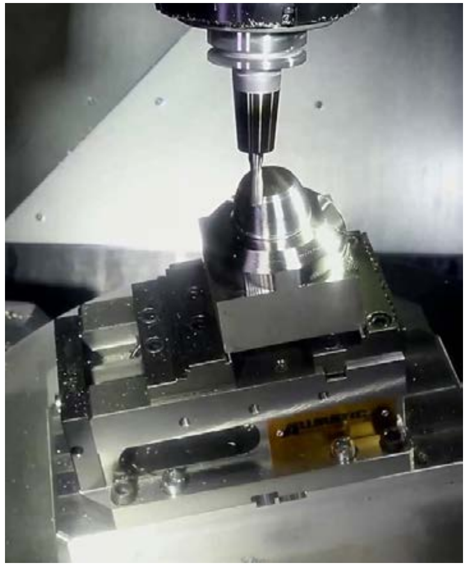
„Special Milling Tools for the Fine Facing Work on Mould & Die Tools"



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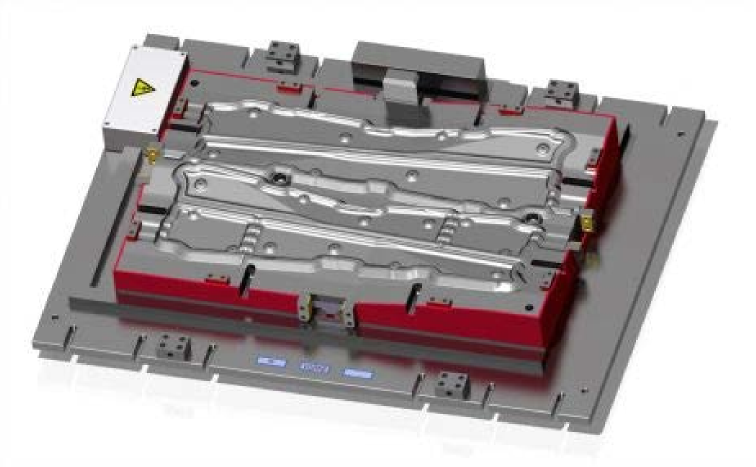
Structure

- Introduction
- Workpieces & Requirements
- Previous Practice
- New Practice
- Tooling
- Cost-effective Analysis
- Summary

Structure



Hot Embossing Tool

Source: Dornbusch GmbH, Hennef (Germany)

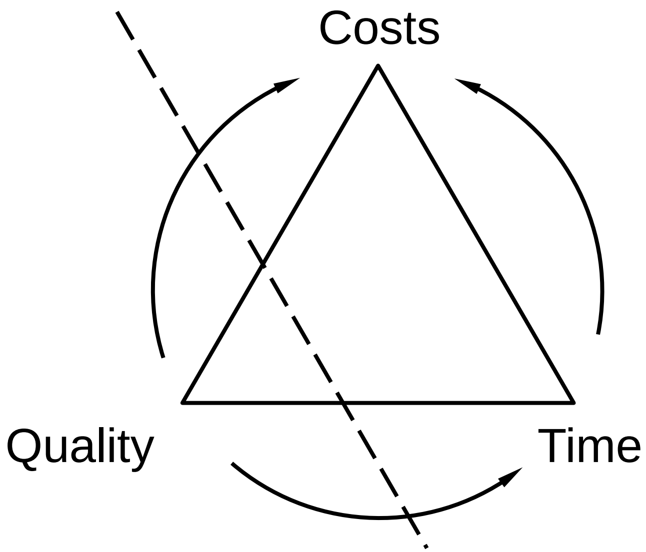
- Introduction
- Workpieces & Requirements
- Previous Practice
- New Practice
- Tooling
- Cost-effective Analysis
- Summary

Variety of Workpieces



- Workpieces of the Mould & Die Industry
- Machining of the cast iron
- characteristic of the surface: free-form surface
- Artefact of Observation: Fine Facing work
- long machining time
- Requirements:
- best surface finish
- fast Manufacturing

Process Improvements: Observation of the Power



-> Quality costs time and capital

To reach the last 5% of the Optimum, very high struggles are necessary.

The objective is, that either the quality increases to a greater extent than the time and capital expenditure, or with the same quality of time and capital expenditure can be reduced!

-> starting points are the sizes that are not yet or only in a small measures are improved, because in these sizes lies the greatest potential!

- For the cutting performance:

$$P_c = z \cdot k_c \cdot A \cdot v_c = k_c \cdot a_p \cdot a_e \cdot v_f$$

- the spec. cutting force can be neglected during finishing work
- the axial cut depth of cut is determined by pre-finishing
- the v_f depends on the f_z and the v_c or from the cutting material or tool-life
- The radial depth of cut can be identified as the design size. Thus:
- $$a_e = B_r \cdot \cos \Delta\kappa$$
- -> analysis of the groove width B_r of the surface profile is necessary

Structure

Blow Moulding

Source: Dornbusch GmbH, Hennef (Germany)

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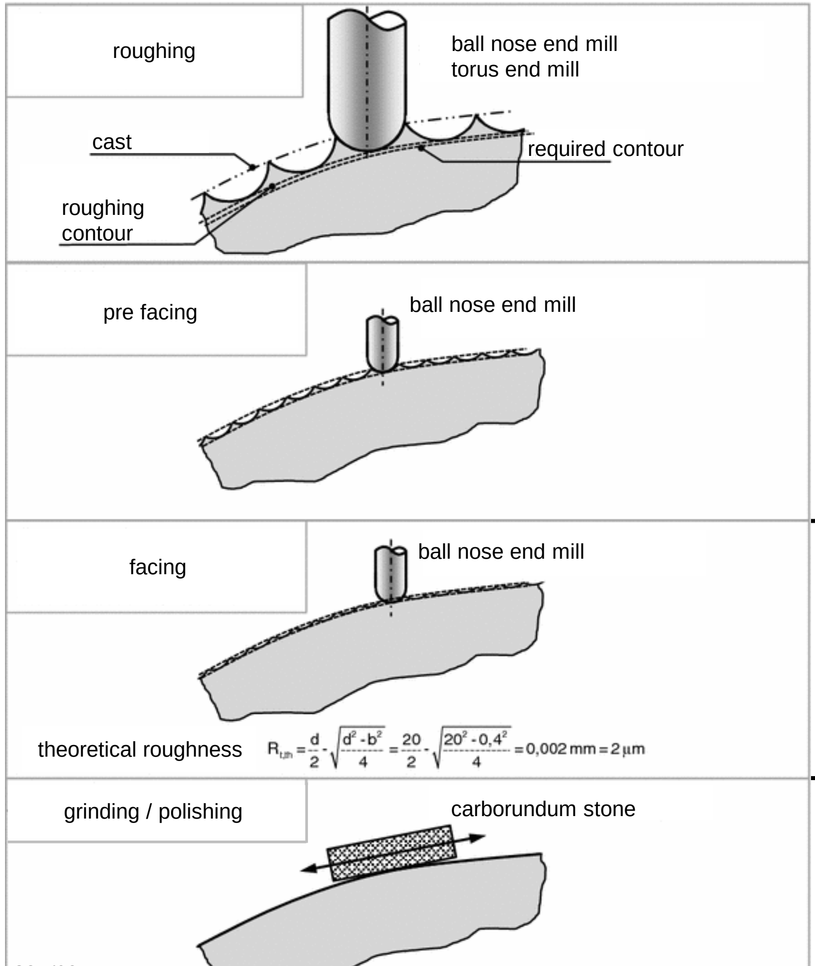
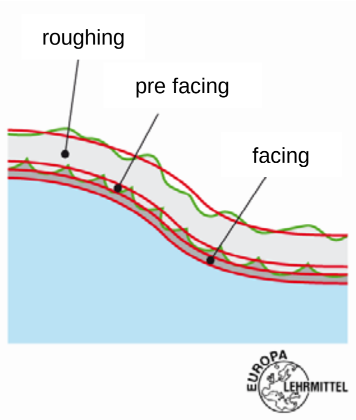
Facing Work – Fine Facing Work



source:
Birkert, Haage Straub:
Umformtechnische Herstellung komplexer Karosserieteile. Springer-Verlag, 2013



common values:

groove width B_r :	1,0 ÷ 1,2 mm
surface roughness R_t:	18,0 ÷ 12,5 µm

material allowance:	0
axial depth of cut a_p :	0,1 mm
corner radius r_ε:	10 mm
groove width B_r :	0,3 ÷ 0,4 mm
surface roughness R_t:	2 µm

- process steps:

