PROCESSES & INNOVATIVE TOOLS FOR HIGH PERFORMANCE GRINDING

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GRINDING CONFERENCE

Level 2

ABRASIVES

SAINT-GOBAIN

1. Who is Saint-Gobain
2. Chip forming mechanism
3. Chip …. thickness, length, and contact time
4. New developments of grinding wheels
4. Summary

Reshaping your world®

? . . . . !

SAINT-GOBAIN

- one of the 100 industrial companies in the world
- More than 180000 employees
- Plants in 67 countries
- Turnover > 41 Mrd €

Many well known brands, such as:

ABRASIVES

SAINT-GOBAIN

SAINT-GOBAIN ABRASIVES

- **Supplier for all product groups**
  - Bonded Abrasives
  - Coated Abrasives
  - Superabrasives
  - Thin- and Cut-off Wheel
  - Construction Products
- **~ 11000 Employees**
- **61 plants in 28 countries**
- **~ 1,5 Mrd € turnover**

NORTON SAINT-GOBAIN
WINTER
flexovit
NORTON SAINT-GOBAIN
clipper
CARBORUNDUM
GRINDING
rasta Abrasives of excellence
MERIT
ATLAS

SAINT-GOBAIN ABRASIVES

PRODUCTGROUPS

- BONDED ABRASIVES
- COATED ABRASIVES
- SUPERABRASIVES
- THIN & CUT-OFF WHEELS
- CONSTRUCTION
- OTHERS

Chip formation mechanism

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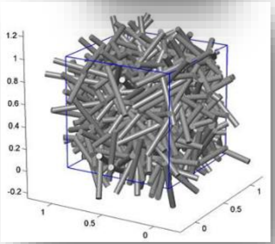
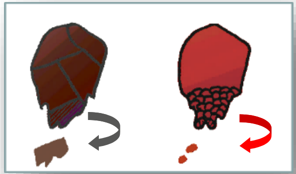
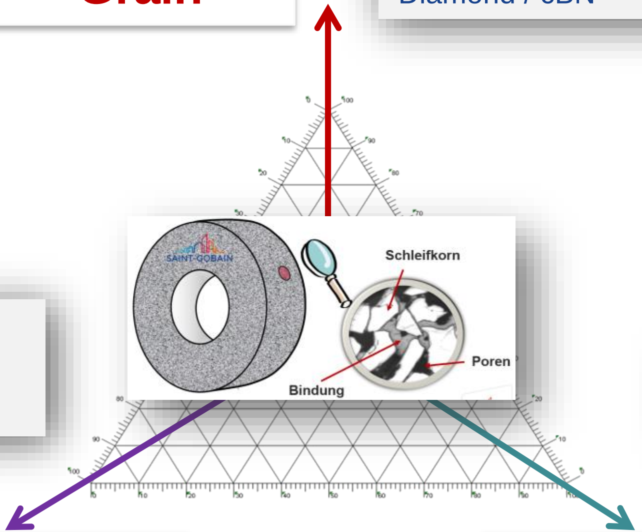
THREE BASIC COMPONENTS FOR OPTIMAL SOLUTIONS



Grain

Fused alumina (white, rose, monocrystalline)
Seeded gels (SG, XG, NQ, …)
Extruded alumina (TG, TGX, …)
Diamond / cBN



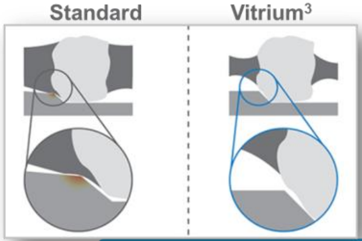


The porosity is formed by a specific matrix technology or by artificial pore inducers

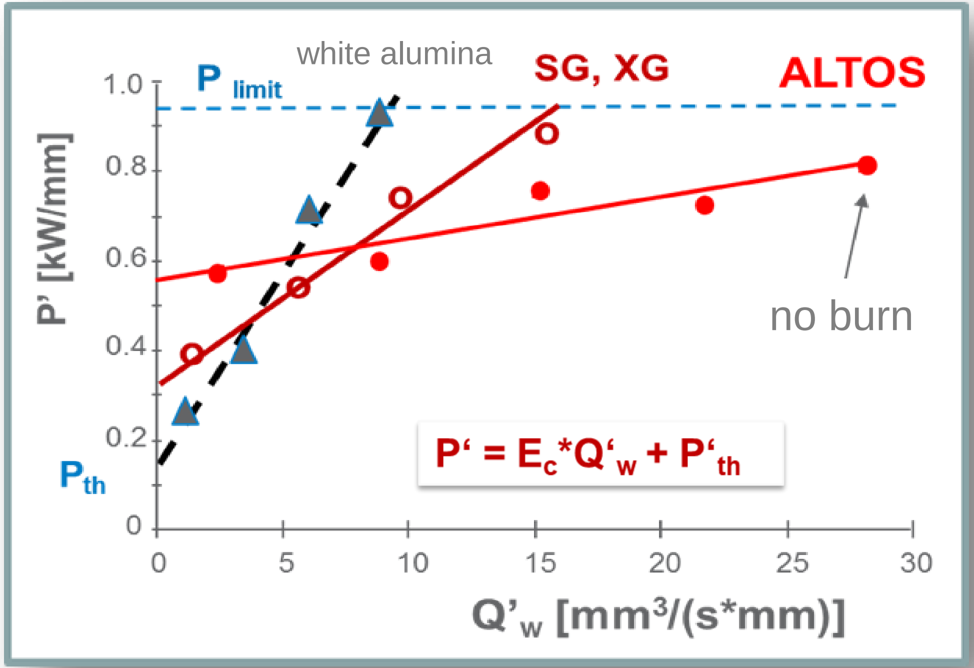
Bonds show different hardness, wear resistance, grit retention capacity

