KUGGMÖTE / GEAR MEETING 2010

Gear rolling technology

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IWP WERKZEUGMASCHINEN UND PRODUKTIONSPROZESSE

Fraunhofer IWU

Agenda

- About Fraunhofer
  - Fraunhofer Gesellschaft
  - Fraunhofer-Institute of Machine Tools and Forming Technologies (IWU)
- Gear rolling process (cold forming)
  - Unique selling position Gear rolling
  - Process phases
  - Forming process (gear rolling video)
  - Gear rolling simulation
- Components and characteristics
  - Gear rolling results
  - Advantages concerning machine and process
  - Advantages concerning component
  - Gear qualities
  - Reference components
  - Finish rolling
- Future research projects and Summary

About Fraunhofer

The Fraunhofer-Gesellschaft

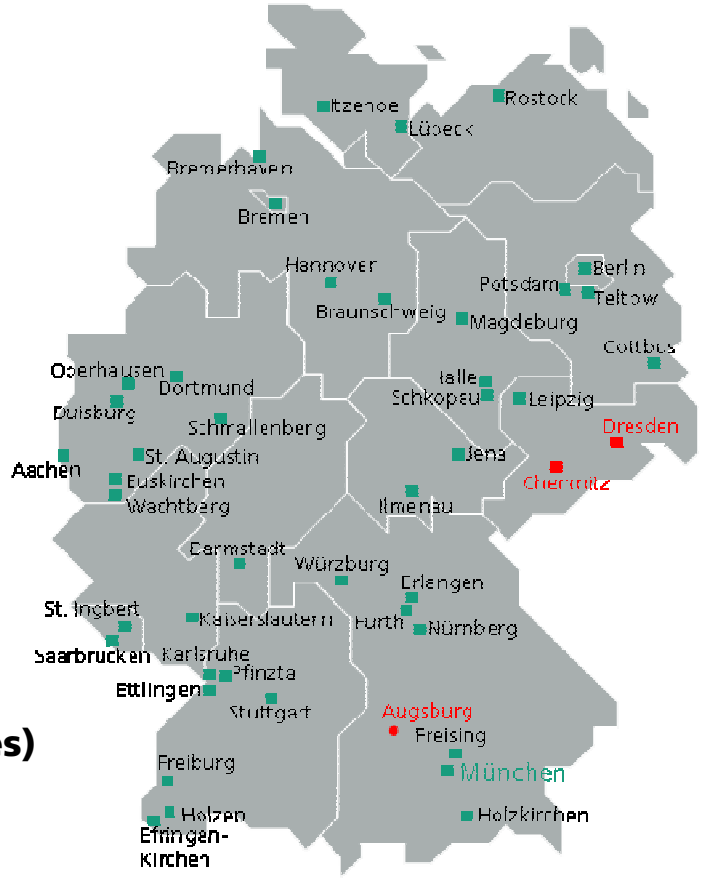
- The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society
- 60 Fraunhofer-Institutes
- Headquarter Munich
- 17.000 employees

- Our Customers:
  - Industry
  - Service sector
  - Public administration

About Fraunhofer

Fraunhofer-Institute of Forming Technologies and Machine Tools

- Founded on July 1st, 1991, located in Chemnitz and Dresden
- About 400 employees
- € 24 million budget
- 4 000 m² test area Chemnitz und Dresden
- Project group in Augsburg since January 2009



Core Competencies

- Machine Tools
- Mechatronics
- **Forming Technologies**
- Cutting Technologies
- System Technologies

Workgroup Gear technologies

- **Gear rolling (single gears, gear shafts)**
- **Profile rolling (hollow profiles, groove profiles)**
- **Rolling of worm gears**
- **Thread rolling**

Gear rolling process (cold forming)

Unique selling position / gear rolling competence

Stub tooth gearing

- Tooth height factor y<2

Normal gearing

- Tooth height factor y=2

High gearing

- Tooth height factor y>2

2001 | 2003/2004 | 2005/2006 | 2008/2009 | 2010

$$\text{tooth height factor } y = \frac{\text{tooth height } h_z}{\text{normal module } m_n}$$

- **Cold rolling of gears** with tooth height factor y>2 **is a development of Fraunhofer IWU Chemnitz**

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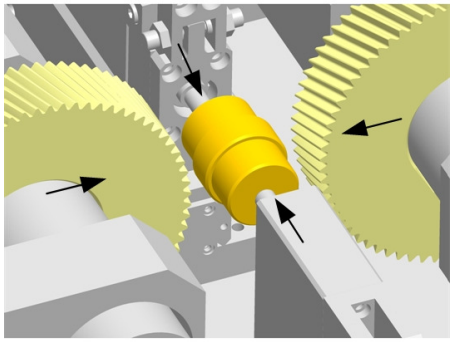
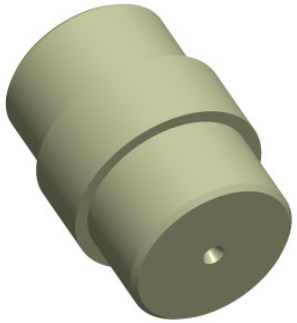
Gear rolling process (cold forming)