I. Roughing Work

II. Facing Work

II.a Pre Facing

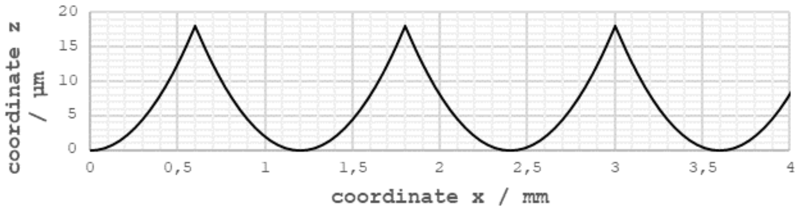
II.b Fine Facing

II.c Grinding / Polishing

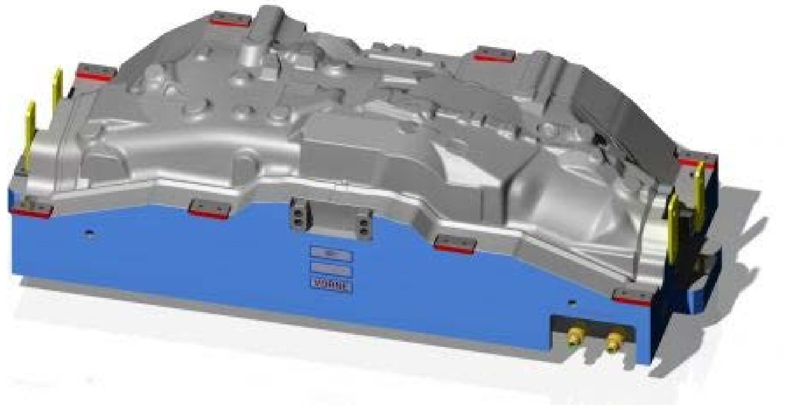
- Geometrical is:

$$R_t = r_\varepsilon - \sqrt{r_\varepsilon^{\,2} - \frac{1}{4}\cdot L_r^{\,2}} \approx R_z \qquad L_r = 2\cdot\sqrt{R_t\cdot\left(2\cdot r_\varepsilon - R_t\right)}$$

- Starting Profile :



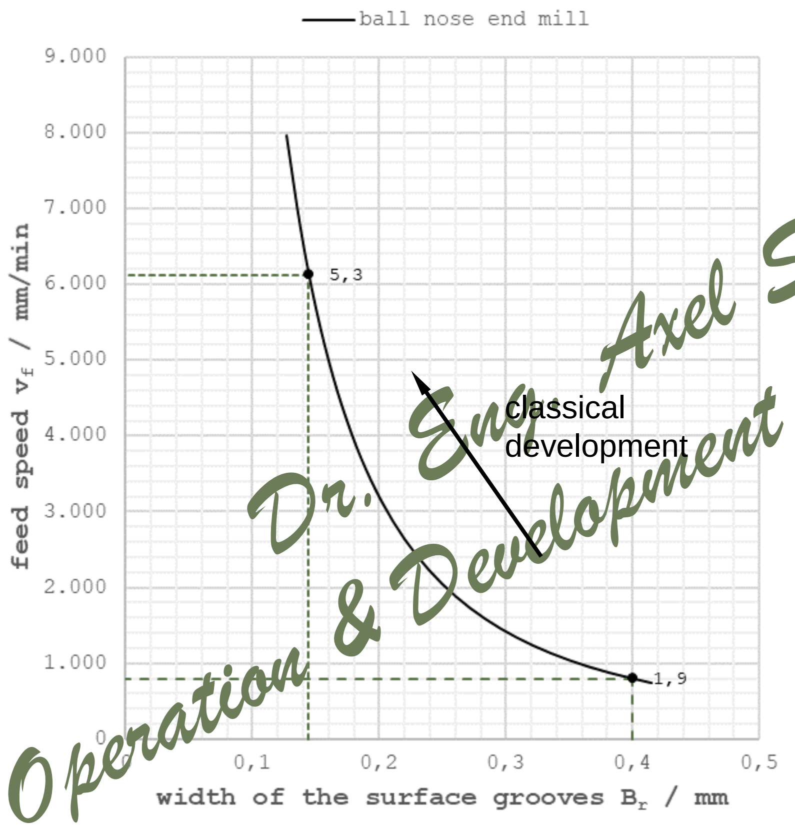
Structure



Foaming Mould

source: Dornbusch GmbH, Hennef (Germany)

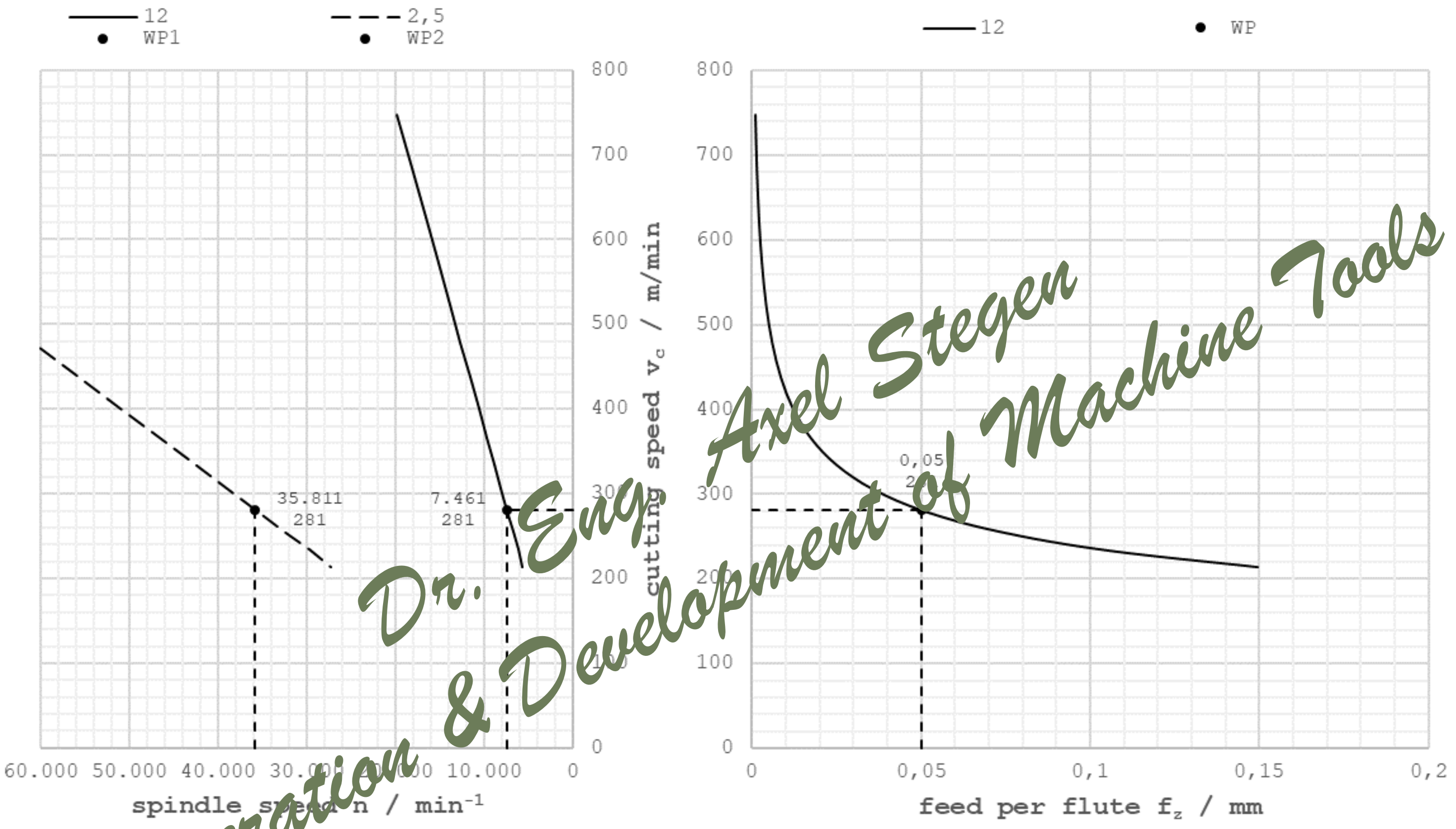
Production Chart – Facing Work



- Abbreviation of the machining time
  -> higher feed speed
- technical limits
- often confusion:
  High-Speed Cutting und
  machining with high rpm respectively
  with higher feed speed
- essential is the realised surface production rate Q_A!

$$Q_A = B_r \cdot v_f = B_r \cdot z \cdot f_z \cdot n$$

Production Chart – Roughing Work



If only the diameter changes, but the cutting speed remains the same, there is no high-speed cutting!

- feed per flute is given
- Tool-life defines the cutting speed
- by facing operations it is important to realise tool changes as low as possible, for not to endanger the surface quality!
- at the same cutting speed, but different diameters you can find the typical rpm range of so-called HSC-machines

-> Please distinguish between *spindle speed* and *surface speed*!

