PROCESSES & TOOLS FOR HIGH PERFORMANCE GRINDING

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GRINDING CONFERENCE

Level 1
1. Who is Saint-Gobain

2. Grinding Basics

3. High Performance Grinding
   • Abrasive Grain and Specification
   • Creepfeed and Surface Grinding
   • Wheel and Cutting Speed
   • Direction of Grinding
   • New Developments

4. Summary
Saint-Gobain
SAINT-GOBAIN
… one of the 100 industrial companies in the world

- More than 170,000 employees
- Manufacturing facilities in 65 countries
- Turnover > 38 Mrd €

- 3 Pillars

- Innovative Materials 23.5%
- Construction-products 27.5%
- Distribution 49%
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 27 countries
- ~ 1,5 Mrd € turnover
- Major brands:

  ![Norton](image1.png)
  ![Winter](image2.png)
  ![Flexovit](image3.png)
Grinding Basics
MOTIVATION

- The **efficiency** of the grinding processes is constantly being increased with regard to material removal, grinding times, surface quality and the complexity of the process sequences.

- Amongst other aspects this is necessary for the processing of **new materials** and also helps reduce grinding costs.

- But how is this achieved?
  - On the one hand, with **modern grinding machines** that allow for fast and optimum processes.
  - On the other hand, through the development of **innovative grinding tools** that make optimum process parameters possible in the first place. The individual combination of the right abrasive grain and the suitable bond leads to a specification that ensures the highest performance for the respective application.
FROM THE GLOBAL DEMANDS TO THE DETAILED SOLUTION

**Market Demand**
- Increase in efficiency
- Noise reduction
- Robustness
- Life time
- Cost reduction
- Environment protection

**Industry Demand**
- Tighter tolerances
- Higher profile accuracy
- Improved surface finishes
- New materials (hard/tough/light/...)
- Cost reduction
- Lean manufacturing

**System Approach**
- Analyze and evaluate the total system

**Technical & Commercial Grinding Solution**
- Comparison of possible processes
- Superabrasive or bonded?
- Grinding:
  - Selection of the grinding tool (grit quality and bond system)
  - Definition of the specification
  - Determination of process parameters

**Knowledge of the Criteria**
- Workpiece properties
- Technical details and workpiece requirements
- Commercial objectives
- Machine equipment and capacity
Grinding Process in Detail

Critical depth of penetration

1. Elastic deformation
2. Plastic deformation
3. Chip formation

Friction
An efficient grinding process means:

- High material removal
- Low spindle power
- Cool grind
- No damaging interactions
- Long wheel life
- High form stability

Chip formation
Deformation elastic / plastic
Friction / interaction grit / workpiece / chip und chip / bond / workpiece
High Performance Grinding
Abrasive Grain and Specification
THREE BASIC COMPONENTS FOR OPTIMAL SOLUTIONS

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

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

**Bond**
- Bonds show different hardness, wear resistance, grit retention capacity

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.
Creepfeed or Surface Grinding
CREEPFEED OR SURFACE GRINDING

- Definition:
  SURFACE  small infeed & high feed rate
  CREEPFEED  large infeed & small feedrate

- A determining factor is the speed ratio $q_s$:

$$q_s = \frac{v_c}{v_w}$$

- $10 < q_s < 50$  
  Risk of chatter & surface issues

- $50 < q_s < 100$  
  Typical surface grinding with small infeed

- $100 < q_s < 1000$  
  Risk of burn & very fine surface

- $1000 < q_s$  
  Typical creepfeed condition with high infeed
SOME MORE THEORY: EQUIVALENT CHIP THICKNESS

This value can easily be used to configure grinding parameters:

\[ h_{ec} = \frac{Q_w}{v_c} \]

- Typical values:
  - Polishing and finishing: \( h_{ec} = 0,01 – 0,1 \ \mu m \)
  - Precision grinding: \( h_{ec} = 0,1 – 0,7 \ \mu m \)
  - Rough and high performance grinding: \( h_{ec} = 0,7 – 3,5 \ \mu m \)

