Investigations in Cutting Mineral Materials with Polycrystalline Diamonds

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AGENDA

- MOTIVATION
- FUNDAMENTALS
- EXPERIMENTAL STUDIES
- CONCLUSION AND SUMMARY
MOTIVATION

- Extraction and processing of natural stone needs a lot of energy and uses up a high amount of material.
- Next step is dividing the primary blocks in sheet material.
- State of the art is machining with geometrically undefined cutting segments:

- Cutting with geometrically defined cutting segments yields:
  - Lower cutting clearance → reduces material waste and reduces energy consumption.
  - Lower cutting speeds with a high feed rate → reduces exposition process.
FUNDAMENTALS

- Cutting tools can generally vary with regard to material, geometry and orientation.
- Negative rake angles change the direction of the cutting force:
  
  - The advantage is the change from tension to pressure.
  - The harder the material the more should the rake angle be negative.

- Implemented PCD cutting segments have negative rake angles of up to -25°.

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Stefan Schwarte – Cutting Mineral Materials with PCD
Optimization of PCD tools in terms of wear and cutting forces

Geometries
- Macro-geometry
- Micro-geometry
- Rake angle, wedge angle
- Cutting edge preparation
- Chip space and order
- Shape of cutting element

Technologies
- Cutting speed
- Feed rate

Cutting materials

Coatings

Source: Schneider
Source: Hilti
Source: Wikus
# EXPERIMENTAL STUDIES

- **Test set-up**
  - Developed for individual **singular cutting segments**
  - **Automatic drive** with a linear motion
  - **Adjustment possibilities** for cutting speed, feed rate and cooling
  - **Online and real time** recording and documentation of the **process forces**, as a function of the cut volume
  - Precise measurements of the **specific behaviour** of the separated cutting segment during the cutting process
  - Very close to the **real machining process**
  - Experimental results are transferred to the **whole cutting tool**

*Linear test station at the tff*
EXPERIMENTAL STUDIES

- Cutting of reinforced concrete
  - Choosing the best rake angle causes conflict:
    - Brittle-hard concrete and soft steel
  - Parameter:
    \[ \alpha = 7^\circ, \beta = 88^\circ, \gamma = -5^\circ \]
    \[ v_c = 50 \text{ m/min} \]
    \[ f_z = 50 \mu \text{m} \]
    Cooling: water
  - High forces in cutting steel, low forces in cutting concrete
EXPERIMENTAL STUDIES

- **AiF-project:** Cutting of sandstone, marble, granite and bricks with bonded cutting segments
  - Choice of cutting materials
  - FEM of the joint
  - Optimization of the cutting segment
  - Design of the saw band
  - Determination of the requirements of the specific adhesive
  - Choice of adhesives
  - Modification of adhesives
  - Design and manufacturing of a bonding jig

- No thermal damages on PCD-cutting segments
  - Easy and fast repair
  - Cutting of granite and marble with water cooling
  - Cutting of sandstone without cooling
  - Bonded elements have a 28 % longer lifetime
  - Verification of mechanical strength
  - Studies at the linear test station
  - Studies at the band saw
  - Investigations on the wear behaviour
EXPERIMENTAL STUDIES

**Bonded Cutting Segment:**
- Condition as new
- After 500 cycles
- After 1000 cycles

Bevel width: 173.8 µm, bevel angle: -57.32°

**Brazed Cutting Segment:**
- Condition as new
- After 500 cycles
- After 1000 cycles

Bevel width: 220.5 µm, bevel angle: -59.54°
EXPERIMENTAL STUDIES

- **BMBF-project**: Engineering of a production line for resource and energy efficient production of stone slabs

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**Feeding device for rocks**
- System selection
- Design of feeding device and rotary unit

**Detection module for rocks**
- Technology selection
- Cut planning module
- CAD/CAM-integration
- Design of the modular unit

**Band saw**
- FEM-based construction of machine stand
- Design of guides and drives
- Tool and workpiece handling

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**Definition of interfaces and supplementary devices**

**Start-up and process capability study of the production line prototype**

**Fully automated production line**
- for process-, resource- and energy-efficient production of natural stone slabs
CONCLUSION AND SUMMARY

- Stone is ten times as hard as metal and has different cutting properties

- Results show great potential with PCD and mineral materials

- With 15 m²/h, the cutting speed of the prototype band saw is about 30 times higher than that of a gang saw in sandstone

- PCD cutting elements have a small cutting width, the band saw produces only 20% of the waste of a gang saw

- PCD works also in concrete-steel compounds, here, the high affinity of the iron to the carbon PCD does not occur

- PCD bonded elements have a 28% longer lifetime than brazed cutting elements

- Results can be transferred to tools such as deep drills, scraper blades, drill bits...
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