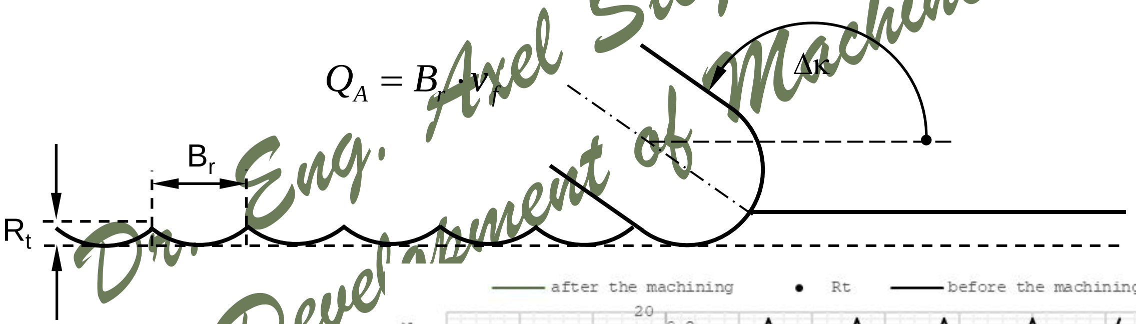
Selection of the Tool

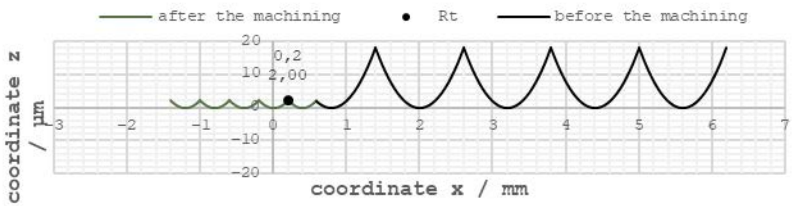
Prof. Dr.-Eng.
Georg Schlesinger
T.H. Berlin

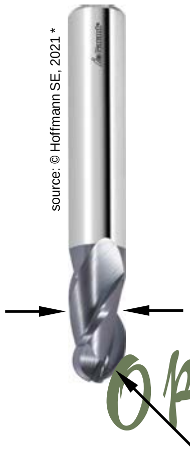
„On the cutting edge of the tool sit the dividends,
the speed of these cutting edges is a function
of the machine moving them, and in the case of the
increasing wages therefore the machine tool is trump.“

source: Z.VDI Bd. 55 Nr. 49 S.2042, 1911

$$Q_A = B_r \cdot v_f$$







tool diameter D_{WZ}

corner radius r_ε

$$r_\varepsilon = \frac{1}{2} \cdot D_{WZ}$$

accuracy of the radius:	±5 µm
costs:	ca. 110,-

- classical Tool:
  ball nose end mill or total radius end mill
- often the corner radius is restricted
  by constricted rooms at the workpiece
- low distance of the machining traces
- enormous expenditure of time for the manufacturing

T.H.: Imperial School of Technology

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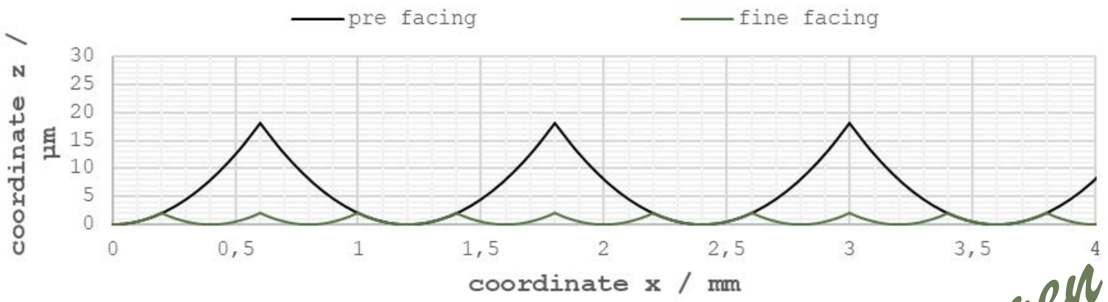
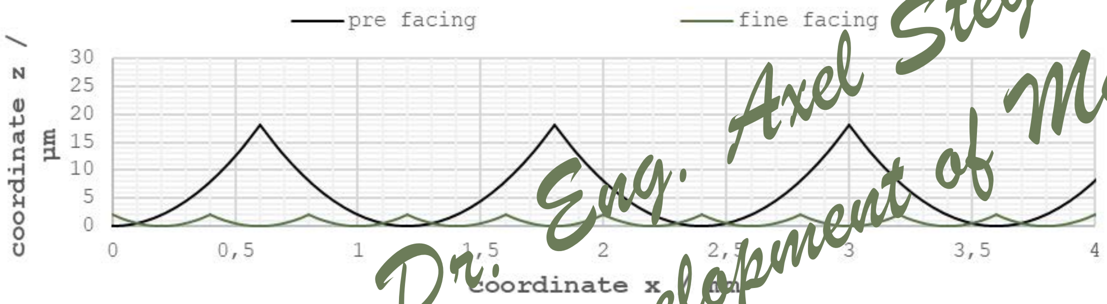
Calculated Surface Profile – Cutting with classical Ball Nose End Mill

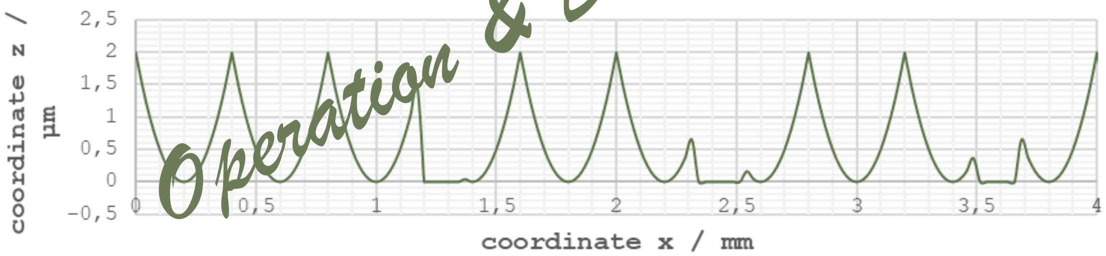


pre-faced
surface profile

fine-faced surface
profile



not founded
pre-face groove



result of a not founded
pre-face groove

- If the width of the profile's grooves are integer of each other, good circum-stances are visible.
- problem: starting point of cutting by fine-facing
- if the pre-face groove is not founded, it follows:

Structure

Reaction-Injection Moulding (RIM)

source: Dornbusch GmbH, Hennef (Germany)

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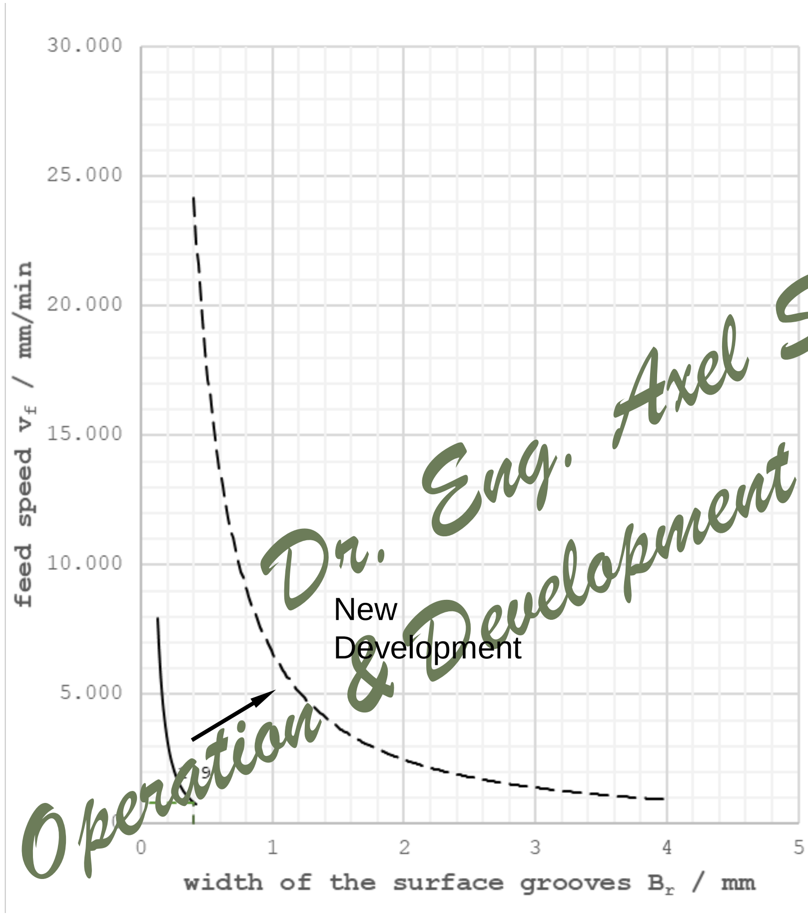
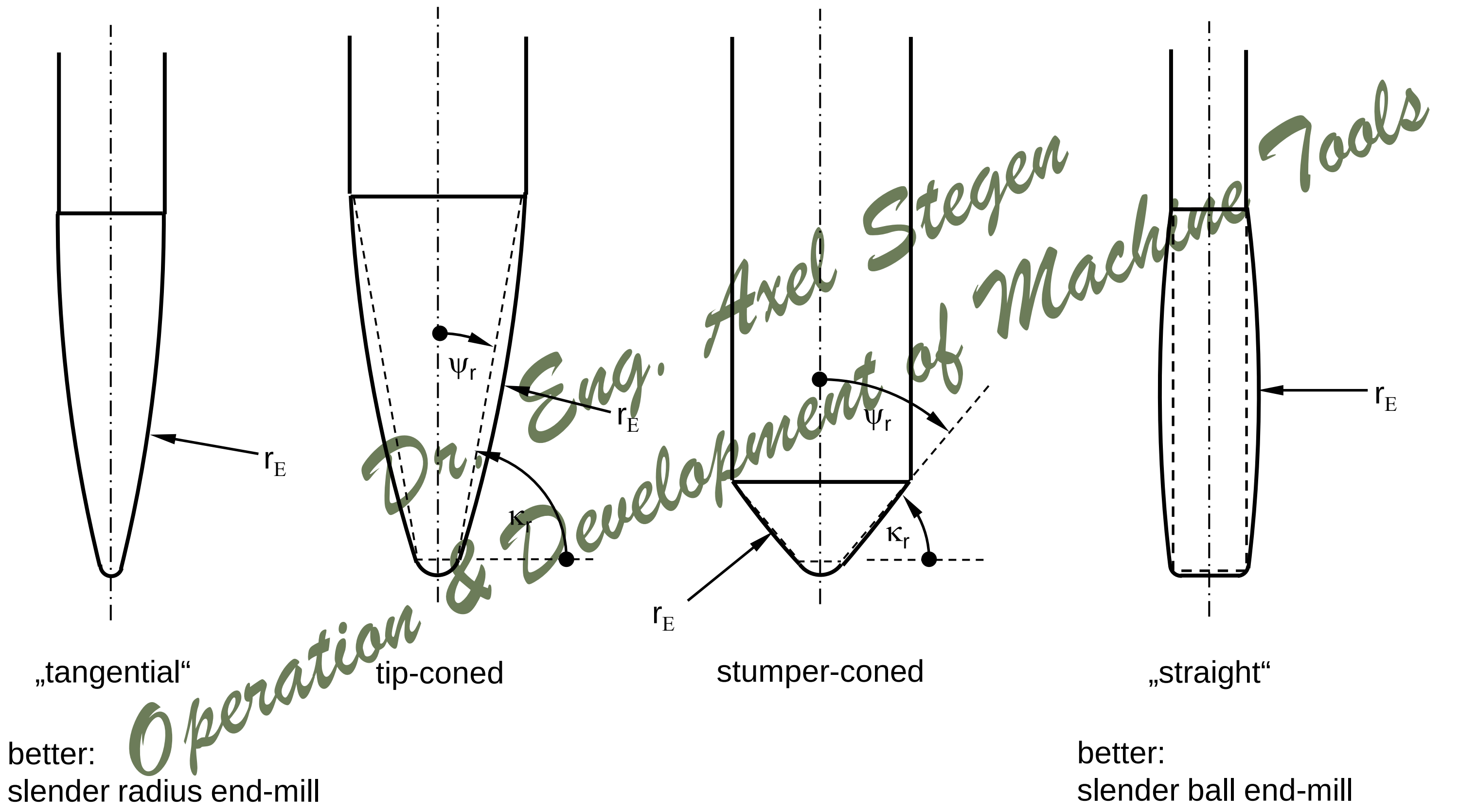
Production Chart – Facing Work



