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TOP 7:
Kaltfließpressen von Verzahnungen im modifizierten Samanta-Verfahren

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Agenda

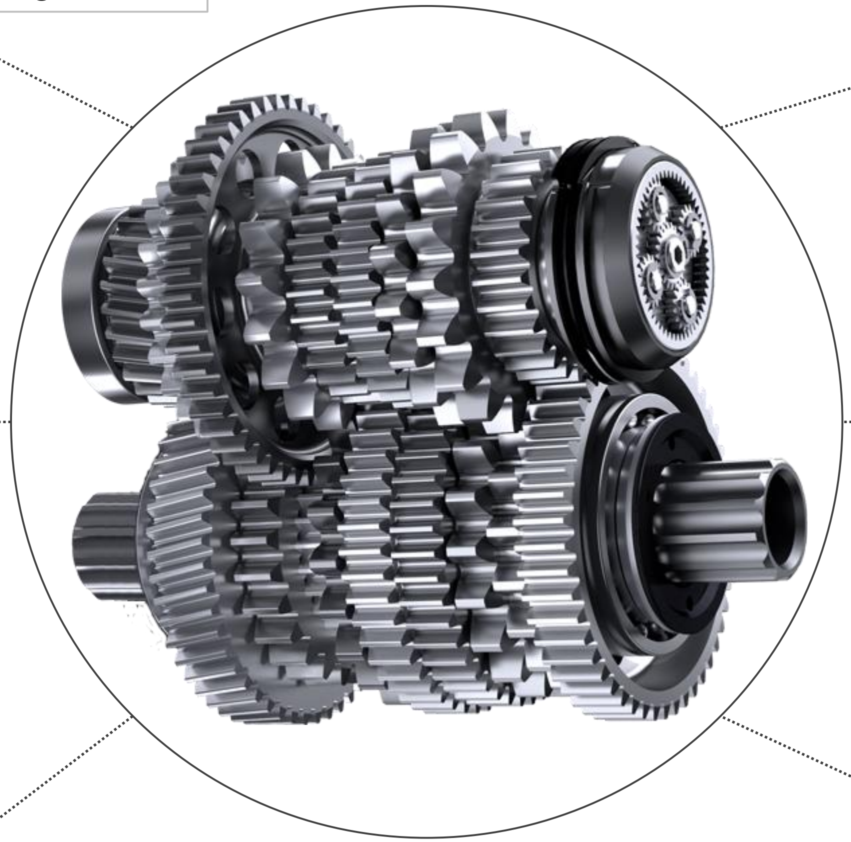
- **Introduction**
- Guided Material Flow (GMF)-process V1
- Guided Material Flow (GMF)-process V2
- Numerical investigations
- Summary and Conclusion

Introduction

Technological challenges of gear manufacturing

Minimal manufacturing costs

High surface quality



Lightweight design

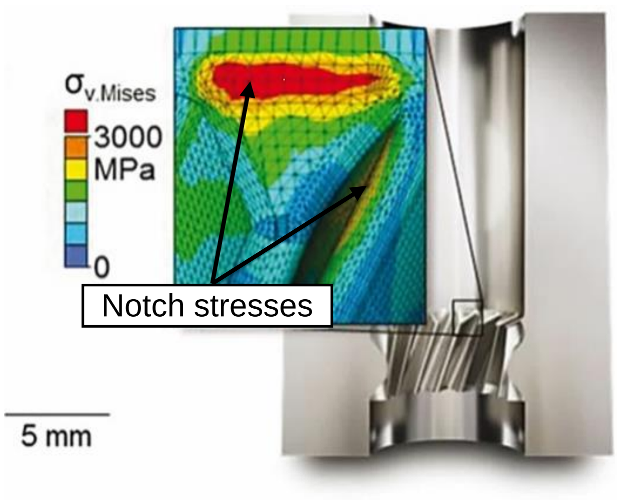
Wear resistance

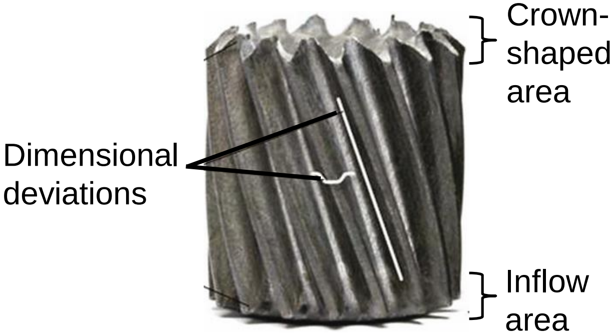
Optimized mechanical properties

High dimensional accuracy

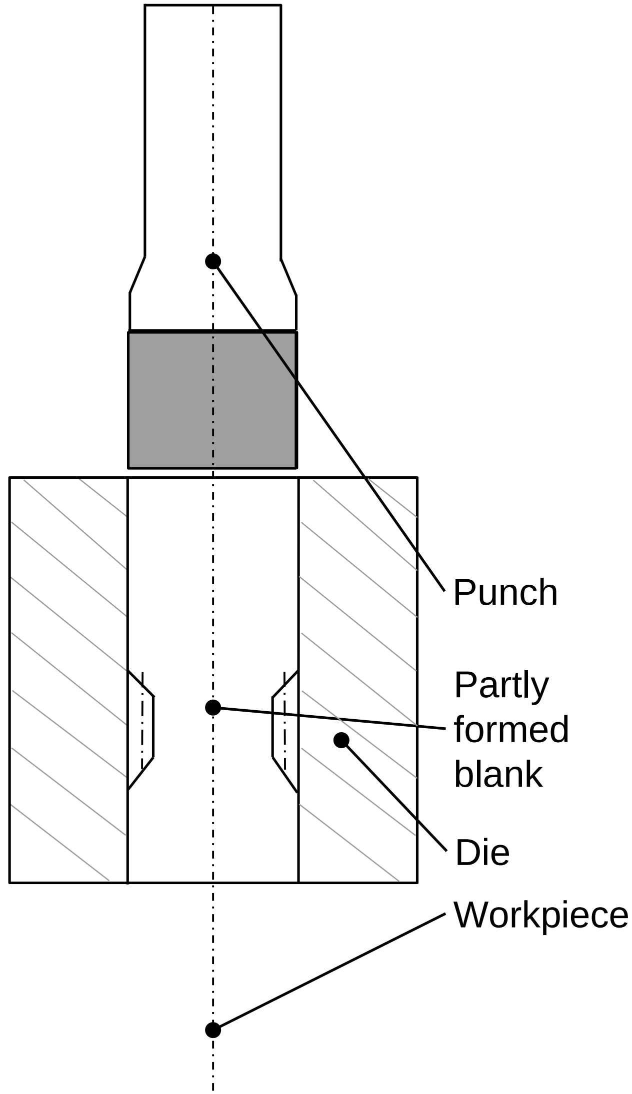
Source: https://pinion.eu/basistechnologie/; Call: 10.07.2019

