Micro Parts Manufacturing by Powder Metallurgy (Micro-PM)

Bernd Kieback, Martin Dressler, Marie Jurisch, Kai Reuter, Sebastian Riecker, Thomas Studnitzky

World PM2016, Hamburg, 9-13 October 2016

TECHNISCHE UNIVERSITÄT DRESDEN

Fraunhofer IFAM Institutsteil Dresden

Content

1. Introduction

Powder Metallurgy:	Mass production of complex shaped parts with highest accuracy (IT 7)
Process:	Powder → Mixing etc. → Compaction → Sintering → Calibration (IT 7)
Compaction:	Multi-level dies for densitiy =const. Powder: >100 µm (flowability)
Limits:	Parts > 2-5 mm (particle size / tools)
	flowability of fine powders: poor

2. Goals

- Production of multi-level parts < 2mm with highest accuracy

Concept:

- Multi-level green parts by screen printing
- Sintering to high density
- Calibration in simple tool

Calibration

- press/sinter

pressing → debindering/sintering → calibration → ready parts

Small parts (< 2 mm) limited
- Rough particles (160 µm) do not flow into small dies
- Even green density necessary -> small complicated pressing tools are expensive

- MIM

extruding → debindering/sintering → ready parts

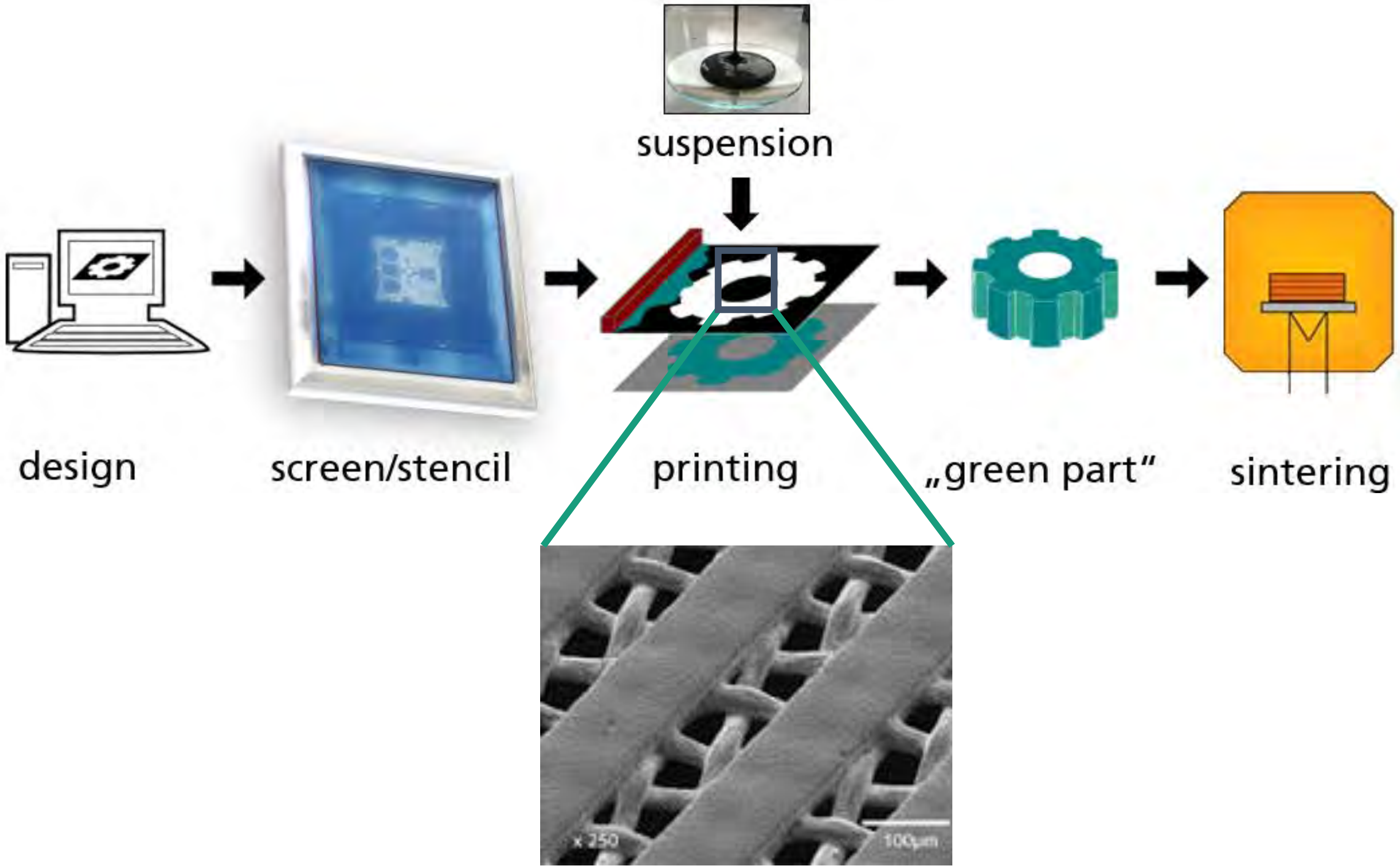
Small parts (< 2 mm) are possible
- Pressing tools are expensive

- 3D screen printing

printing → debindering/sintering → calibration → ready parts

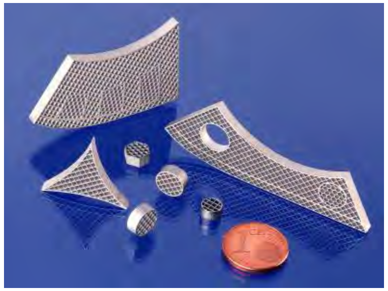
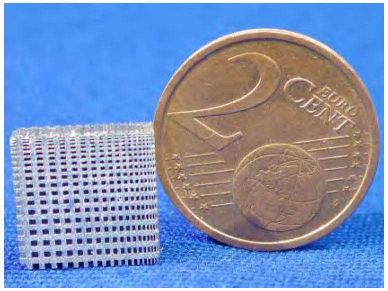
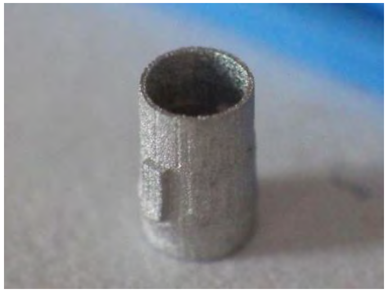
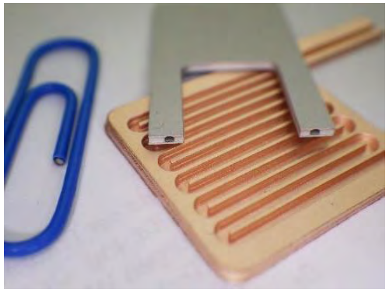
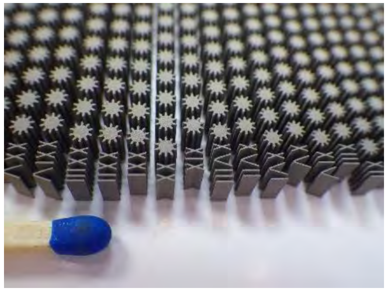
Small parts (< 2 mm) are possible
- Tools (screens) are inexpensive
- Mass production capable
- No complicated pressing tools for powder compaction necessary

3D screen printing – process scheme



3D screen printing – possibilities

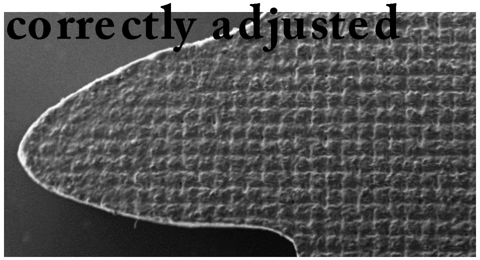
- Fine details
- Complex structures
- Cavities
- Material combinations
- Mass production


3D screen printing – surface quality artifacts

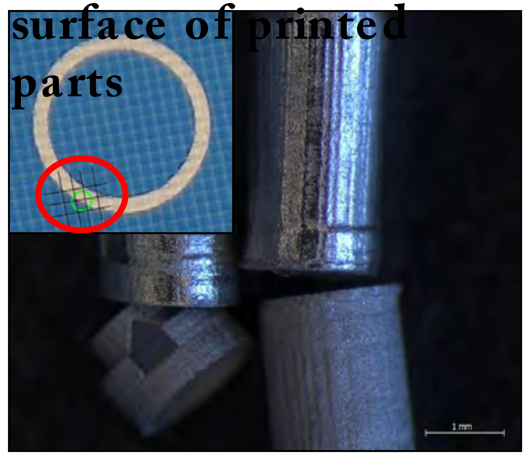
Mesh imprint

screen mesh is visible if paste viscosity is not correctly adjusted



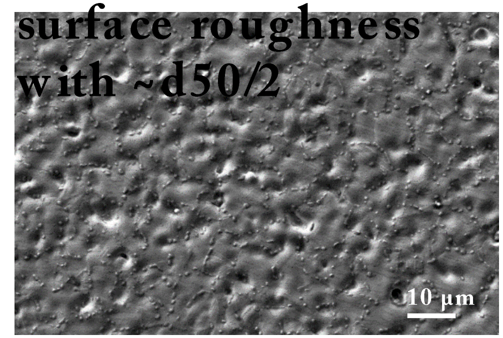
Grooves

junction points at screen can cause grooves at the surface of printed parts



Particle roughness

The spherical shape of the sintered particles causes surface roughness with ~d50/2

