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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

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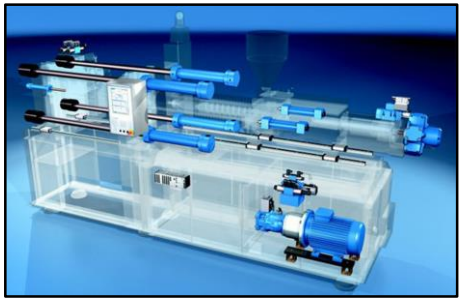
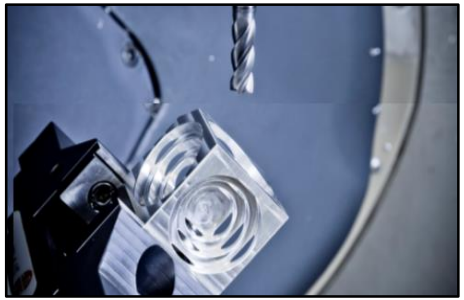
Precision Machining

Additive Manufacturing

Fluid Technology



High Performance Machining



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Adaptive Grinding Process - Burning

$$U_s = \frac{F'_t \cdot v_c}{Q'_w}$$

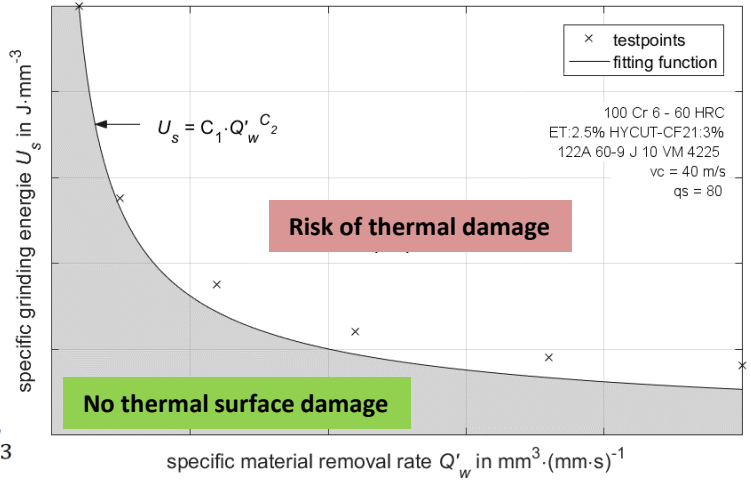
$$F'_t = \frac{F_t}{b_{eff}}$$

$$Q'_w = d_w \cdot \pi \cdot v_{fr}$$

$$U_s(Q'_w) = C_1 \cdot Q'_w{}^{C_2}$$

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

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



v_c … cutting velocity

v_{fr} … feed rate