- Increasing of the surface production rate
- Increasing of the radial infeed
- Feed speed do not has to increase so much
- Decoupling of corner radius and tool diameter is necessary
- Result: Special Milling Tools

Tool: Width-Facing-End-Mills – Available Variances



- skin surface of cylindrical tools can be curved convex

->crown bow

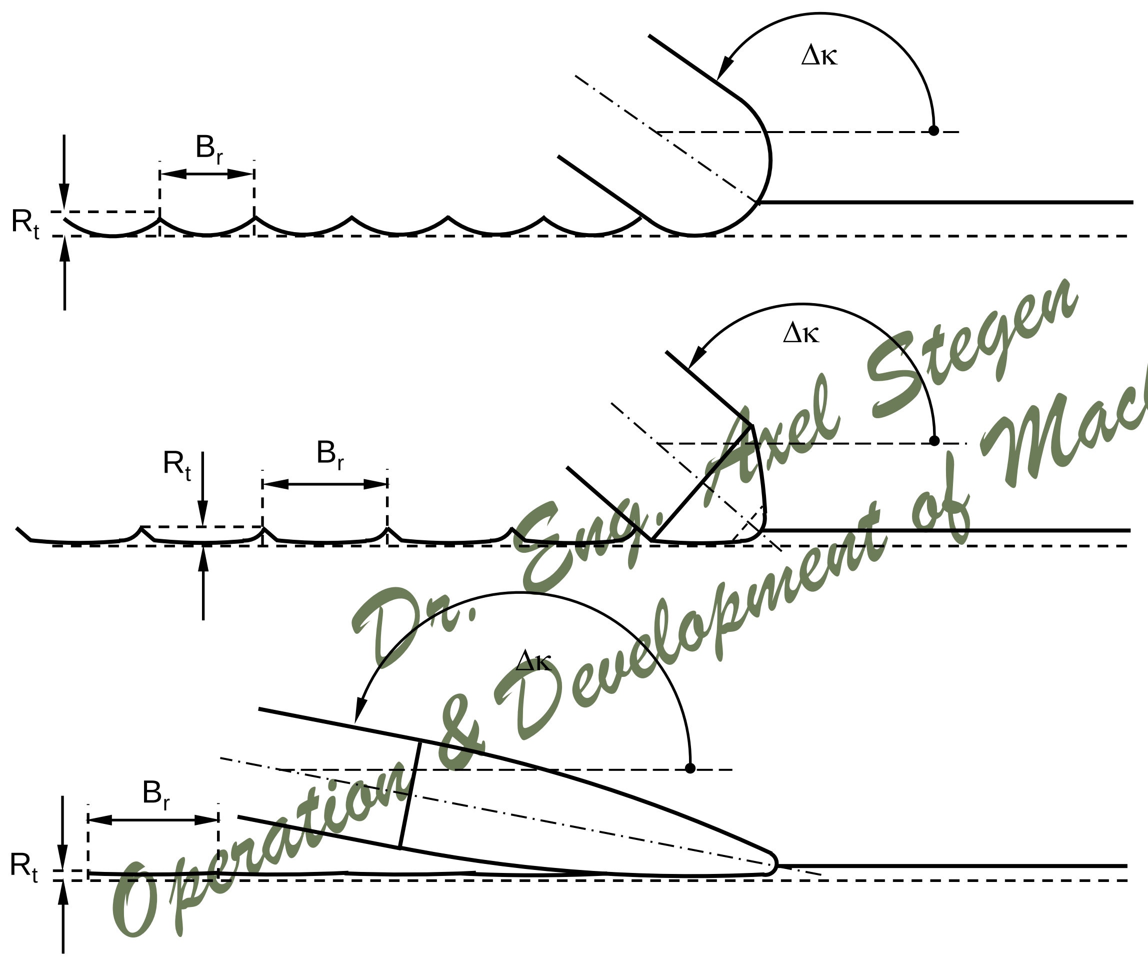
- trade description: „Parabolic Performance Cutting“

$$y = a \cdot x^2 + b \cdot x + c$$

$$y = -\left(a \cdot x^2 + b \cdot x + c\right) - \frac{1}{d} \cdot y^2$$

- Data Processing: Circle is approximated by polynomials (CAD) !

Tool: Width-Facing-End-Mills – Orientation in Practice



- For the difference tool cutting edge angle of the ball nose end mill is:

$$\cos \Delta\kappa = 1 - \frac{a_p}{r_\varepsilon}$$

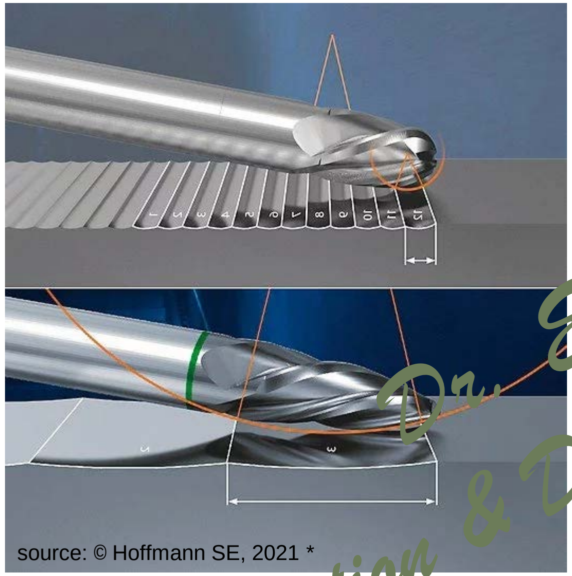
- For the difference tool cutting edge angle of the conical barrel mill is:

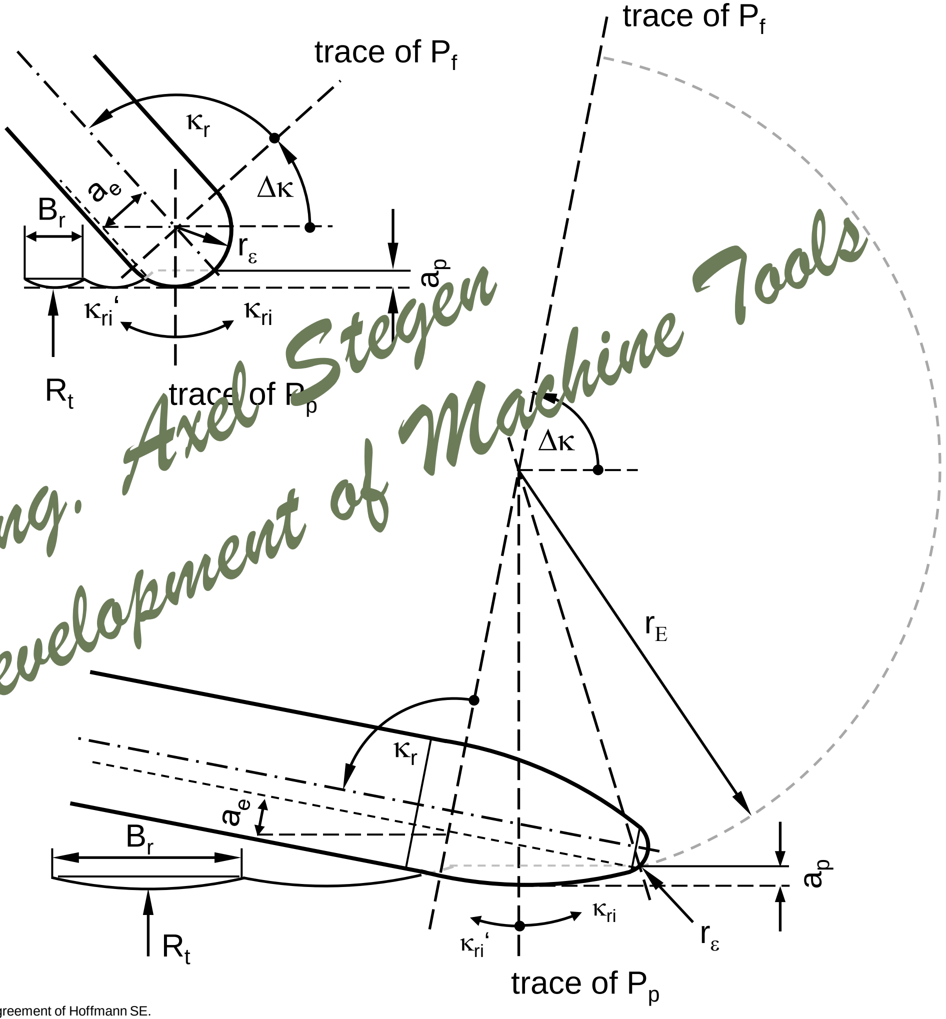
$$\Delta\kappa = \kappa_r$$

- For the difference tool cutting edge angle of the tangential barrel mill is:

$$\sin \Delta\kappa = 1 - \frac{a_p}{r_E}$$

Tool: Width-Facing-End-Mills





Accuracy of the radius: ±5 µm
costs: ca. 300,-

- Design plane: tool reference plane P_r
- available skin radii r_E :
  80÷1.200 mm

$$B_r = 2 \cdot B_r' = 2 \cdot r_\varepsilon \cdot \sin\kappa_r' = 2 \cdot \sqrt{R_t \cdot (2 \cdot r_\varepsilon - R_t)}$$

$$B_r = 2 \cdot B_r' = 2 \cdot r_E \cdot \sin\kappa_r' = 2 \cdot \sqrt{R_t \cdot (2 \cdot r_E - R_t)}$$

$$\cos\kappa_{ri}' = 1 - \frac{R_t}{r_E} \qquad \cos\kappa_r = 1 - \frac{a_p}{r_E}$$

$$a_e = (B_r' + B_r) \cdot \cos\Delta\kappa$$

$$a_e = \left[\sqrt{R_t \cdot (2 \cdot r_\varepsilon - R_t)} + \sqrt{a_p \cdot (2 \cdot r_\varepsilon - a_p)}\right] \cdot \cos\Delta\kappa$$

$$a_e = \left[\sqrt{R_t \cdot (2 \cdot r_E - R_t)} + \sqrt{a_p \cdot (2 \cdot r_E - a_p)}\right] \cdot \cos\Delta\kappa$$

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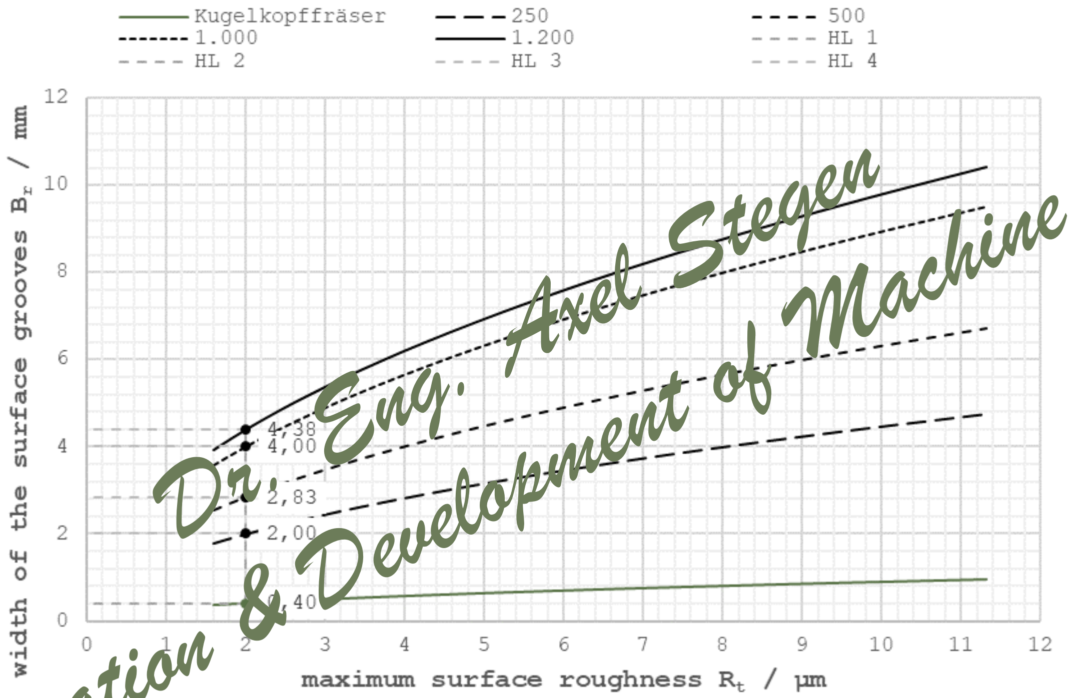
Tool: Width-Facing-End-Mills


source: © Hoffmann SE, 2021 *




source: © Hoffmann SE, 2021 *

- Comparison of the reachable width of the groove for different tools:

$$B_r = 2 \cdot B_r' = 2 \cdot r_\varepsilon \cdot \sin\kappa_r' = 2 \cdot \sqrt{R_t \cdot (2 \cdot r_\varepsilon - R_t)}$$

$$B_r = 2 \cdot B_r' = 2 \cdot r_\mathrm{E} \cdot \sin\kappa_r' = 2 \cdot \sqrt{R_t \cdot (2 \cdot r_\mathrm{E} - R_t)}$$

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Tool: Width-Facing-End-Mills

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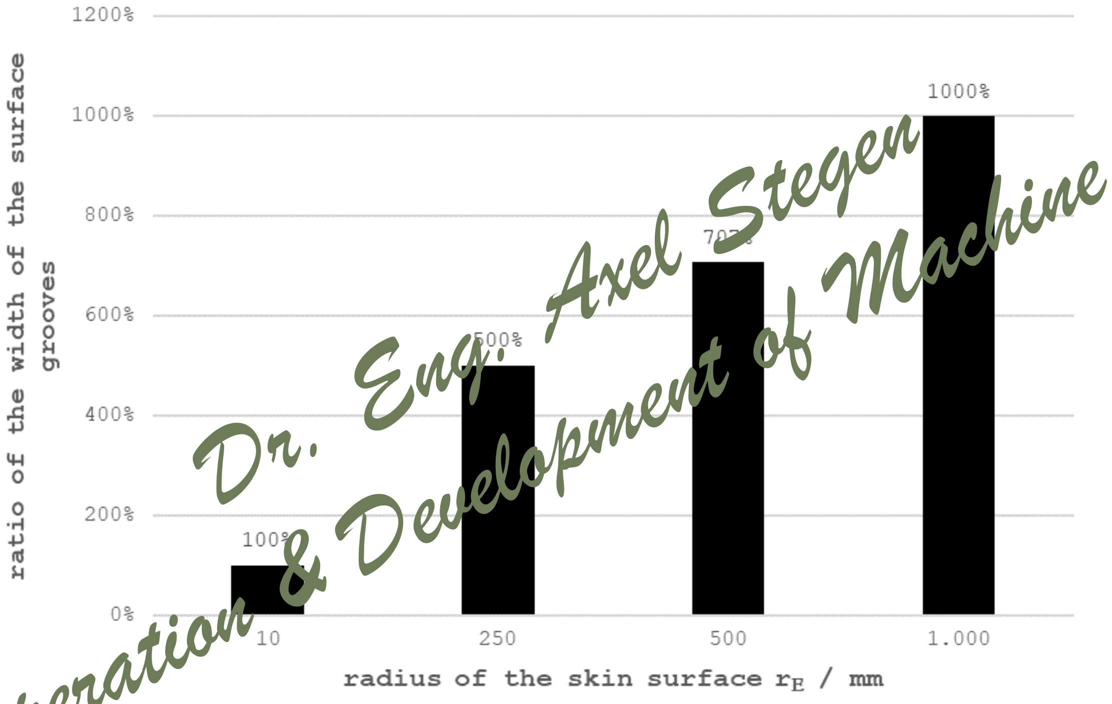

