TU Graz

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TECHNIK
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FFG
Forschung wirkt.

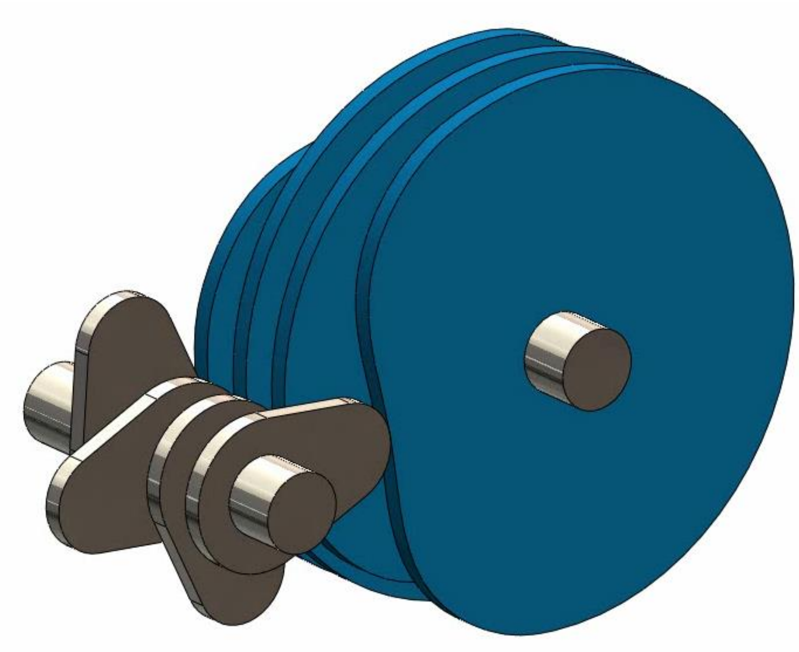
Simulationsgestütztes Design von drehzahlsynchronen Finishprozessen (SynchroFinish) für Hochleistungswerkstoffe

Univ.-Prof. Dipl.-Ing. Dr.techn. Franz Haas

14.12.2023

Agenda - Was erwartet Sie?

- Vorstellung TU Graz - Institut für Fertigungstechnik
- Drehzahlsynchrones Unrundschleifen - Kinematik
- Setup für Experimente
- Ergebnisse
- Molekulardynamische Simulation
- Zusammenfassung und Ausblick



IFT – Das Produktions-Institut der TU Graz

- Wir sind ein hoch motiviertes Team aus ca. 30 Kolleginnen und Kollegen im Dienst der Lehre und Forschung.
- Wir gliedern uns in vier große Arbeitsbereiche.
  - Präzisionsfertigung, Robotik/Automation, Fertigung für E-Mobilität
  - Additive Fertigung
  - Fluidtechnik
  - Smart Factory – Pilotfabrik für digitale und nachhaltige Produktion
- Wir stehen für die Umsetzung unserer Ideen. Wir konstruieren, bauen, programmieren und liefern Qualität.

Production Lab / Produktionslabor für Zerspanungsforschung

- Forschungs-Schleifmaschine
- CNC-5-Achs-Fräsen mit Ultraschallunterstützung
- CAM-Systeme
- Koordinatenmessmaschine
- CNC-Drehzentren
- Präzisionsfertigung für Prototypen

Training Workshop / Neue Lehrwerkstätte seit 2020

- Viel Tradition und didaktisches Know-How in der Werkstattfertigung
- Neue Drehmaschinen mit Zyklenautomatik
- 2 CNC-Fräsmaschinen
- CNC-Unrundschleifen für Höchstpräzision
- Zentrierbohrungsschleifen
- Polymer-3D-Druck

Battery Innovation Center / Fertigung für die Mobilität der Zukunft

- Geometrische Vermessung von Batteriezellen
- Modul-Assemblierung
- Kollaborative Robotik
- Fuel-Stack-Stacking
- „Reinraum“ für Stapelprozesse
- Messtechnik
- Life Cycle Analysen

AddLab@tugraz / Metall-Additive Fertigung für Serienprodukte

- Polymerdrucker für Prototypen
- L-PBF (Pulverbettverfahren)
- WAAM (Drahtbasiertes Verfahren –Schenkung der AMAG AG an TUG/AddLab)
- SLEDM-Demonstrator
- Topologieoptimierung
- Mess- und Analysetechnik