d_w … diameter of the workpiece

$C_{1,2}$ … empirically calculated constants

C_3 … geometrical constant

b_{eff} … effective grinding wheel width

U_s … specific grinding energy

Q'_w … specific material removal rate

F_t … actual tangential force

F'_t … tangential force related to b_{eff}

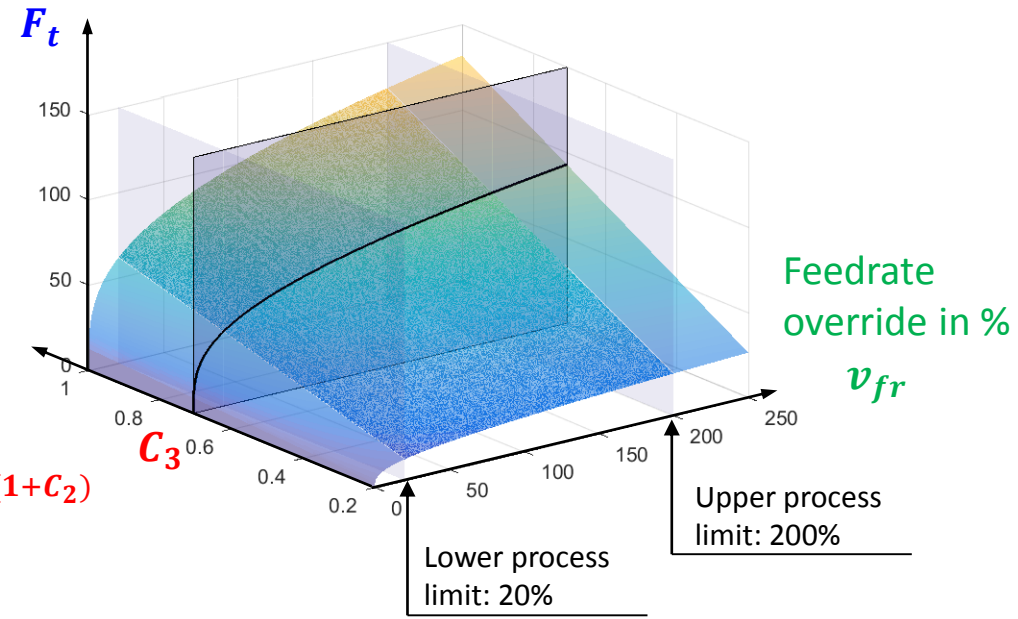
$F_{t,max}$ … boundary tangential force

Vgl. Vits, R., 1985, „Technologische Aspekte der Kühlschmierung beim Schleifen“, PhD thesis, City Print Verlag, pp.71-73.

Tangential force as reference value

Tangential force / N

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

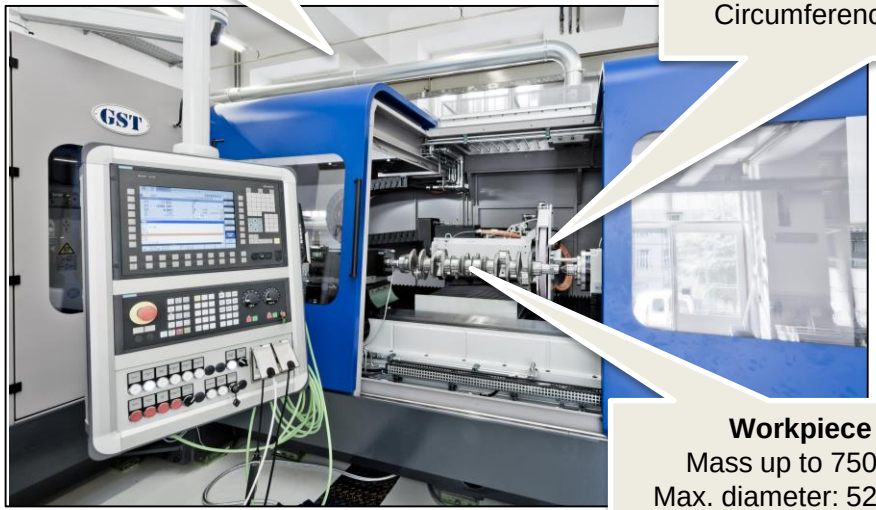


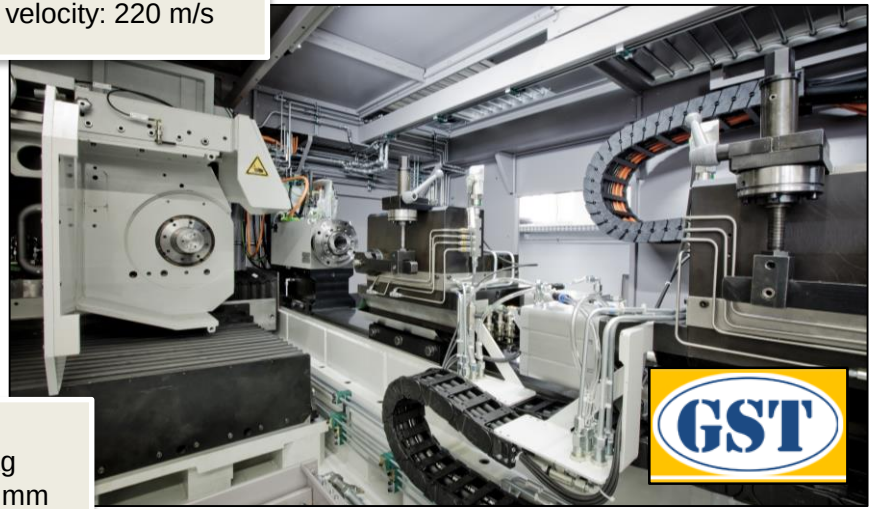
$$C_3 = \frac{b_{eff}}{v_c} \cdot \left[\frac{\pi \cdot d_w}{60}\right]^{(1+C_2)}$$

