CIRP ICME '22 Virtual Conference
16th CIRP International Conference on
INTELLIGENT COMPUTATION IN MANUFACTURING ENGINEERING
13 - 15 July 2022

Practical analysis of productivity of grinding tools in the process of internal generating gear grinding

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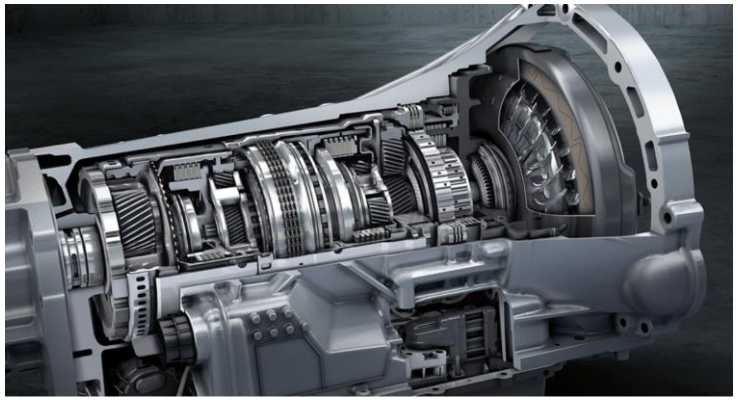
- 1. Introduction
- 2. Description of Materials and Methods
- 3. Analysis of Gear Quality
  - 3.1. Analogy Process Trial
  - 3.2. Standard Process Trial
- 4. Economic Evaluation
- 5. Conclusions

Transmission trend

High reduction ratio
Up to 40% smaller*1
Up to 50% lighter *1

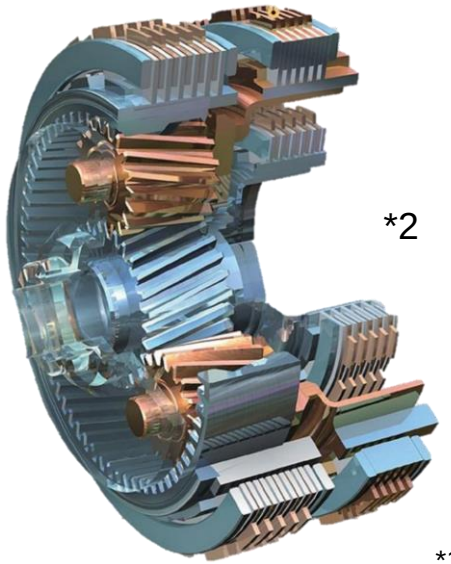


*3

Multi speed
Complex structure

*4

Single speed
Simple structure
⇨ Sensitive to noise, vibration



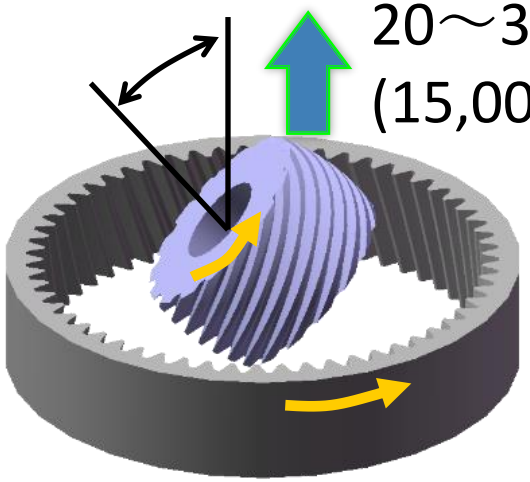
*2

Ring gear application with high accuracy increasing

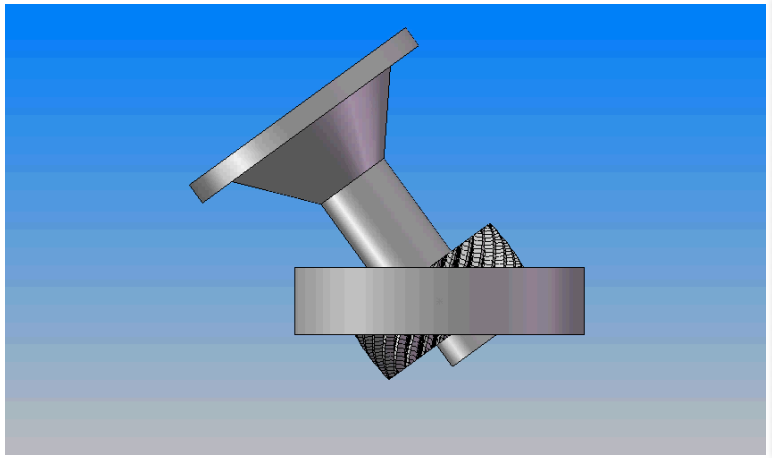
*1 Klocke, F.; Brecher, C.: Zahnrad- und Getriebetechnik. Auslegung – Herstellung – Untersuchung – Simulation. Munich: Hanser 2017
*2 Motor Fan illustrated Vol.124
*3 https://automotivepowertraintechnologyinternational.com/news/transmissions-technologies/transit-gains-10-speed-transmission.html#prettyPhoto
*4 CTI symposium

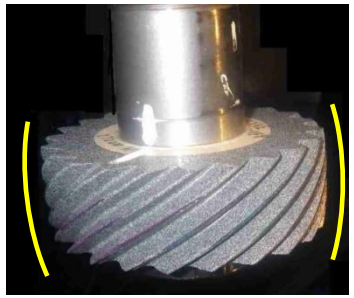
Internal generating grinding

20～35 deg.