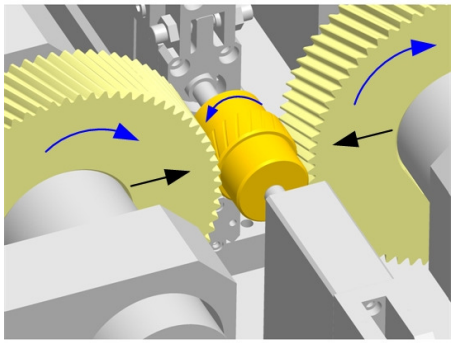
Process phases

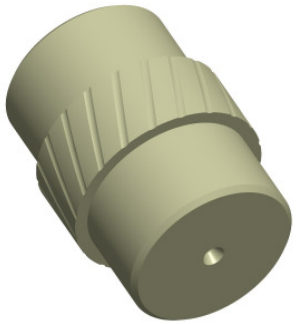




1 Component clamping

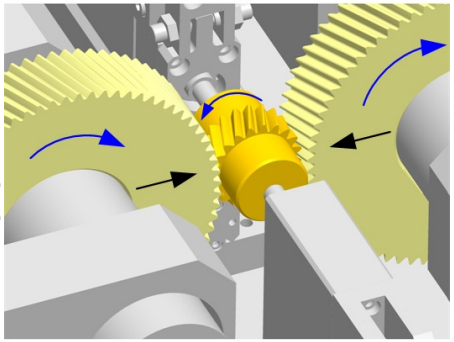
- Clamping between tips
- Radial tool feed until preform diameter
- Preform diameter calculated according to volume constancy

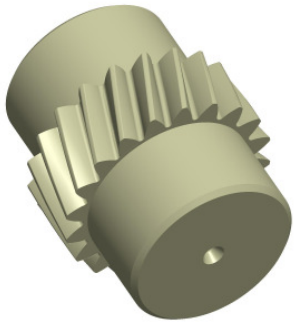




2 Initial rolling phase

- 0,1mm penetration of both tools into the part
- Initial rolling of exact number of teeth





3 Penetration and calibration phase

- Penetration of the tools until desired tooth root diameter
- Changes of rolling direction of the rolling tools
- Final calibrating

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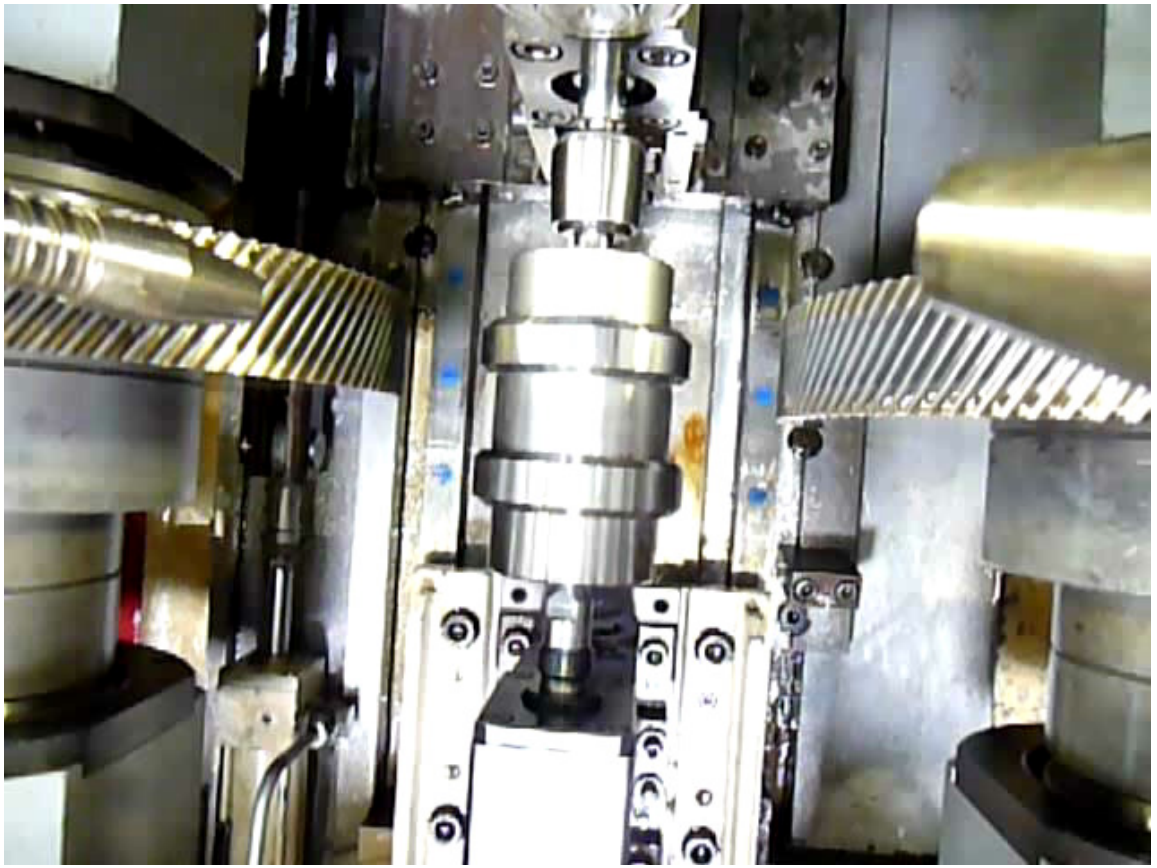
Gear rolling process (cold forming)