Fluid Lab / Systementwicklung und Testung in der Fluidtechnik

- Charakterisierung von Ventilen und Aktuatoren in der Hydraulik
- Fahrzeughydraulik
- Piezo-Ventiltechnik
- Neue Medien und Nachhaltigkeit
- Schaltungs-Simulation
- CFD-Analysen

smartfactory@tugraz / Pilotfabrik für Digitale Transformation

- CNC-Fräsen und Drehen mit Edge-Computing
- Assemblierung des Demonstrator-Produkts „Wellgetriebe“
- PDM-WebConnector
- 5G-Kommunikation in Echtzeit
- Kollaborative Robotik
- Mobile Arbeitsstationen

RPM-Synchronous Grinding - Introduction

- Grinding for economic finishing of hardened components
- Requirement of tailored finishing processes
  - Defined surface topography
  - Various workpiece geometries (2D/3D, round/non-circular)
  - Customized surface properties

Potential of RSG

- RSG-Production of defined textures on surfaces during grinding
  - Minimize friction, increase lifetime through optimal lubrication
  - Patterned wheels
- Finishing with RSG
  - Precision machining using RSG (Ra = 0.2 - 0.35 µm and Rz = 1.5 – 3 µm)
  - Influence on surface by varying parameters
  - High shape accuracy
- 3D-unround profiles
- Production of a high variety of workpiece geometries in a simple plunge grinding process (Oscillation of the infeed-axis isn´t necessary.)

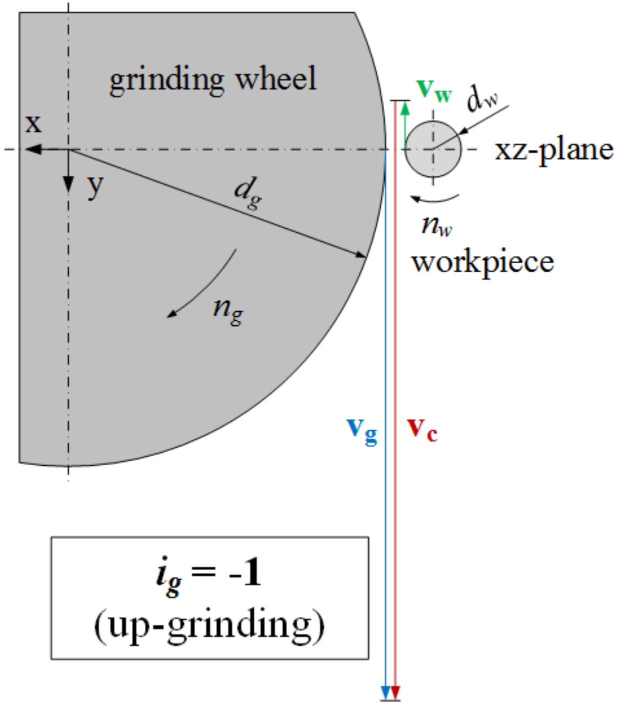
Fixed speed ratio

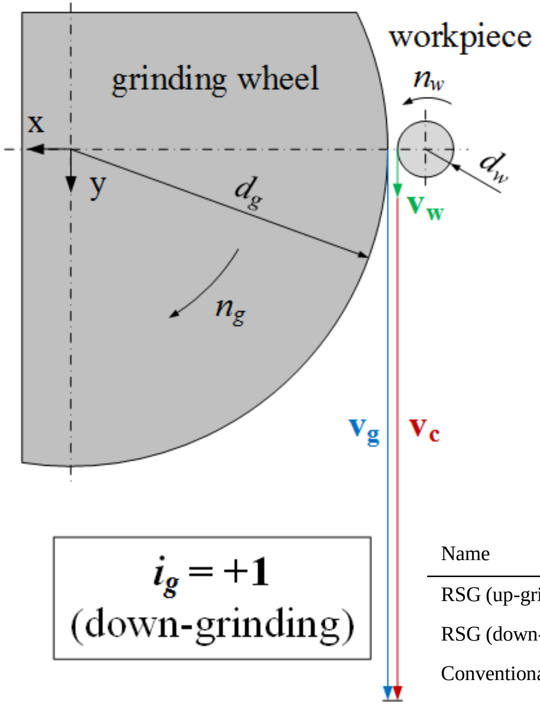
- Fixed rotational speed ratio of the grinding wheel and the workpiece