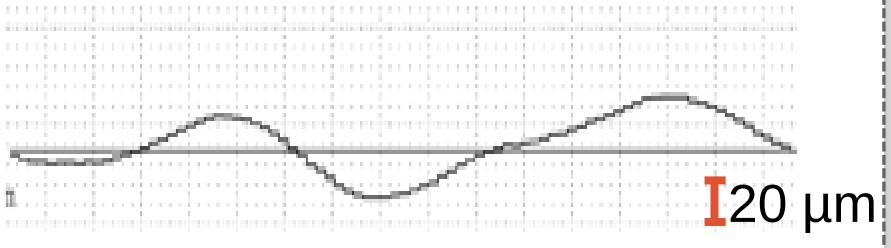
Ground by axial motion





Before Grinding

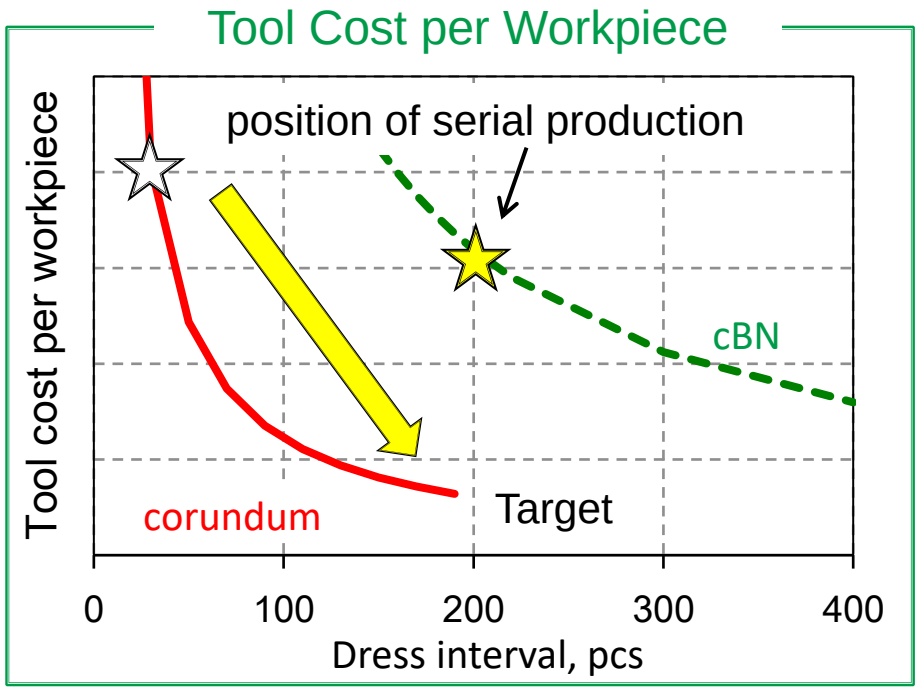
Pitch Deviation – Left Flank F_p

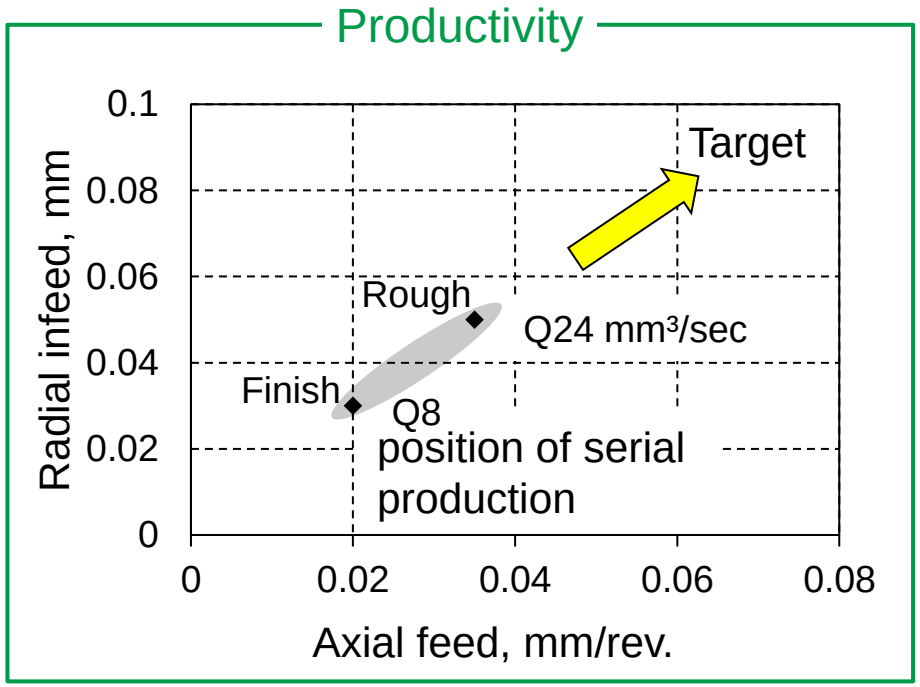


After Grinding

Motivation

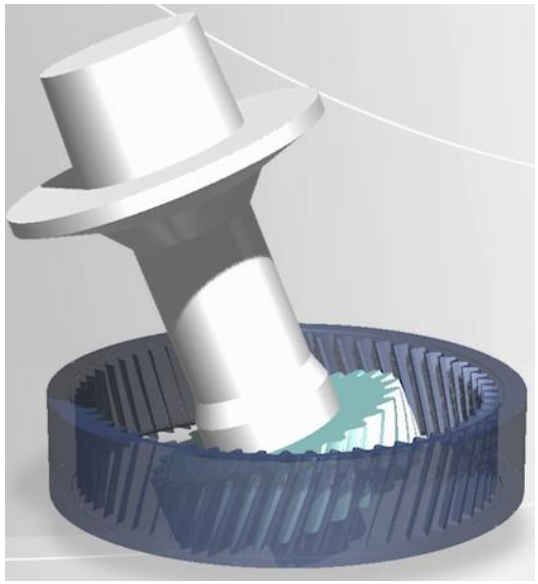
- Further improvements in tool cost and productivity are required.
- The Application of corundom wheels is key, but the investigation of corundum wheel's possibility is not yet done.

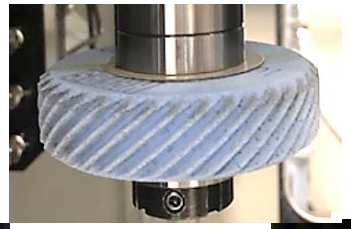


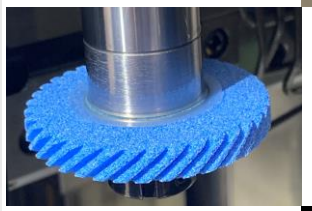


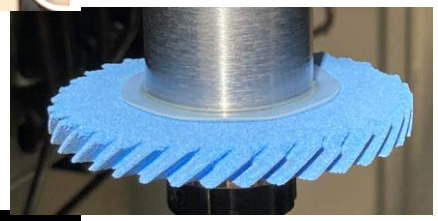
Objective

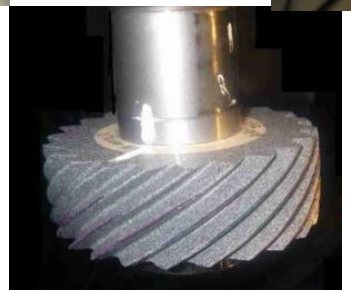
The investigation of the influence of cBN and corundum grinding wheels on the productivity as well as gear quality for the process of internal generating gear grinding.











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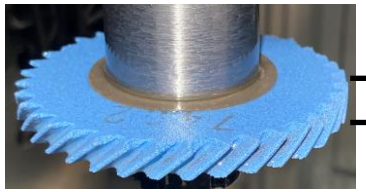
Description of methods

Step 1

Analogy process trial



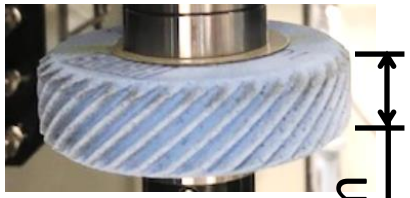
7mm

50 gears x 6 corundom, 1 cBN

Width of wheel ×1/3
Tool wear ×3

Step 2

Standard process trial



20mm

Same as serial production

145 parts x 1 Best specification

Step 1, 2 common

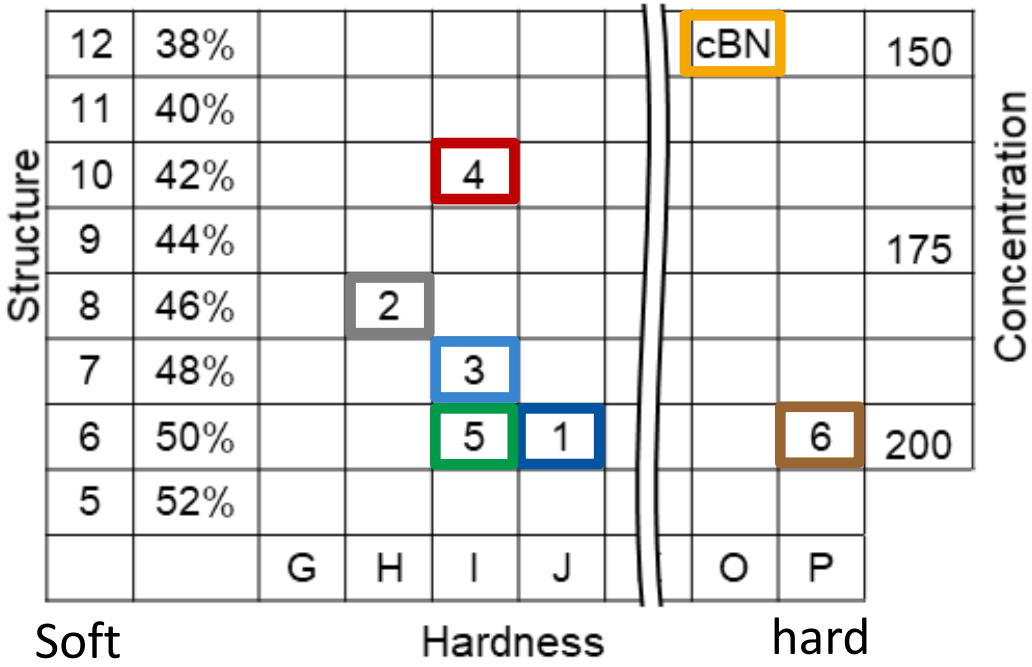
Inspection: geometry, surface roughness on every 4 gear, Nital etching on last gear

Criteria : ISO class5, Ra 0.4

Wheel selection for analogy process trials

		grain size	grain
corundom	1	120/180	● mixed
	2	120	●
	3	90	●
	4	100	
	5	120	●
	6	120	
cBN		200	