Porosity

Bond



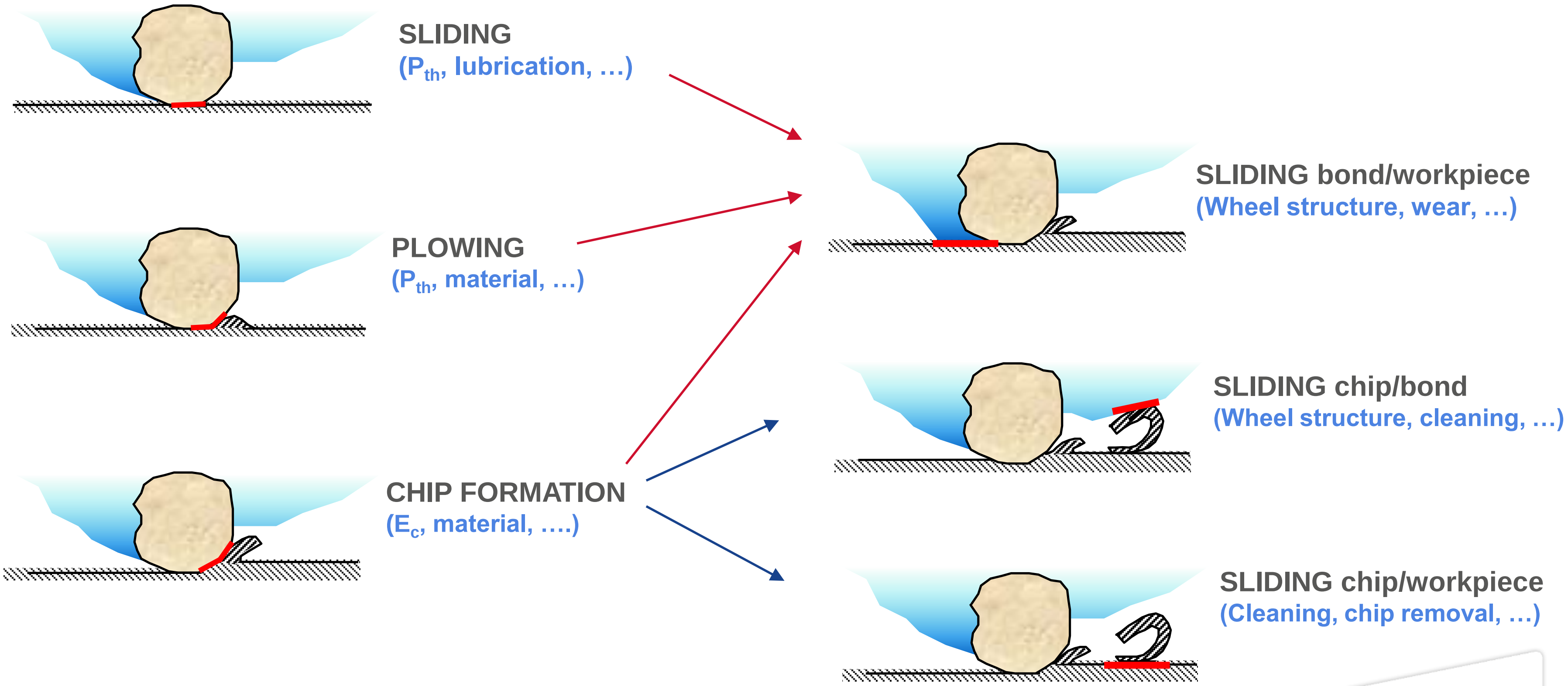
THE VARIETY LEADS TO THE OPTIMUM



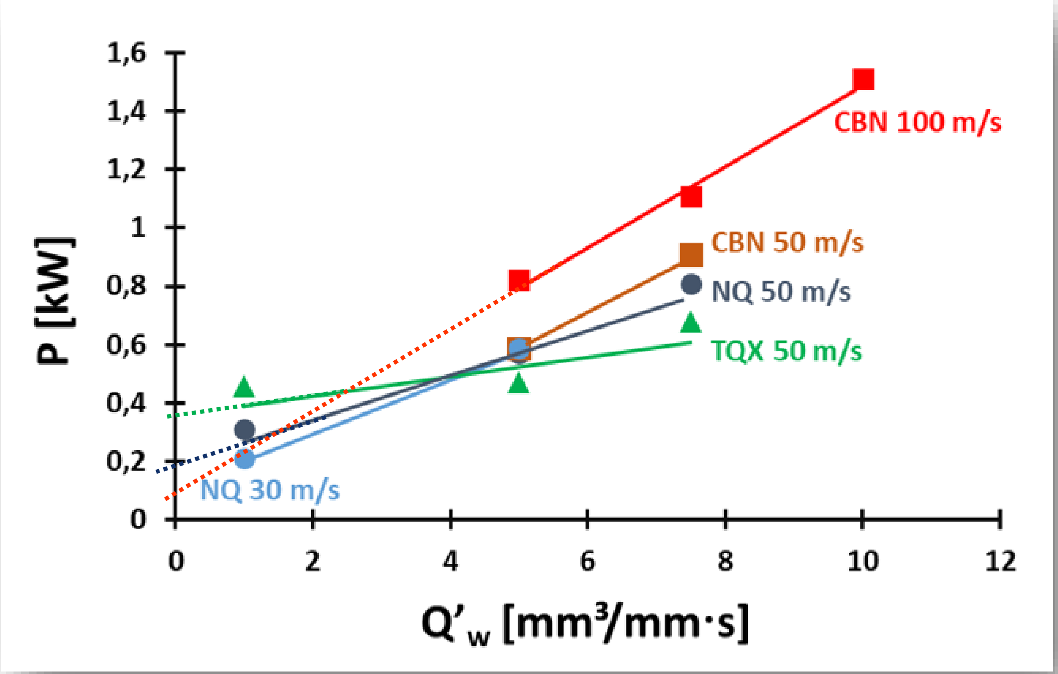
Why not only one single specification?

- Each abrasive grain/bond/porosity shows its strengths in certain areas
- The following points are influenced by specification:
  - Specific grinding energy E_c
  - Threshold power P_{th}
  - Aggressiveness / chip thickness
  - Surface roughness
  - Maximum metal removal rate Q
  - Wheel wear
  - Self-sharpening effect
  - Wheel life
- The grinding behavior can also be optimized by an adapted dressing strategy.

GRINDING PROCESS … INTERACTIONS



CASE STUDY: CBN VERSUS SINTERED CORUNDUM



OD Plunge Grinding

Wheels:	Vit-bond, 400 mm Ø cBN B126, NQ 60, TQX 80
Work piece:	100Cr6, 60 HRC 130 – 90 mm Ø
Machine:	Blohm, Emulsion

Results:

- Der extruded „longish“ TQX shows the lowest specific grinding energy, followed by the sintered corundum NQ and cBN
- The cBN wheel has the lowest threshold power…. easiest chip formation!

The chip….

and its thickness and length

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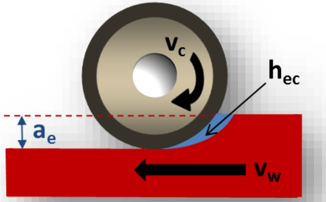
CHIP THICKNESS



The equivalent chip thickness h_{ec} is an important indication for the process

$$h_{ec} = \frac{Q'_w}{v_c} = \frac{v_w \cdot a_e}{v_c}$$

Polishing and finishing:	h_{ec} = 0,01 – 0,1 µm
Precision grinding:	h_{ec} = 0,1 – 0,7 µm
Rough and high performance grinding:	h_{ec} = 0,7 – 3,5 µm

For more accuracy the undeformed chip thickness h_{cu} shows the influence of the abrasive concentration c, the abrasive shape r and the wheel diameter d_e.

$$h_{cu} \sim \sqrt[2]{\frac{v_w}{v_c \cdot c \cdot r}} \cdot \sqrt[4]{\frac{a_e}{d_e}}$$