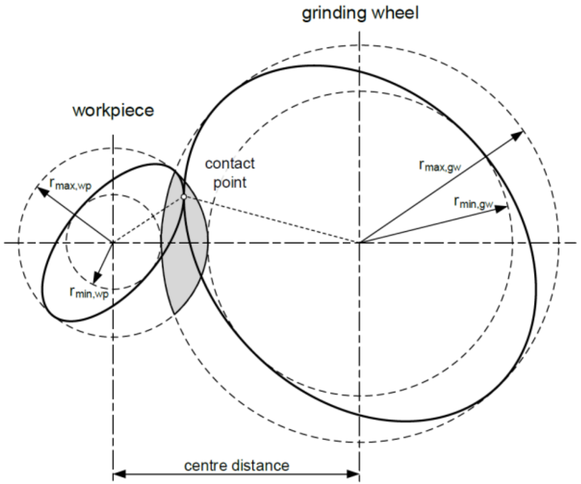
$i_g = \frac{n_g}{n_w} = \frac{v_g \cdot d_w}{d_g \cdot v_w} \qquad i_g \in \mathbb{Q}$	$v_g = \frac{d_g \cdot \pi \cdot n_g}{1000 \cdot 60}$

- In manufacturing process, both grinding wheel and workpiece always meet at the same surface points.
- Definite influence of every specific abrasive grain to workpiece texture.
- This process behavior differs fundamentally from the conventional grinding process.

Cinematics for up- and down-grinding

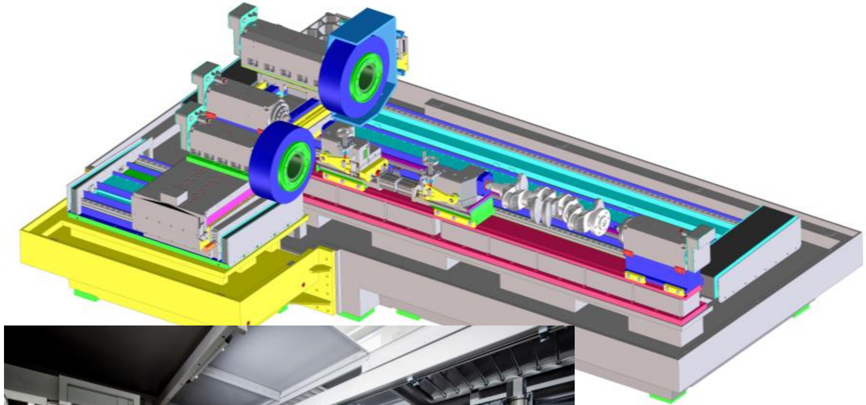






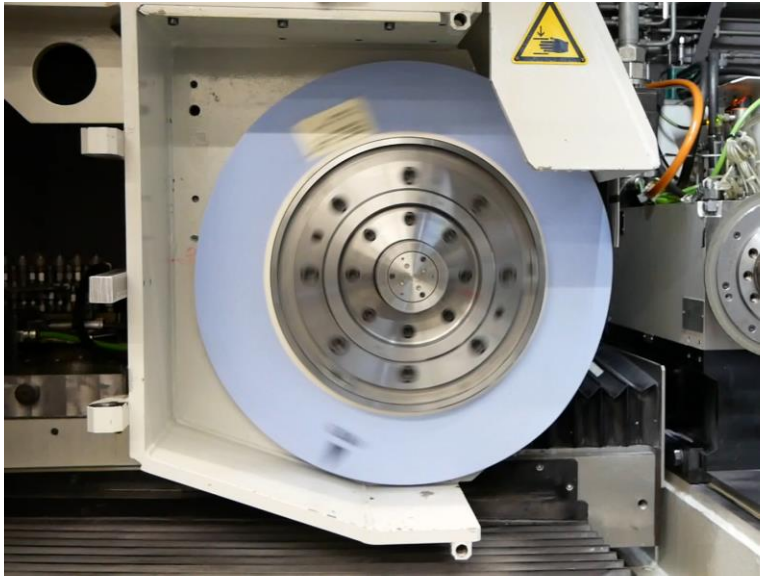
Name	d_g	v_g	i_g	d_w	v_c/v_g
RSG (up-grinding)	610	50	-1	54	1.09
RSG (down-grinding)	610	50	+1	54	0.91
Conventional grinding (up-grinding)	610	50	-9.35	54	1.01

Machine Setup (Research Grinding Machine)