●special shape grain



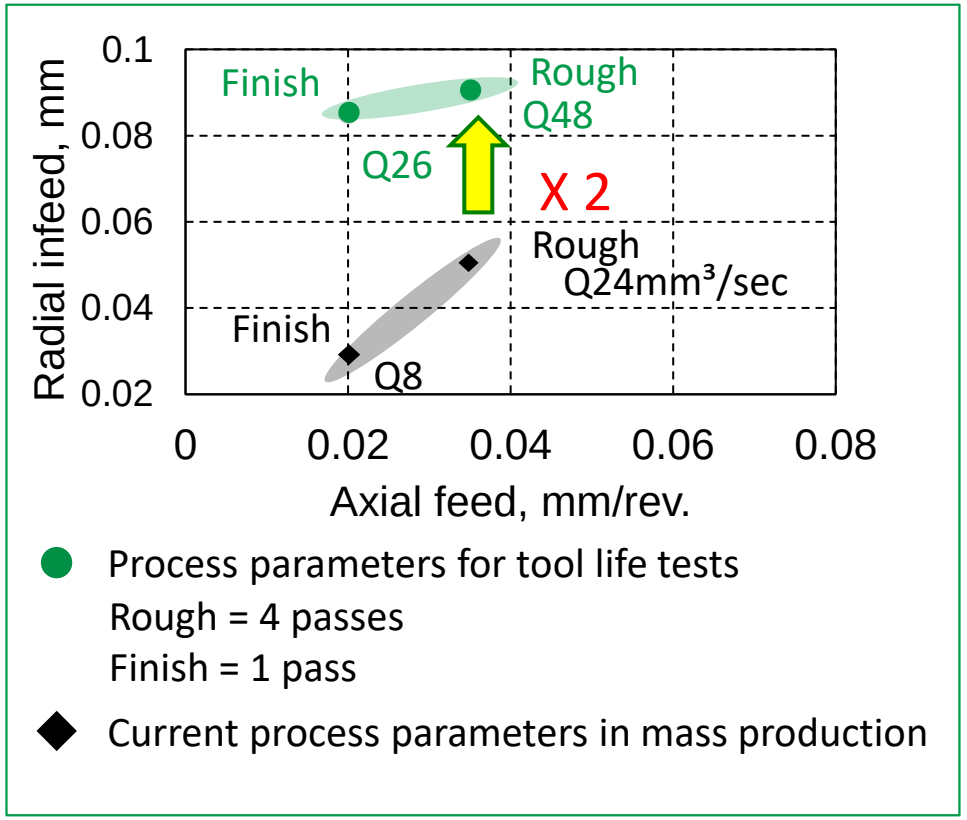
Grinding conditions

Workpiece Specifications

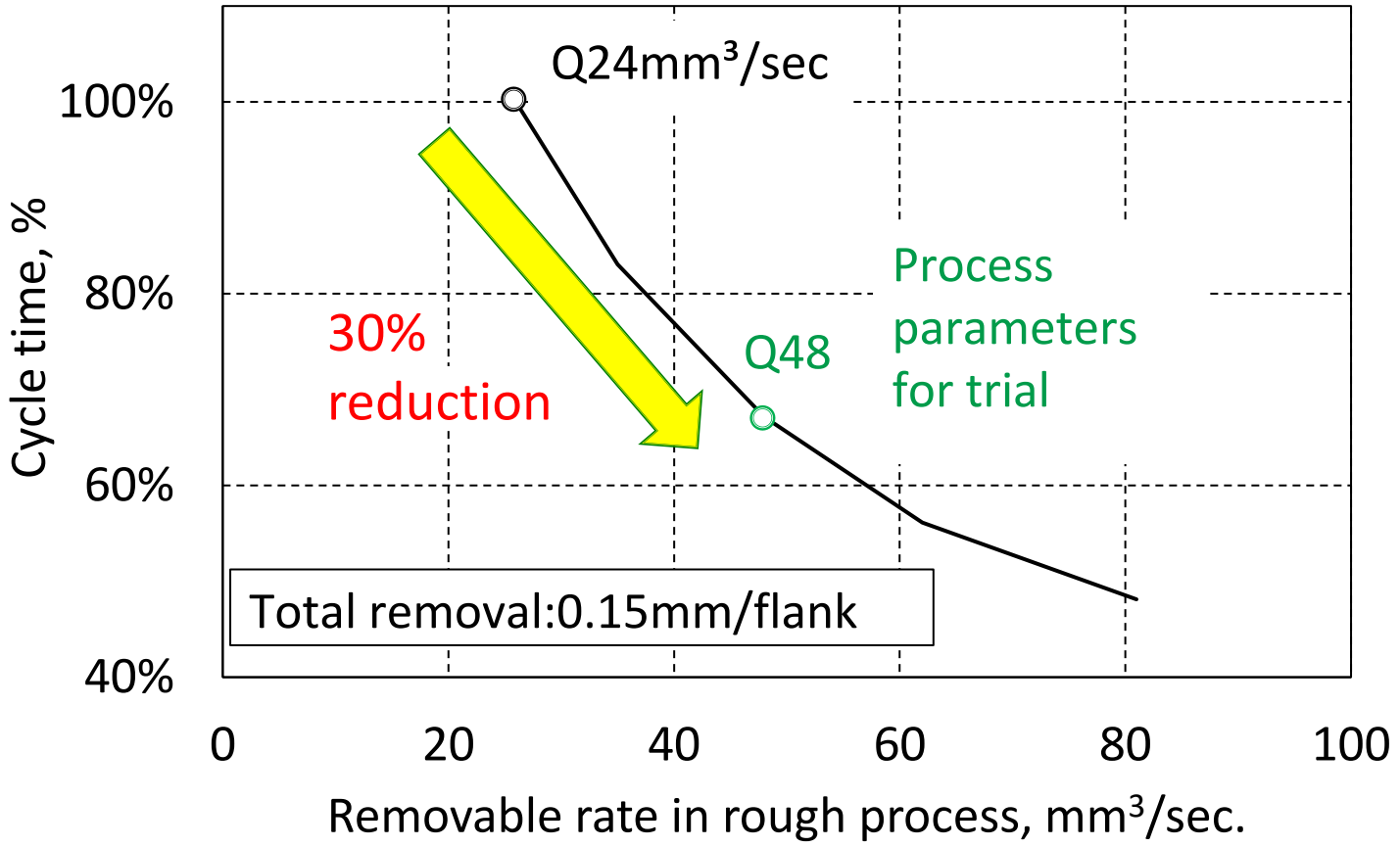
- Module m_n = 1.25mm
- Number of teeth z = 85
- Pressure angle α_n = 20°
- Helix angle β = 20°
- Tip diameter d_a = 111.17mm

Grinding Parameters for Tool life Test

- Fixed for all tools
- Wheel spindle speed = 12,000 min^{-1}
- Table Speed = 5,200 min^{-1}
- Sliding speed = 25 m/s
- Total removal per flank = 0.15 mm
- Cycle time = 125 seconds