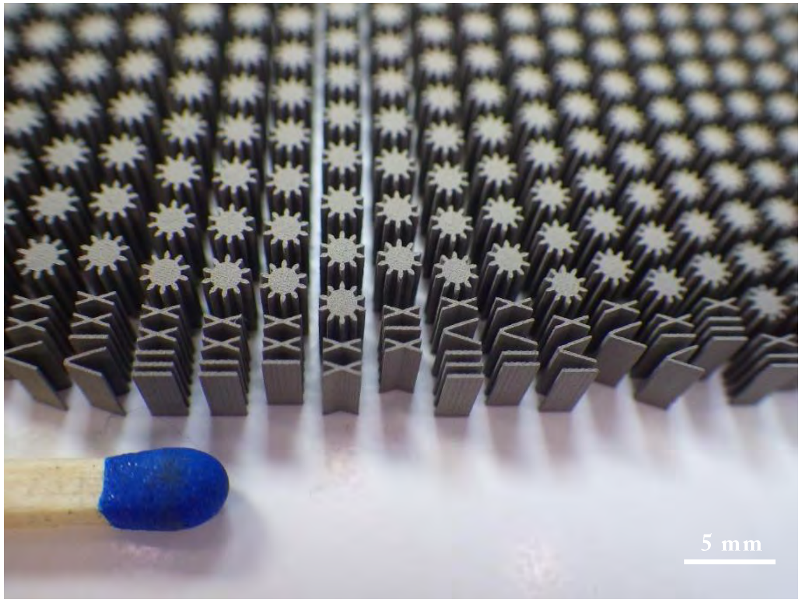


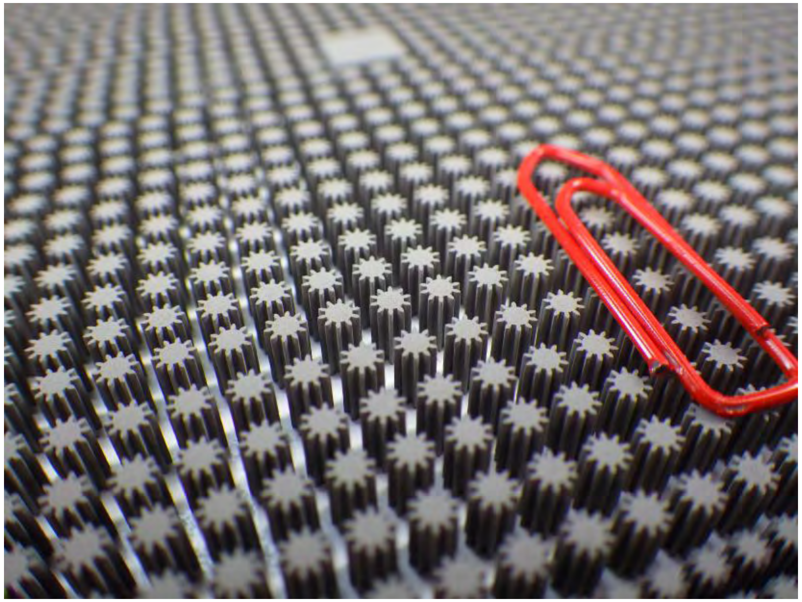
R_a ~ 5 µm

Methods und Materials

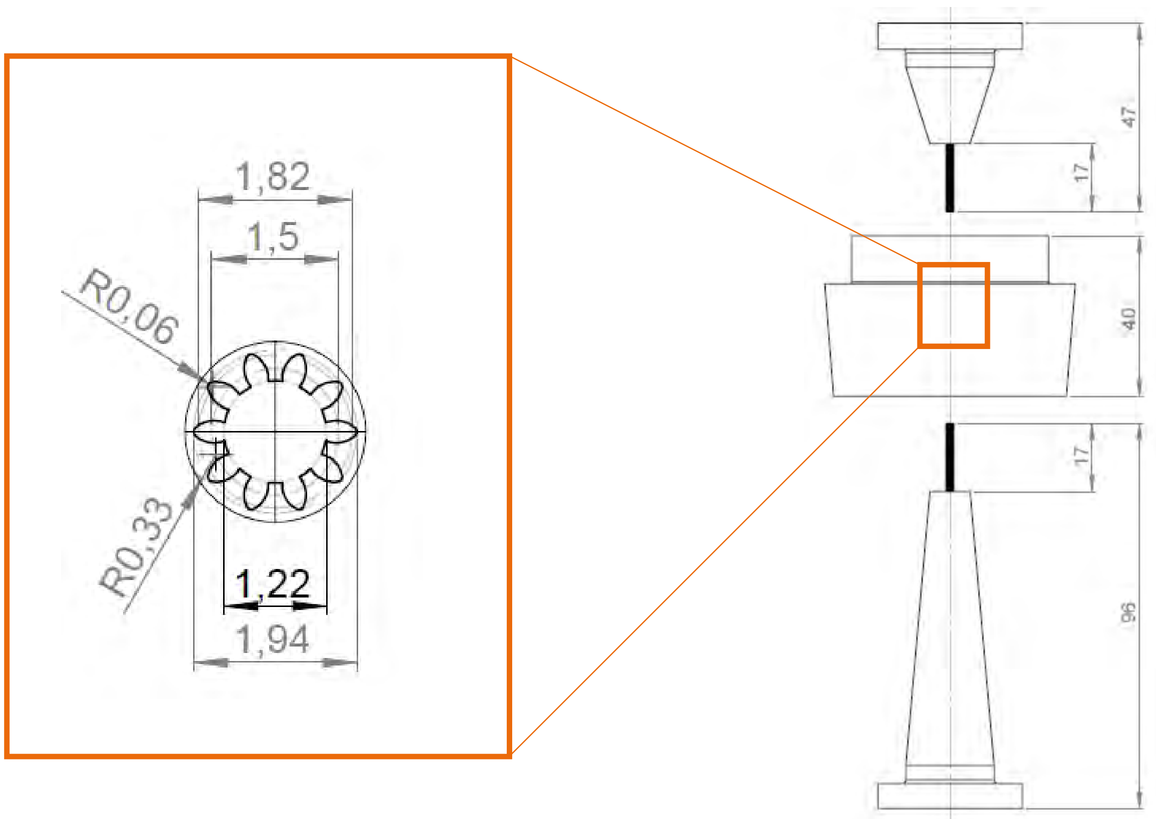
- 316L – powder PF-10F (5-10 µm)
- Sintering temperature → nearly full density
- Calibration pressure: ~1000 MPa
- Lubricant: M25
- Calibration speed: 0,1 mm/min