State of the Art
Conventional Samanta process





Reference: C. Kiener, M. Merklein, 2018

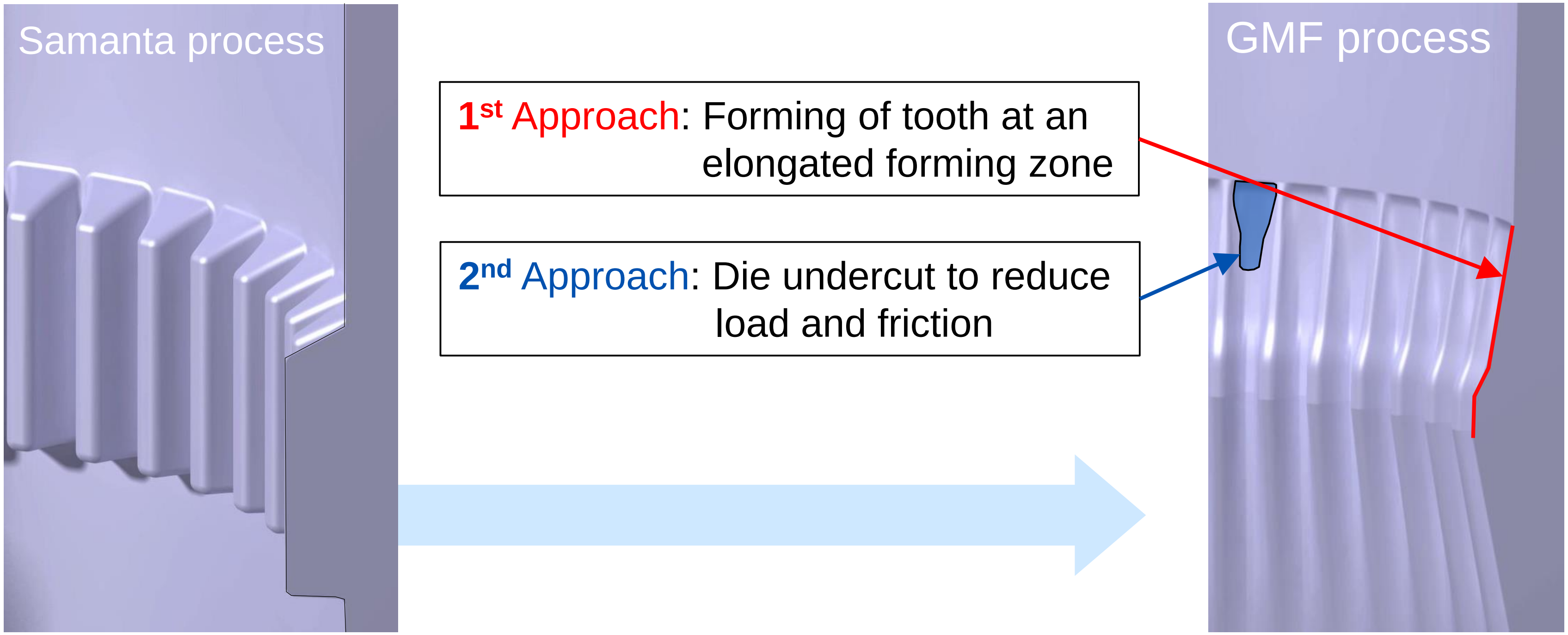


Process-related challenges

- High punch forces
→large press with high energy consumption is required
- High tool loads and critical notch stresses
→high tool wear and expensive tool steels required
- Large elastic deformation of tool components
→low accuracy of gears
- Dimensional deviations on workpieces
→post-machining required

Guided Material Flow (GMF) process – Version 1

Process development



- Extension of the forming zone distributes required forming work over longer stroke
- Consequently, the friction surface increases → Die undercut provides compensation of this friction surface expansion

Hypothesis

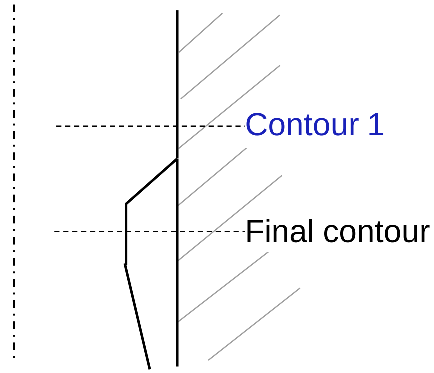
Extending the forming zone while maintaining the same amount of forming work results in a reduction of the max. punch force. This leads to a reduced tool load and therefore to an increased accuracy of the formed gears

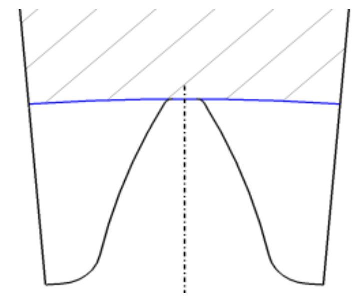
Guided Material Flow (GMF) process – Version 1

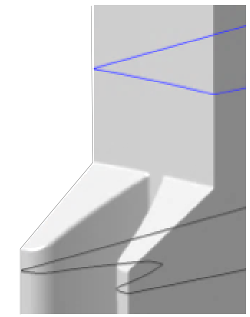
Initial GMF process design in comparison to the Samanta process

Samanta process

- Extrusion shoulder with const. shoulder angle
- Large friction surface between material and die
- Short forming zone length



