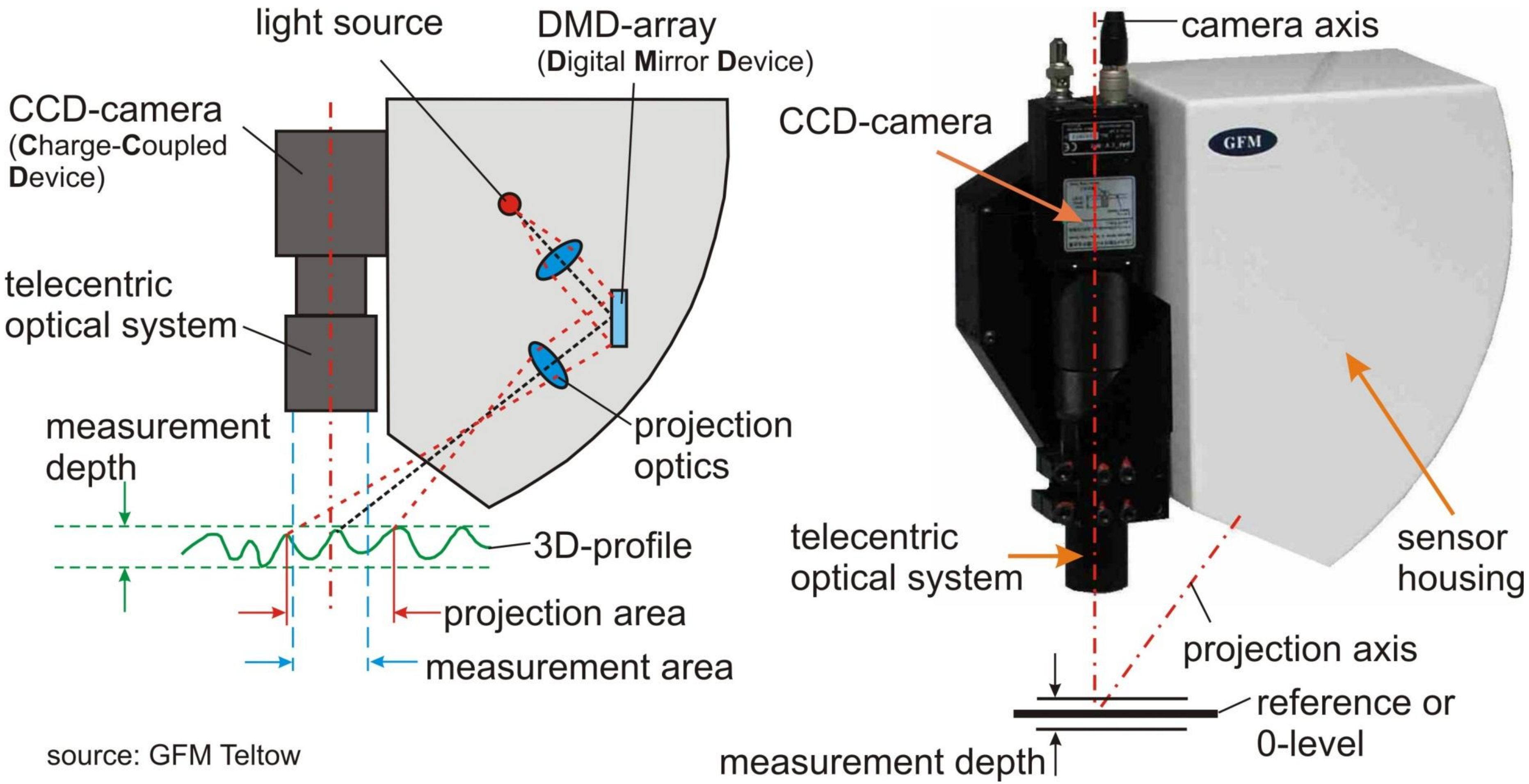


Micro geometry of a cutting edge



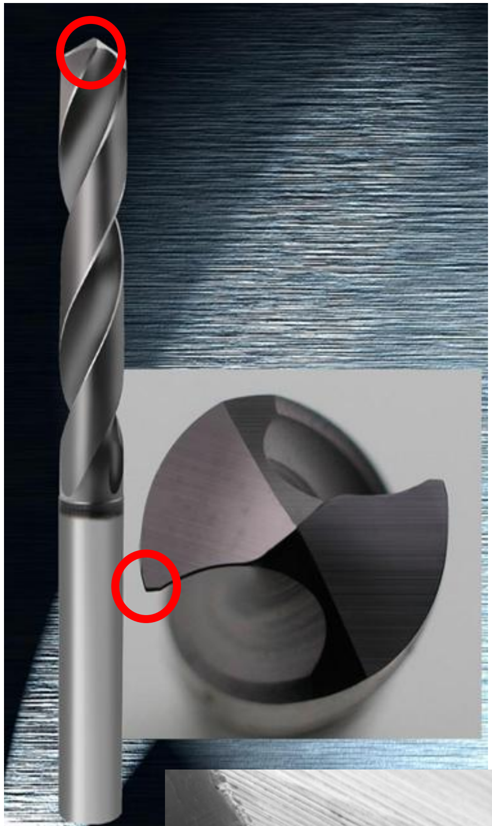
source: IFW

Principle of fringe projection



source: GFM Teltow

Influence of Corner Edge Preparation on the Performance of Drills

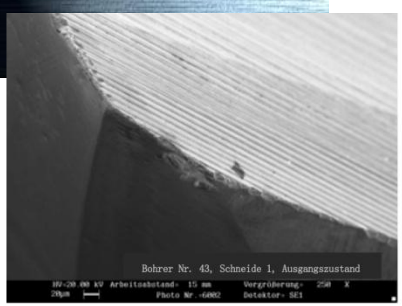


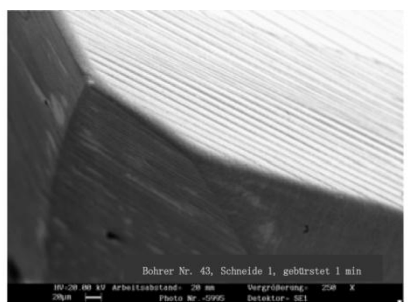
Edge brushing of inclided driven tools