Green parts



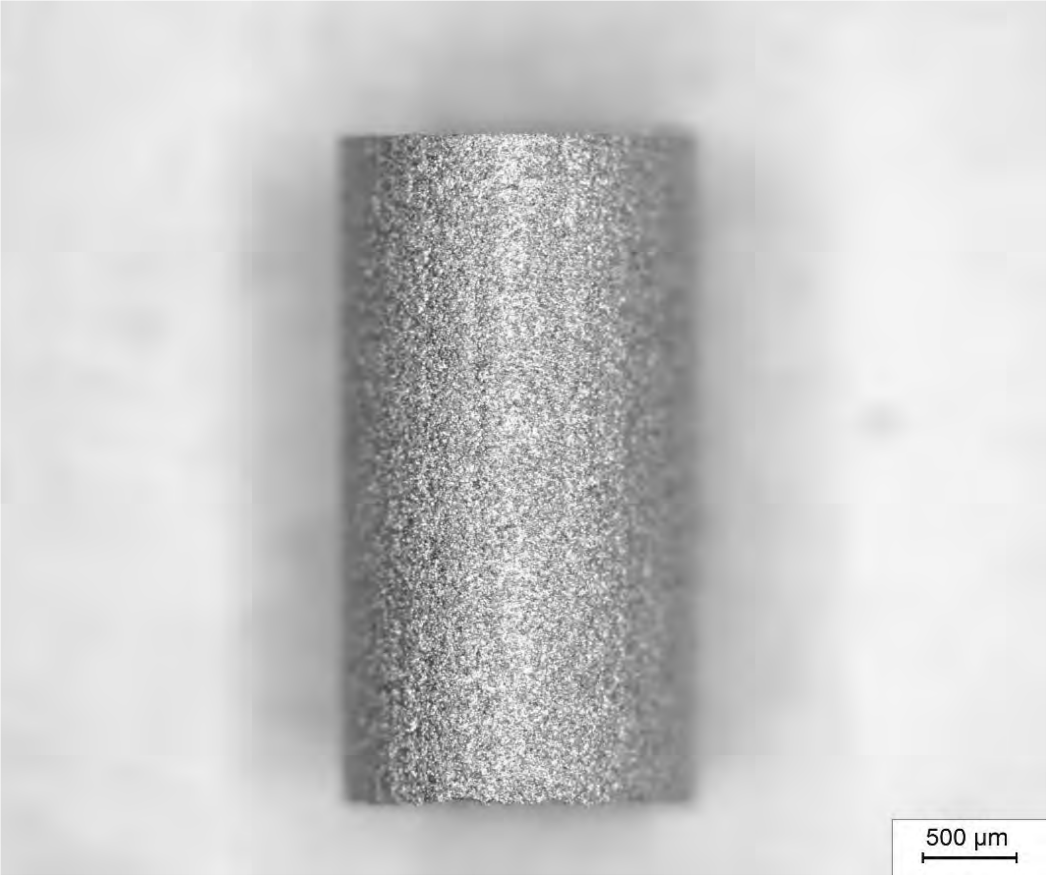


Calibration Tool



Cylinders

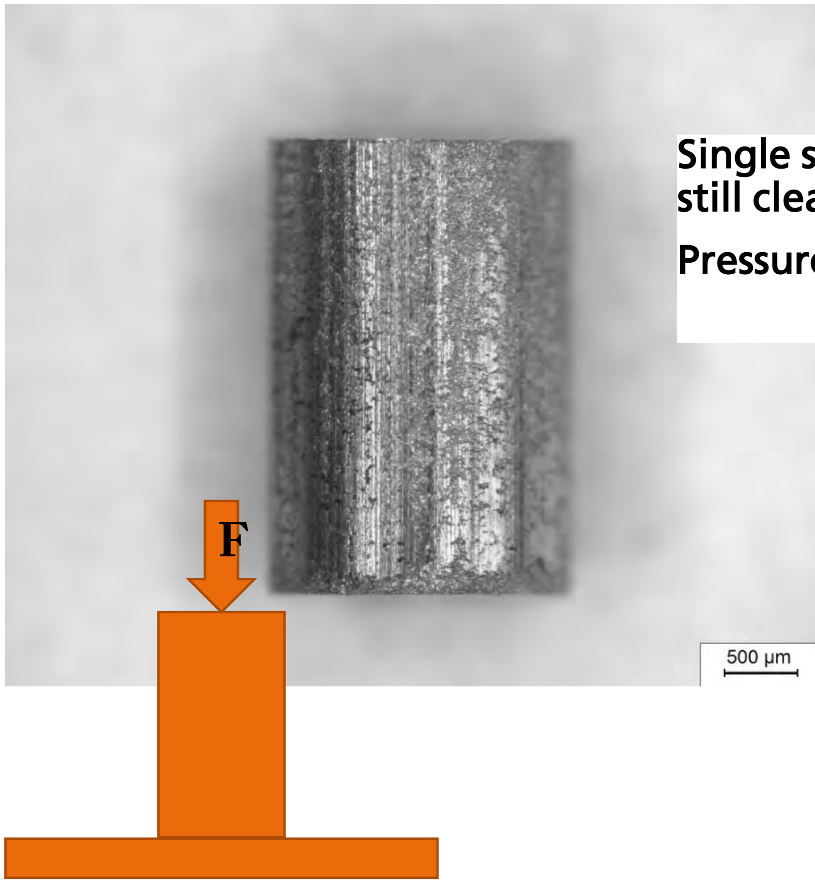
Cylinder – sintered



o.k. high!

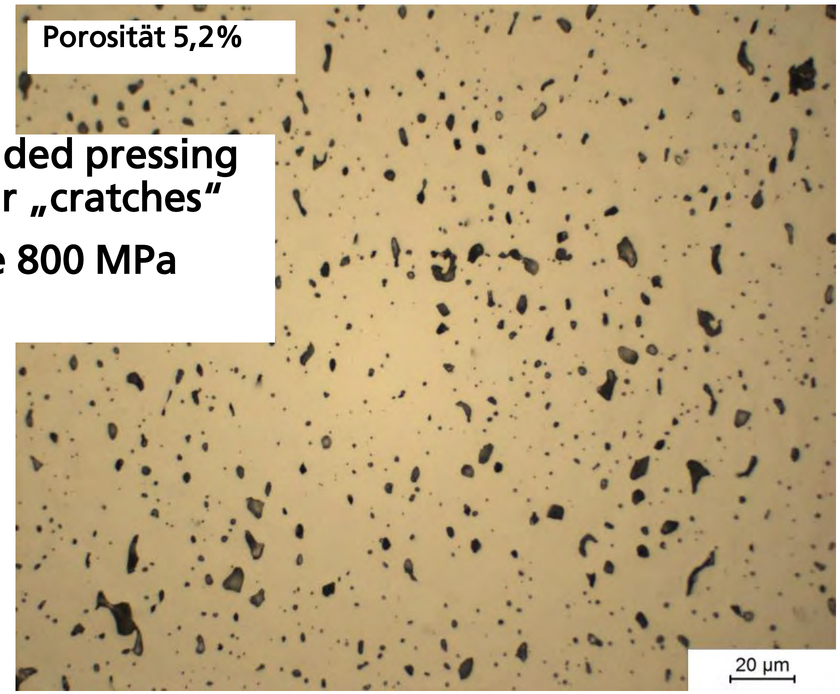
R_a (µm)	R_z (µm)
3,0	15,6

Row XXV – „big gap“ – single sided pressing



Single sided pressing
still clear „cratches“

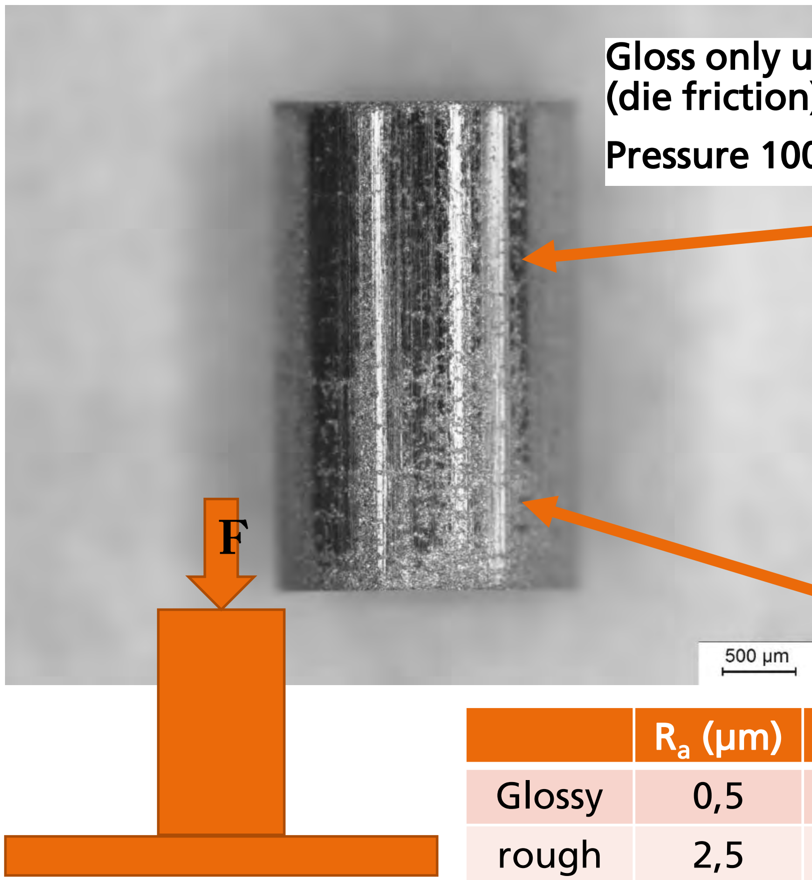
Pressure 800 MPa



better!