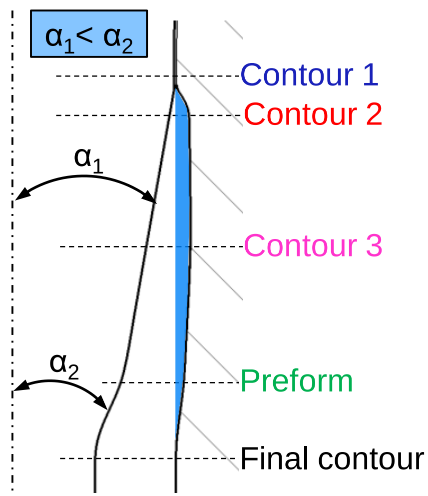


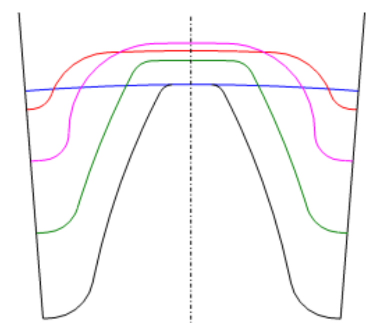


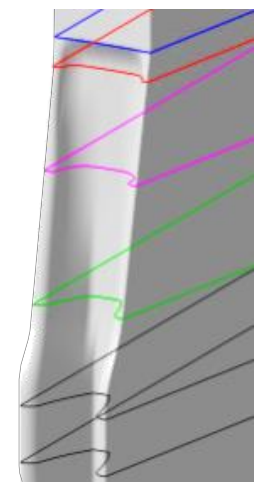
GMF process (Initial version)

- Elongated forming zone with complex free-form surface
- Two different shoulder angles (α_1 and α_2)
- Die undercut between contour 2 and final contour

→ Reduced friction surface and die load

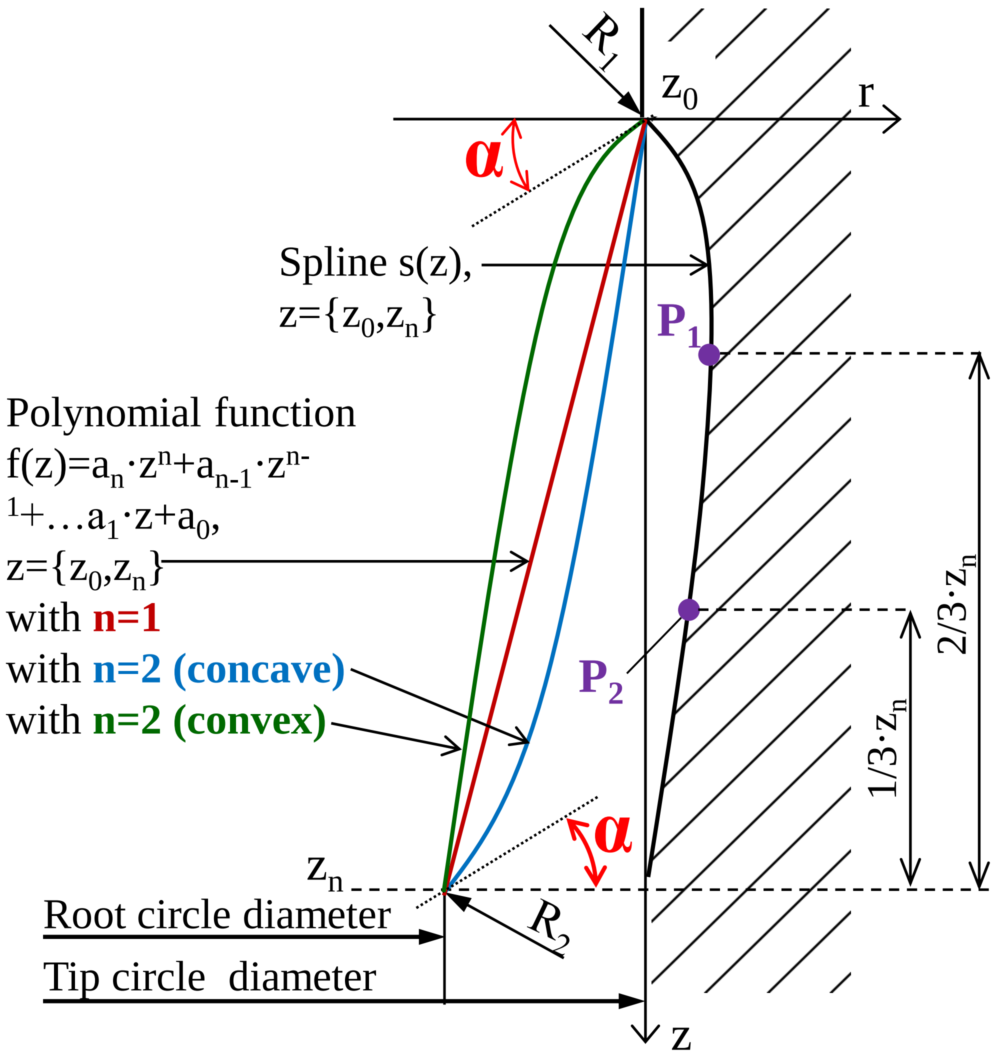






Guided Material Flow (GMF) process – Version 2

Modified die design for GMF process V2



GMF process V2

- Simplification to reduction the number of geometric die parameters
- New die design based on splines and mathematical functions
- Boundary conditions consist at z_0 (blank diameter) and z_n (tooth geometry)
- Shape of extrusion shoulder is defined by polynomial function
- Concave and convex extrusion shoulders variation using tangent angle α
- Undercut as spline with P_1(r=0.3mm) and P2(0.1mm) depending on length of forming zone