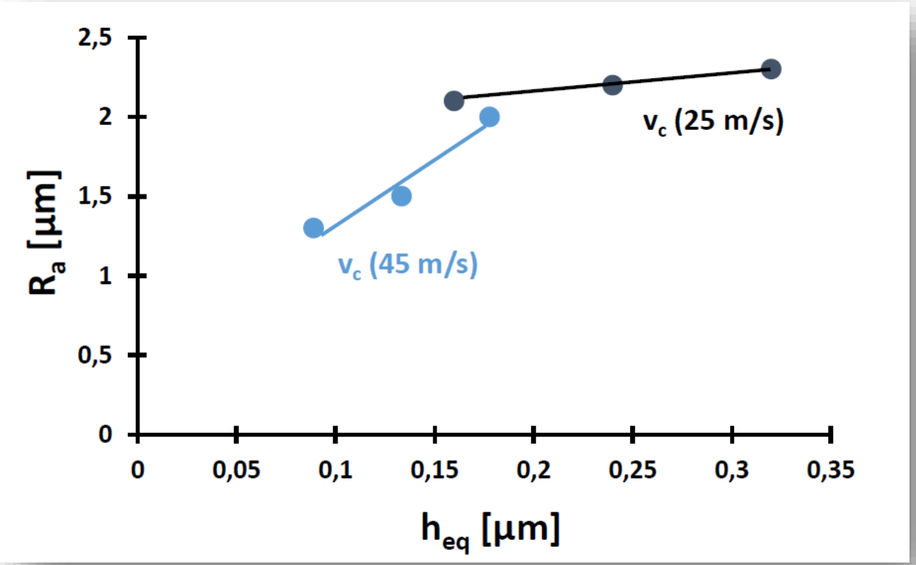
c	Active grain concentration at the surface
r	Shape factor (round=1, long~0)
d_e	Equivalent wheel diameter

Acc. Malkin et al, & Shaw

Practical impact of chip thickness:

- h too small: burn, burrs, surface too fine … „wheel acts hard“
- h too high: rough surface, noise, high wheel wear …. „wheel acts soft“

CASE STUDY: CHIP THICKNESS AND ROUGHNESS



OD Plunge Grinding

Wheels: Vit bond, 300 mm Ø
NQ 80 VS3

Work piece: 100Cr6, 60 HRC
160 mm Ø

Q'w: 4, 6, and 8 mm³/mm·s

Machine: Studer, Emulsion

Only roughing…

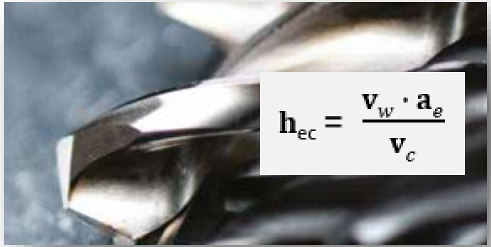
Results:

- Direct relation between h_{ec} and R_a
- Other parameters like v_c show a significant influence on this relation

CASE STUDY: END MILL - FLUTEGRINDING

Starting point: Currently, the customer has issues with the process times and with burrs….. Significant optimization required

End mill 50 mm x 6,5 mm	Stainless steel 1.4028
Flute depth 2 mm	Rollomatic GrindSmart 628XS, Oil



Competition, tool and parameters:

v_c = 55 m/s, v_w = 50 mm/min, a_e = 1 mm (2 passes)

>>> Surface too fine, squeezing, creation of burrs

➡ **h_{ec} = 0,015 µm** (Chip thickness too low, but more „aggressive" parameters impossible due to wear)

Saint-Gobain: Q-Flute B64 EVO …. To realize a larger chip thickness!

v_c = 35 m/s, v_w = 120 mm/min, a_e = 2 mm (1 pass)

➡ **h_{ec} = 0,11 µm**

>>> and thus: **50% reduction of process time, no burrs!**

LENGTH OF CONTACT / CHIP LENGTH

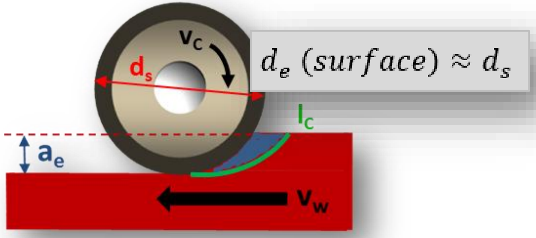
Another important parameter in the grinding process is the length of contact / chip length l_c:

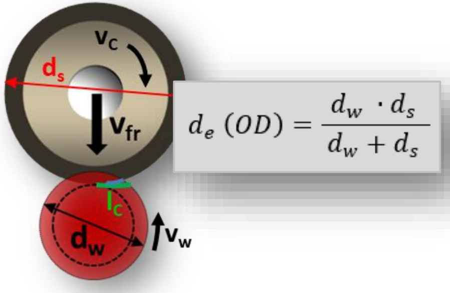
Surface and traverse grinding

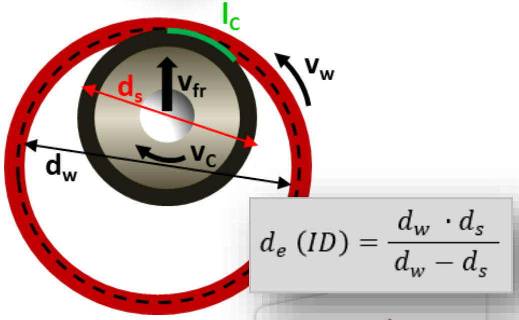
$$l_c = \sqrt{a_e \cdot d_e} \cdot \left(1 + \frac{v_w}{v_c}\right)$$

Plunge grinding

$$l_c = \sqrt{\frac{v_{fr}}{v_w} \cdot \pi \cdot d_w \cdot d_e} \cdot \left(1 + \frac{v_w}{v_c}\right)$$







Example:

Surface, OD and ID grinding with Q'_w 6,7 mm³/mm·s

d_s 125 mm, a_e 0,01 mm, v_c 50 m/s, v_w 40000 mm/min (..h_{ec} 0,13 µm)

- Surface grinding — l_c = **1.1 mm**
- OD grinding (d_w 20 mm) — l_c = **0,4 mm**
- ID grinding (d_w 170 mm) — l_c = **2,2 mm**

!