R_a (µm)	R_z (µm)
1,5	6,9

Row XXVIII – „small gap“ – single sided pressing

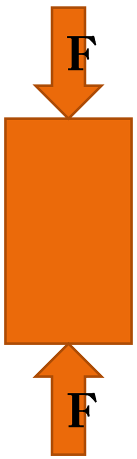


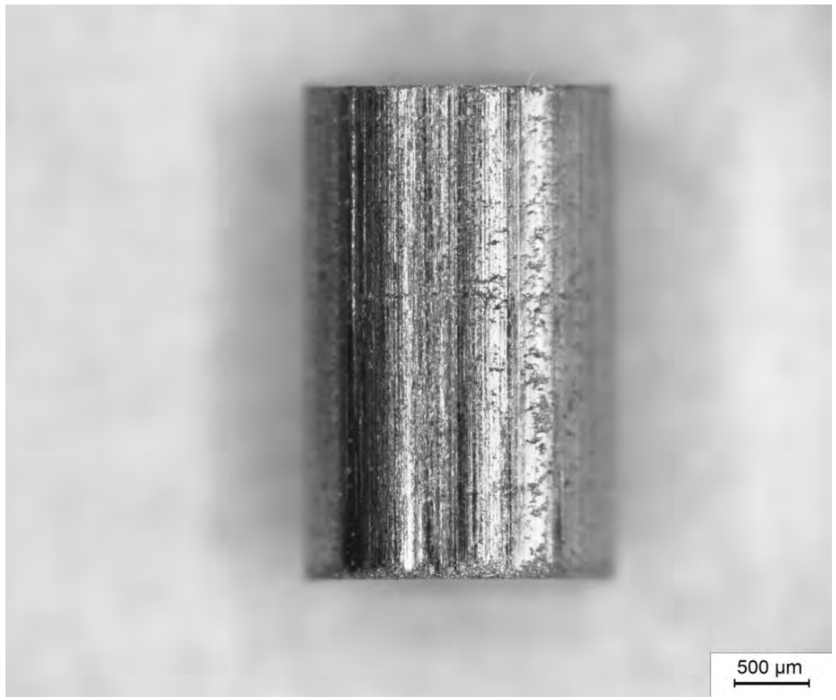
Gloss only upper part
(die friction)

Pressure 1000 MPa

	R_a (µm)	R_z (µm)
Glossy	0,5	2,8
rough	2,5	13,6

Row XXVIII – „small gap“ – double sided pressing



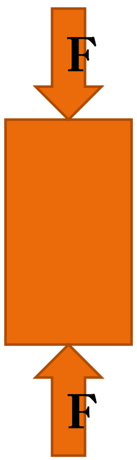


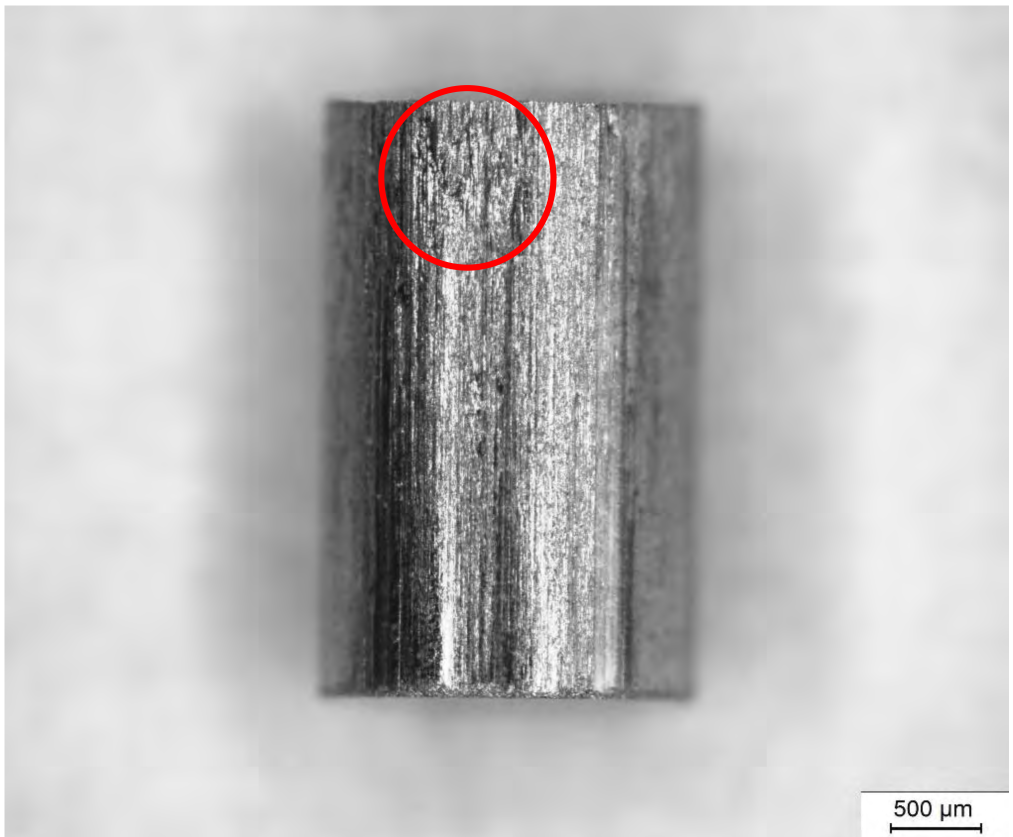
Double sided pressing, glossy surface !!

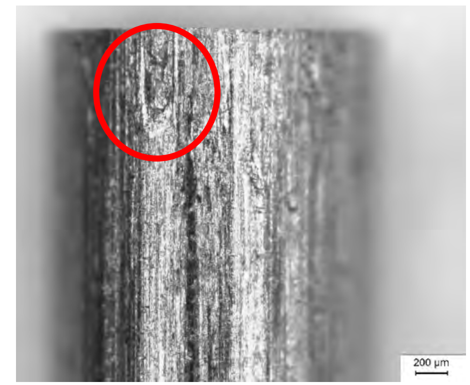
1000 MPa

R_a (µm)	R_z (µm)
0,6	3,8

Row XXVIII – „small gap“ – double sides pressing 1200 MPa







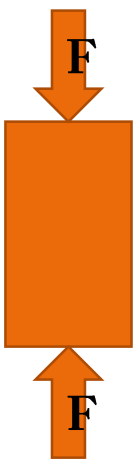
Cold welding with the tool!!

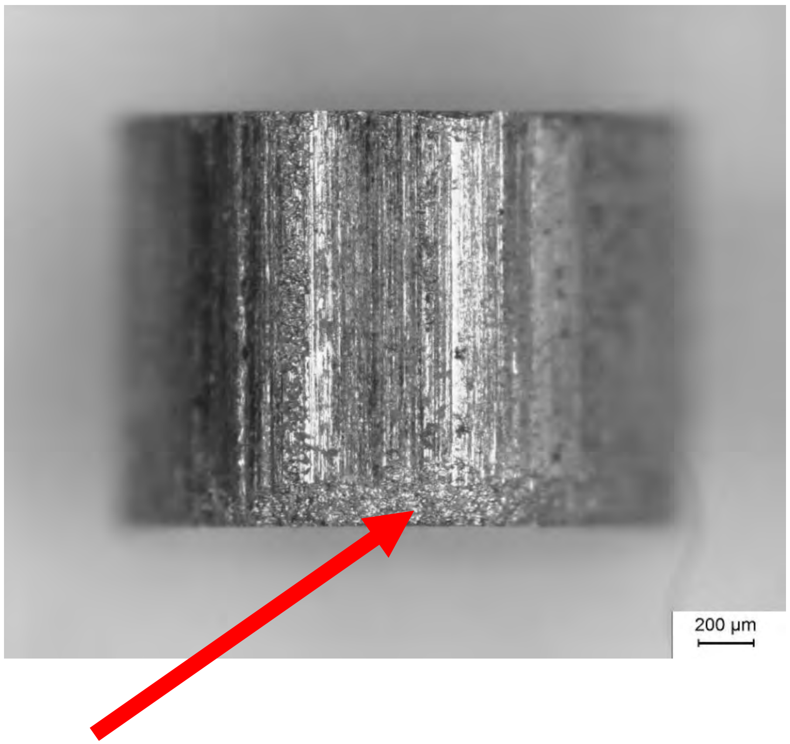
Pressure1200 Mpa

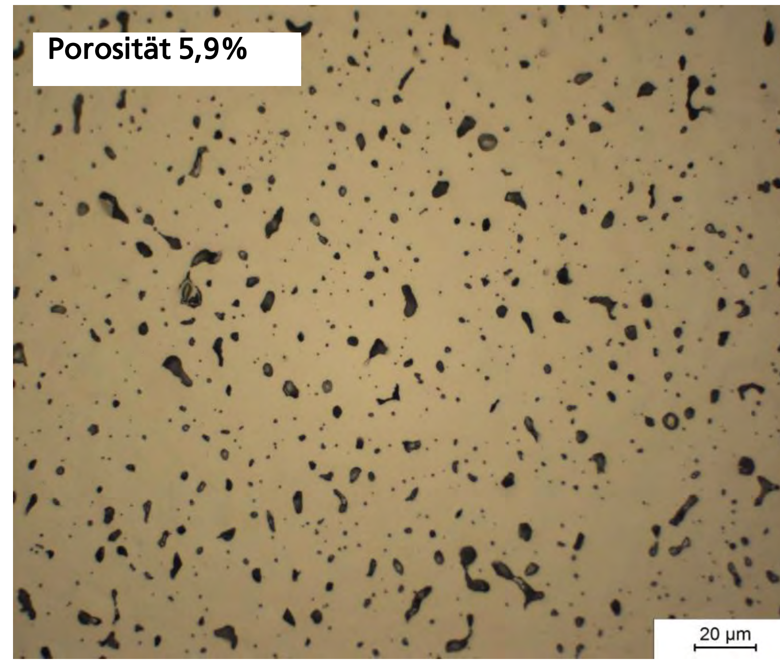
→ To high !!!