Grinding conditions



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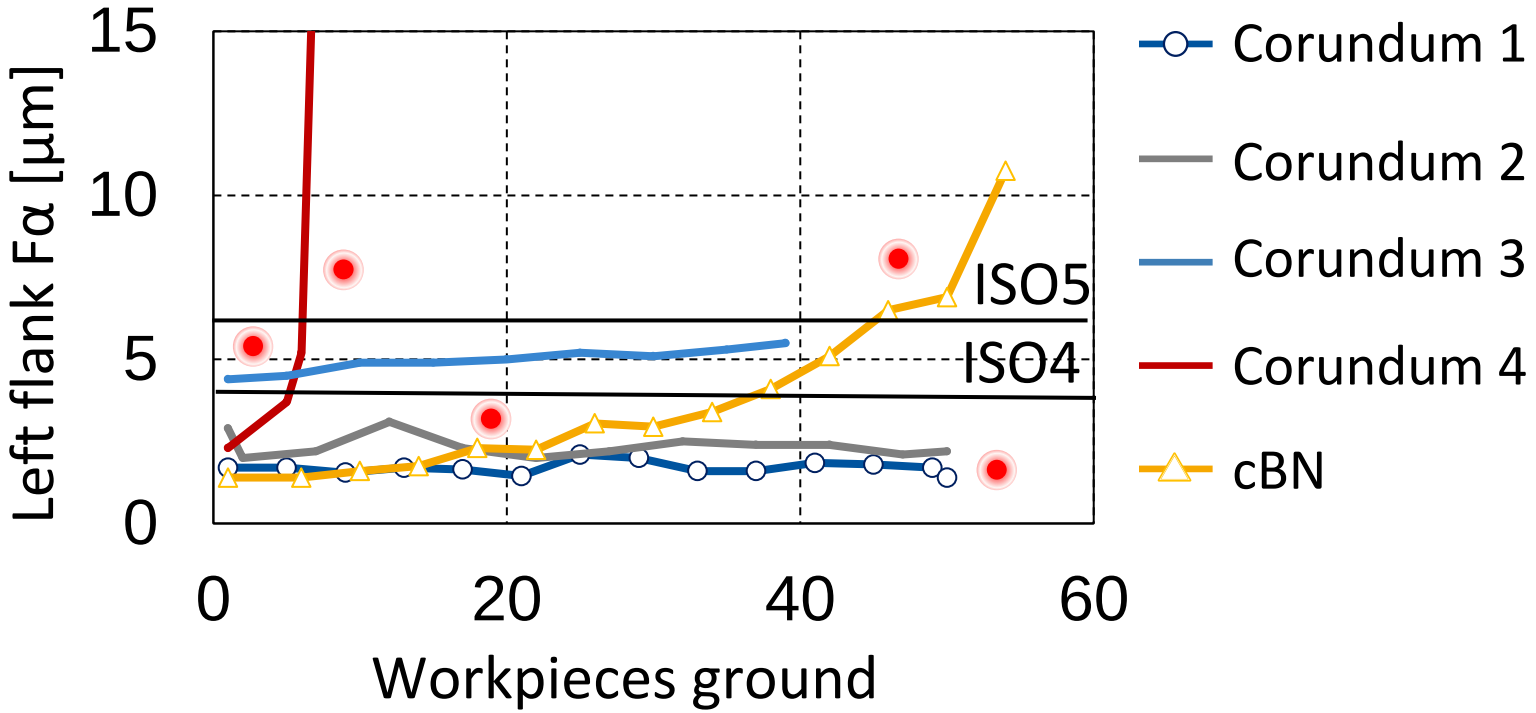
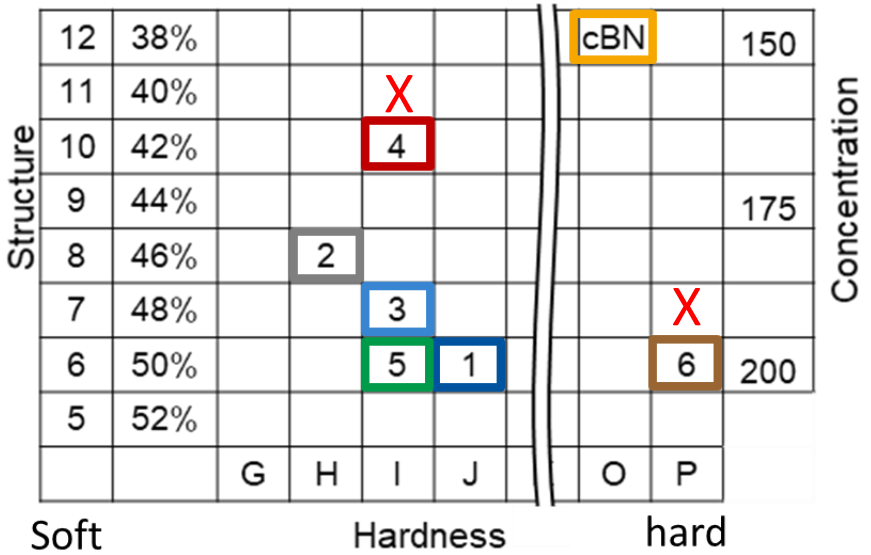
Results of analogy trials



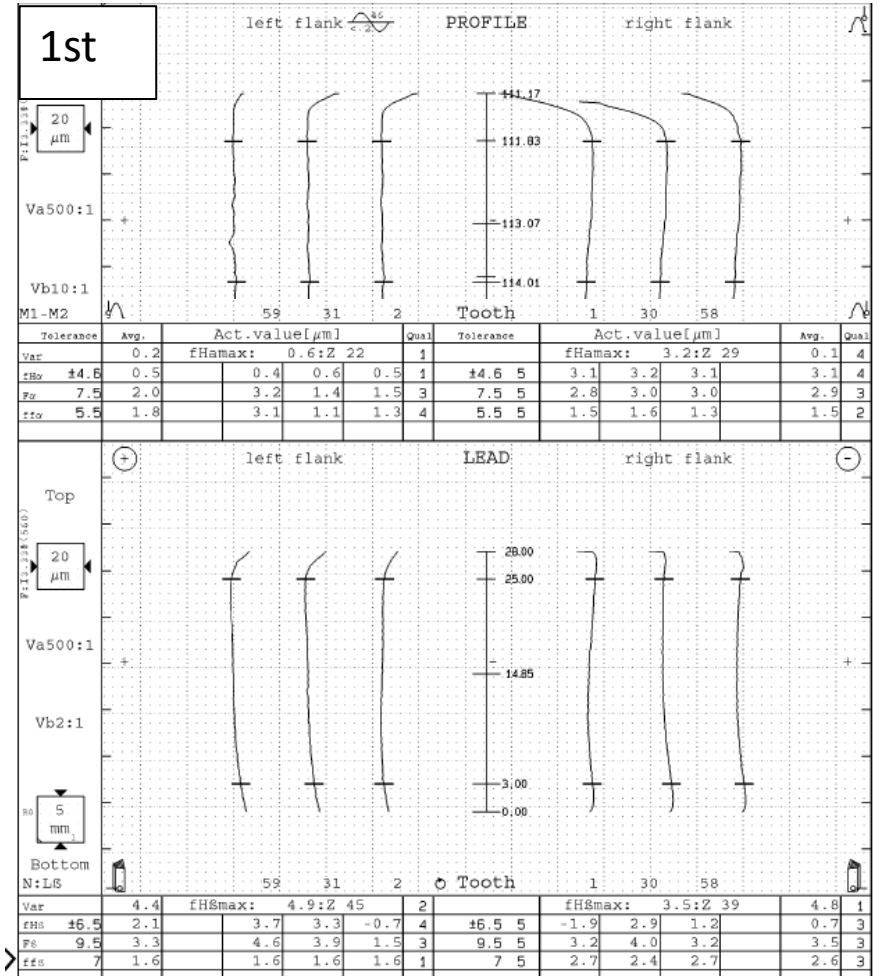


Corundum 5, 6 are not shown because of breakage after the first trial

Results of analogy trials

Corundom 1

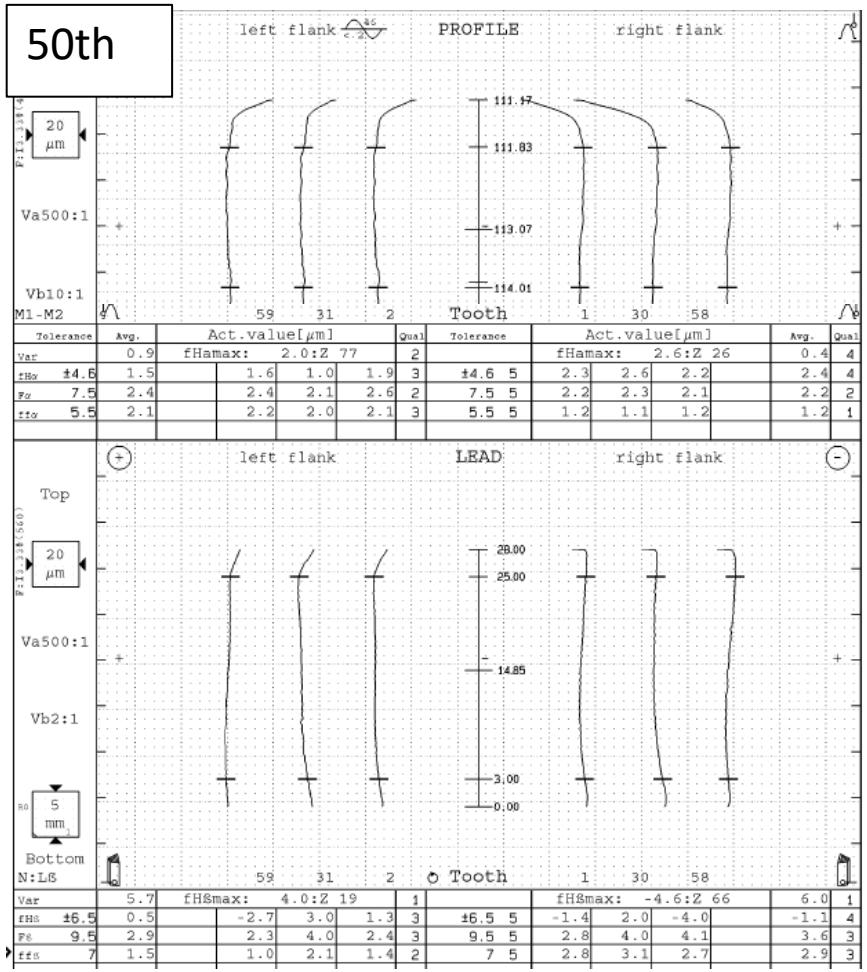
1st



Tolerance	Avg.	Act.value[µm]			Qual	Tolerance	Act.value[µm]			Avg.	Qual
Var	0.2	fHamax: 0.6:Z 22			1		fHamax: 3.2:Z 29			0.1	4
fHα ±4.6	0.5	0.4	0.6	0.5	1	±4.6 5	3.1	3.2	3.1	3.1	4
Fα 7.5	2.0	3.2	1.4	1.5	3	7.5 5	2.8	3.0	3.0	2.9	3
ffα 5.5	1.8	3.1	1.1	1.3	4	5.5 5	1.5	1.6	1.3	1.5	2