Tool Setup

- Grinding wheel: CS 55/85A 220 II5 VK1
- Conventional vitrified bonded
- F220mesh, mean grain size 58 µm
- High single grain loads (RSG)
- Necessity of high bond strength
- Two types of aluminium oxides were used. (fused CS 55… and sintered CS 85…)



Experimental procedure

- Workpieces

Circular steel workpieces

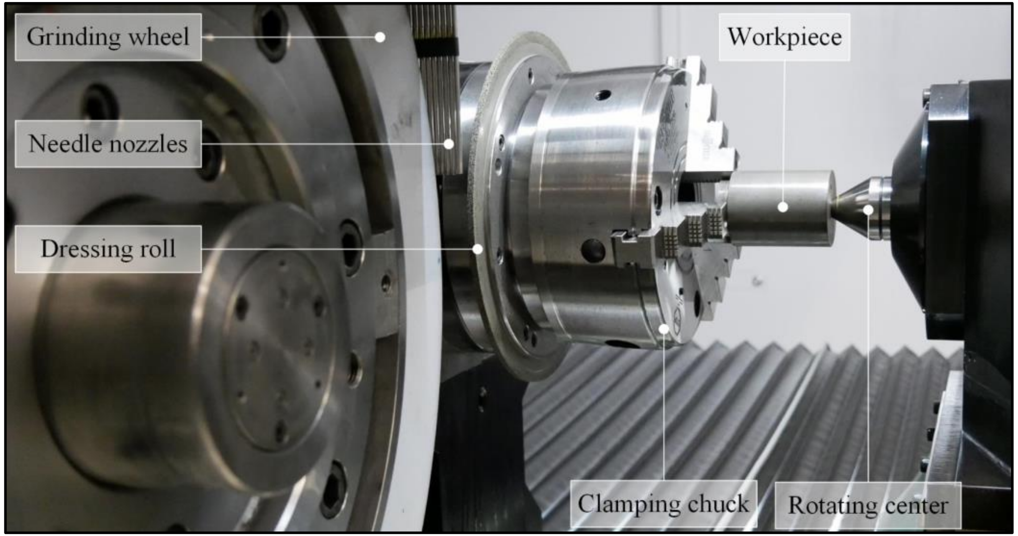
16MnCrS5 (1.7139) } hardened condition { 61 HRC

100Cr6 (1.3505) } hardened condition { 57 HRC

L=80mm / D=54mm

Experimental procedure

- Machining conditions (dressing, grinding)