Research Grinding Machine at the Institute

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

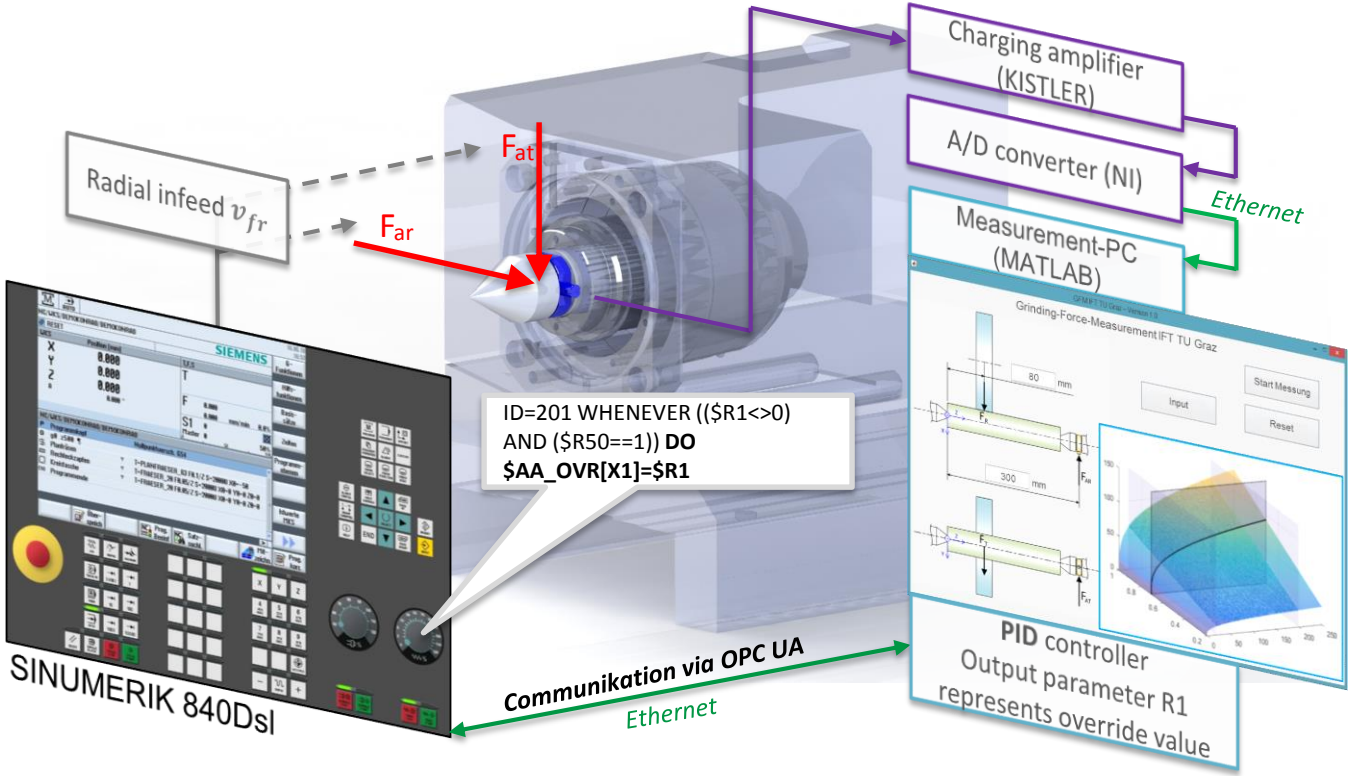
Main spindle
Power: 72.5 kW
Grinding wheel diameter: 650 mm
Grinding wheel width: 200 mm
Rotary speed: 6500 min^{-1}
Circumference velocity: 220 m/s