Var	4.4	fHßmax: 4.9:Z 45			2		fHßmax: 3.5:Z 39			4.8	1
fHß ±6.5	2.1	3.7	3.3	-0.7	4	±6.5 5	-1.9	2.9	1.2	0.7	3
Fß 9.5	3.3	4.6	3.9	1.5	3	9.5 5	3.2	4.0	3.2	3.5	3
ffß 7	1.6	1.6	1.6	1.6	1	7 5	2.7	2.4	2.7	2.6	3

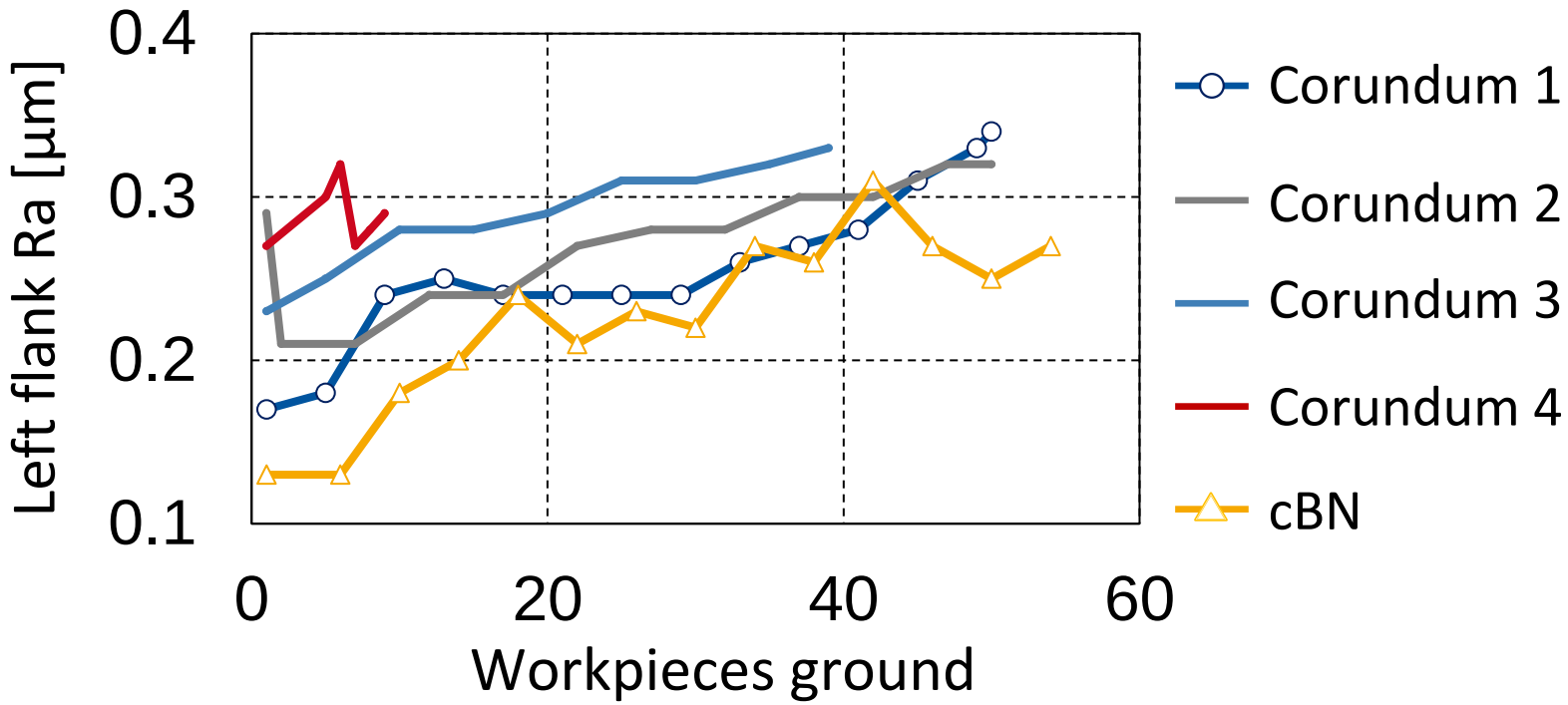
50th



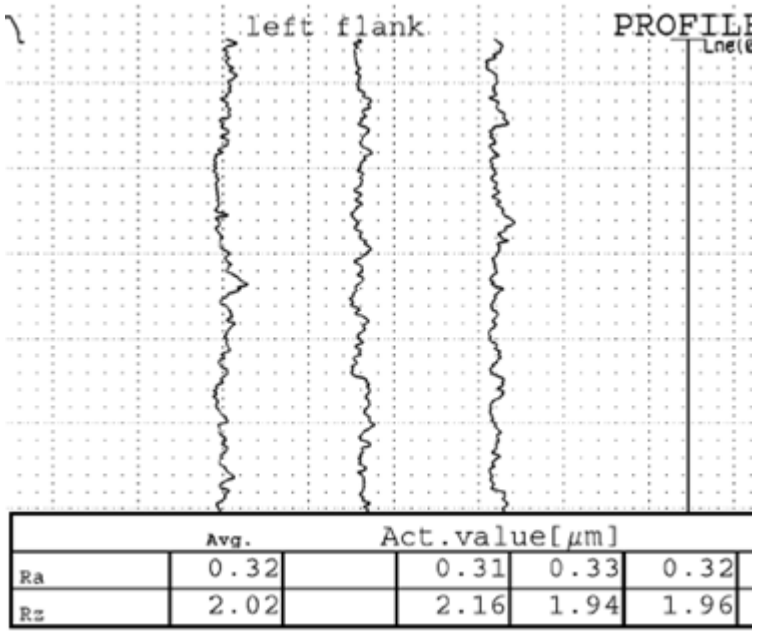
Tolerance	Avg.	Act.value[µm]			Qual	Tolerance	Act.value[µm]			Avg.	Qual
Var	0.9	fHamax: 2.0:Z 77			2		fHamax: 2.6:Z 26			0.4	4
fHα ±4.6	1.5	1.6	1.0	1.9	3	±4.6 5	2.3	2.6	2.2	2.4	4
Fα 7.5	2.4	2.4	2.1	2.6	2	7.5 5	2.2	2.3	2.1	2.2	2
ffα 5.5	2.1	2.2	2.0	2.1	3	5.5 5	1.2	1.1	1.2	1.2	1

Var	5.7	fHßmax: 4.0:Z 19			1		fHßmax: -4.6:Z 66			6.0	1
fHß ±6.5	0.5	-2.7	3.0	1.3	3	±6.5 5	-1.4	2.0	-4.0	-1.1	4
Fß 9.5	2.9	2.3	4.0	2.4	3	9.5 5	2.8	4.0	4.1	3.6	3
ffß 7	1.5	1.0	2.1	1.4	2	7 5	2.8	3.1	2.7	2.9	3