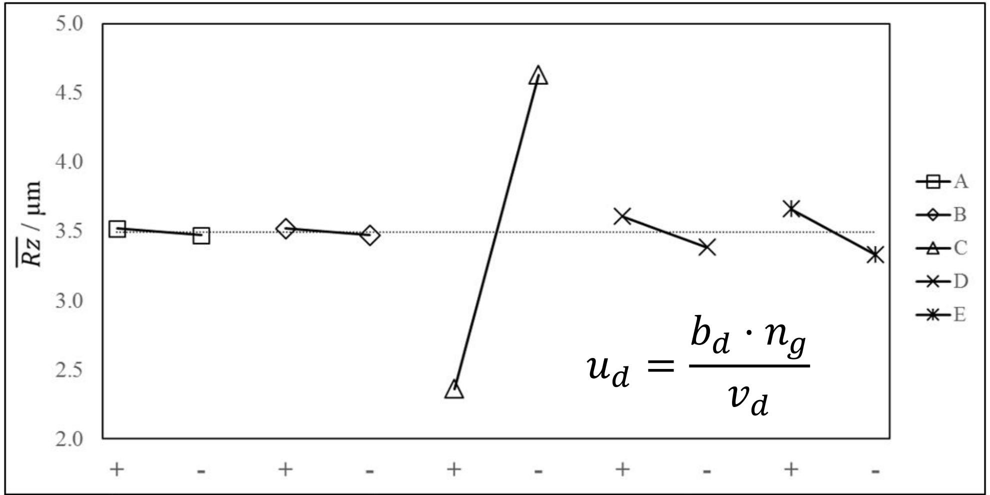


u_d	q_d	v_g	a_d
8 / 80	-0.7	50	0.005

Q'_w	i_g	a_e	v_g	t_s
0.5 / 1.5	-1/+1/-9.35	0.075	50	3

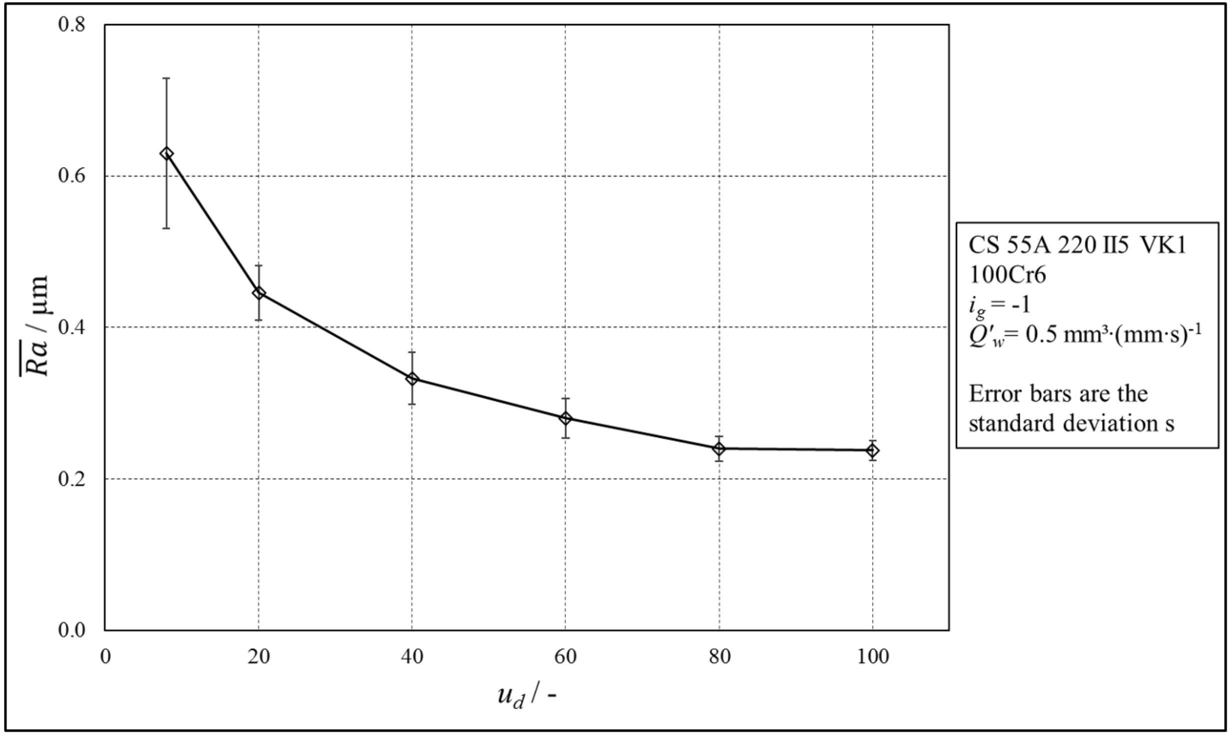
n_g	grinding wheel speed (min^{-1})
n_w	workpiece speed (min^{-1})
d_g	diameter of grinding wheel (mm)
d_w	diameter of workpiece (mm)
v_c	cutting speed (m·s^{-1})
v_g	circumference velocity of grinding wheel (m·s^{-1})
v_w	circumference velocity of workpiece (m·s^{-1})
i_g	rotational ratio at grinding / speed ratio (-)
q_d	dressing roll speed ratio (-)
u_d	overlap ratio (-)
a_d	depth of cut at dressing (mm)
Q'_w	specific material removal rate (mm³·(mm·s)$^{-1}$)
a_e	depth of cut / amount of infeed (mm)
t_s	sparking time (s)

Effect diagram for quality criterion R_z



Symbol	Factor / parameter	Setting +	Setting -
A	Workpiece material	16MnCrS5	100Cr6
B	Grinding wheel	CS 85A 220 II5 VK1	CS 55A 220 II5 VK1
C	u_d	80	8
D	i_g	+1	-1
E	Q'_w	1.5	0.5