R_a (µm)	R_z (µm)
0,7	3,8

Row XXVIII – „small gap“ – Asp.-ratio: 1:1 – single sided pressing – 800 MPa

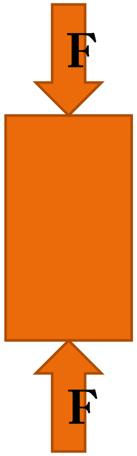


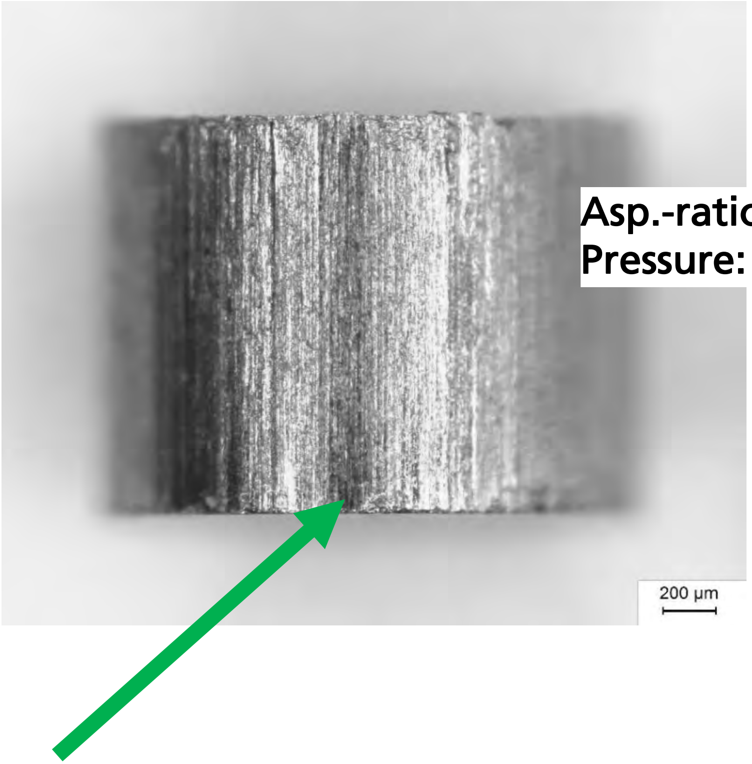


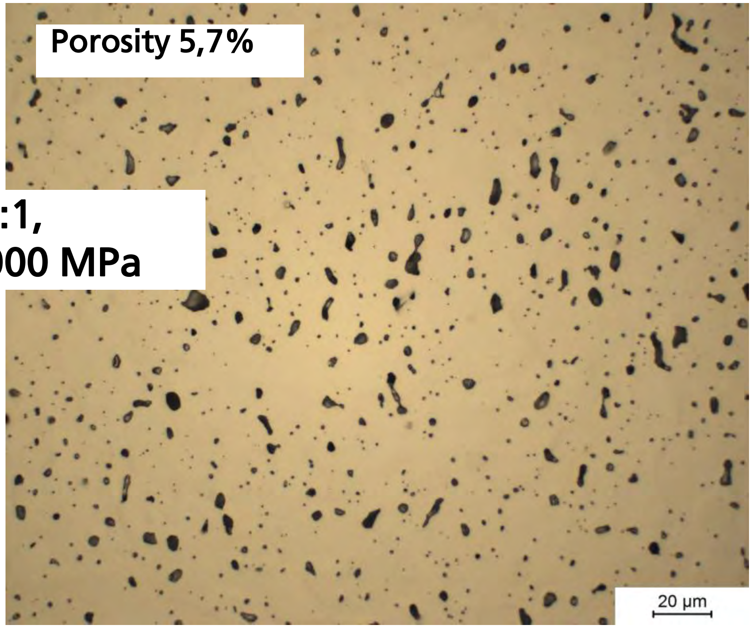


R_a (µm)	R_z (µm)
0,4	2,2

Row XXVIII – „small gap" – Asp.-ratio 1:1 –single sided pressing – 1000 MPa





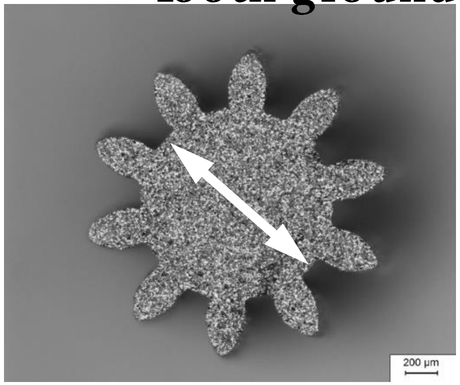


R_a (µm)	R_z (µm)
0,4	1,7

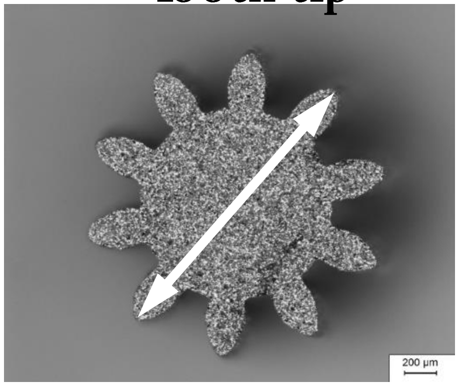
GEAR-WHEELS

Dimensions

Tooth ground

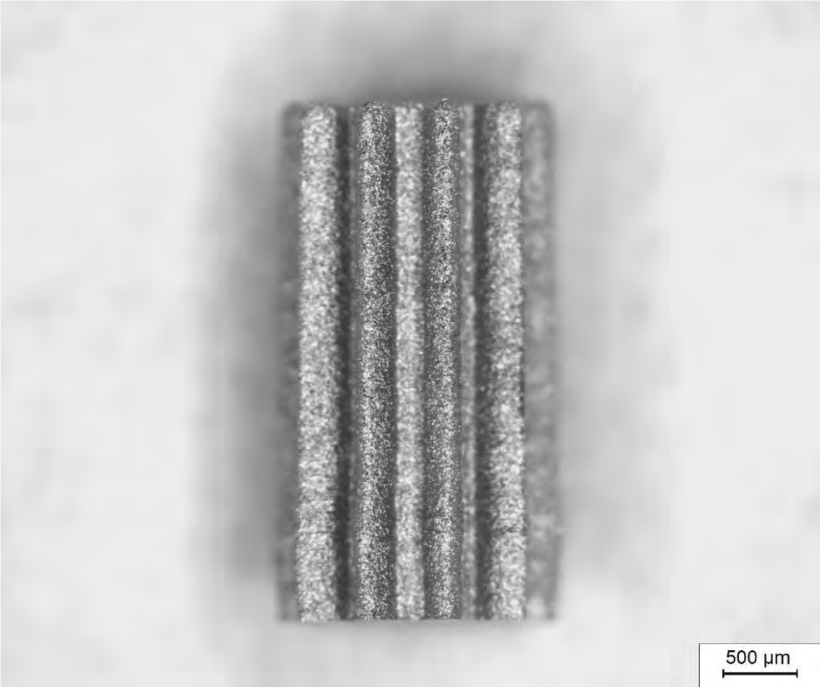