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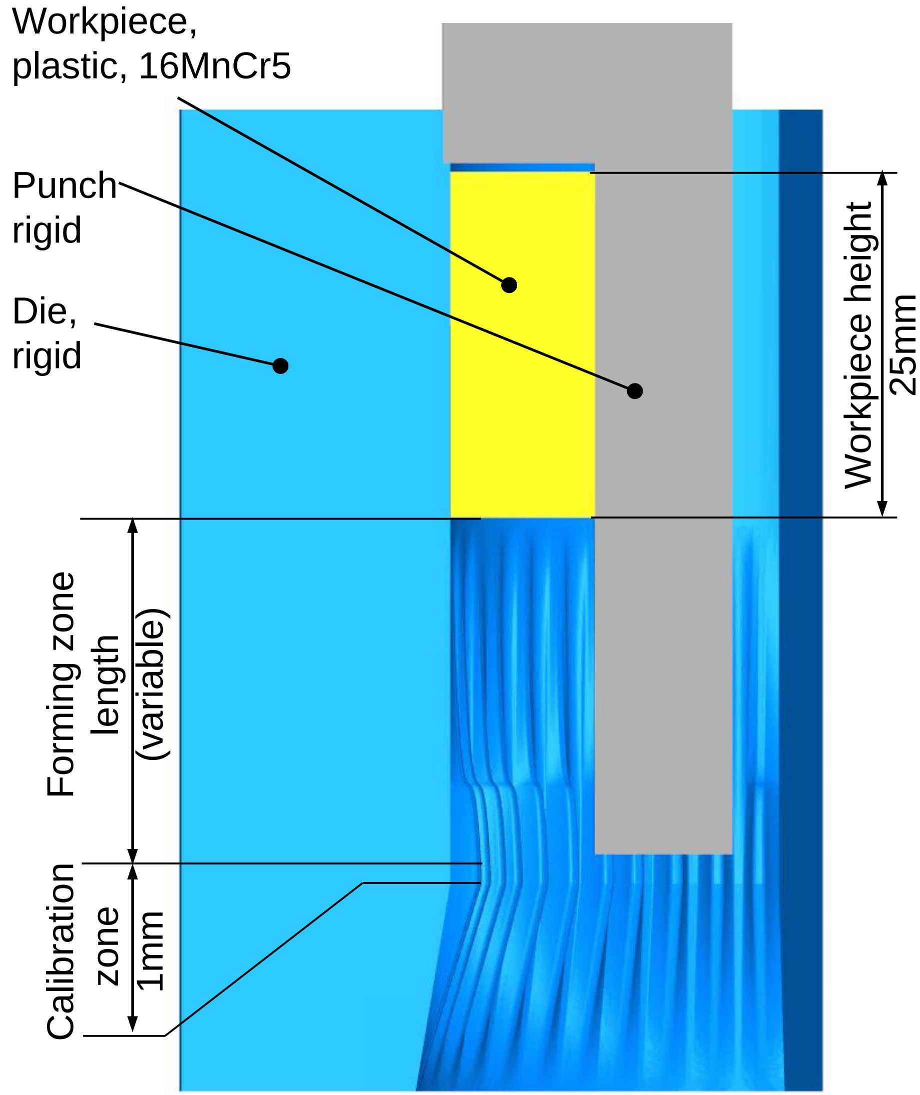
Numerical investigations

Simulation setup in Deform 3D™

Gear dimensions	
Tooth geometry	Involute
Nr. of teeth	39
Module m	1.00 mm
Tooth height	2.17 mm
Tooth width	1.57 mm
Tip circle diameter	41,00 mm
Root circle diameter	36.67 mm

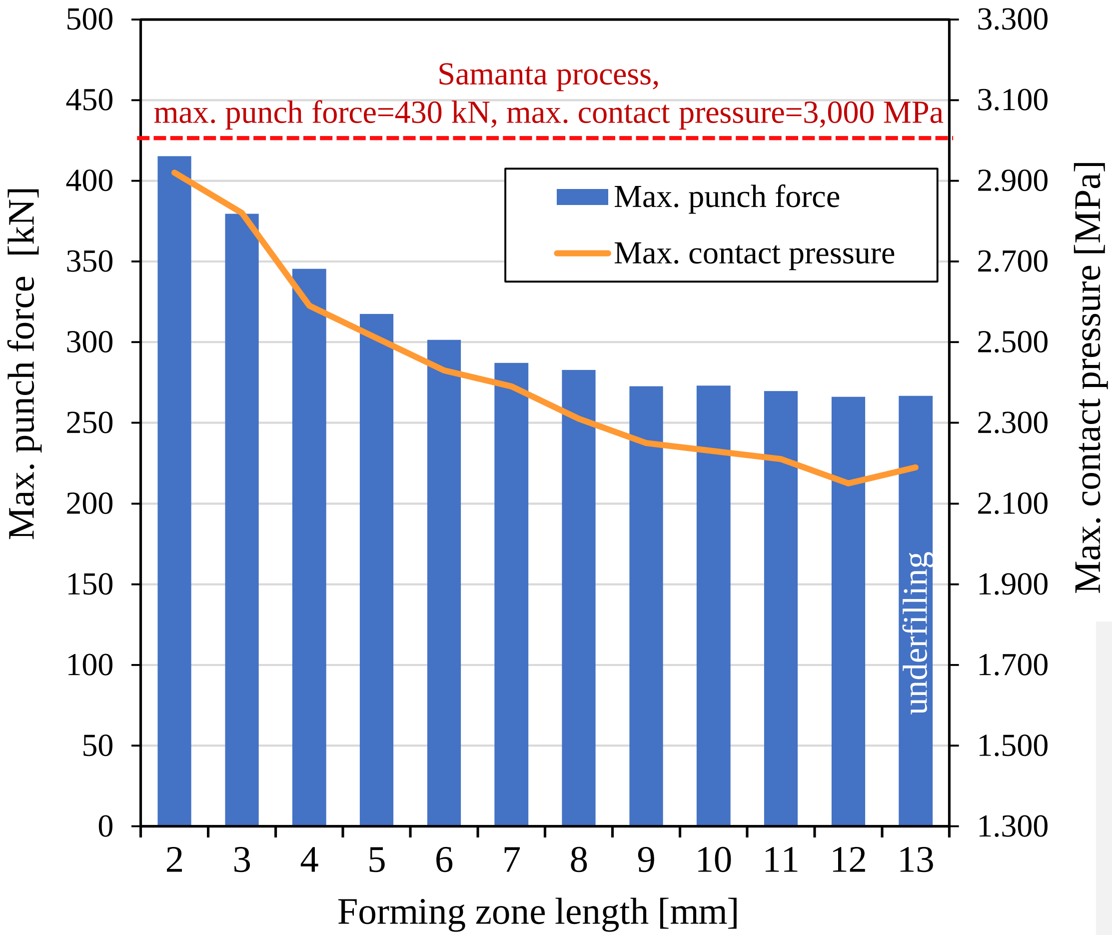
Simulation parameters	
Software	DEFORM 3D
Mesh workpiece	80,000
Temperature	20 °C
Friction	shear, 0.12
Punch speed	40 mm/s
Simulation type	Lagrangian incremental
Solver	SPOOLES