Influence of the overlap ratio u_d to surface roughness R_a



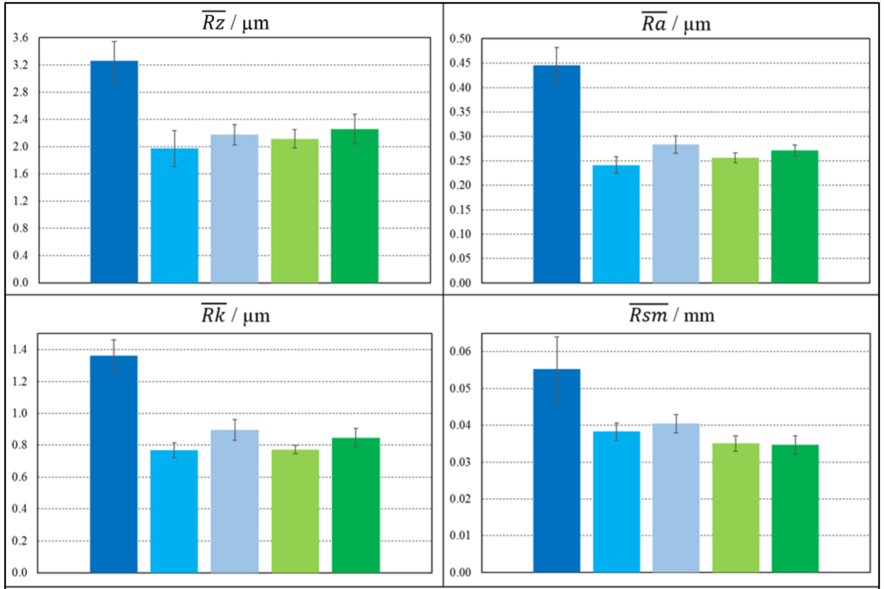
Experimental results and discussion

- Comparison of selected line parameters (surface roughness)

synchronous ←→ synchronous

and

synchronous ←→ conventional



Error bars show the standard deviation s

	u_d	Q'_w	i_g	Workpiece material	Grinding wheel
(dark blue)	20	0.5	-1	100Cr6	CS 55A 220 II5 VK1
(light blue)	80				
(pale blue)			+1		
(light green)	20		-9.35		
(green)	8				