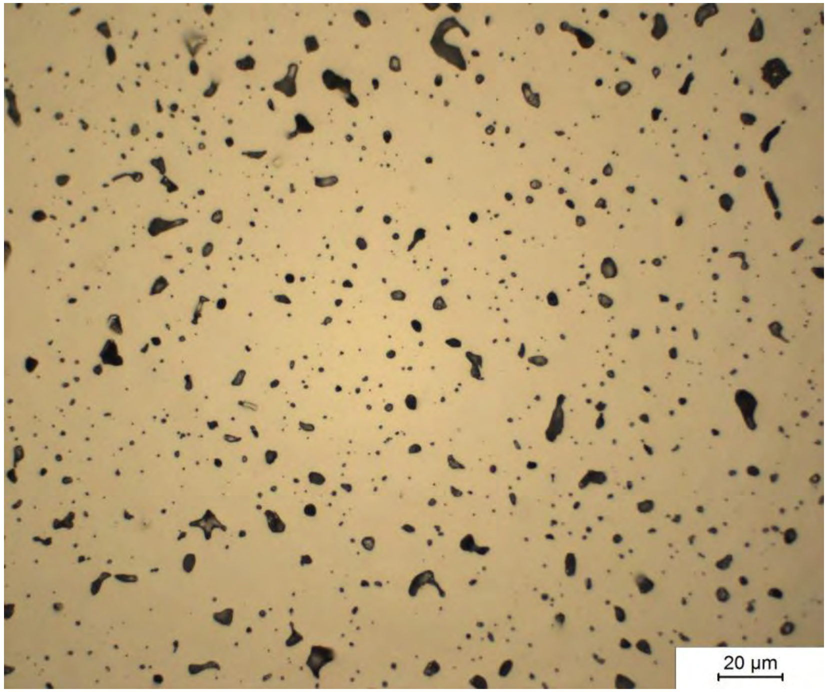
Tooth tip



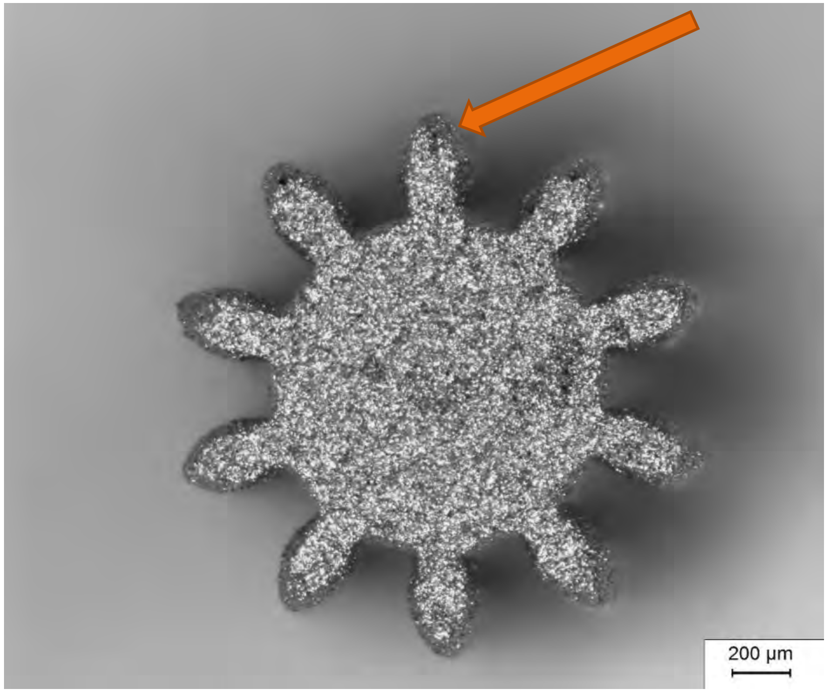
	Tooth ground	Tooth tip
Ø Diameter (n=3)	1,15 mm	1,83 mm
Height (Asp-ratio 1:2)	3,54 mm	

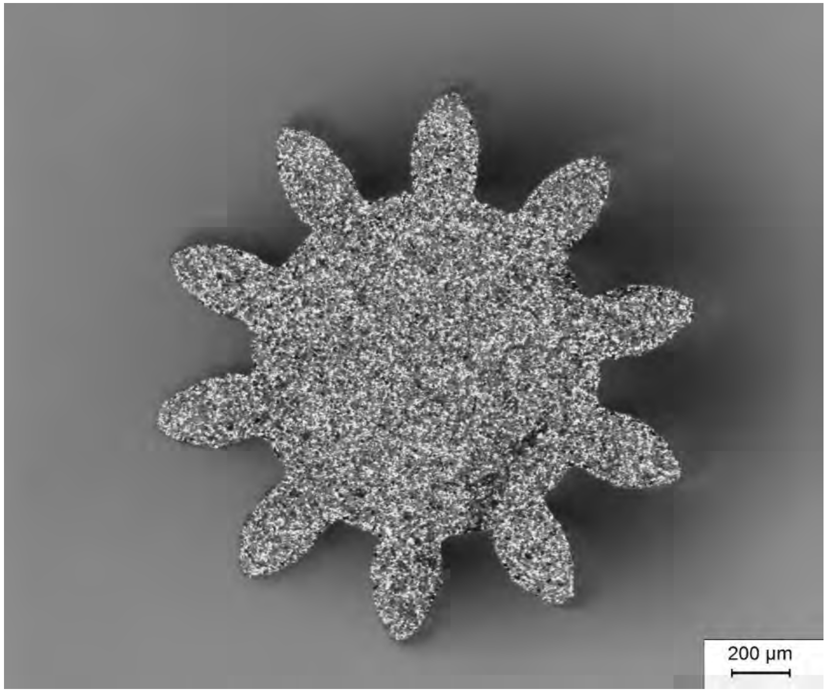
Row XXIII (big gap) before pressing





Row XXIII (big gap) (sintered)



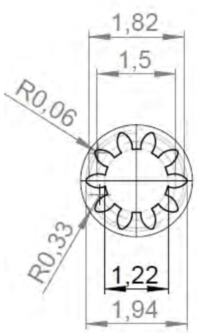


Top:
Some rounding of edges during sintering

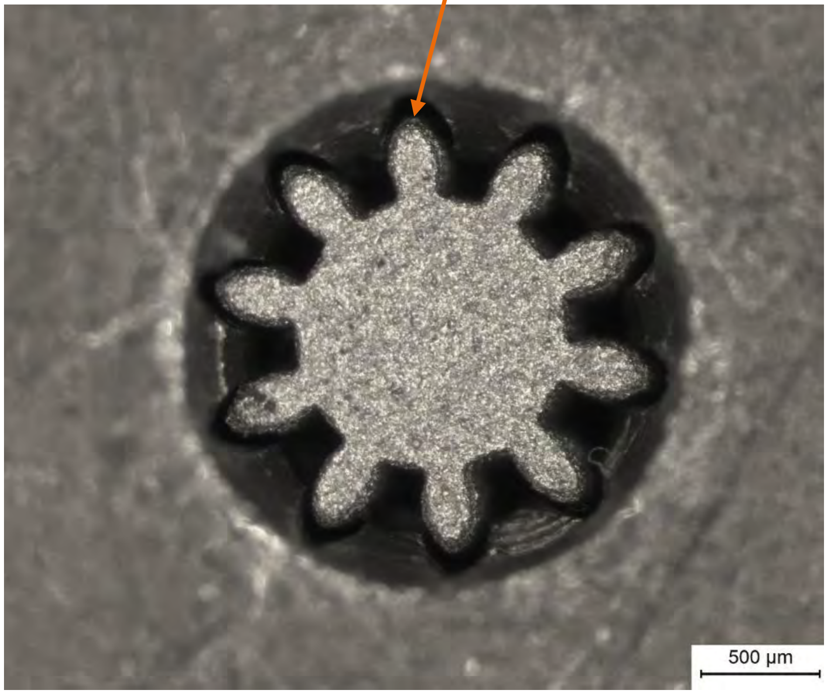
Bottom:
Sharp edges due to constrained sintering on the substrate

Row XXIII before pressing (with die)