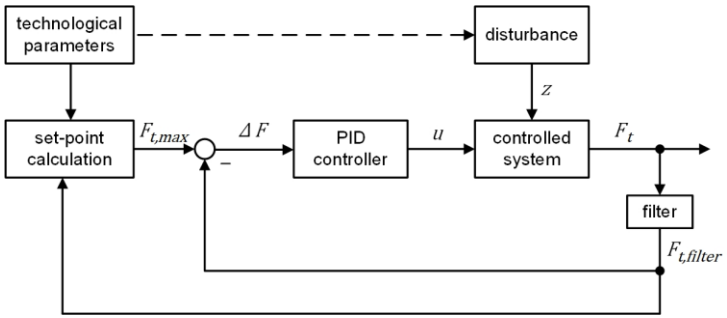


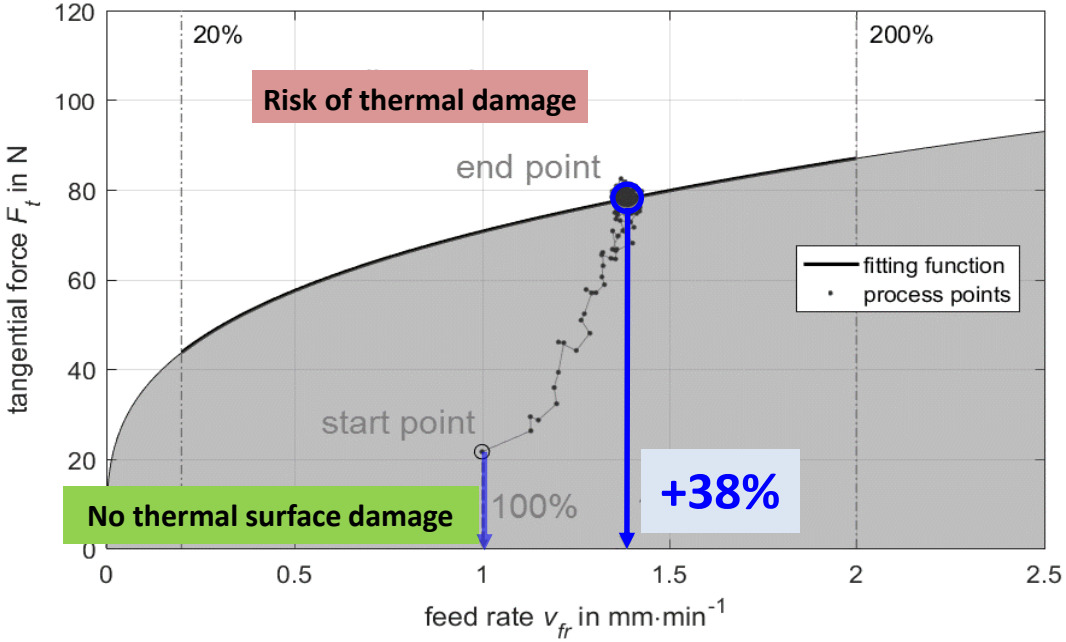
Workpiece
Mass up to 750 kg
Max. diameter: 520 mm
Length: 1.5 m