Forming process

- Component clamping
- Initial rolling
- Penetration with changes of direction
- Calibrating
- Component output



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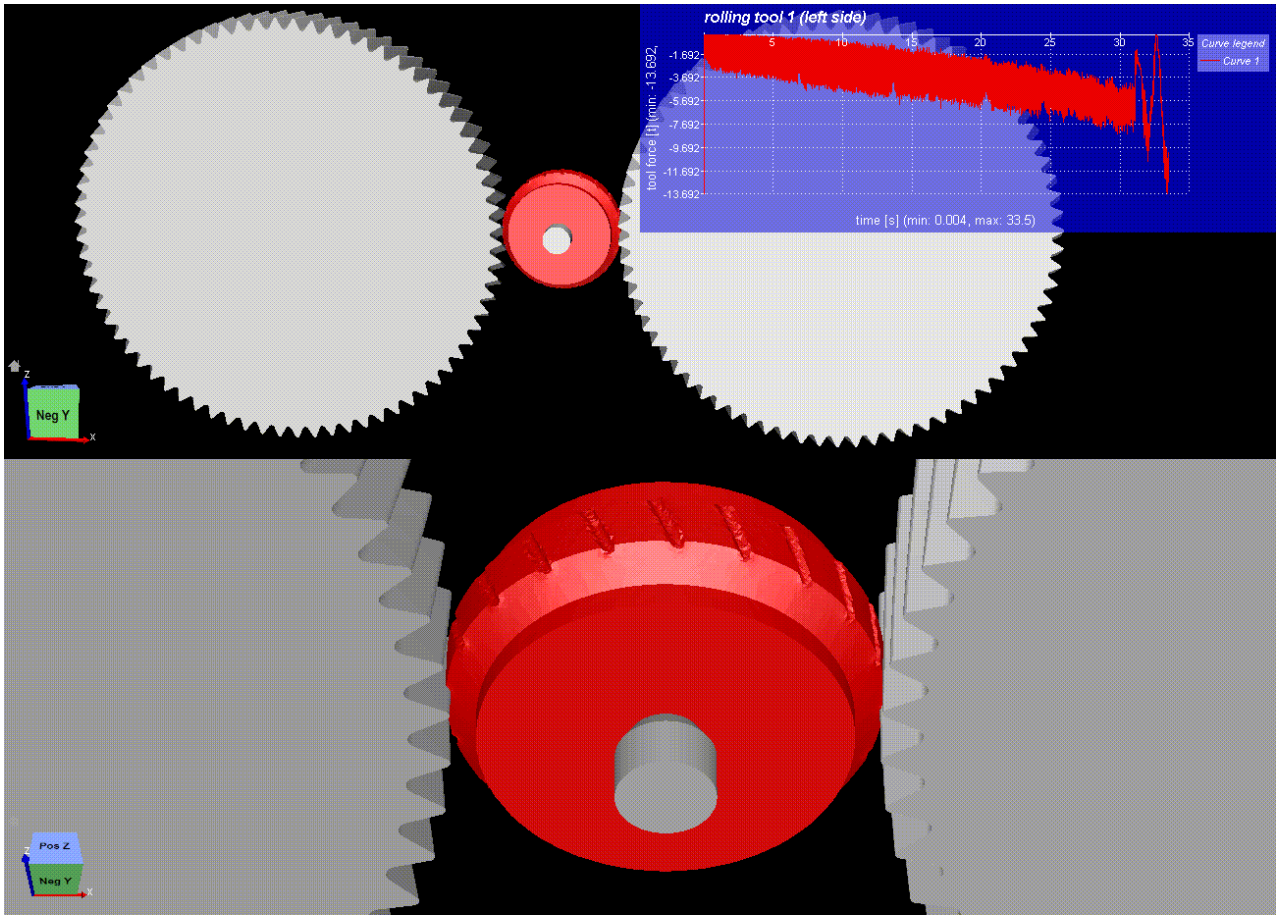
Gear rolling process (cold forming)