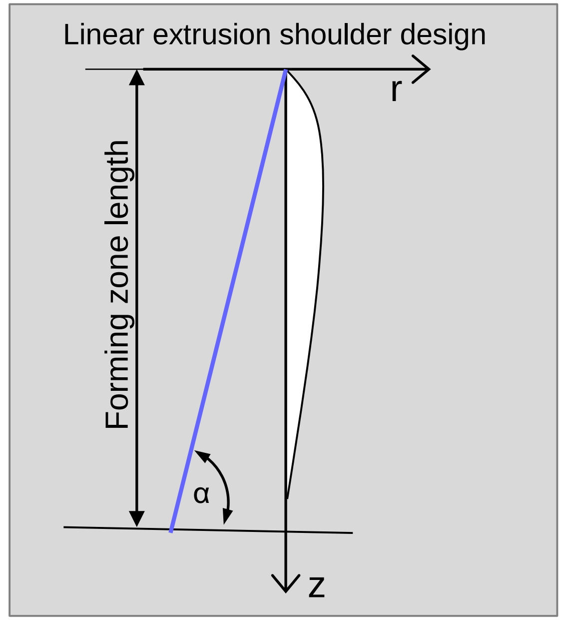
- Simplification of Samanta process through single-stroke forming
- No effect on gear forming and material flow along the cavity
- Marginal deviations with regard to face deformations



Numerical investigations

Numerical results – Linear extrusion shoulder design

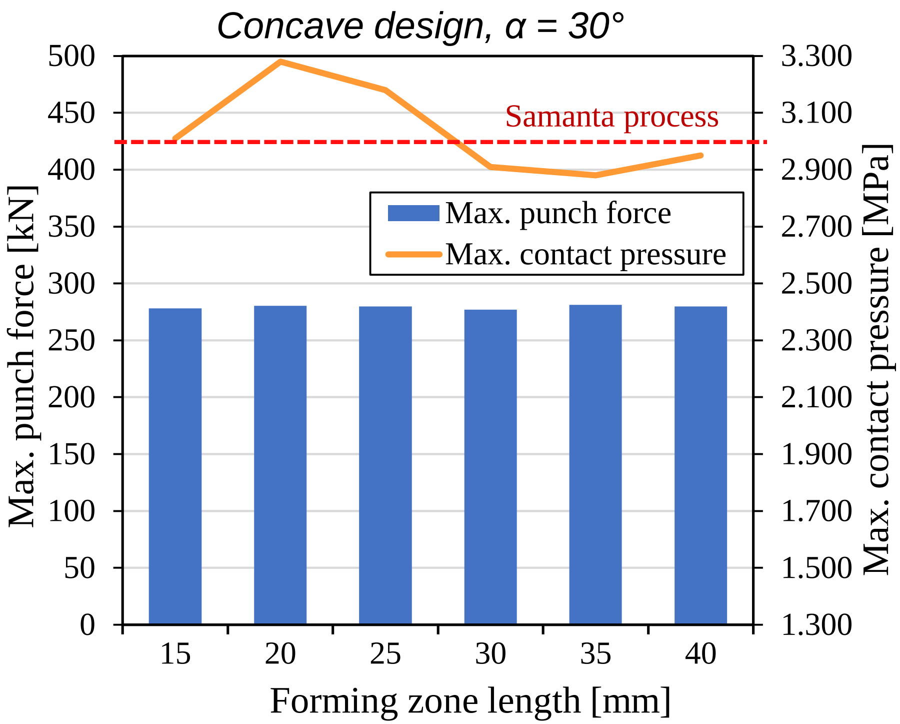


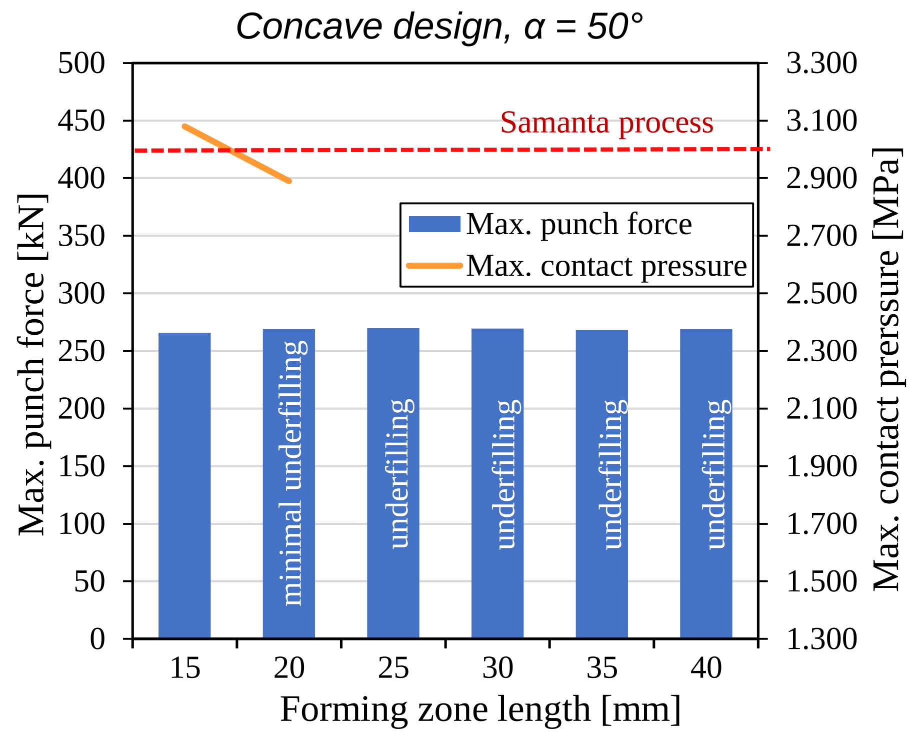


- Forming zone length ↑ → Max. punch force ↓
- Forming zone length ↑ → Max. contact pressure↓
- Compared to the Samanta process, the max. punch force could be reduced by 38% and the contact pressure by 28%
- Above a forming zone length of 12 mm, underfilling of the toothing occurs