Schematic representation of the control loop



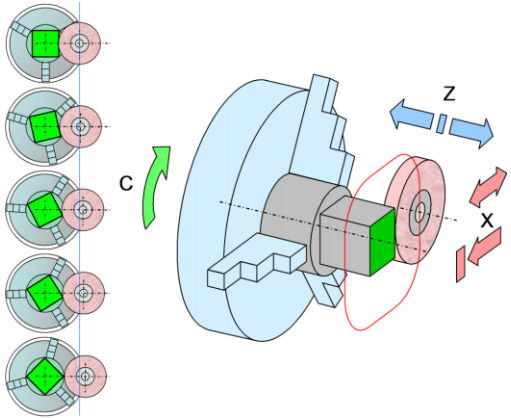
Optimization by infeed control



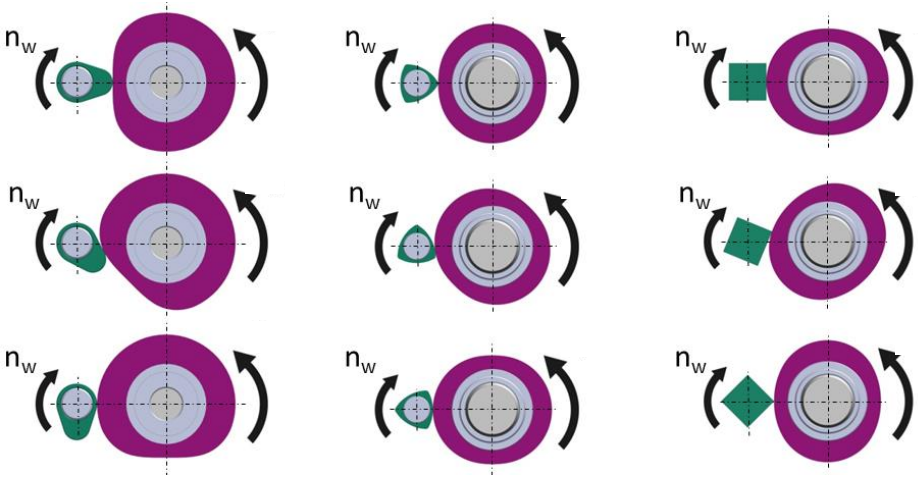


Non-circular grinding principles

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

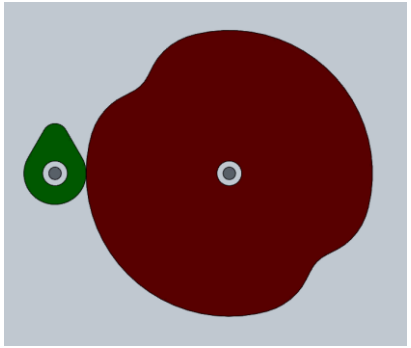
Machine parameters

Workpiece spindle 2:

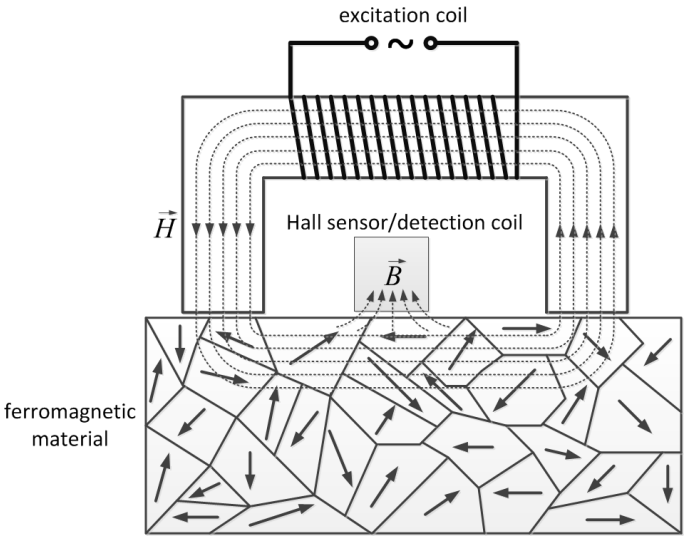
n_{max} = 4.500 min^{-1}

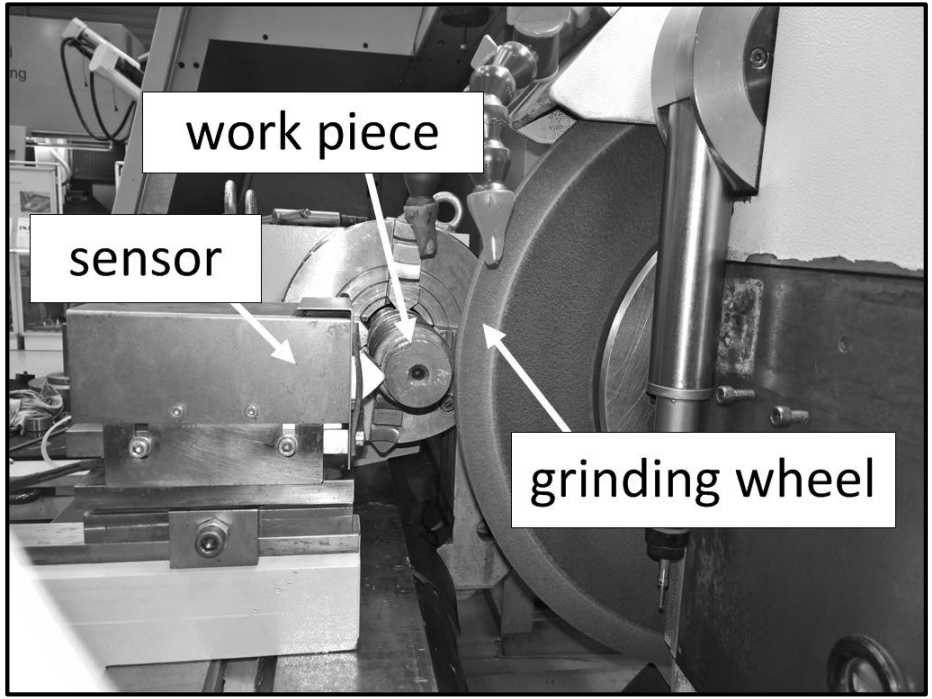
Second grinding wheel:

Ø 600 mm x 200 mm



Barkhausen noise principle and Machine Set-up



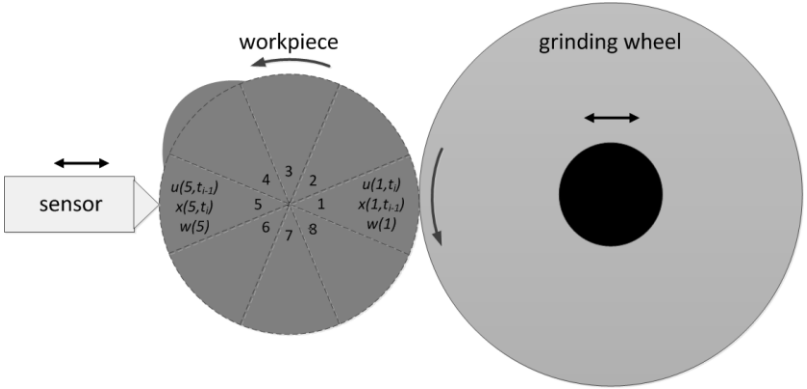


Assignment of workpiece sections

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

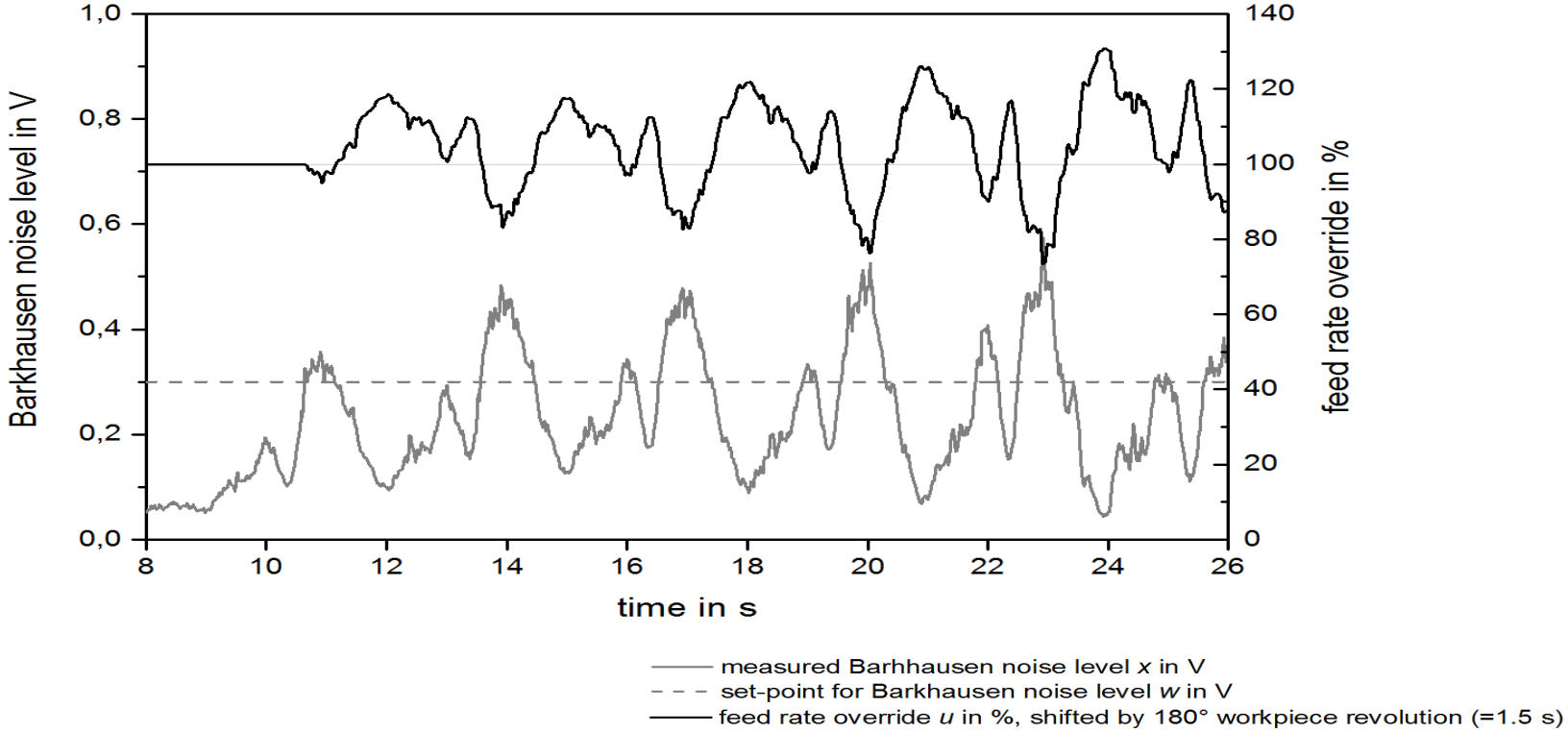
$$u_{prop}(n,t_i) = K_{prop} \cdot \big(w(n) - x(n,t_i)\big)$$

$$u(n,t_i) = u_{int}(n,t_i) + u_{prop}(n,t_i)$$



n	… index of angular workpiece segment
i	… index of workpiece revolution
t_i	… time stamp of i-th workpiece revolution
x	… measured Barkhausen noise level
w	… set-point Barkhausen noise level
K_{int}	… integral gain of PI-controller
K_{prop}	… proportional gain of PI-controller
u_{int}	… integral part of controller output
u_{prop}	… integral part of controller output
u	… feed rate override (controller output) when segment is ground

Grinding experiment (CBN tool, 100Cr6 with 62 HRC)



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