Process simulation

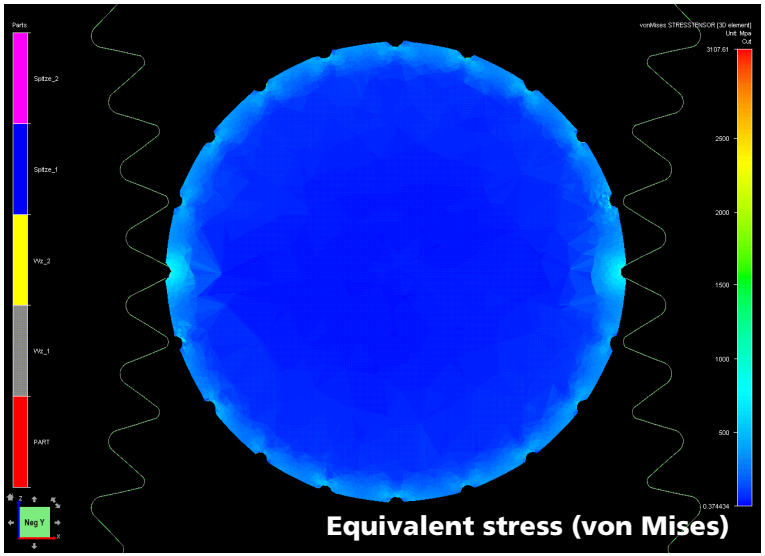
- Tool calculation
- Material flow
- Process parameters



Gear rolling process (cold forming)

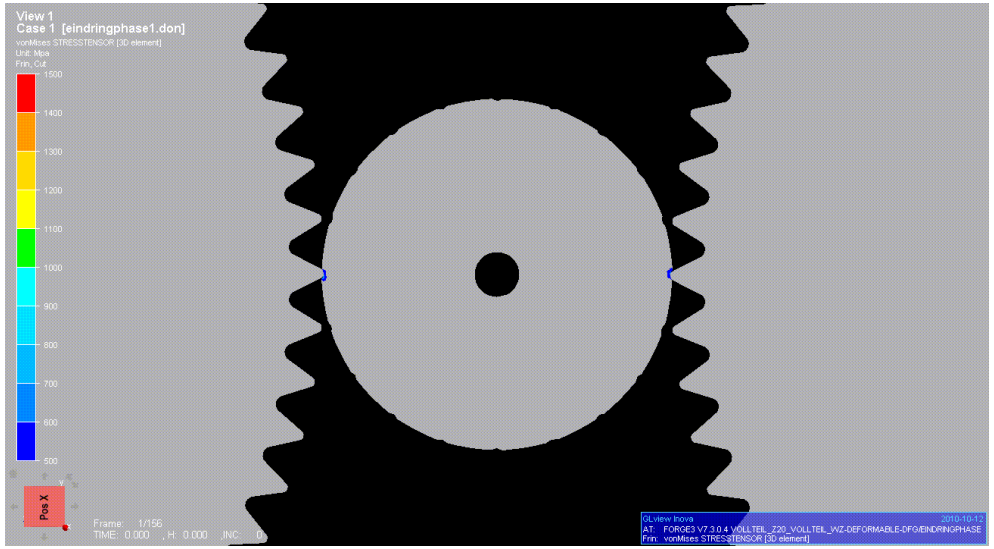
Simulation

Simulation with **rigid dies** (3D simulation, transverse section)



- Analyses of tool loads (qualitative)
- Optimisation of tool construction (influence of root/tip radius, etc.)
- Conclusion concerning tool steels

Simulation with **deformable dies** (3D simulation, transverse section)



Funded by the DFG in cooperation with the Technical University Chemnitz

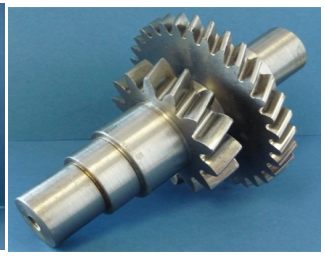
Components and characteristics

Gear rolling results

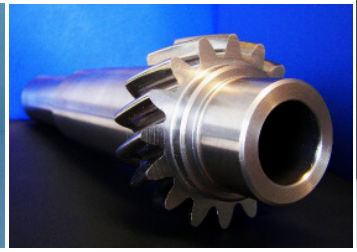
Real gears – cold rolled into the full work piece material

Gear wheels

Straight gears



Gear shaft
(narrow located gears)



Gear shaft
(hollow, not assembled / gear and shaft in one part)

Sprocket gear

Gear parameters:

normal module:	< 4	[mm]
tooth height:	< 13	[mm]
pressure angle :	16 … 24	[°]
helix angle:	12 … 34	[°]
tooth height factor:	< 2,7	

Rolling parameters:

cycle time:	5…45	[sec.]
rolling force:	80 … 200	[kN]
quality (DIN3962):	9 … 11	**(pre-gearing)**
	6	**(finished)**
material:	case hardening steels, heat treated steels	