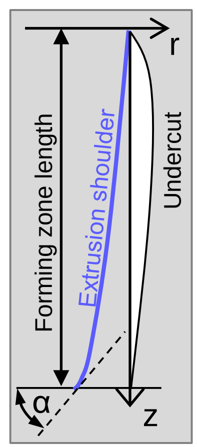
Numerical investigations

Numerical results – Concave extrusion shoulder design





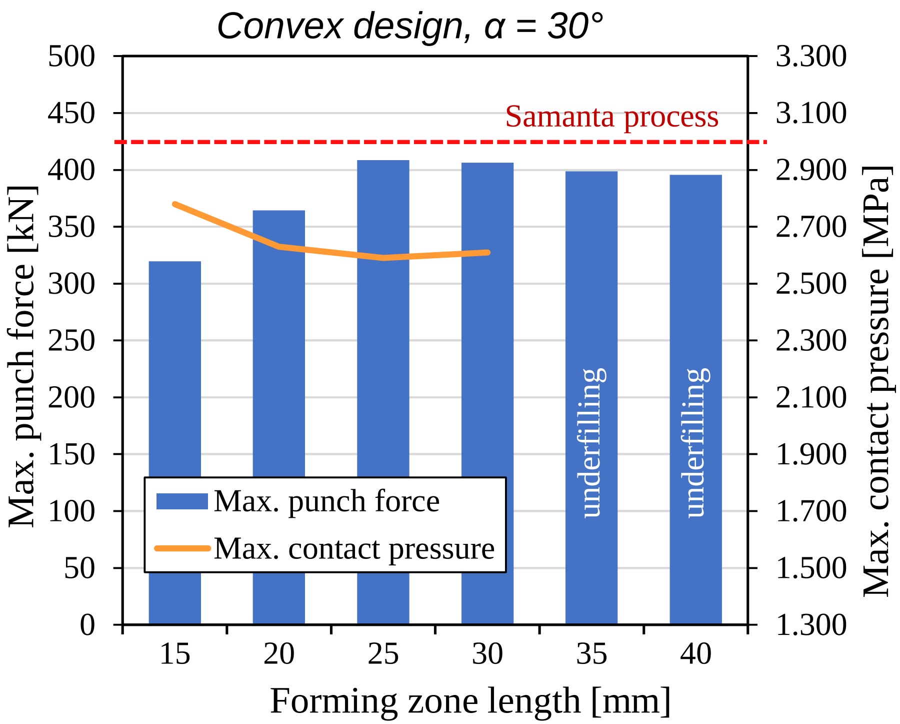
- Reduction of max. punch force by approx. 36%
- No effect of forming zone length on punch force
- Contact pressure at similar level as with the Samanta process

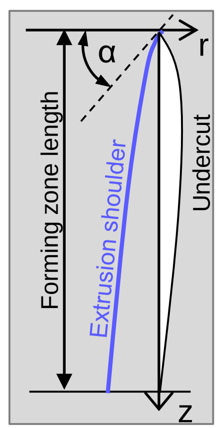


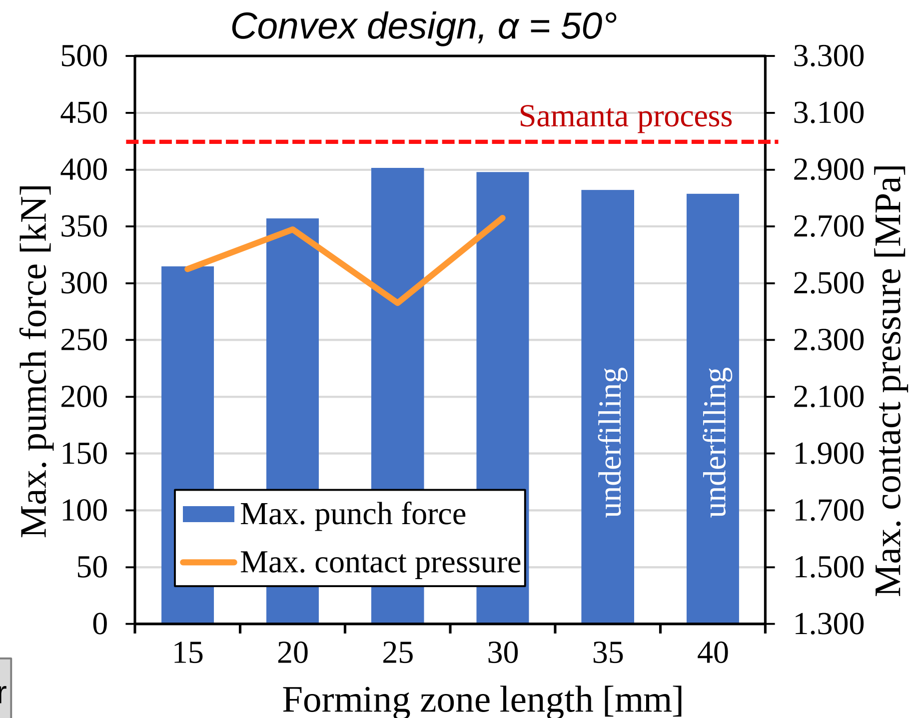
- Increase of tangent angle α results in marginal reduction of max. punch force (approx. 1%)
- No effect of forming zone length on punch force
- Underfilling starts from 20mm forming zone length
- Underfilling throughout with α =70°