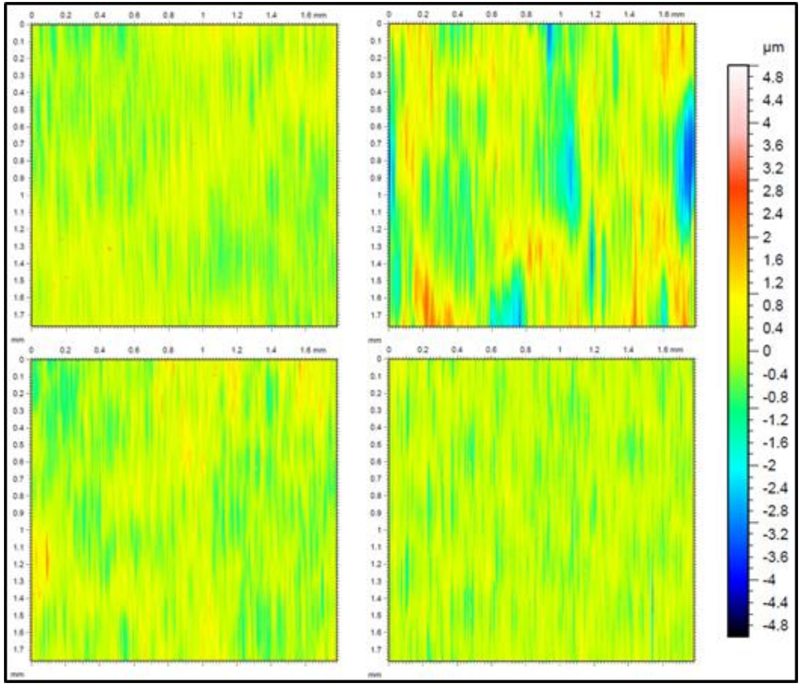
Experimental results and discussion

100Cr6
CS 55A 220 II5 VK1
$Q'_w = 0.5\ mm^3\cdot(mm\cdot s)^{-1}$

- Graphical comparison of ground surfaces

i_g = -1
u_d = 80
RSG

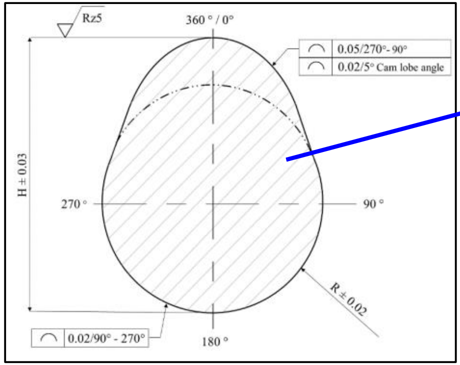
i_g = +1
u_d = 80
RSG

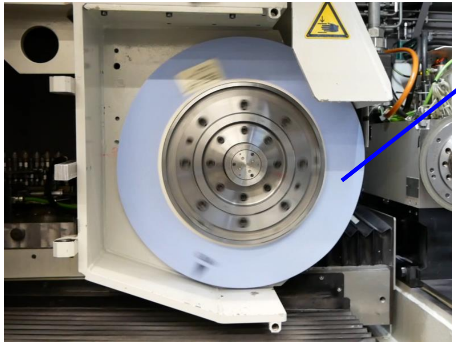


i_g = -1
u_d = 8
RSG

i_g = -9.35
u_d = 20
Conv. grinding

RSG-Workflow





Workpiece geometry $r_w(\psi)$

↓

IFT-RSG-Software

↓

Grinding wheel geometry $r_g(\varphi)$

↓

CCG compiler
Cam Contour Grinding
(Product of SIEMENS)

↓

NC-Code for **Dressing** (1) ⟷ NC-Code for **Dressing** (2)

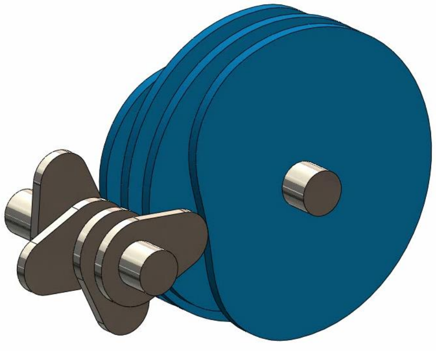
Pendulum stroke dressing cycle for generating a non-circular grinding wheel geometry

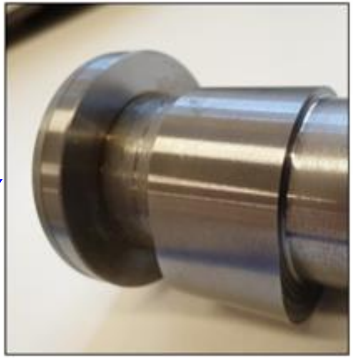
↓

NC-Code for **Grinding** (RSG)

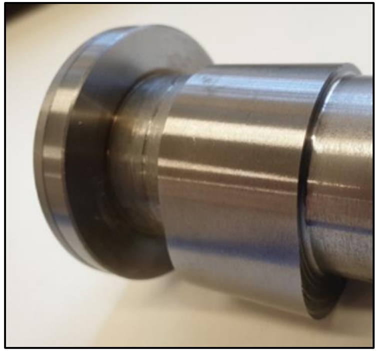
Plunge grinding process for generating a non-circular workpiece geometry