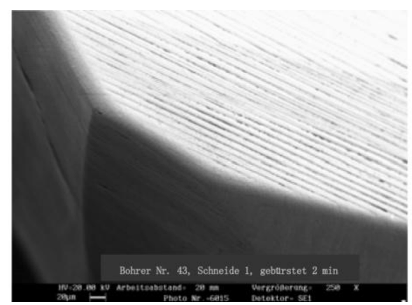
T1 = 1 min

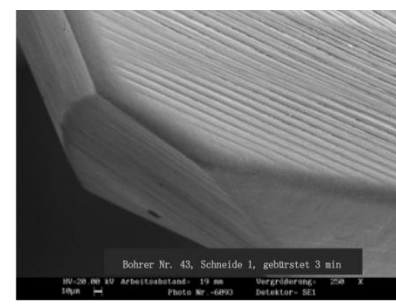
T2 = 2 min

T3 = 3 min









source: PLATIT

as ground R = 3 µm

R1 = 11 µm

R2 = 15 µm

R3 = 21 µm

Influence of edge preparation on the performance of coated inserts

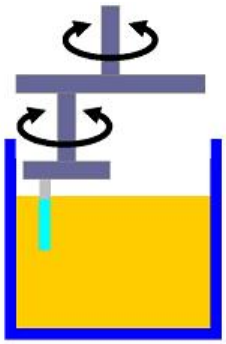
Drag Finishing in polishing machine by special powder