Die entry



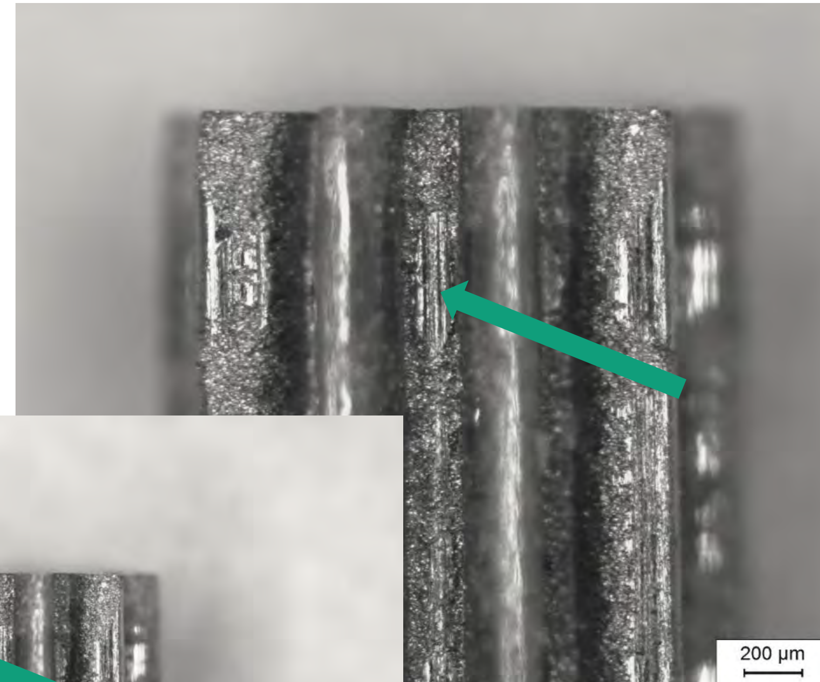
Gap

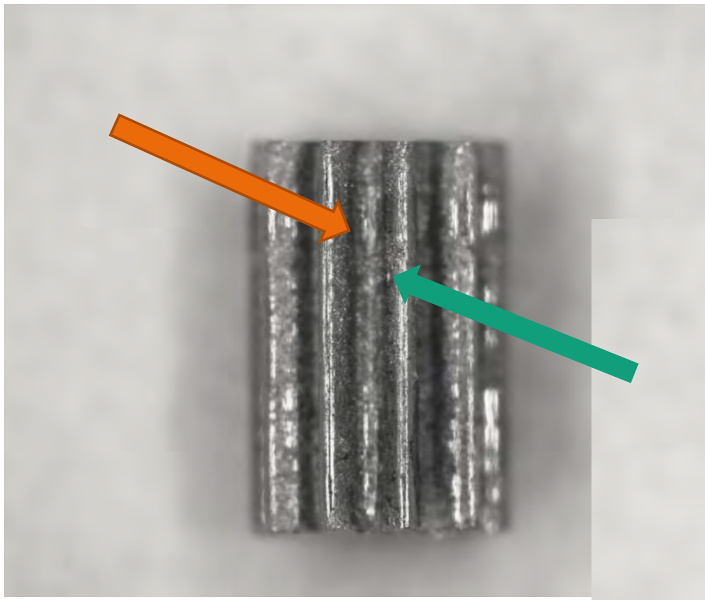


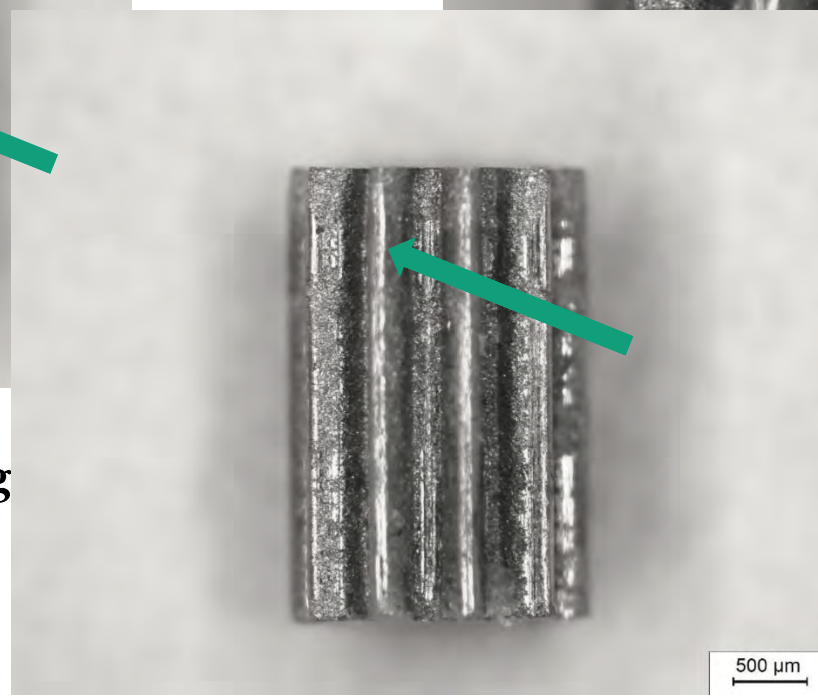
Ø Die = 1,94 mm
Ø Gear = 1,83 mm
Gap = 0,055 mm

Row XXII (big gap) after pressing (1000 MPa)

Tooth tip



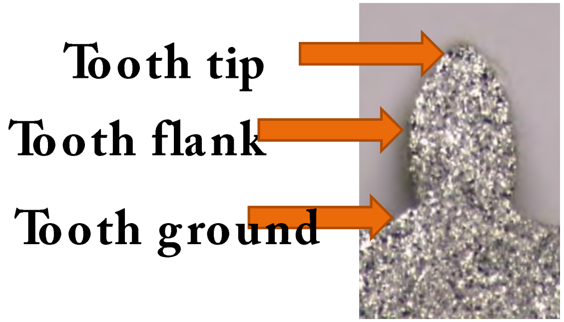




Tooth ground

Only partial smoothening due to big gap

Roughness Row XXIII (big gap) → Aspect ratio: 1:2



sintered

	Tooth ground	Tooth tip	Tooth flank
R_a (µm)	4,5	3,6	4,9
R_z (µm)	22,6	20,5	26,8

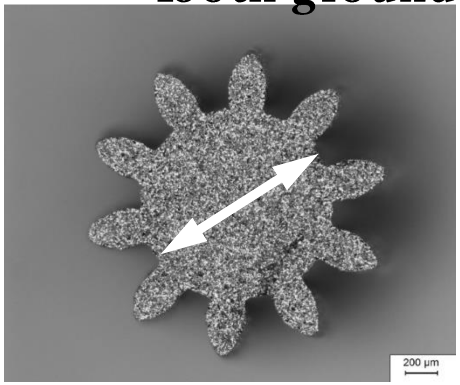
pressed

	Tooth ground	Tooth tip	Tooth flank
R_a (µm)	6,9	1,0	2,9
R_z (µm)	37,0	4,4	16,0

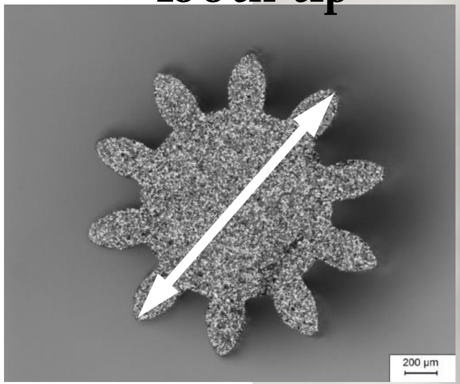
Result: („big gap“)
Calibration at Tool tip: good. Tooth ground and flanke: NO calibration.

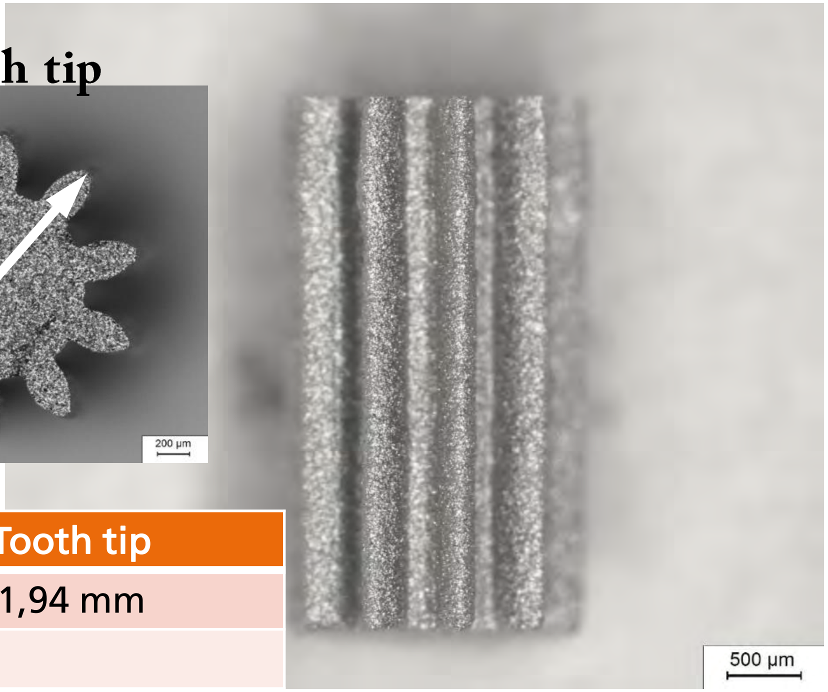
Row XXVIII (small gap): Aspect ratio 1:2