Further dressing cycles





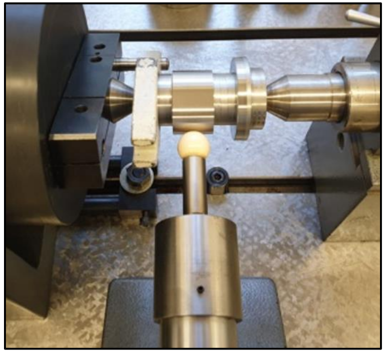
RSG-profile Measurements

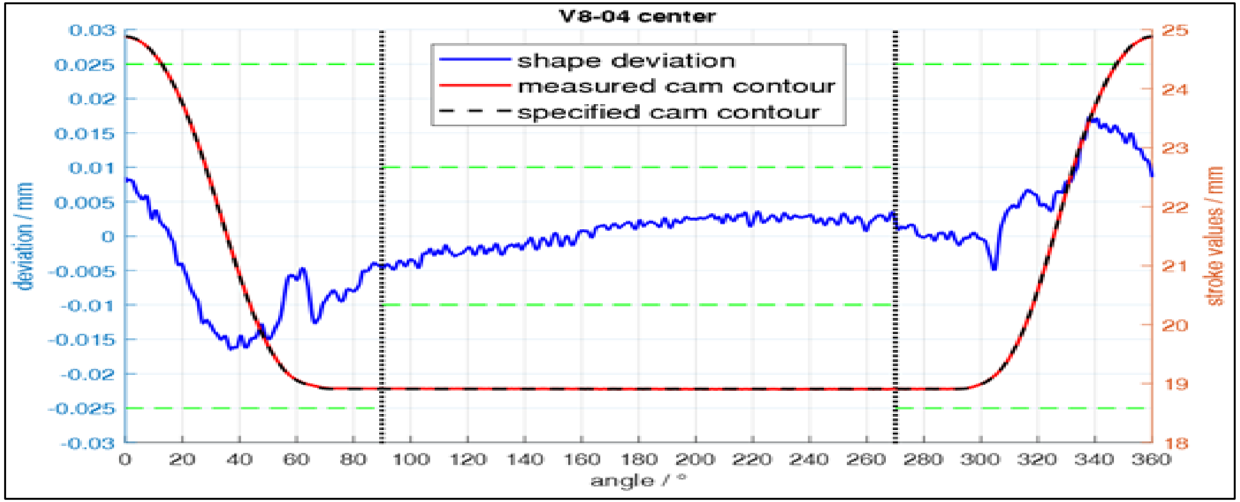


SPECIFICATION	TOLERANCE LIMITS / mm	MMD /mm
shape (270°-90°)	0.05 ≙ ± 0.025	+ 0.017
shape within 5° (270°-90°)	< 0.02	+ 0.009
shape (90°-270°)	0.02 ≙ ± 0.01	+ 0.005
base circle	R ± 0.02	R + 0.007
cam height	H ± 0.03	H - 0.017

Surface requirement : **Rz 5**

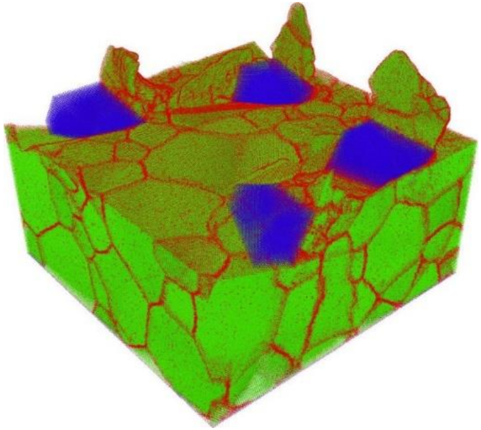
✓





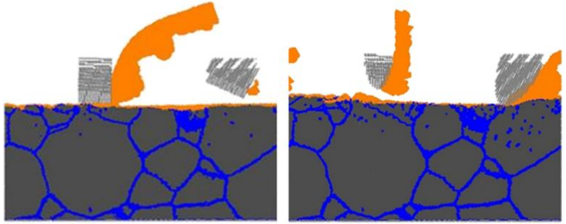
Molecular Dynamic Simulation (MD)

Sketch of a polycrystalline, periodic, ferritic workpiece.

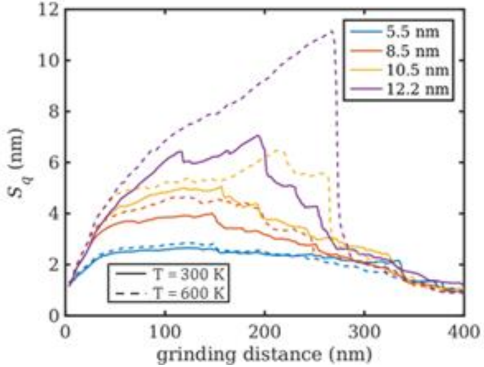


Representative tomographic section through the workpiece (grain orientation).

Chip (orange) formation with sharp (LEFT) and blunt (RIGHT) abrasives.



Development of the surface roughness (Sq)



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- Thanks to the SyFi-project partner
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    - Tyrolit - Schleifmittelwerke Swarovski KG
    - AVL List GmbH
    - GST - Gesellschaft für Schleiftechnik GmbH.

Conclusion and Outlook

- **Influence of parameters** (u_d, Q'_w, i_g), grinding wheel and workpiece specifications on surface topography **was documented**.
- By using RSG a **significantly higher dressing overlap ratio** is mandatory to achieve excellent surface results.
- **Target roughness values** (R_a, R_z) could be successfully **achieved**.
- High surface qualities also with **special structured segments** can be produced with RSG.
- **In the future industrial applications** together with the development of appropriate dressing- and grinding strategies **should be implemented**.
- **Molecular Dynamic Simulation** will increase both process knowledge and productivity.

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