Numerical investigations

Numerical results – Convex extrusion shoulder design





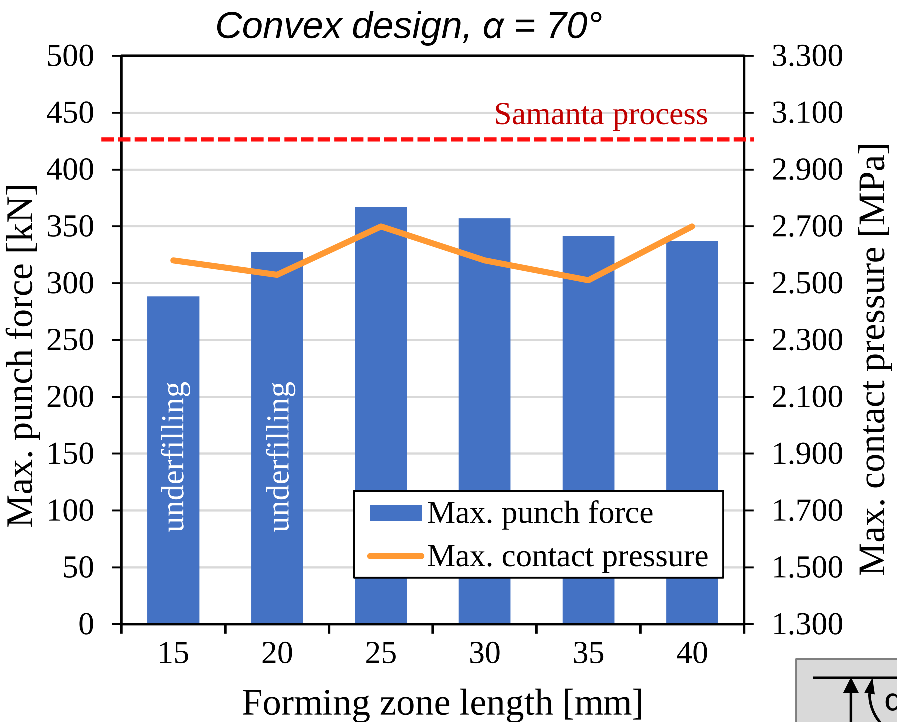


- Punch force decreased by 25%
- Punch force increases with increasing forming zone length → maximum at 25 mm
- Contact pressure decreased by approx. 10%
- Underfilling occurs with increasing forming zone length starting at 35 mm

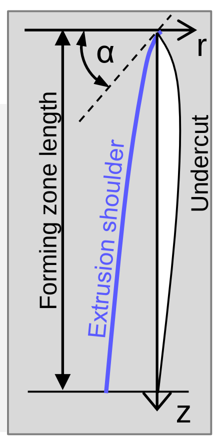
- Measured values of punch force nearly the same as for convex design with α = 30°
- Contact stresses also at a similar level to convex design with 30°
- Underfilling occurs with increasing forming zone length starting at 35 mm

Numerical investigations

Numerical results – Convex extrusion shoulder design

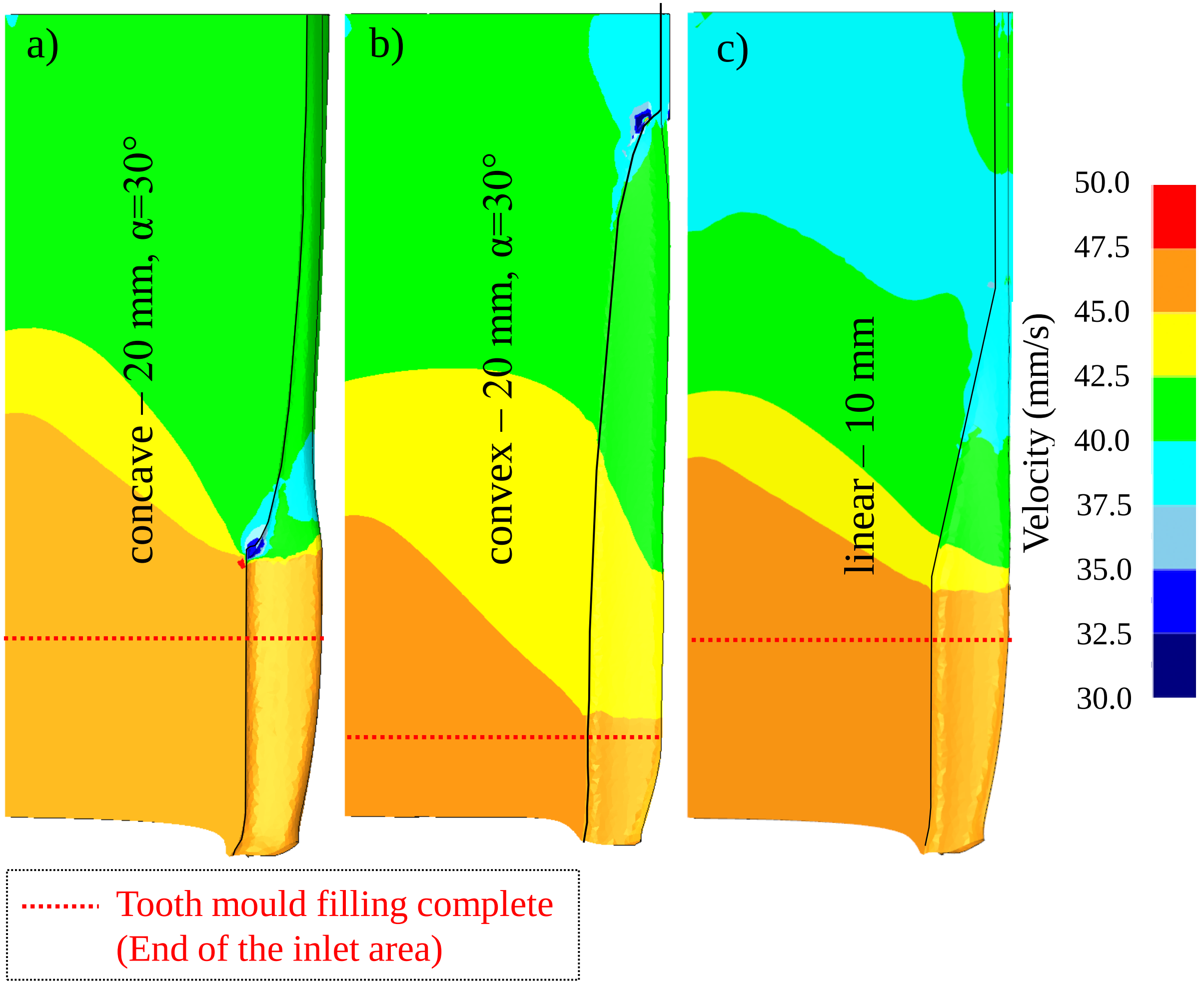


- Underfilling at 15 & 20 mm forming zone length
- Complete die filling starts at 25mm
- Punch force and contact pressure nearly independent of tangent angle α for convex design