Results of analogy trials



50th, Corundom 1



Corundom 1 was chosen for standard process trial

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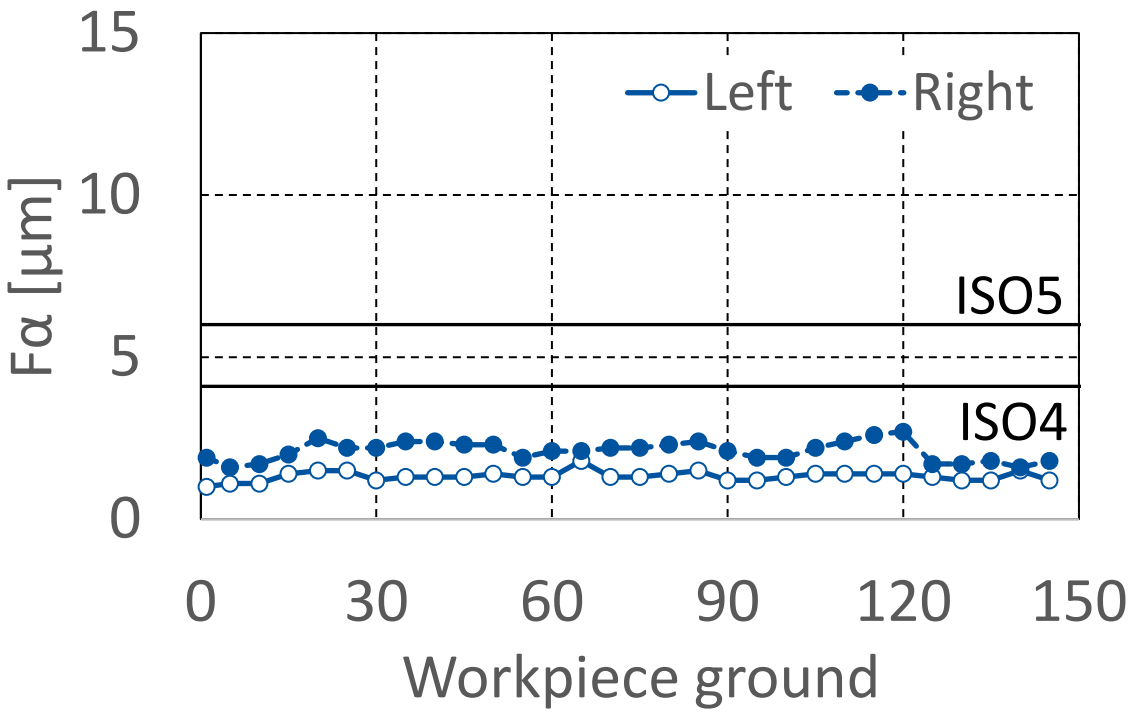
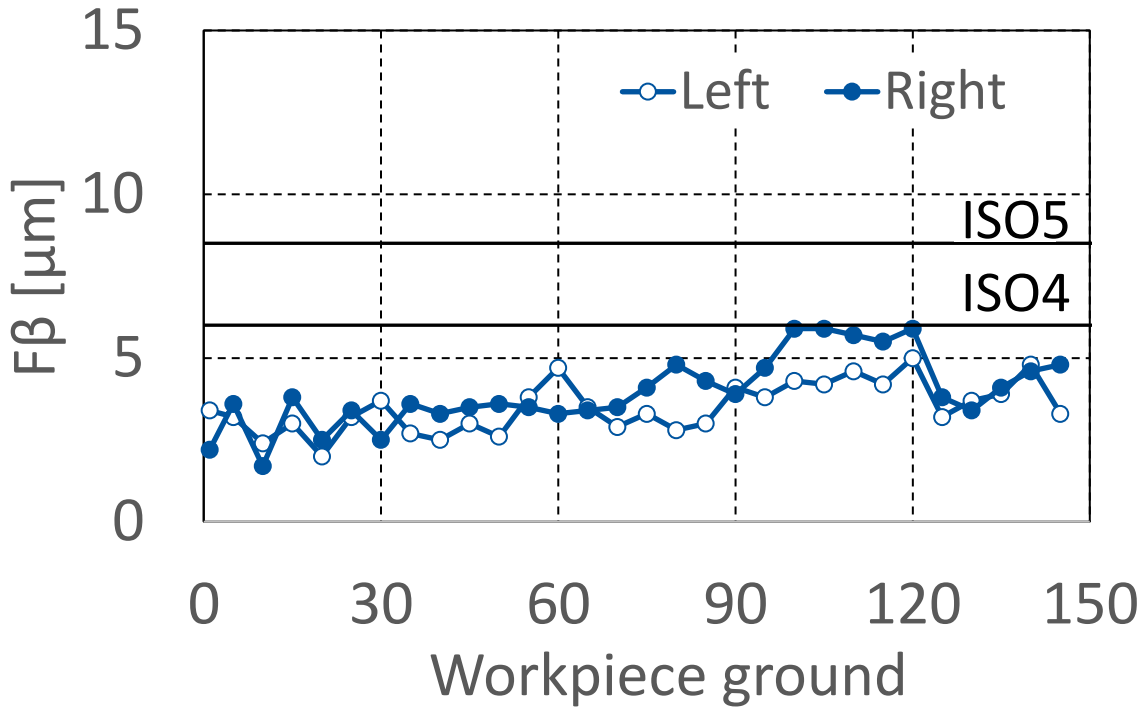
Results of standard process trials