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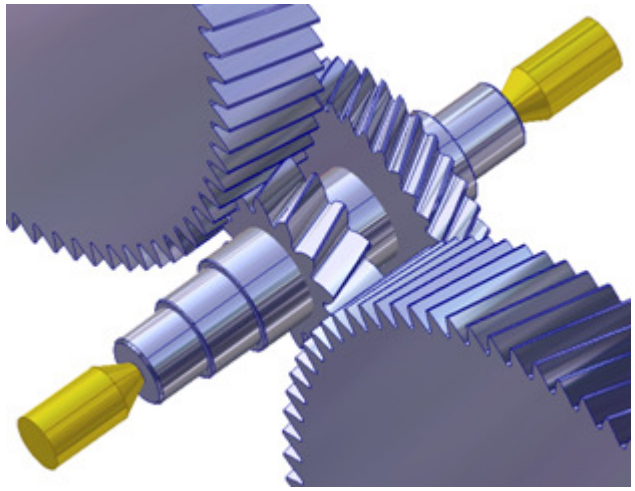
Components and characteristics

Advantages concerning machine and process

- **Short process cycles** (up to 50% of gear hobbing, depending on the gear geometry)
- **Material saving** by forming process
  (no chips, initial work piece diameter for rolling **<** initial work piece diameter for hobbing)
- **Low forming forces** because of incremental forming (small contact area between gaer and tools)
- Rolling of **narrow located gears** on shafts (no joining of gears on the shaft necessary)
- Rolling of **multiple gears** in one process by using multiple clamping concepts
  (reduction of cycle time)