Numerical investigations

Numerical results – Material flow analysis



a) Concave design

- High velocity difference at inner and outer diameter (approx. 10 mm/s)
- Tip diameter of gearing temporarily decreases during the process
- High inlet area

b) Convex design

- Cavity filled at start of process (except tooth tip)
- Reduced velocity difference on inner and outer diameter (approx. 7mm/s)
- Complete die filling due to gradual tapering of the tooth cavity
- Tip diameter of gearing temporarily decreases marginally during the process
- Reduced inlet area → improved material utilization

c) Linear design

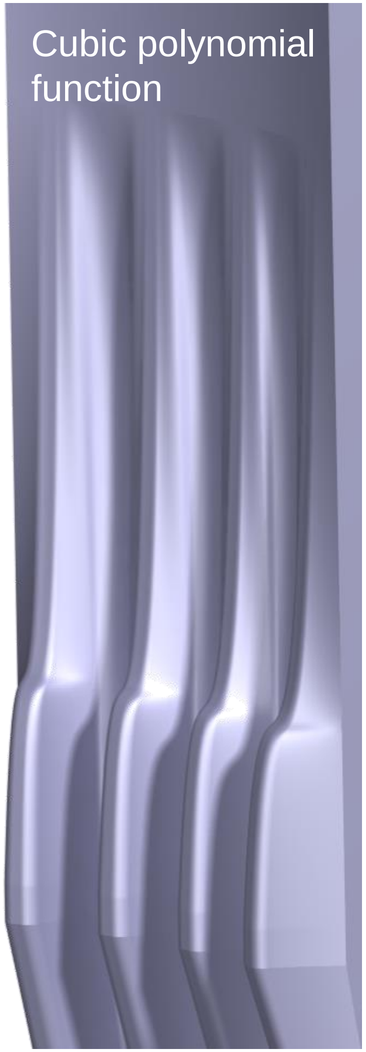
- Cavity filled steadily during process
- Similar velocity distribution as concave design
- Constant tooth tip diameter
- High inlet area

→ Correlation between flow velocity of the workpiece material and the extent of tooth underfill in the inlet area

Summary & Conclusion

Summary

- First numerical investigations of the GMF process (V2) was performed
- Influence of extrusion shoulder designs were evaluated with regard to punch force, contact pressure and die filling
- Linear design vs. Samanta process: punch force was reduced by 38% and contact pressure by 28%
- Concave design vs. Samanta process: similar reduction for punch force as linear design, but no reduction of contact pressure
- Convex design vs. Samanta process: a noticeable reduction of punch force was achieved only at low forming zone lengths, contact pressure was only slightly reduced
- Convex design achieved the best material utilisation as low underfilling was observed in the inlet area → reason: lower velocity differences in the material flow at the outer and inner diameter.



Outlook

- Additional numerical analysis of the die active surface in the area of the tooth flanks with regard to the taper angle of the cavity and the geometry of the tooth flank negative contour
- Focus on progressive optimisation of the die´s active surface → cubic polynomial function
- Further numerical investigations to analyse the tooth underfilling in the inlet area and the face side deformations → maximisation of material utilization

Thank you for your attention!

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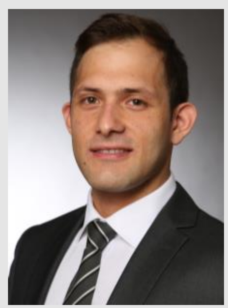

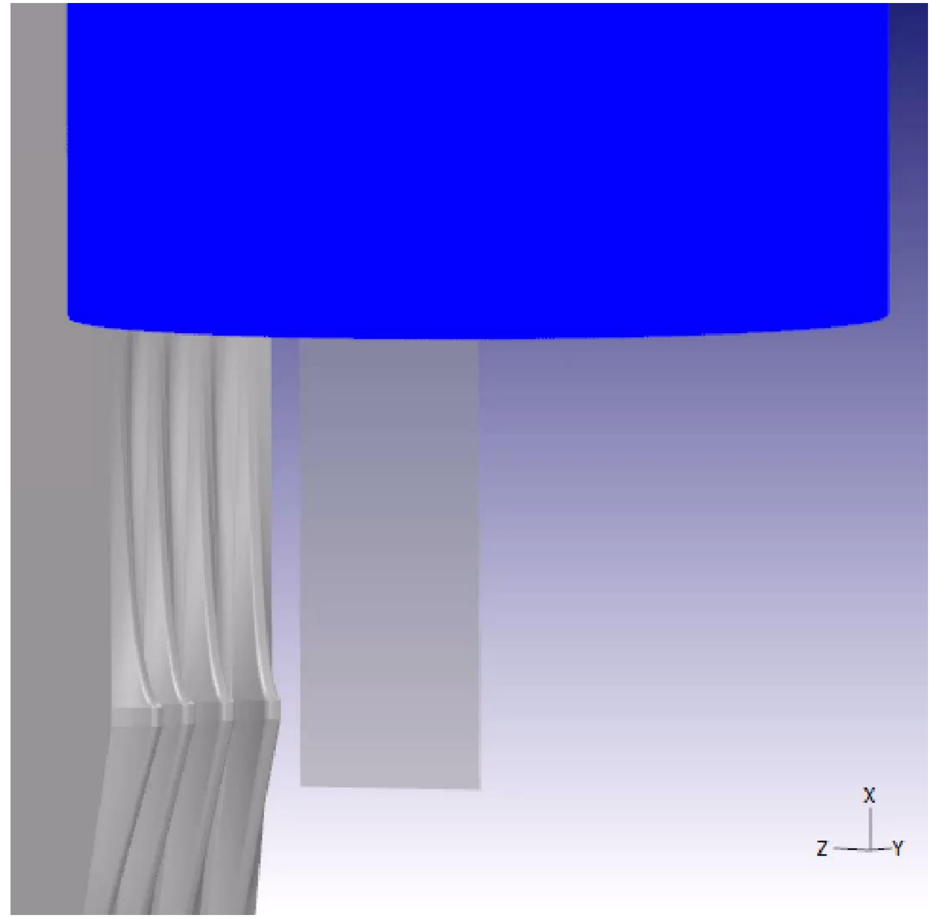

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