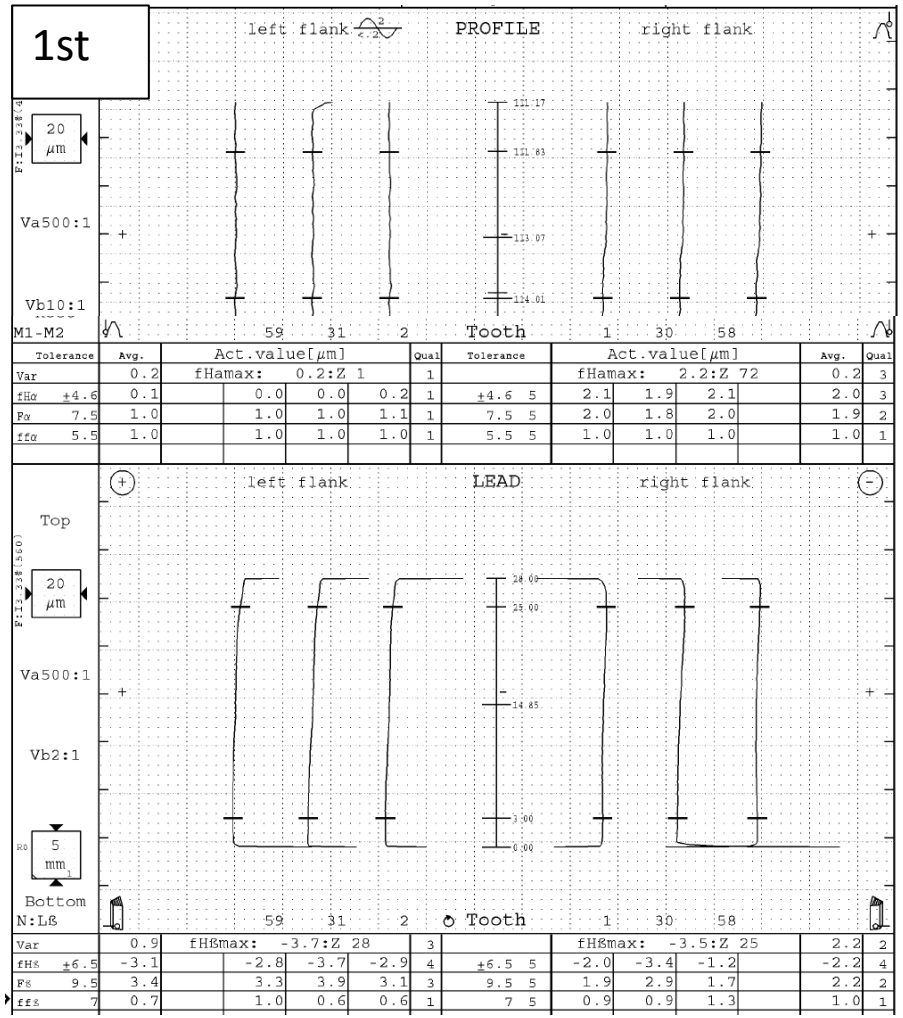
Corundom 1

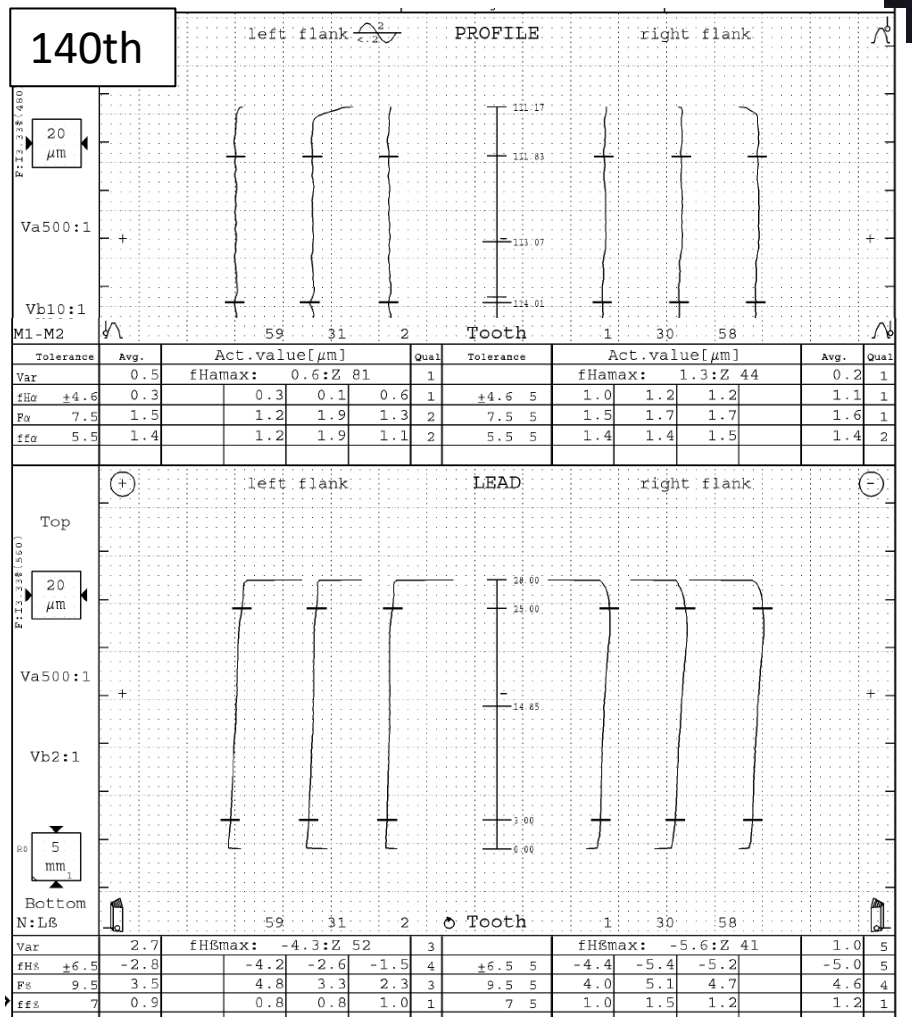




Results of standard process trials

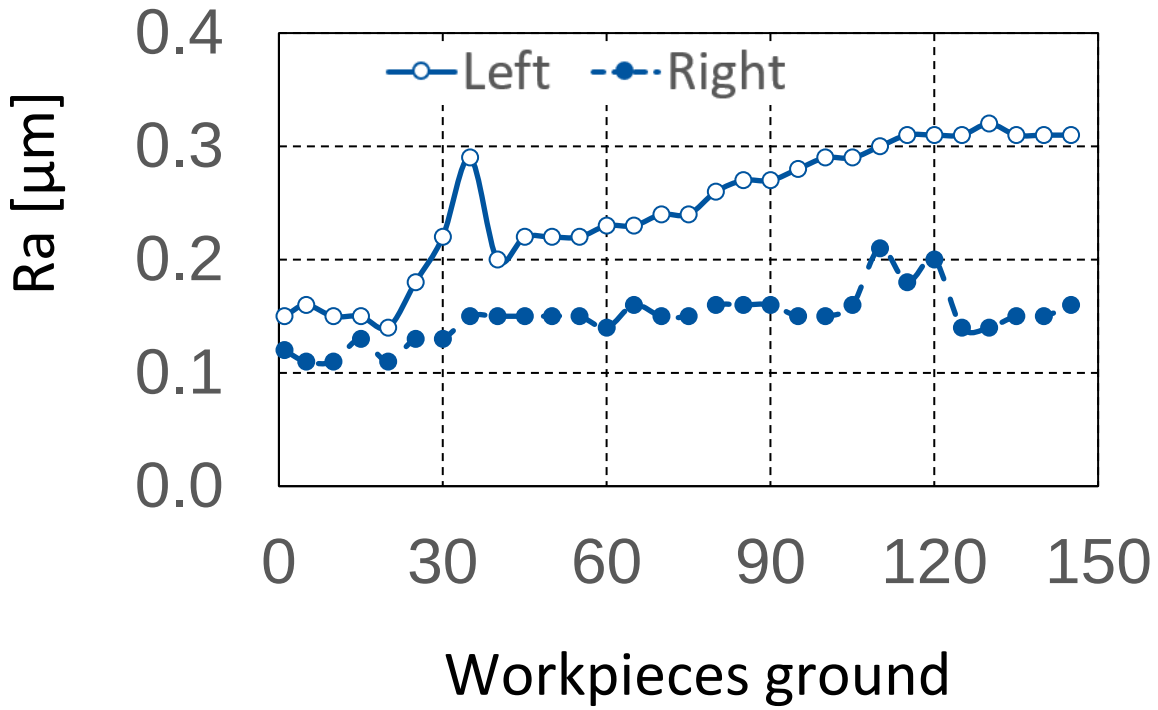
Corundom 1

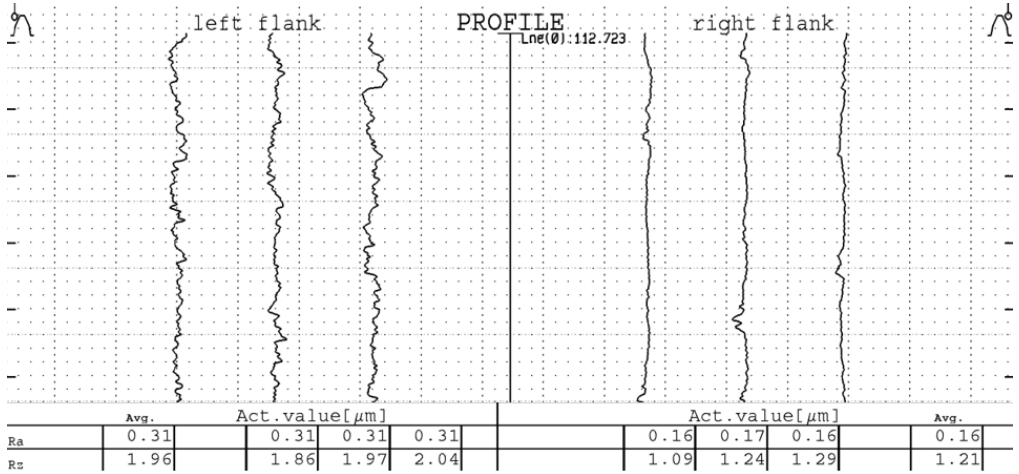




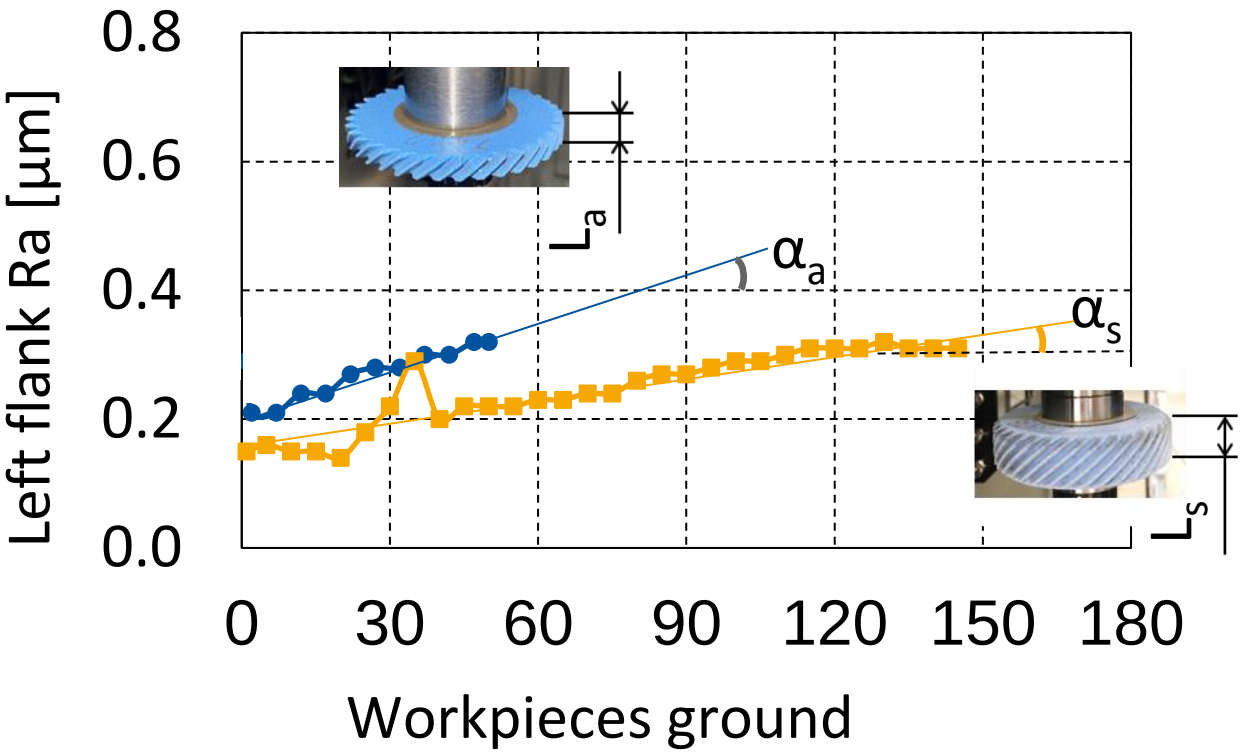
Results of standard process trials

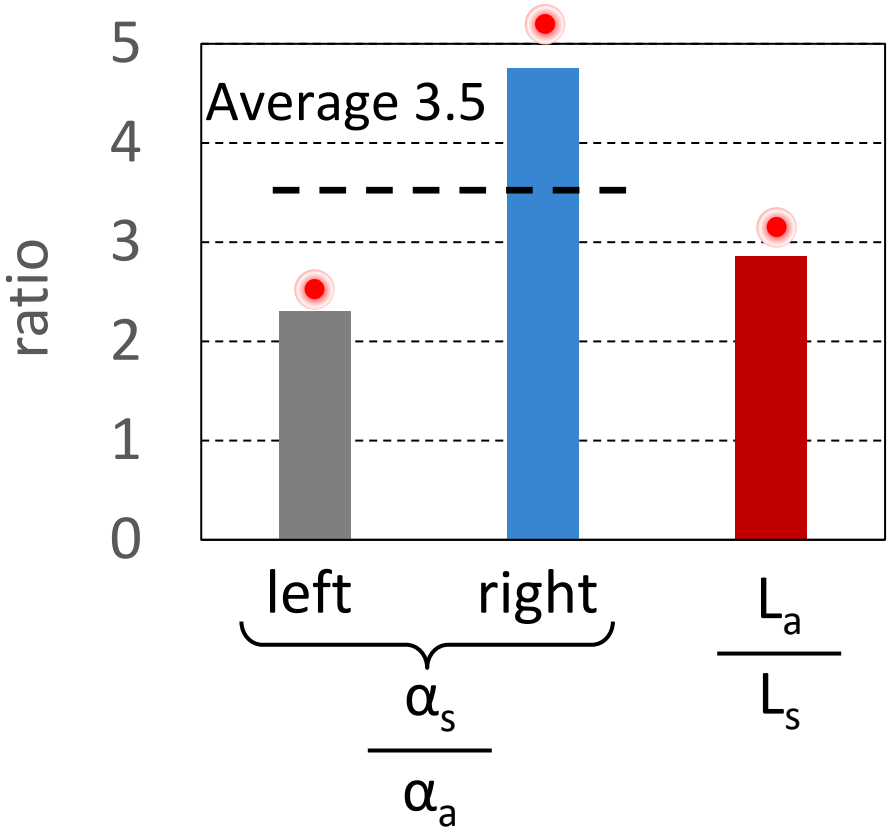
Corundom 1





Evaluation of analogy trials developed





Analogy trial can estimate tool wear in the standard process in a short period efficiently

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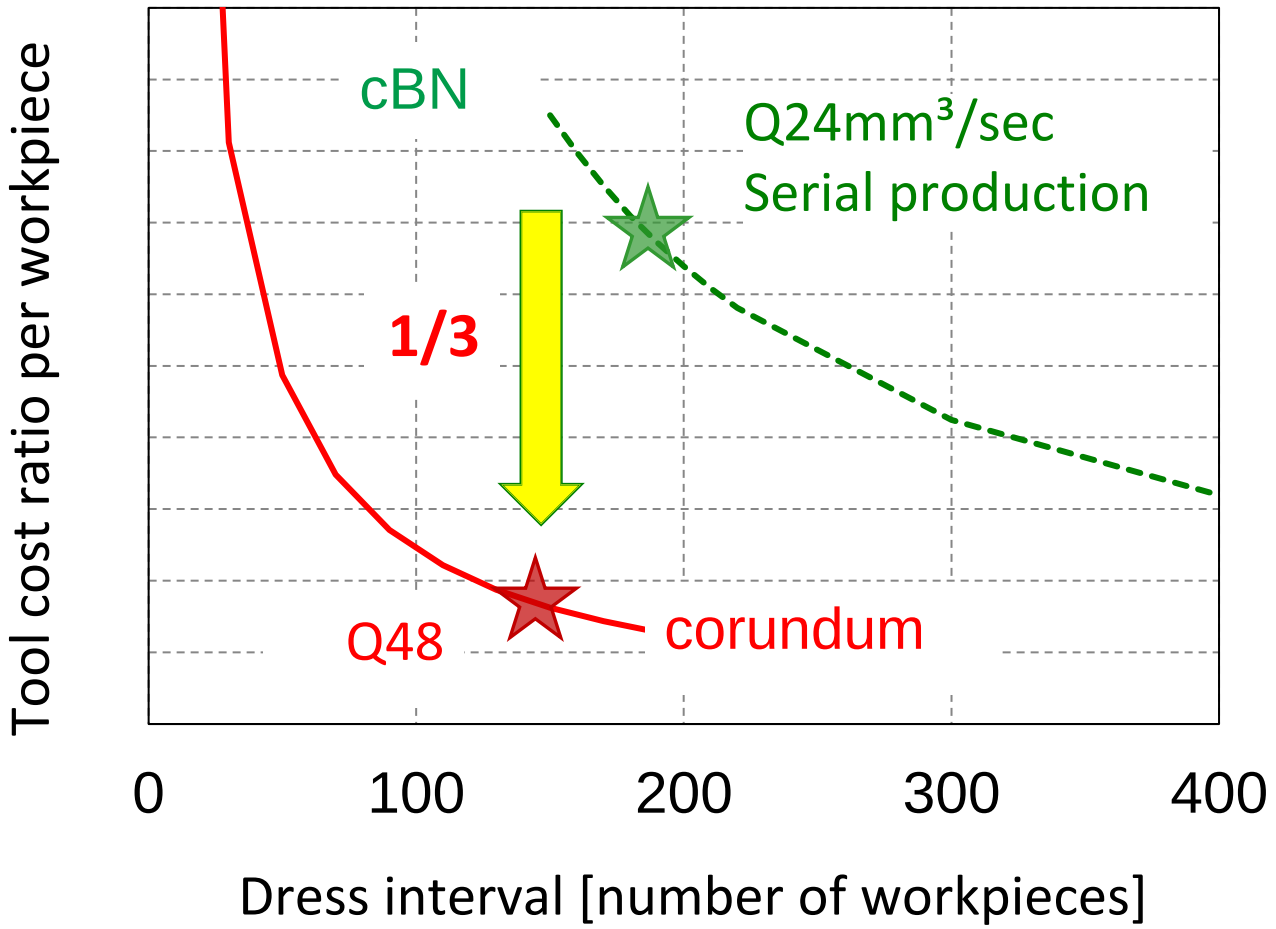
Economic evaluation



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Conclusions

To analyze the influence of corundum and cBN grinding wheels, 2 step trials were performed.

- In the analogy trial, six corundum and one cBN wheels were evaluated. Corundum type 1, which combines normal corundum grains and special shape grains with hardness J, structure 5, showed the best result, quality below ISO4 even after 50 gears ground
- In the Standard process trial, Corundum type 1 showed below ISO4 after 145 gears ground with two times higher removal rate than conventional conditions of cBN. This indicated Corundum type 1 can reduce tooling cost by one third with 30% cycle time reduction than current serial production.
- A correlation between the grinding wheel thickness and the tool ware by means of the surface roughness slope angle can be found. The analogy trial developed is able to estimate tool wear in the standard process in a short period efficiently.

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THANK YOU!
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