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- Ratio of the width of the grooves for different tools:

$$\frac{B_{rBS}}{B_{rKF}} = \sqrt{\frac{2 \cdot r_E - R_t}{2 \cdot r_\varepsilon - R_t}}$$

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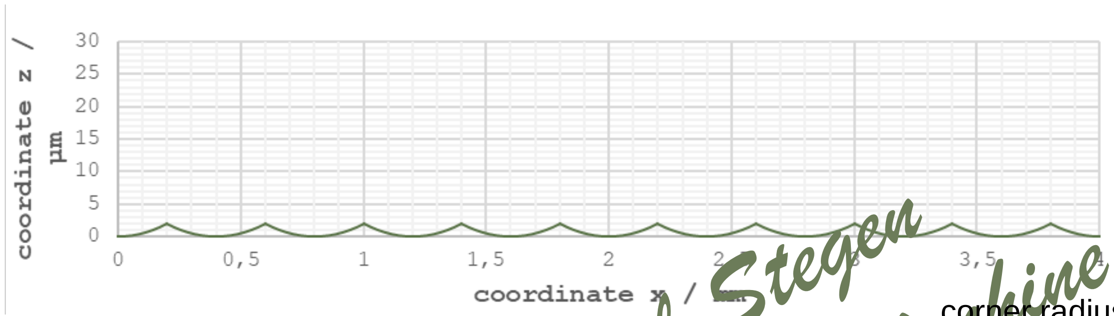
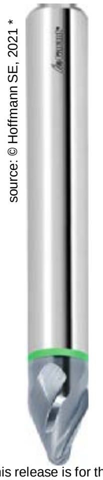
Comparison of Surface Profiles

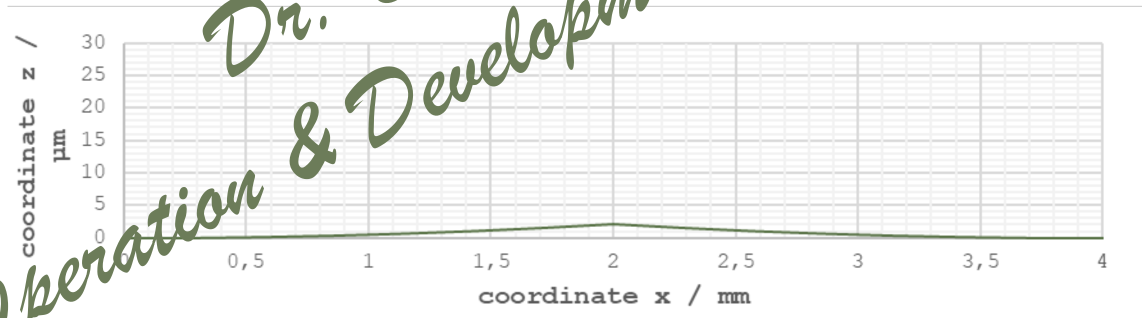
source: © Hoffmann SE, 2021 *



corner radius r_ε = 10 mm

source: © Hoffmann SE, 2021 *





skin surface radius r_E = 1.000 mm

- Difference of the grooves for ball nose end-mill:
  B_{rKK} = 0,4 mm (100%)
- Difference of the grooves for the width-facing-end mill:
  B_{rBS} = 2,2 mm (548 %)
- Consideration of the rest area informs about the average surface finish R_a.
- previous: Considerations by the same maximum roughness R_t
- The situation changes, if the average surface finish should be the same.
- The width of the grooves B_r is thereby limited!

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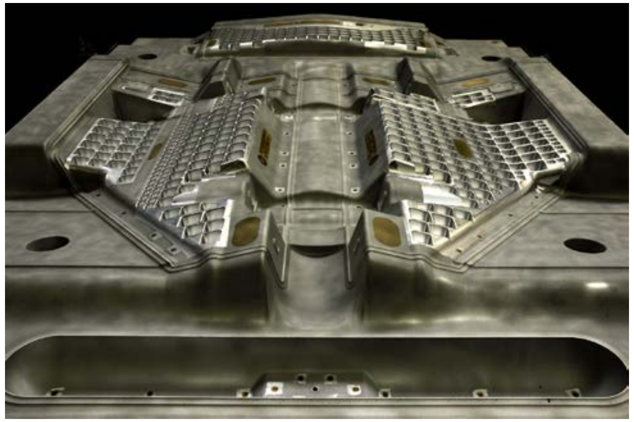
Structure

Forming- & Punching Tool

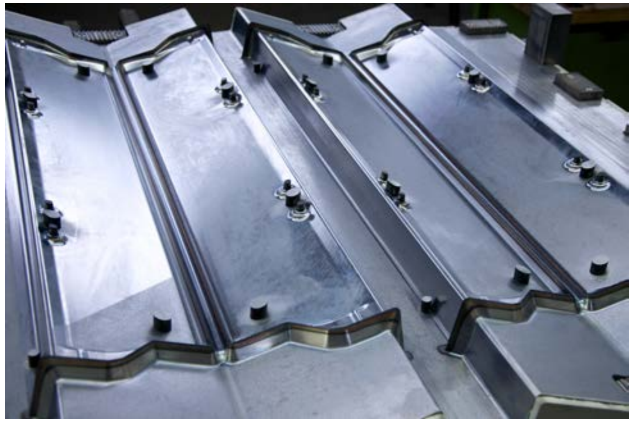
source: Dornbusch GmbH, Hennef (Germany)

Different Tools

Blow form of a Tank



Blow form of a Casing of a Powertrain



Embossing-Clinching-Tool Soil of a Boot

Forming-Punching-Tool Heat Shield

source: Dornbusch GmbH, Hennef (Germany)

- Blow Forms
- Hot Embossing Tools
- Vehicle Manufacturing

Machine Tool


source: WISA Werkzeug & Formenbau

source: F. Zimmermann

- Appropriation and coordination of 5-Achsen
- 3 translational and 2 rotatory axes
- all axes have to be controlled or moved simultaneously
- Programming is carried out by a pro-gramming system (CAM)

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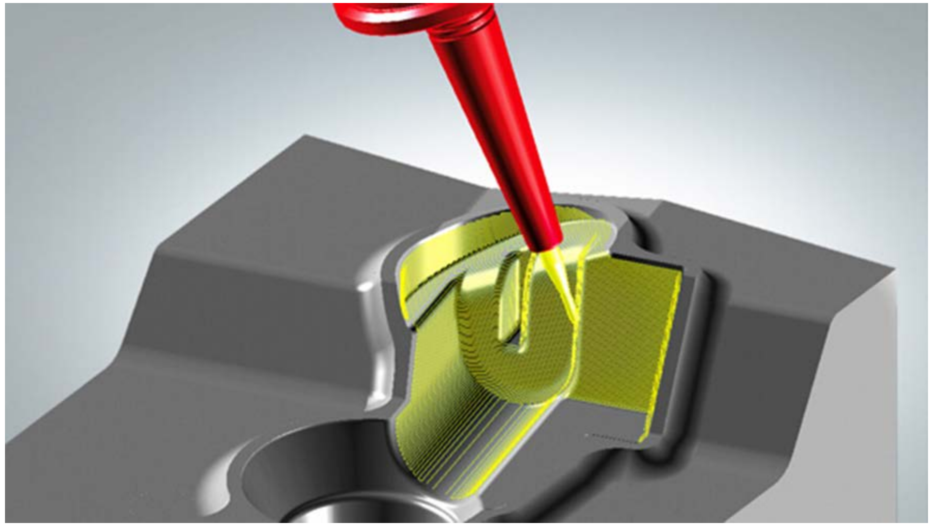
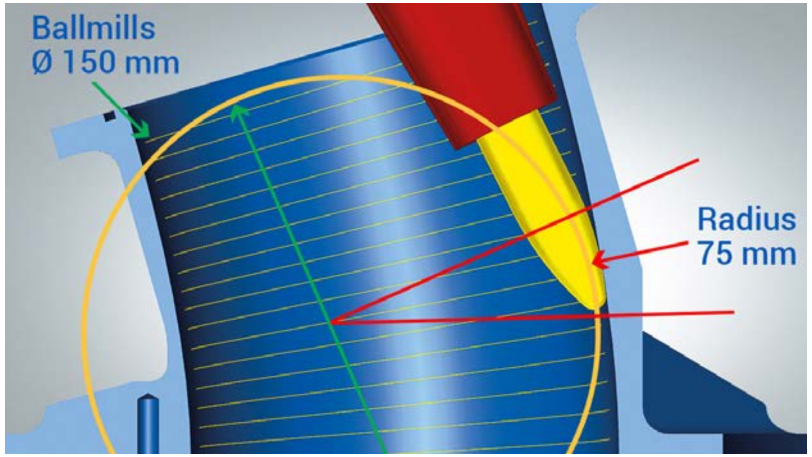
Programming Systems