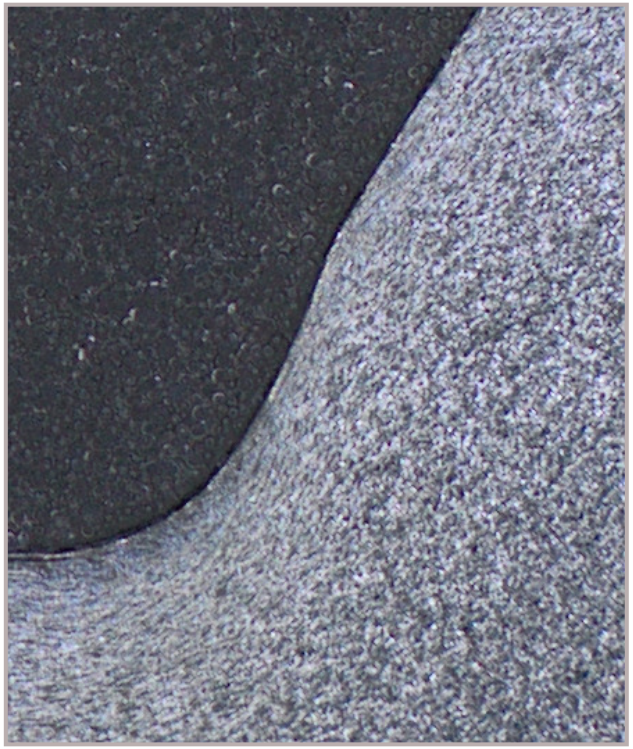


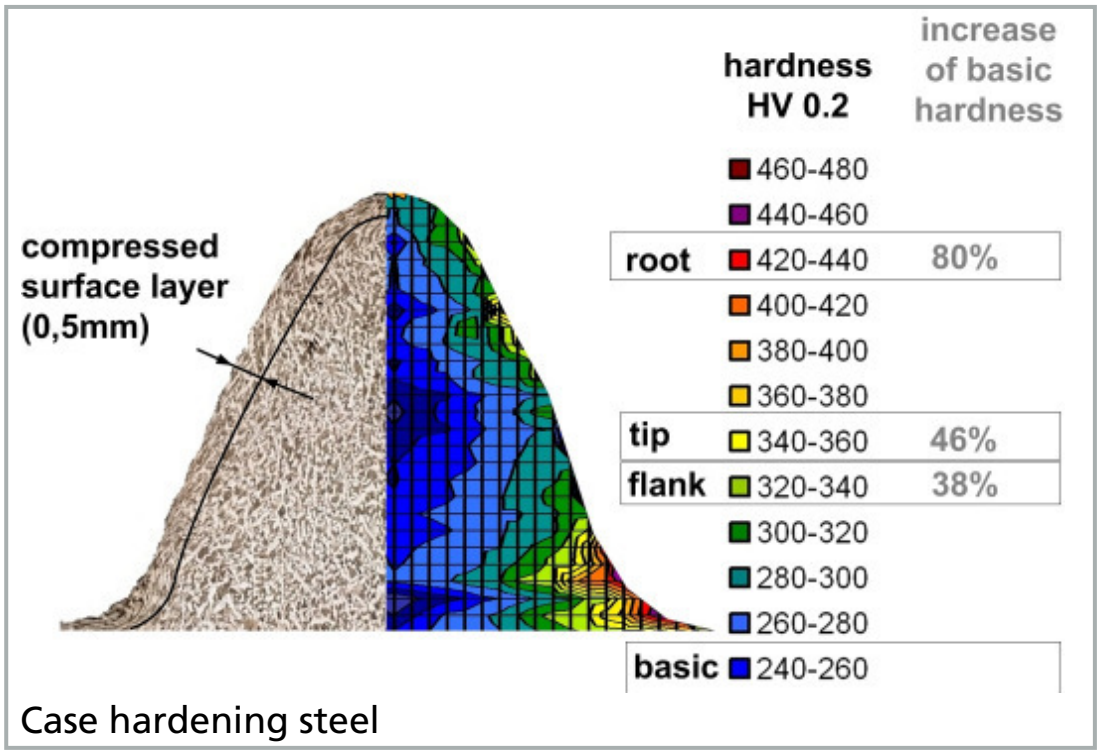
Narrow located gears on shafts

Components and characteristics

Advantages concerning component

- **Strain hardened surface layer (for low loaded components, elimination of hardening)**
- **Contour related and not cutted material fibre**
- **Excellent contour stability after case hardening**
- **Increased tooth root strengths and flank load capacity** compared to cutted gears
- **Excellent surface roughness after rolling** (R_a= 0,3- 0,5µm; R_z= 1,9- 3µm)



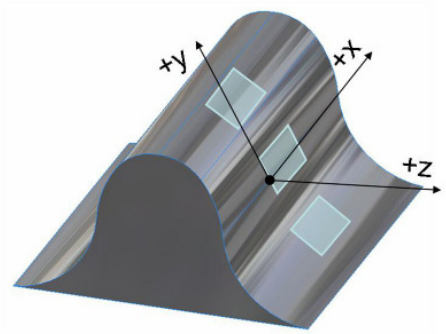


Case hardening steel

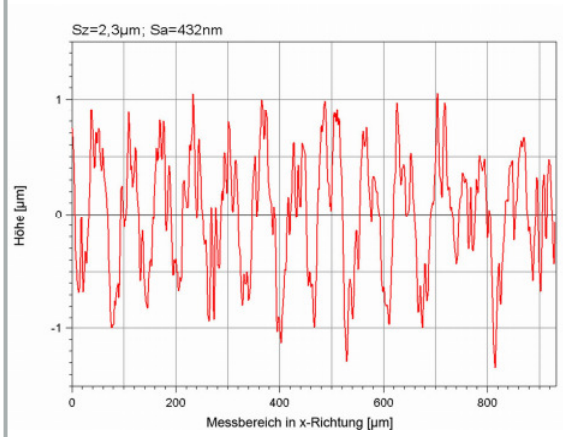
Components and characteristics

Advantages concerning component

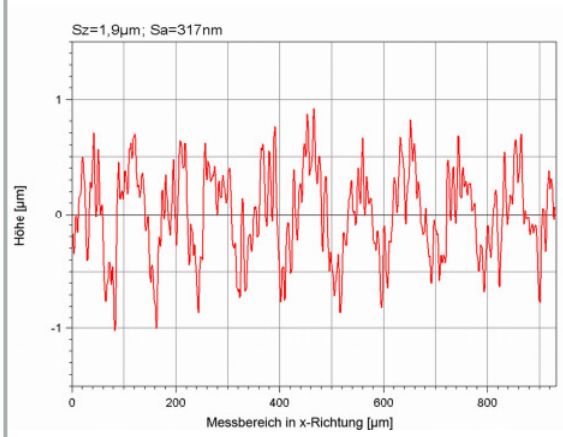
- z14
- module: 3,45mm
- d_f= 48,30mm
- d_a= 58,94mm
- cold rolled
- x= 0,5507
- α_N= 24°
- β= 20°
- y= 2,2



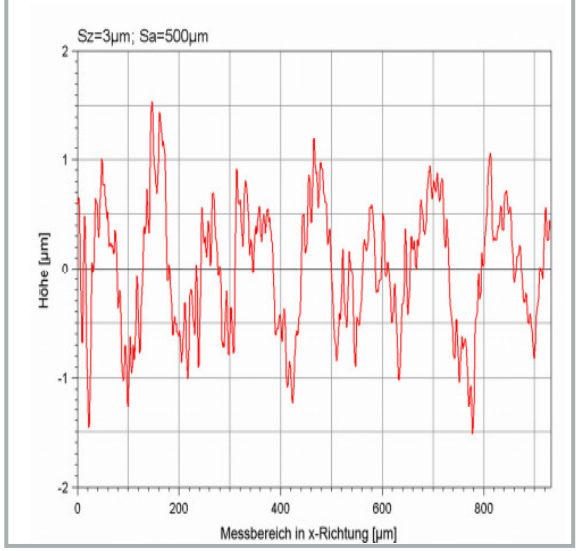
tip: R_z=2,3µm; R_a=0,4µm



flank: R_z=1,9µm; R_a=0,3µm

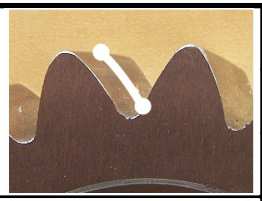
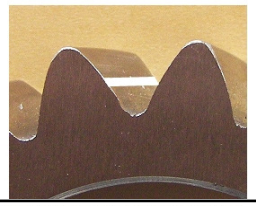
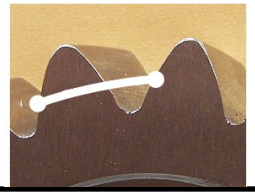