with 2 driven axes

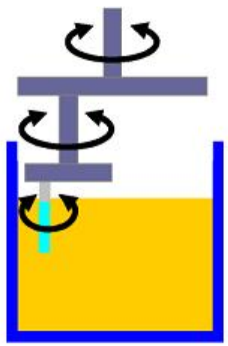
with 3 driven axes

source: PLATIT

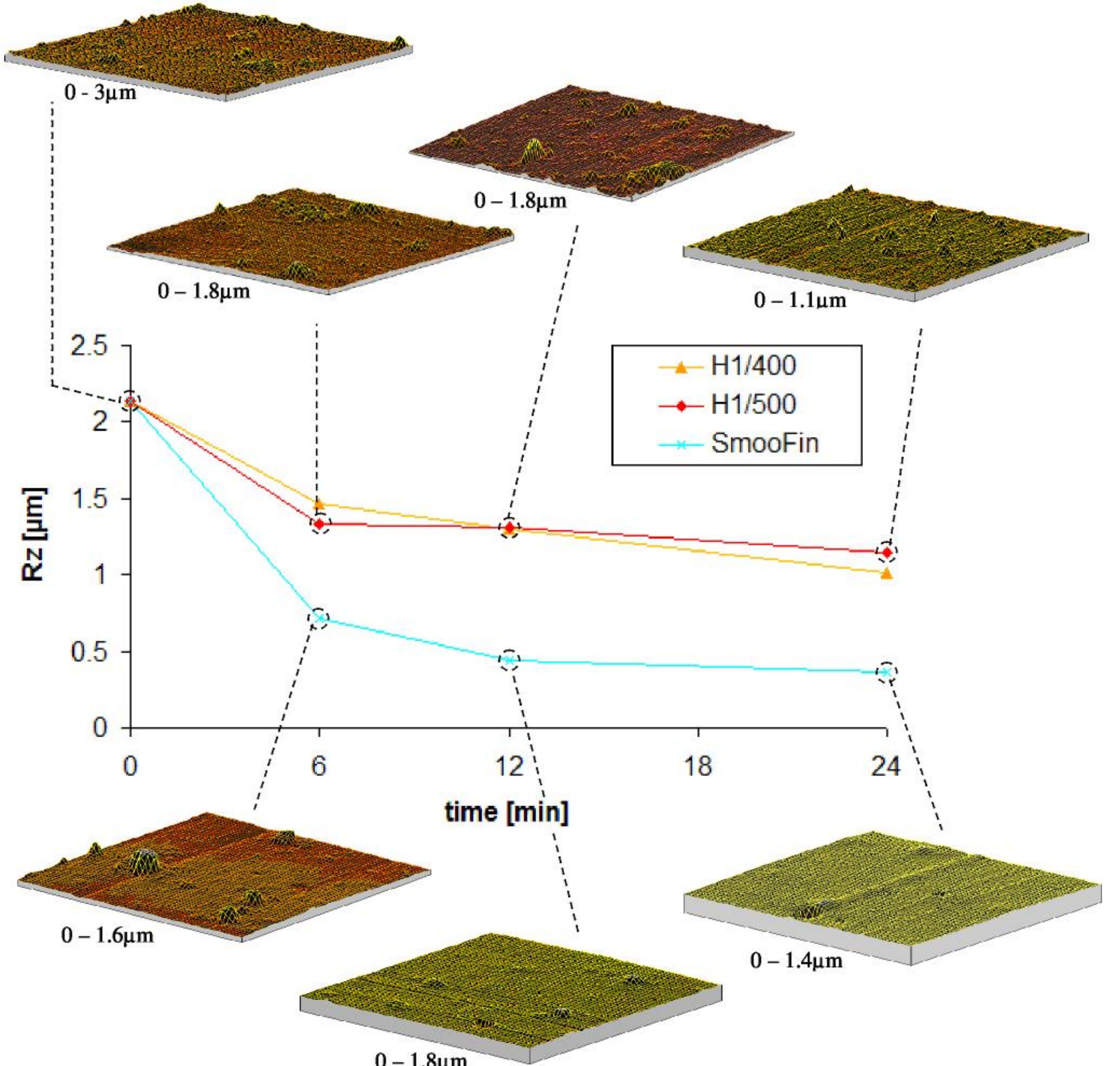
Influence of edge preparation on the performance of coated inserts



2 axes



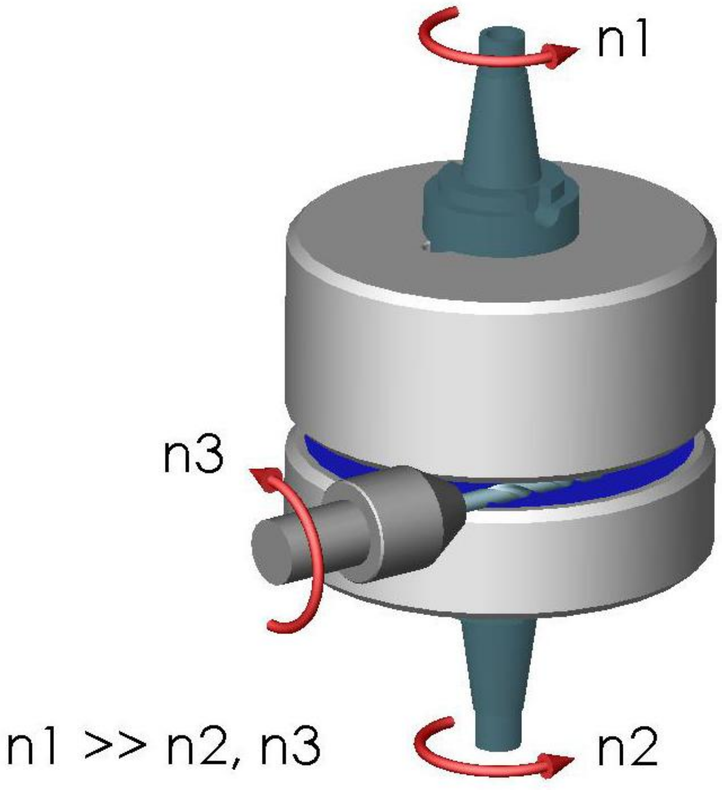
3 axes



source: PLATIT

Edge preparation with magnetic powder with robot manipulation for large scale tool production

MF
magnetfinish



source: PLATIT

Edge preparation of small tools (d > 1mm) with magnetic powder head as a „grinding wheel"

source: MF & Schütte