Practical impact of chip thickness:

- \( h_{ec} \) too small: burn, surface too fine … „wheel acts hard“
- \( h_{ec} \) too high: rough surface, noise, high wheel wear …. „wheel acts soft“
CASE STUDY FOR ROLL GRINDING

Problem: work too rough at both roll tails
- $R_a$ in center 0.4 µm, at tails $R_a = 1.7$ µm 😞

- Traverse cut
  \[ h_{ec} = \frac{v_w \cdot a_e}{v_c} \]
  \[ h_{ec} = 0.29 \mu m \]

- Plunge cut
  \[ h_{ec} = \frac{\pi \cdot d_w \cdot v_{fr}}{v_c} \]
  \[ h_{ec} = 2.6 \mu m \quad \text{(at } v_{fr} = 5 \text{ mm/min)} \]

- Equivalent chip thickness is much too large during plunge cut!!!

Solution: Reduce $v_{fr} = 0.5$ mm/min
\[ h_{ec} = 0.26 \mu m \rightarrow R_a = 0.4 \mu m \] 😊
Cutting Speed $v_c$
CUTTING SPEED

Does an increase of the cutting speeds $v_c$ result in an increased material removal rate?

- Firstly, let’s look at the equivalent chip thickness $h_{ec}$:

- Thus, if we strive to keep the chip formation mechanism constant .... same $h_{ec}$:

  higher $v_c$ = higher $Q_w'$

But please note:
- More heat ..... Thus, optimized coolant needed!!!
- Higher load on grain ..... Thus, need to select suitable specification!!!
Plunge grinding, Studer, 100 Cr6, Emulsion
\( v_c = 25 \text{ und } 45 \text{ m/s}, \ Q'_w = 4, 6, \text{ und } 8 \text{ mm}^3/\text{mm s}, \ d_w = 160 \text{ mm} \)
Quantum NQ 80

Result:

- Higher cutting speeds \( v_c \) result in higher material removal rate \( Q'_w \) at same chip thickness \( h_{ec} \).
- However, it required a higher power draw \( P \).
- Higher chip thicknesses \( h_{ec} \) lead to an higher roughness \( R_a \).
- We have to use grit qualities with can resist to these demands.
Grinding Direction

Counter or Uni Direction?  
Up or Down Grinding?
So what is the point here:

- Counter directional: easy chip building
- Uni-directional: grit toughness & resistance
CASE STUDY: OD PEEL GRINDING

Problem: Counter directional cut, HSS, Emulsion
\( v_c = 30 \text{ m/s}, \ v_w = 19 \text{ m/min}, \ v_{fa} = 6 \text{ mm/min}, \ a_e = 0,1 \text{ mm} \)

- Noisy, wheel clogging, burn

Solution: Change to uni directional cut
No other change in parameters!

- Smooth, nicely cutting wheel, no burn, no chatter

Next step: The infeed could be increased by a factor of 3…. Higher performance!
New Developments of Grinding Tools
DEVELOPMENT OF NEW GRINDING SOLUTIONS

- Based on the understanding of the microscopic mechanisms a suitable tool can be specified.
- We consider and analyze the kinematics and individual loading of the abrasive grains and the entire system.
- Saint-Gobain regularly develops new abrasive grains and tools to meet the increasing demands of the market.

More to come in Level II presentation
Summary
SUMMARY

Selection of grain type

Specific Grinding energy

Threshold power

Chip thickness

Chip formation

Deformation elastic / plastic

Specification

Porosity

Cooling

Direction of Grinding

Speed ratio
Knowing the microscopic processes and understanding the properties of grain, bond, machine, and workpiece, we are capable to specify a grinding solution, in order to optimize the performance of the grinding process!
Thanks for your attention