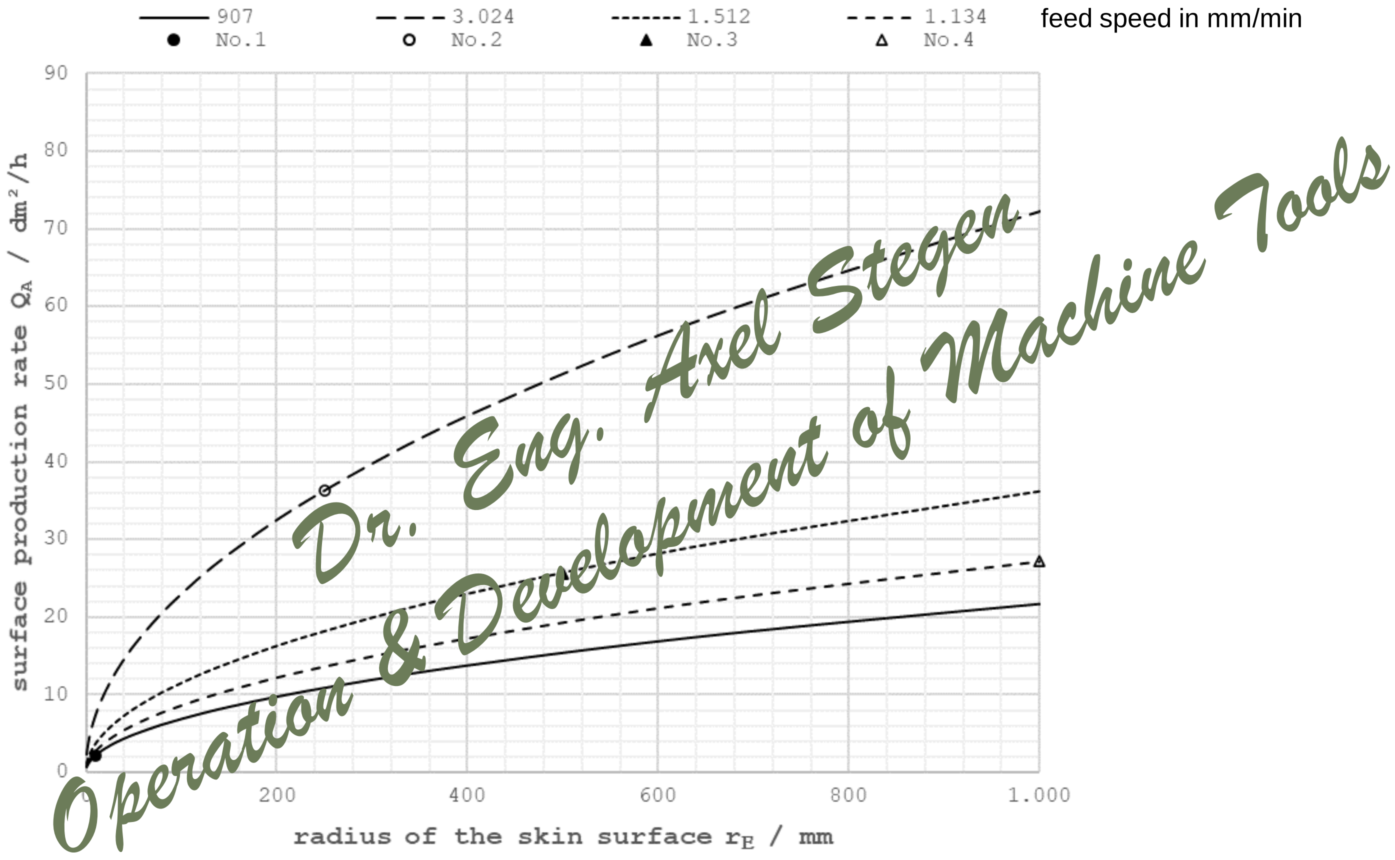
source: OPEN MIND



- Programming systems enables a continuous orientation between workpiece and tool or vice versa
- A cooperation between a producer of programming systems and a tool manufacturer makes this progress available!
- Science and machine tool manufac-turers do not take part by the progress.

Structure

Cost-effective Analysis: The Delivery Quantity – Surface Production Rate



- For the delivery quantity by facing work is:

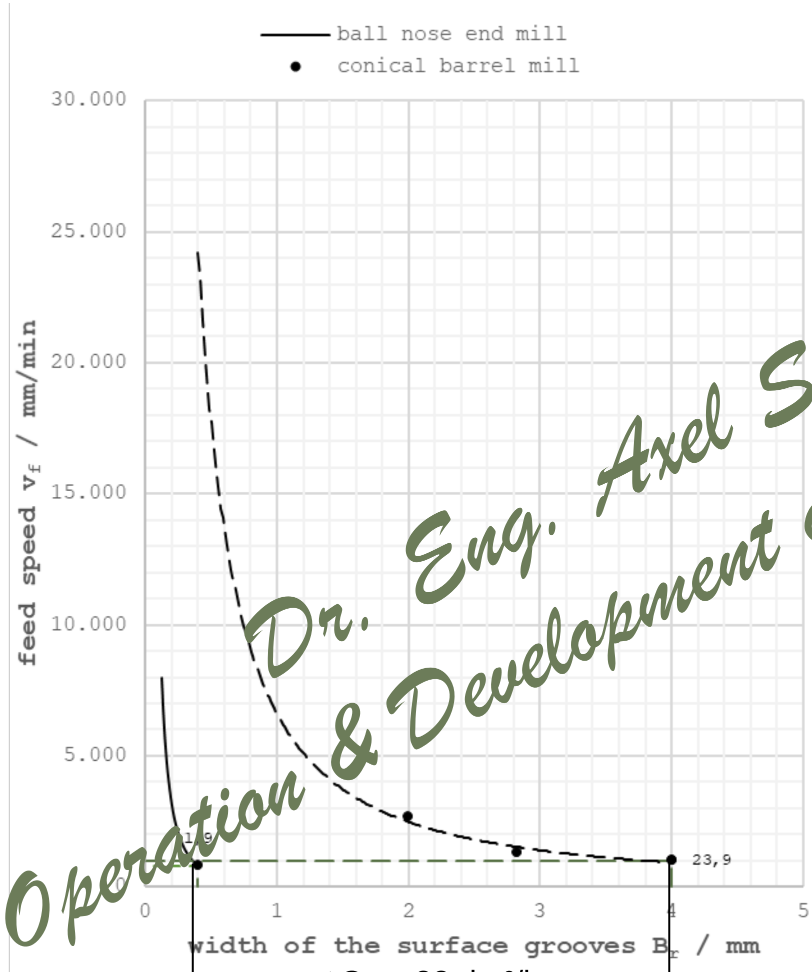
$$Q_A = B_r \cdot v_f$$

- By the same cutting conditions, the width of the grooves B_r can also be considered as removal rate!
- It is also:

$$Q_A = 2 \cdot \sqrt{R_t \cdot (2 \cdot r_E - R_t)} \cdot v_f$$

- large corner radii also increase the delivery quantity!
- but low radial depth of cut a_e leads to shorter contact times of cutting edge and workpiece, so tool-life is longer!

Cost-effective Analysis: The delivery quantity – Surface Production Rate



ΔQ_A = 22 dm²/h
(+1.150%)

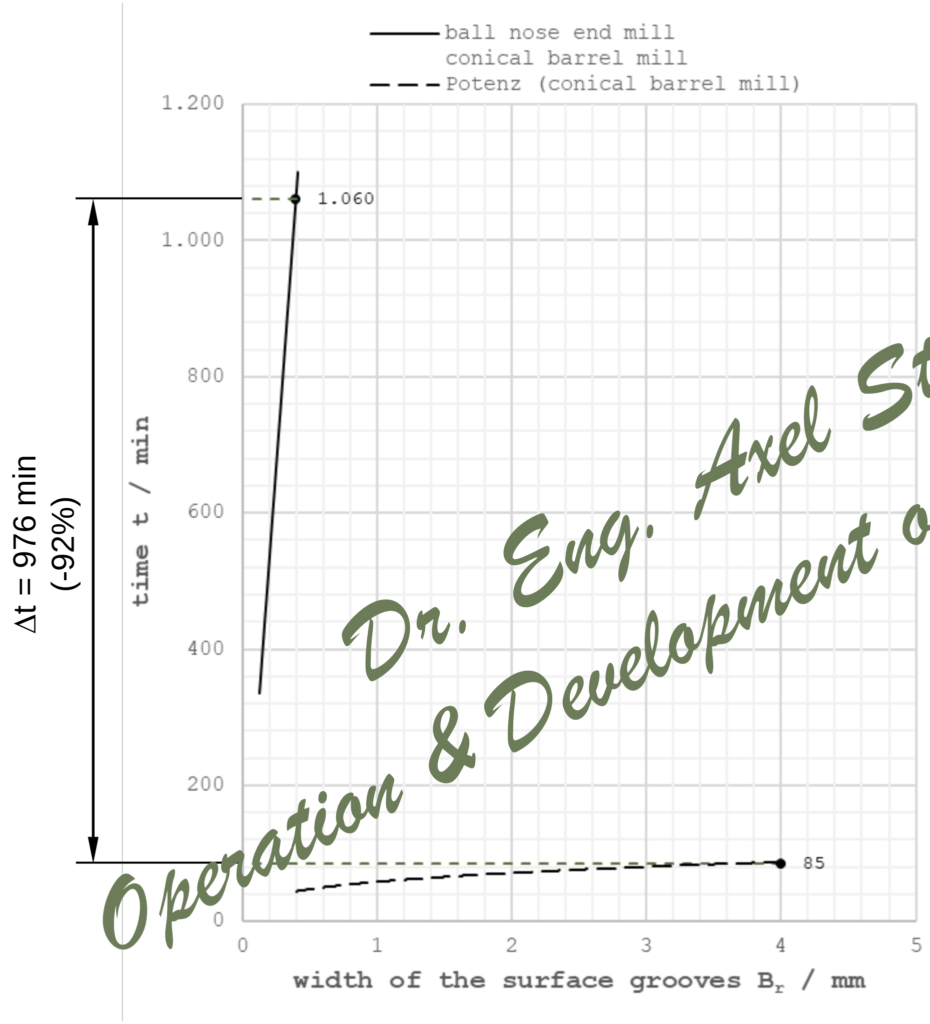
- constant cutting speed v_c
- constant feed per tooth f_z
- same diameter of the tool D_{WZ}