root: R_z=3µm; R_a=0,5µm



Components and characteristics

Gear qualities after gear rolling
Gear qualities after case hardening

Test parameters			Gear quality before case hardening		Gear quality after case hardening	
			Q_a	µm $_{max}$	Q_a	µm $_{max}$
Profile measurement		Profile total deviation F_f	**10**	40	**10**	44
		Profile form deviation f_f	**11**	39	**11**	42
		Profile angular deviation $f_{H\alpha}$	**9**	13	**9**	16
Flank line (lead) measurement		Flank line total deviation F_β	**10**	40	**11**	63
		Flank line form deviation $f_{f\beta}$	**10**	25	**11**	29
		Flank line angular deviation $f_{H\beta}$	**12**	69	**12**	92
Pitch measurement		Pitch single deviation f_p	**9**	18	**9**	19
		Pitch total deviation F_p	**10**	79	**10**	79
		Pitch error f_u	**7**	11	**8**	13

- **Gear quality after gear rolling equivalent to gear hobbing (gear prefom manufacturing)**
- **Quality improvement by better tool quality and process optimisation**
- **Deviation through case hardening: maximum one gear quality**

Components and characteristics

Reference components - cold rolled (into the full material)

- **Paramters of shown work pieces**
  - Module: 2 … 4 [mm]
  - Pressure angle: 16 … 24 [°]
  - Tooth height: 5 … 11 [mm]
  - Helix angle: 12 … 34 [°]
  - Tooth height coefficient: up to 2.7
  - Quality (DIN3962): 8 … 11 **(pregearing)**
    6 / 7 **(finished)**
  - Materials: case hardening steel, heat treated steels

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Components and characteristics

Reference components - cold rolled (into the full material)

