Adaptive Grinding Process (AGriPro) –
Prevention of Thermal Damage using OPC UA Technique and in-Situ Metrology

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Agenda

• Institute of Production Engineering, TU Graz, Austria
• Fundamentals of “burning” during grinding
• Control Concept „1“ with force measurement
• Experiments and Results
• Micro-magnetic Measurement of Thermal Damage
• Control Concept „2“ with in-process “Barkhausen” noise measurement
• Summary and Acknowledgements
Institute of Production Engineering

- Precision Machining
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ERP
MES
PLC AND SCADA
MACHINES
Adaptive Grinding Process - Burning

\[ U_s = \frac{F_t'}{Q_w'} \]

\[ F_t' = \frac{F_t}{b_{eff}} \]

\[ Q_w' = d_w \cdot \pi \cdot v_{fr} \]

\[ U_s(Q_w') = C_1 \cdot Q_w'^{C_2} \]

\[ F_{t,\text{max}}(v_{fr}) = C_1 \cdot [v_{fr}]^{(1+C_2)} \cdot C_3 \]

\[ C_3 = \frac{b_{eff}}{v_c} \cdot [\pi \cdot d_w]^{(1+C_2)} \]

Tangential force as reference value

Tangential force / N

\[ F_t = C_1 \cdot [v_{fr}]^{(1+C_2)} \cdot C_3 \]

\[ C_3 = \frac{b_{\text{eff}}}{v_c} \cdot \left[ \frac{\pi \cdot d_w}{60} \right]^{(1+C_2)} \]
Research Grinding Machine at the Institute

**Main spindle**
- Power: 72.5 kW
- Grinding wheel diameter: 650 mm
- Grinding wheel width: 200 mm
- Rotary speed: 6500 min⁻¹
- Circumference velocity: 220 m/s

**Dimensions**
- Mass: 42 t
- Length and width: 6 m x 3.5 m

**Workpiece**
- Mass up to 750 kg
- Max. diameter: 520 mm
- Length: 1.5 m
Schematic representation of the control loop

```
Far
ID=201 WHENEVER (($R1<>0)
AND ($R50==1)) DO
$AA_OVR[X1]=$R1
```

Charging amplifier (KISTLER)
A/D converter (NI)
Measurement-PC (MATLAB)
PID controller
Output parameter R1 represents override value

SINUMERIK 840Dsl

Radial infeed $v_{fr}$

Far

ID=201 WHENEVER (($R1<>0)
AND ($R50==1)) DO
$AA_OVR[X1]=$R1

Communicated via OPC UA

Ethernet

Univ.-Prof. DI Dr.techn. Franz Haas
Optimization by infeed control

Risk of thermal damage

No thermal surface damage

+38%
Non-circular grinding principles

Oscillating non-circular grinding

Tool synchronous non-circular grinding

Cam
\[ n_s : n_w = 1 : 1 \]

Polygon
\[ n_s : n_w = 3 : 2 \]

Square
\[ n_s : n_w = 2 : 1 \]
Tool synchronous grinding

Machine parameters

Workpiece spindle 2:
\[ n_{\text{max}} = 4.500 \text{ min}^{-1} \]
Second grinding wheel:
\[ \varnothing \text{ 600 mm x 200 mm} \]
Barkhausen noise principle and Machine Set-up
Assignment of workpiece sections

\[ u_{int}(n, t_i) = u_{int}(n, t_{i-1}) + K_{int} \cdot (w(n) - x(n, t_i)) \]

\[ u_{prop}(n, t_i) = K_{prop} \cdot (w(n) - x(n, t_i)) \]

\[ u(n, t_i) = u_{int}(n, t_i) + u_{prop}(n, t_i) \]

- \( n \) \ldots index of angular workpiece segment
- \( i \) \ldots index of workpiece revolution
- \( t_i \) \ldots time stamp of \( i \)-th workpiece revolution
- \( x \) \ldots measured Barkhausen noise level
- \( w \) \ldots set-point Barkhausen noise level
- \( K_{int} \) \ldots integral gain of PI-controller
- \( K_{prop} \) \ldots proportional gain of PI-controller
- \( u_{int} \) \ldots integral part of controller output
- \( u_{prop} \) \ldots integral part of controller output
- \( u \) \ldots feed rate override (controller output) when segment is ground
Grinding experiment (CBN tool, 100Cr6 with 62 HRC)
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