TIME OF CONTACT

These large differences of the contact lengths influence the contact time t_c (grit to work piece) accordingly:

$$t_c = \frac{l_c}{v_c}$$

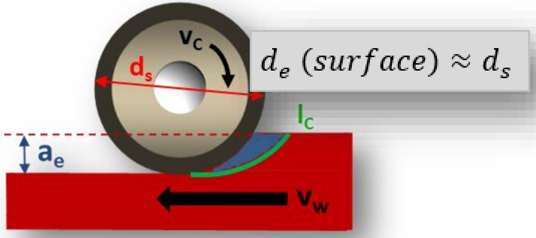
Example:

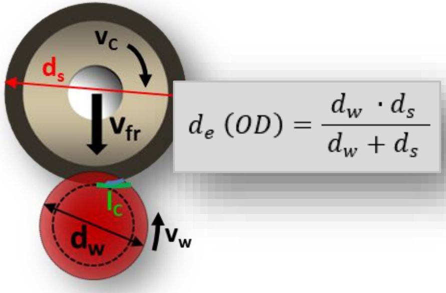
Surface, OD and ID grinding with Q'_w 6,7 mm³/mm·s

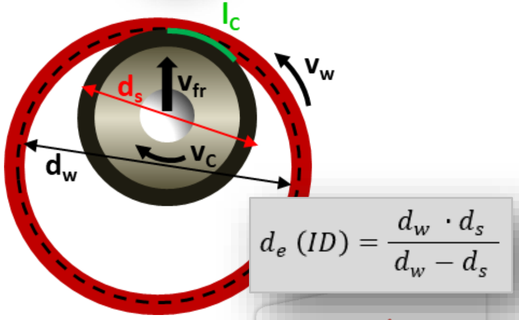
d_s 125 mm, a_e 0,01 mm, v_c 50 m/s, v_w 40000 mm/min (..h_{ec} 0,13 µm)

➢ Surface grinding	**l_c = 1.1 mm**	**t_c = 23 µs**
➢ OD grinding (d_w 20 mm)	**l_c = 0,4 mm**	**t_c = 8,4 µs**
➢ ID grinding (d_w 170 mm)	**l_c = 2,2 mm**	**t_c = 44 µs**

Conclusion: At the same material removal rate the variation of the contact times are significant (factor of ~5) …. Consequently, there is a huge difference in the load on the grits !!!







NUMBER OF ACTIVE ABRASIVE GRAINS

Rough estimation for eg diamond tools:

Assumption of a mean grit size and a consistent average grit shape (between ball and cubus).

Grit shielding, shielding angles, different heights etc. are excluded from this estimation.

Concentration	FEPA grit size	Mesh size	Grit size [µm]	Particles per ct	Particles per mm³ (volume)	Particles per mm² (area)	Particles per mm (line)
C50 = 2,2 ct/cm³	D181	80/100	167	16000	35	11	3,3
	D151	100/120	140	28000	62	16	3,9
	D126	120/140	118	46000	101	22	4,7
	D107	140/170	99	80000	176	31	5,6
	D91	170/200	83	135000	297	45	6,7
C100 = 4,4 ct/cm³	D181	80/100	167	16000	70	17	4,1
	D151	100/120	140	28000	123	25	5,0
	D126	120/140	118	46000	202	34	5,9
	D107	140/170	99	80000	352	50	7,1
	D91	170/200	83	135000	594	71	8,4
C150 = 6,6 ct/cm³	D181	80/100	167	16000	106	22	4,7
	D151	100/120	140	28000	185	32	5,7
	D126	120/140	118	46000	304	45	6,7
	D107	140/170	99	80000	528	65	8,1
	D91	170/200	83	135000	891	93	9,6

INTERMEDIATE CONCLUSION 1

Active grain concentration

The chip thickness and surface roughness are strongly influenced by the concentration of active abrasive grains at the surface.

This number can be modified by the total abrasive concentration, but also (and very importantly) by the grit size.

$$h_{cu} \sim \sqrt[2]{\frac{v_w}{v_c \cdot c \cdot r}} \cdot \sqrt[4]{\frac{a_e}{d_e}}$$

Concentration	FEPA grit size	Particles per mm² (area)	Particles per mm (line)
C50 = 2,2 ct/cm³	D181	11	3,3
	D151	16	3,9
	D126	22	4,7
	D107	31	5,6
	D91	45	6,7
C100 = 4,4 ct/cm³	D181	17	4,1
	D151	25	5,0
	D126	34	5,9
	D107	50	7,1
	D91	71	8,4
C150 = 6,6 ct/cm³	D181	22	4,7
	D151	32	5,7
	D126	45	6,7
	D107	65	8,1
	D91	93	9,6

INTERMEDIATE CONCLUSION 2

Load on the grits / chip lengths

Based on our example with concentration C100 und D126, we see that 5,9 grits per mm are in action (= distance between the grits 0,17 mm).