- Worms
- Pinions
- Threads
- Drill bits
- Rotor profiles

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Finish rolling

Finish rolling of sinter gears

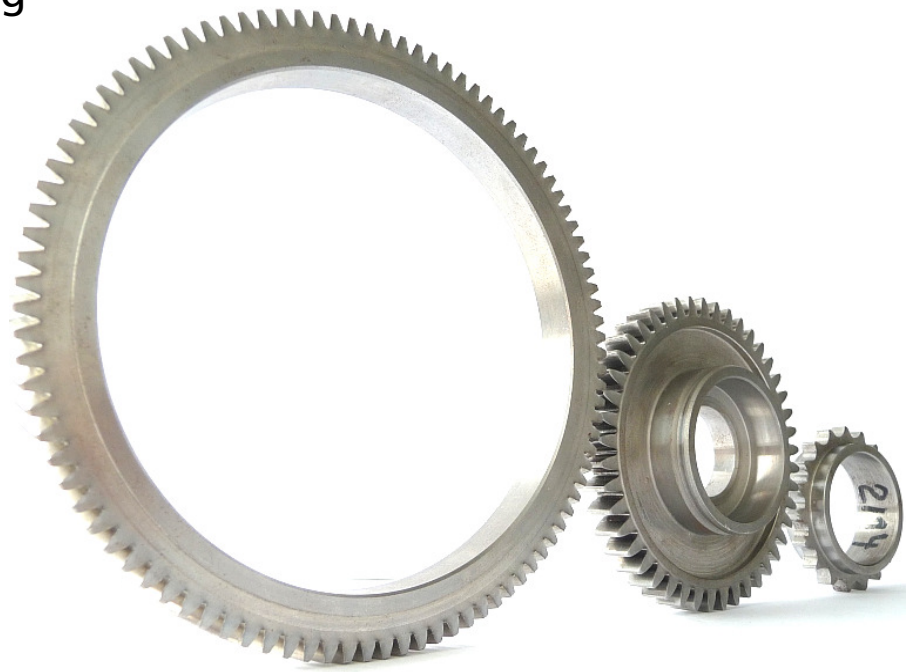
Process chain

- Preform manufacturing by cutting
- Heat treatment
- **Finish rolling**

Benefit

- Compression of the surface layer
- Surface smoothing
- Quality improvement

Reference parts



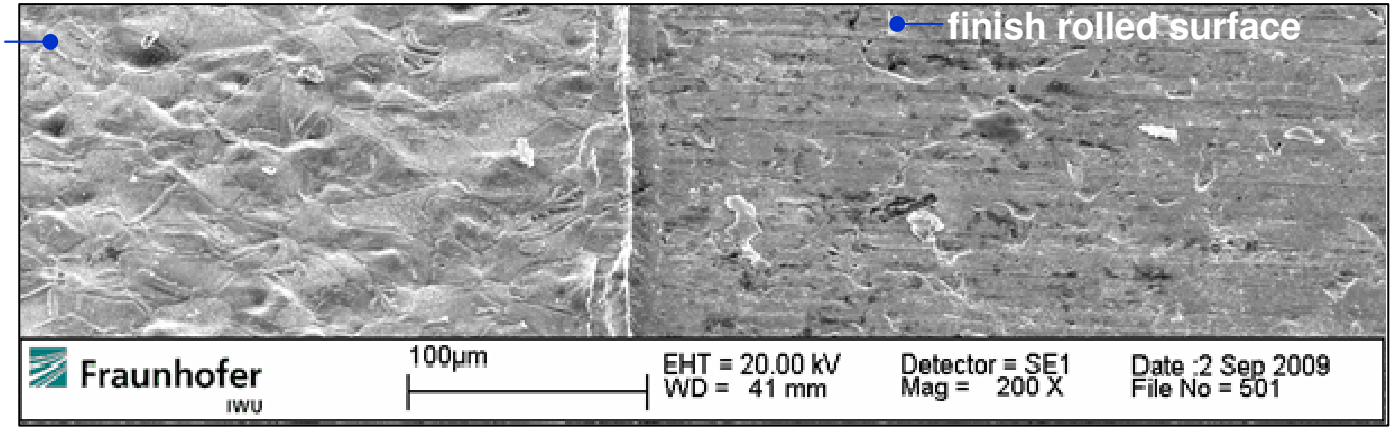
Finish rolling

+ excellent surfaces (R_a=0,5 - 0,2µm R_z=1,2 - 1,0µm)

+ compacted, strain hardened surface layer, improvement of gear load capacity

Surface after gear hobbing and case hardening

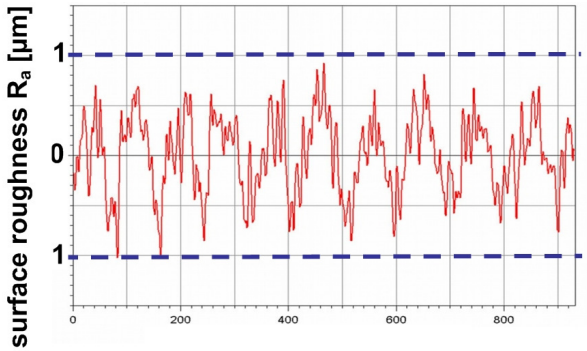
(not finish rolled)



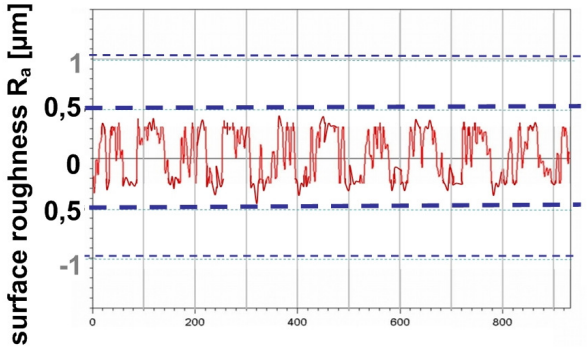
aim:

smoothing of surface roughness by finish rolling

Roughness after gear hobbing and case hardening



Roughness after finish rolling

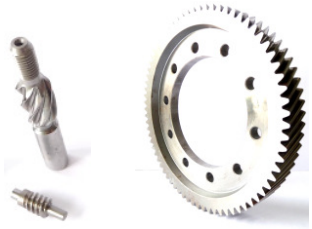


Summary

Division gear technologies - competence, equipment, contact

Competences

- Gear rolling (single gears, gear shafts)
- Profile rolling (hollow profiles, groove profiles)
- Rolling of worm gears
- Thread rolling

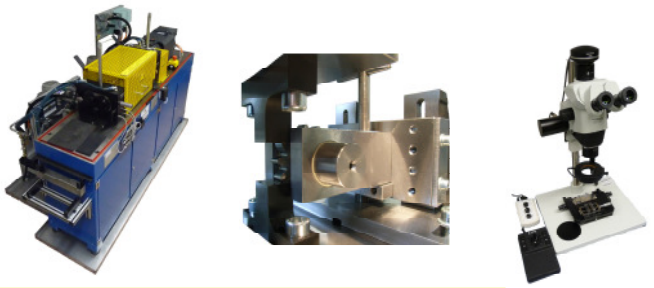


Equipment

- Two rolling machines (cross rolling with 2/3 tools)
- Lab for metallographic investigations
- FZG-torque change device (load capacity test)
- Pulsator test bench for tooth root strength analyses
- ZEISS gear measurement machine (acc. DIN 3960 / 3962)
- Simulation software: Forge 2009, Simufact
- 4 engineers, 3 student assistants, 1 technician

Project cooperation (Industry, public research)

- Research from development studies to the serial production



Contact

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- Member Gear Technologies: Dipl.-Ing. Sven Schiller Email: sven.schiller@iwu.fraunhofer.de

Thank you very much for your attention.

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