- For the delivery quantity by the facing work is:

$$Q_A = \frac{A_{WST}}{t} = B_r \cdot v_f$$

- By the same feed speed, the surface production rate can increase by 22 dm²/h (1.150%)

Cost-effective Analysis: The Machining Time

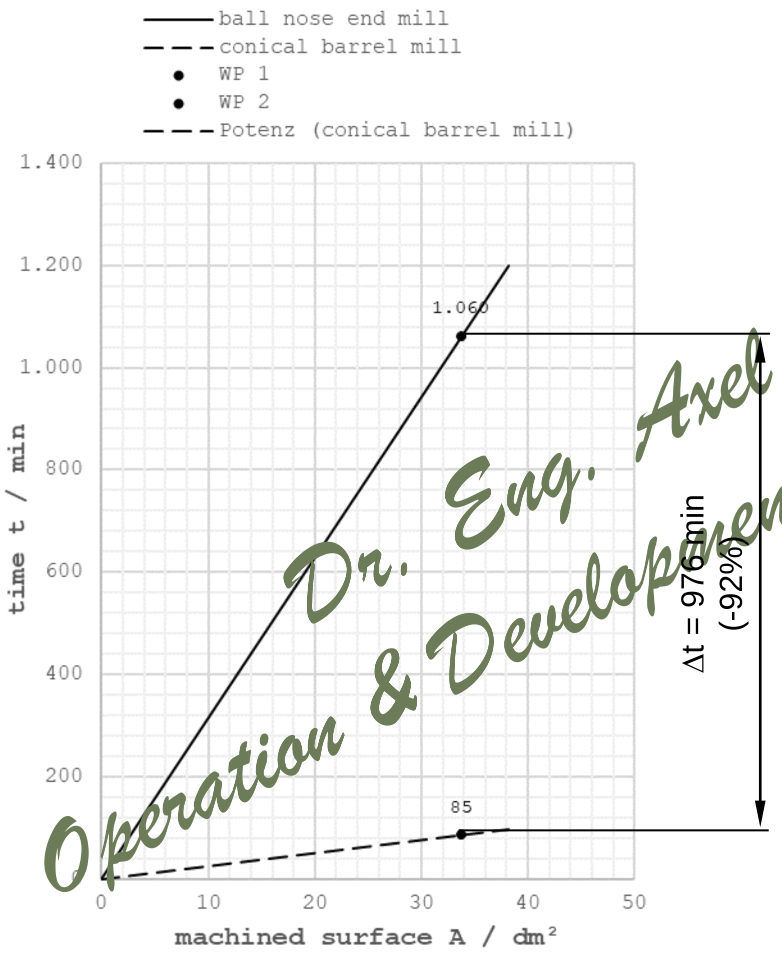


- For the delivery quantity by the facing work is:

$$Q_A = \frac{A_{WST}}{t} = B_r \cdot v_f$$

- What is the influence on the machining time?
- By the same conditions, the machining time can reduce of 976 min (-92%)

Cost-effective Analysis: The Machining Time



- Note:
- The surface production rate is improved.
- The effect of the time is higher, if the manufactured surface is larger!

$$t = \frac{A}{Q_A} = \frac{A}{L_f \cdot v_f}$$

$$\Delta t = \frac{A}{Q_{A2}} - \frac{A}{Q_{A1}} = \frac{Q_{A1} - Q_{A2}}{Q_{A2} \cdot Q_{A2}} \cdot A$$

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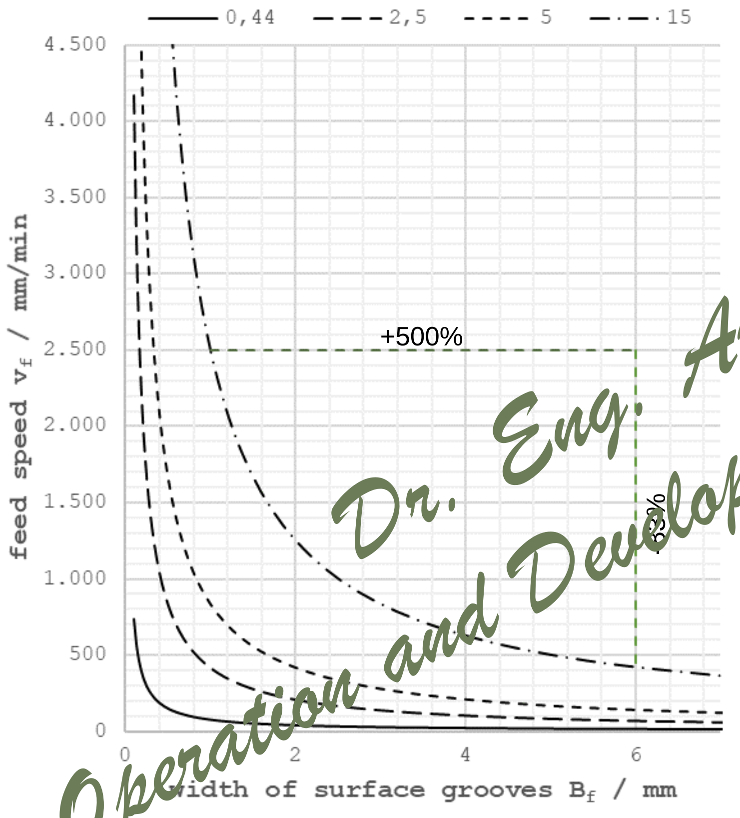
Cost-effective Success: The Trick of Improvement

- For generating a surface rapidly, a width groove and a high feed speed has to be select.
- previous: generating a lot of grooves and every groove has to be generated fast.
- new: generating less grooves, so that there is more time for every groove.

Cost-Effective Success: The Trick of Improvement



- The width of the groove B_r will be much more increased by the same surface production rate, as the feed speed is decreased.

Structure

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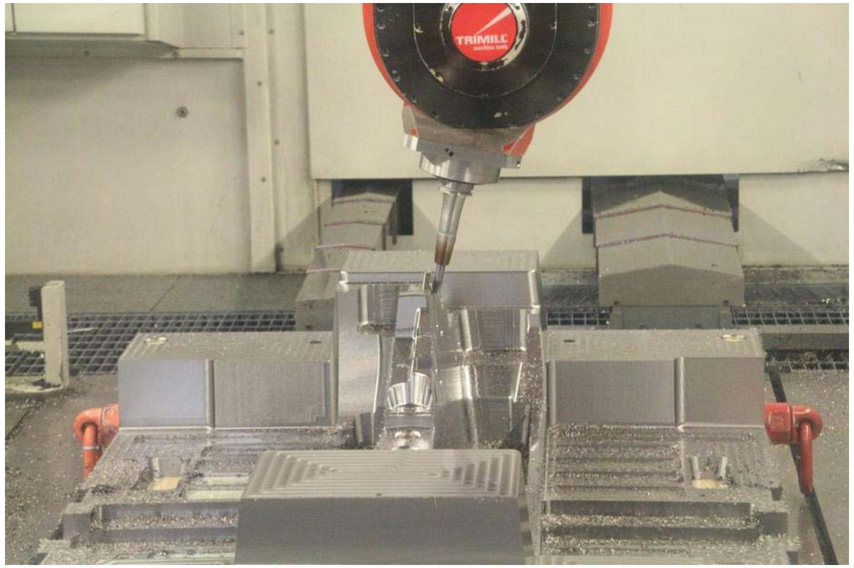
Summary



source: Koller Formenbau

- Overview over the workpieces
- Analysis of the previous machining
- Identification of the tool design as improvement
- by the possibilities of modern machine tools and programming systems cutting advantages are available, which were utilised exemplarily.

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