- Surface-: l_c = 1.1 mm t_c = 23 µs mit 6,5 grits
- OD- (d_w 20 mm) l_c = 0,4 mm t_c = 8,4 µs mit 2,5 grits
- ID- (d_w 170 mm) l_c = 2,2 mm t_c = 44 µs mit 13 grits

With ID grinding the „work“ is done by 13 abrasive grits….
Larger time and length of contact,
and lower chip thickness!

Risk → Grit polishing, burn, low surface roughness

On the opposite, with OD grinding it‘s only 2,5 grits,
in a small time and at a short length

Risik → High wear due to heavy load on the grit and the bond

Concentration	FEPA grit size	Particles per mm² (area)	Particles per mm (line)
C50 = 2,2 ct/cm³	D181	11	3,3
	D151	16	3,9
	D126	22	4,7
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C100 = 4,4 ct/cm³	D181	17	4,1
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	D107	50	7,1
	D91	71	8,4
C150 = 6,6 ct/cm³	D181	22	4,7
	D151	32	5,7
	D126	45	6,7
	D107	65	8,1
	D91	93	9,6

Adjustment of the specification required

- Grit: Toughness, size and concentration
- Bond: Hardness, structure
- Porosity

CASE STUDY: CREEPFEED GRINDING

Starting point: Thermal damage at the surface (burn), when the grinding wheels wear down to a lower diameter

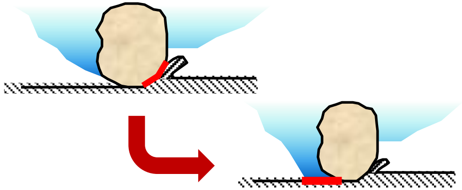
Grinding wheel 300 – 180 mm Ø, NQ vit bond, 2 grade of hardness (hard = bond volume + 50%)
Inconel, oil, v_c = 22 m/s, v_w = 500 mm/min, a_e = 1 mm >>> Q'_w 8,3 mm³/mm·s, h_{ec} 0,38 µm

Grinding results:

Large diameter(300 mm): Everything OK, no burn neither at soft nor at hard specification
Small diameter(180 mm): Burn with hard spec, but the soft spec is alright!

Calculations:

Length and time of contact: at 300 mm: l_c = 17,3 mm; t_c = 0,78 ms
at 180 mm: l_c = 13,4 mm; t_c = 0,61 ms



With the small diameter the length and time of contact is 22% shorter, and therefore the load on the grit is much higher, leading to increased wear. As the bond at the hard spec can‘t cover this wear, it leads to friction and subsequently burn!
With the soft wheel (lower bond volume) this problem could be solved!

New developments of grinding tools

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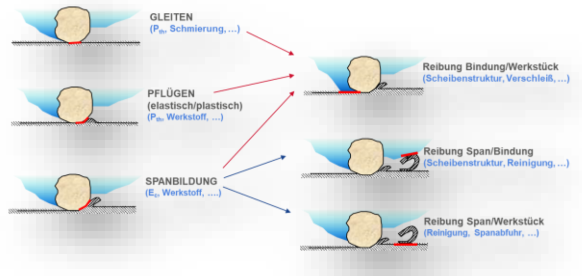
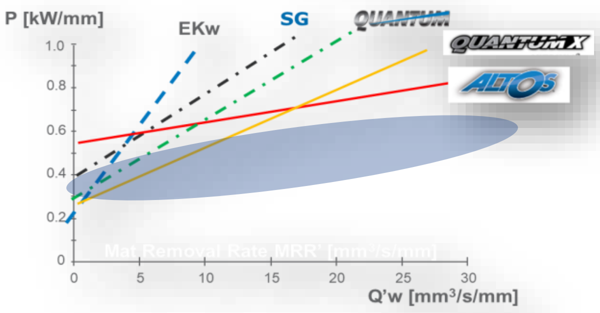
BASIC REQUIREMENTS FOR NEW DEVELOPMENTS:

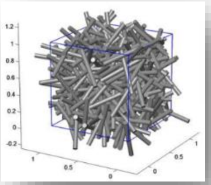
- **High porosity and low bond volume**



- **Low specific grinding energy and threshold power**



- **Low abrasive shape factor…. Elongated grain**



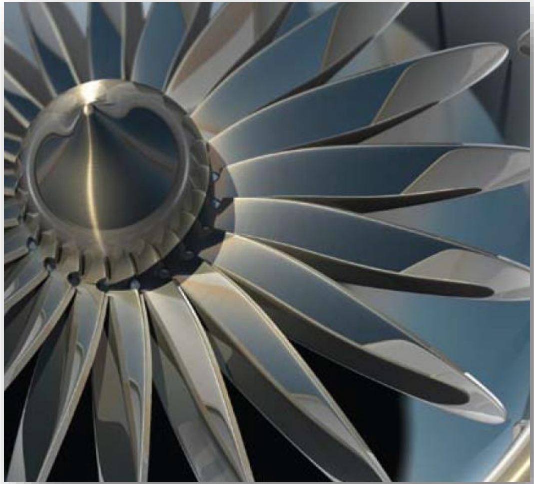
$$h_{cu} \sim \sqrt[2]{\frac{v_w}{v_c \cdot c \cdot r}} \cdot \sqrt[4]{\frac{a_e}{d_e}}$$

TQX

CASE STUDY: CREEP FEED GRINDING

Starting point:

Process optimization required, as the customer suffered from problems with the competition tool such as low life time and partly thermal damages

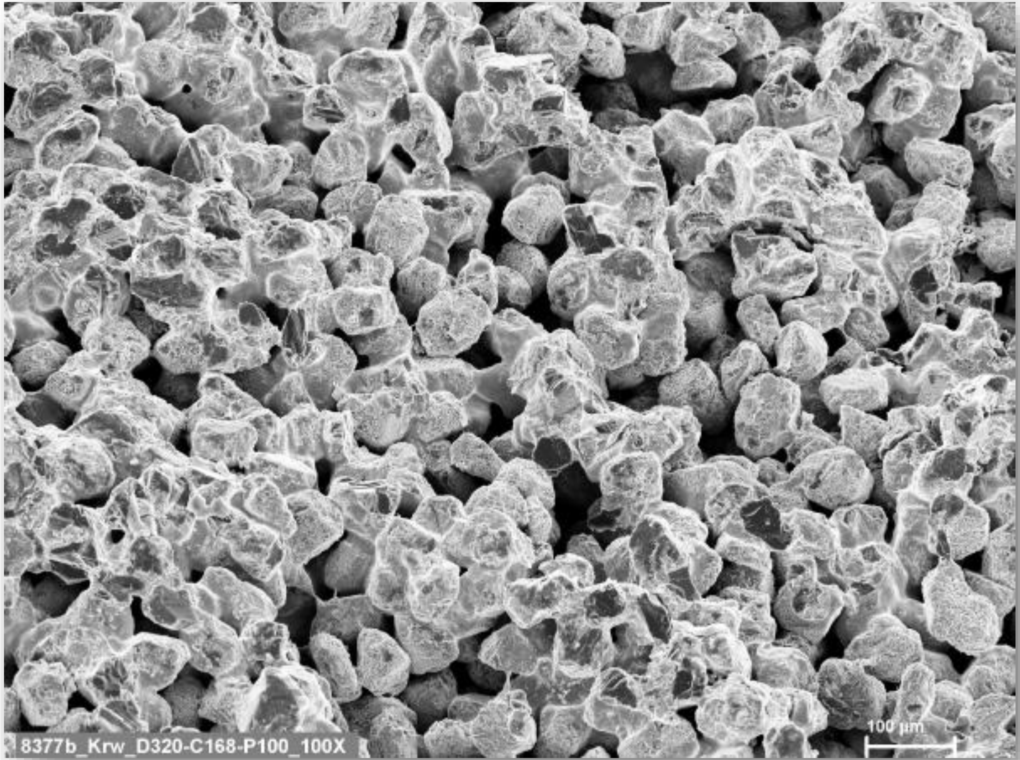


Grinding wheel 300 mm Ø, TQX vit bond, high porosity Ni based aloy, v_c = 15-25 m/s, v_w = 250 - 600 mm/min, a_e = 3 – 0,3 mm

Results:

- Burn free grinding
- High flexibility of parameters
- 10 times higher life time compared to competition
- Process times reduced by 40%

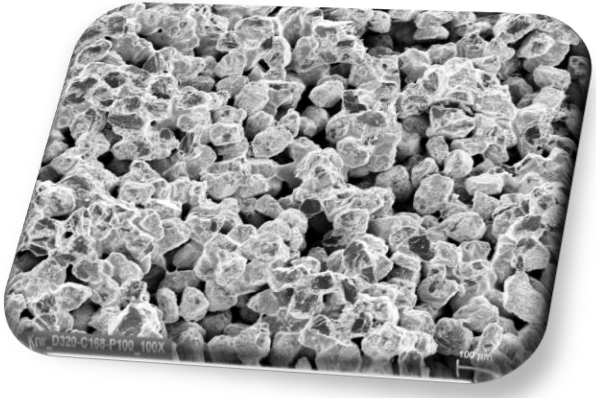
PARADIGM



PARADIGM …. THE INNOVATION

Properties of this diamond tool

- Highly porous metal bond, up to 46% porosity
- High thermal conductivity
- Very high grit retention due to chemically active components
- Homogeneous structure
- Easily dressable (profile- und CNC-dressing)