Tooth ground



Tooth tip

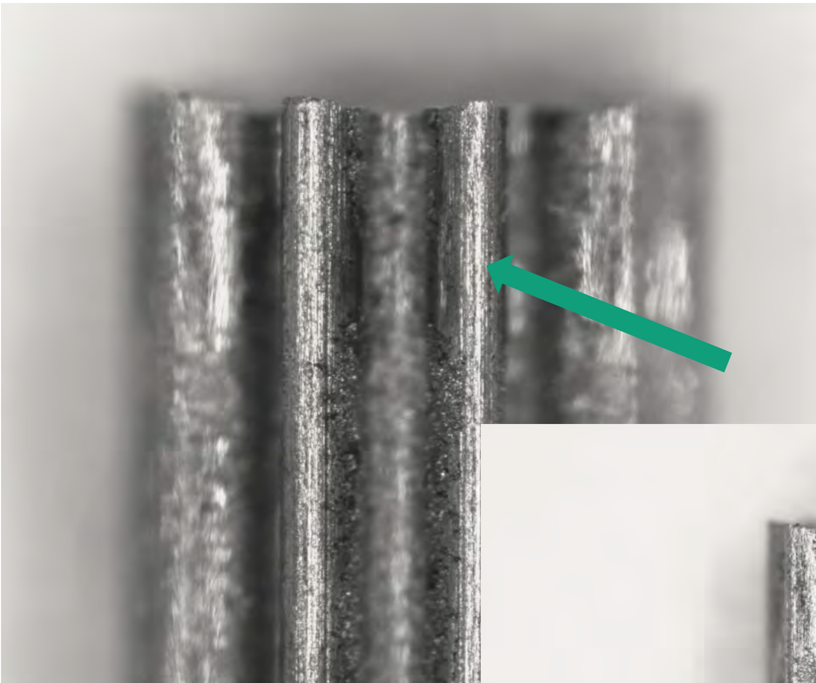


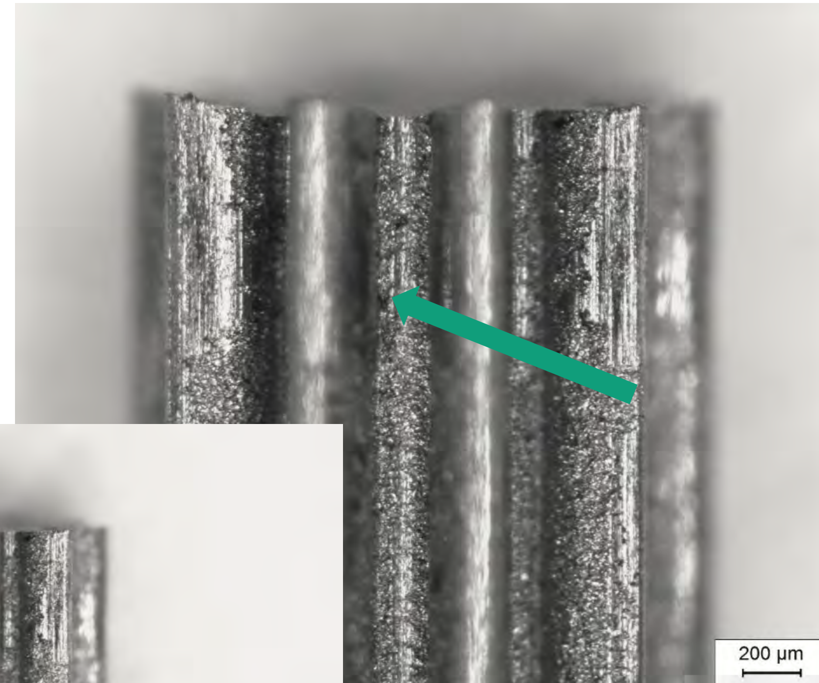


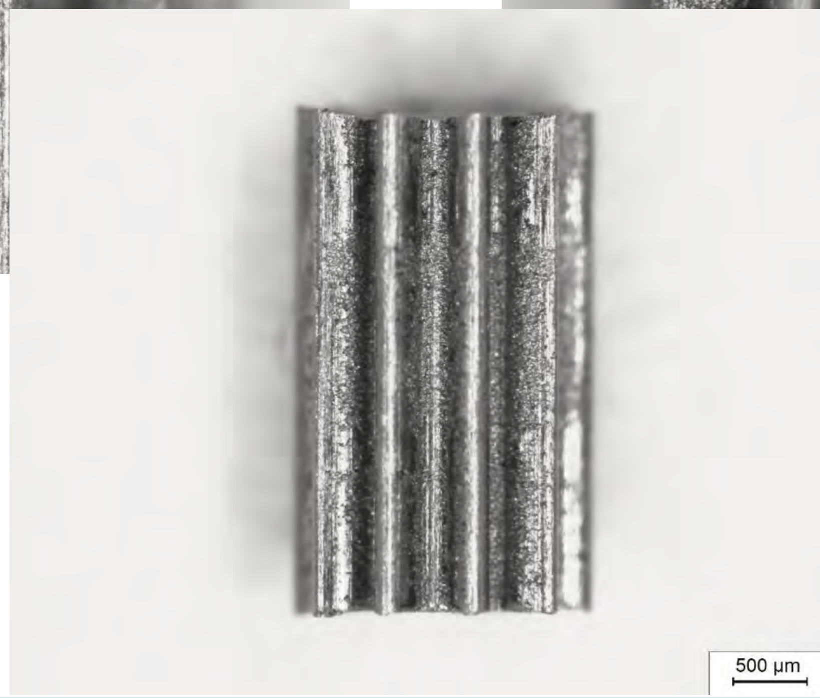
	Tooth ground	Tooth tip
Ø Diameter (n=3)	1,21 mm	1,94 mm
Hight (n=3)	3,55 mm	

Exact fit in the die!!

Row XXVIII (small gap): after pressing 1000 MPa



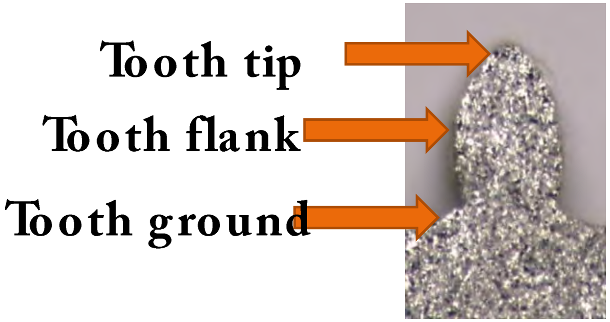




Tooth tip: smoothend

Tooth ground: smoothend

Roughness Row XXVIII (small gap) → Aspect ratio: 1:2



sintered

	Tooth ground	Tooth ground	Tooth flank
R_a (µm)	4,5	3,6	4,9
R_z (µm)	22,6	20,5	26,8

pressed

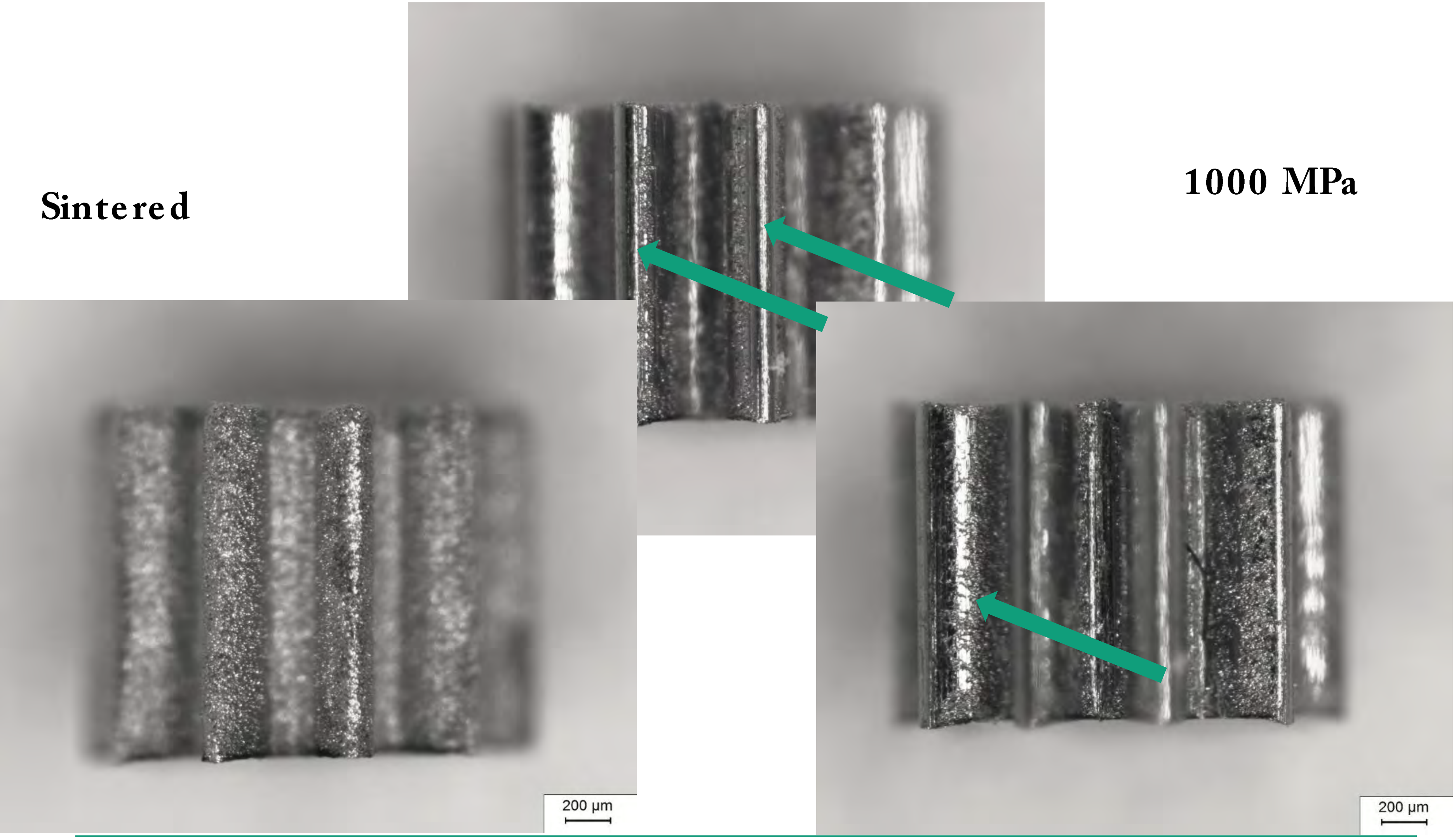
	Tooth ground	Tooth tip	Tooth flank
R_a (µm)	0,7	1,0	5,5
R_z (µm)	3,7	5,7	25,6

Result: („small gap“)
Calibration at Tool tip: GOOD. Tooth ground: GOOD. Flanke: POOR

Row XXVIII (small gap) → Aspect ratio: 1:1

Sintered

1000 MPa



Stress-strain curve for the calibration of gear-wheels

„Big gap“

„Small gap“

Wall friction

Yield strength

Ejection Forces

Clearance = Gap (between tool and part)

Future work (To-do list)

- Influence of sintered density
- Aspect ratio
- Smaller dimensions (<< 2 mm)
- Other materials (steels, Pt, Au,…, Ti)
- Complex shapes (multi-level parts, holes)
- Micro-tools and calibration presses
- Automation

Summary /Outlook

- Mass production (10.000 – x Mio. parts/year) of complex shaped small parts by 3D-printing and calibration is possible
- High accuracy (~ 1-5 µm)
- Low cost processes
- Development from Lab-scale to production
- Possible applications: microparts in medical, electronic, microsystems applications
- Alternative to cost-intensive machining for ductile materials

Thank you for your attention!