Benefits

- Combines the best properties of metal and vitrified bond
- Low grinding forces
- Avoids thermal damages
- High G-ratios
- Excellent process stability
- Low specific grinding energy
- Perfectly suitable for difficult-to-grind materials, such as TiAl, CMC, Carbide, …

PARADIGM …. GRINDING OF TITANIUM-ALUMINIDES

Comparison between SiC und Paradigm (Diamant)

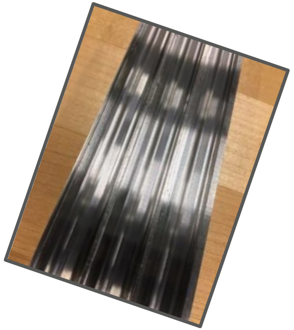
- Blohm Planomat HP
- Grinding of grooves
- Total infeed 4 mm, per cut 0,2 mm

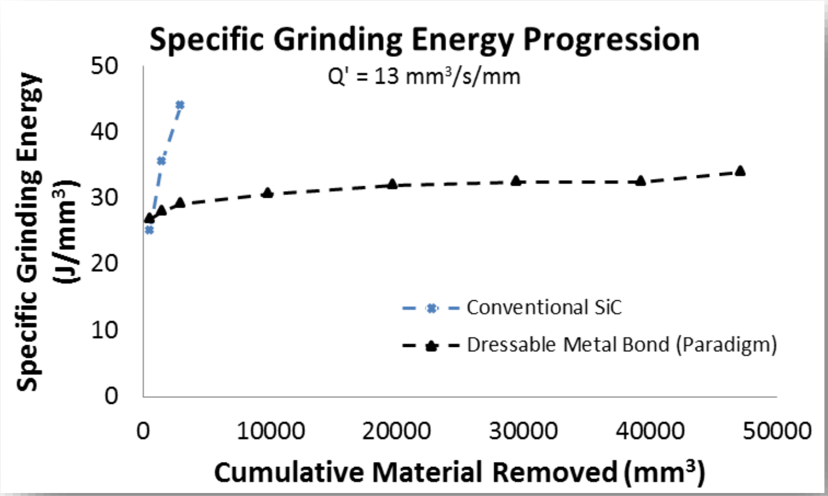
Benefits of TiAl for the Turbine-Industry

- Low density (50% lower than Ni-Superalloys)
- High temperature stability
- High specific toughness

BUT:

- Difficult to grind
- Risk of burn and cracks





Results

- Grinding with **SiC** showed burn from the beginning
- With the **Paradigm** several cuts could be performed at a constant power and without burn and cracks.
- Dressing of the Paradigm was only necessary to keep the form, but not due to burn.

Summary

SUMMARY

Selection of grain type

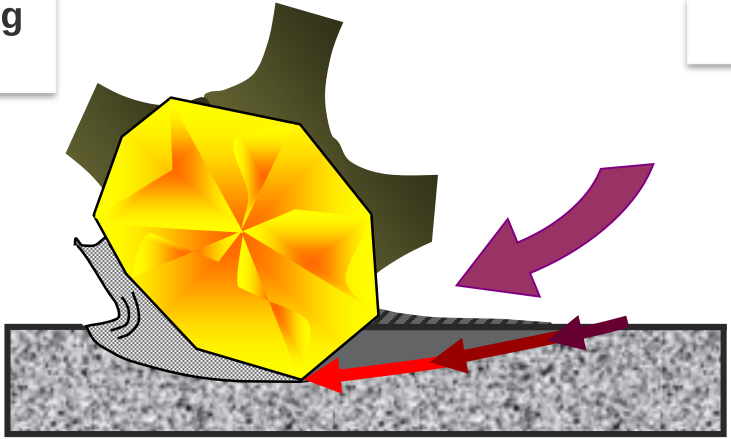
Specification

Specific Grinding energy

Porosity

Cooling

Threshold power



Direction of Grinding

Chip thickness

Speed ratio

Chip formation

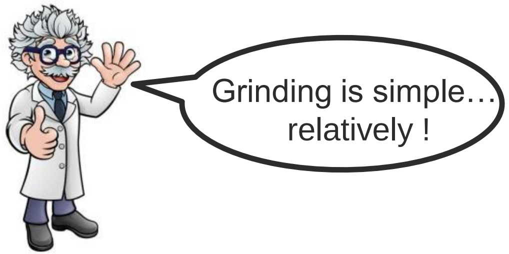
Deformation elastic / plastic

The performance of a grinding process

can easily be optimized:

We just need…

- ✓ **Some simple calculations**
- ✓ **Understanding of the microscopic mechanism**
- ✓ **and the properties of the grains, bonds, machine & workpiece**



SAINT-GOBAIN

Thanks
for your attention

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