# Forming manufacturing of Powertrain Components

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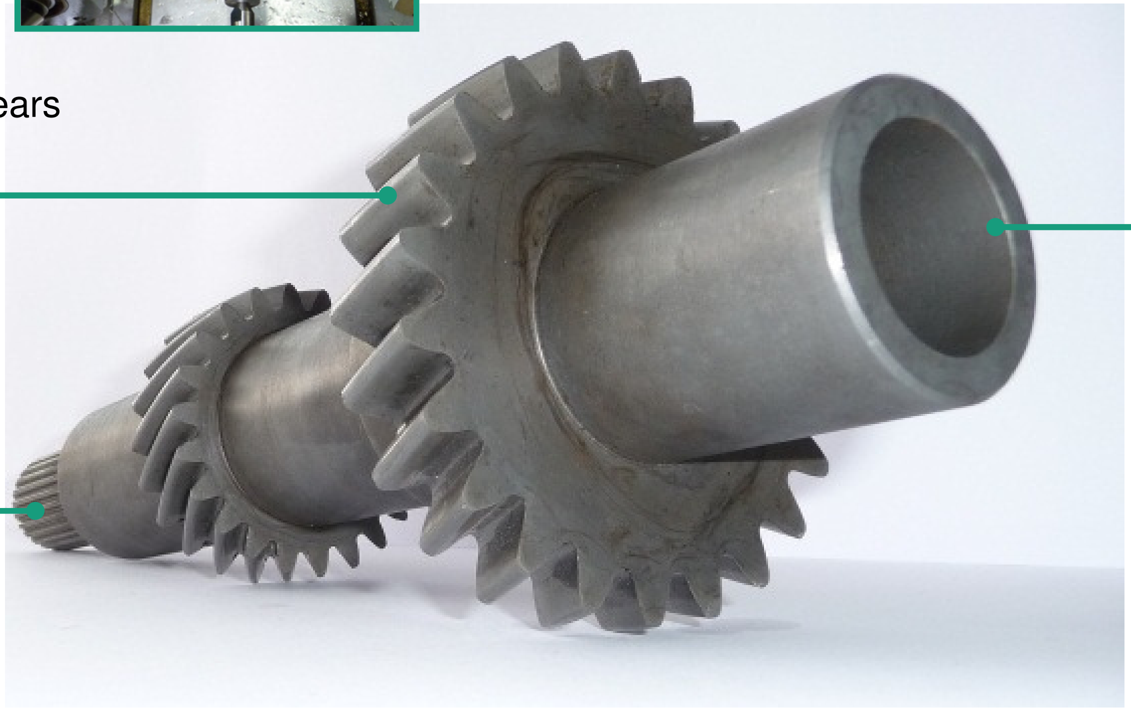
# Manufacturing processes for hollow gear shafts



Manufacturing of Gears by **Gear Rolling**

Manufacturing of straight gears by **Axial Forming**

Manufacturing of Hollow Geometry by **Spin Extrusion**

Manufacturing of Diameter reductions by **Swaging** or **Wedge Rolling** or **Cross Rolling**

# Manufacturing processes for hollow gear shafts

Actual **cut manufacturing** of hollow gear shafts

**MACHINING (State of the art):**

Solid bar → Forging → Deep hole drilling → Cutting → Gear hobbing, Deburring → Heat treatment → Grinding, Shot peening

Solid bar (smaller) → Forging (smaller) → Spin extrusion / Wedge Rolling / Cross Rolling → Swaging → Gear rolling, Deburring / Axial Forming → Heat treatment → Grinding



Holistic **Forming** of hollow shafts and gears

**FORMING (State of research at Fraunhofer IWU)**



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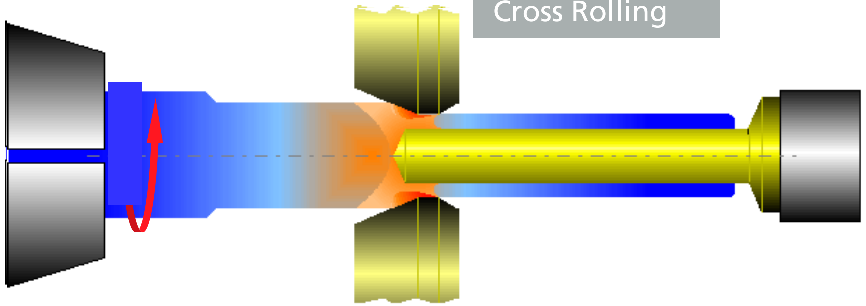
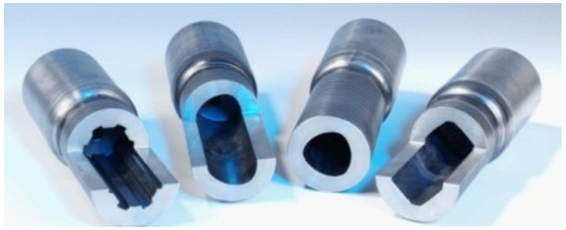
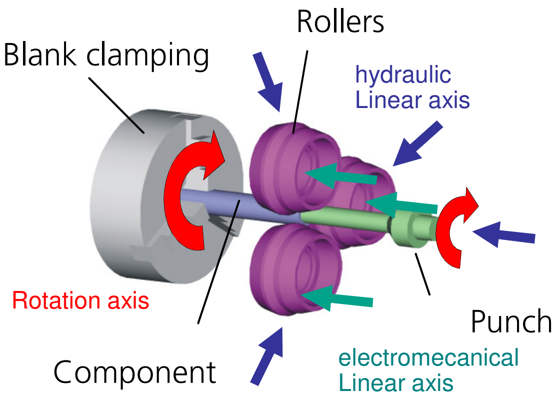
# Spin Extrusion (hot forming)

Solid bar (smaller) → Forging (smaller) → **Spin extrusion** / Wedge Rolling / Cross Rolling → Swaging → Gear Rolling / Axial Forming → Heat Treatment → Grinding



| | |
|---|---|
| Max. blank diameter | 80mm |
| Outer diameter | 20 ≤ D ≤ 70mm |
| Inner diameter | 16 ≤ d ≤ 50mm |
| L-D-ratio | l : d ≤ 15 |
| Wall thickness | 2 ≤ s ≤23mm |






- **Efficient material utilisation** (< 40% comp. to deep drilling)
- **Short process cycles** (up to 50% of deep drilling)
- Forming possibility of **length-diameter ratios of L : d < 15**
- **Forming of high strength steels, e.g. titanium alloys**
- **Forming of inner profiles**
- **Low forming forces** because of incremental forming

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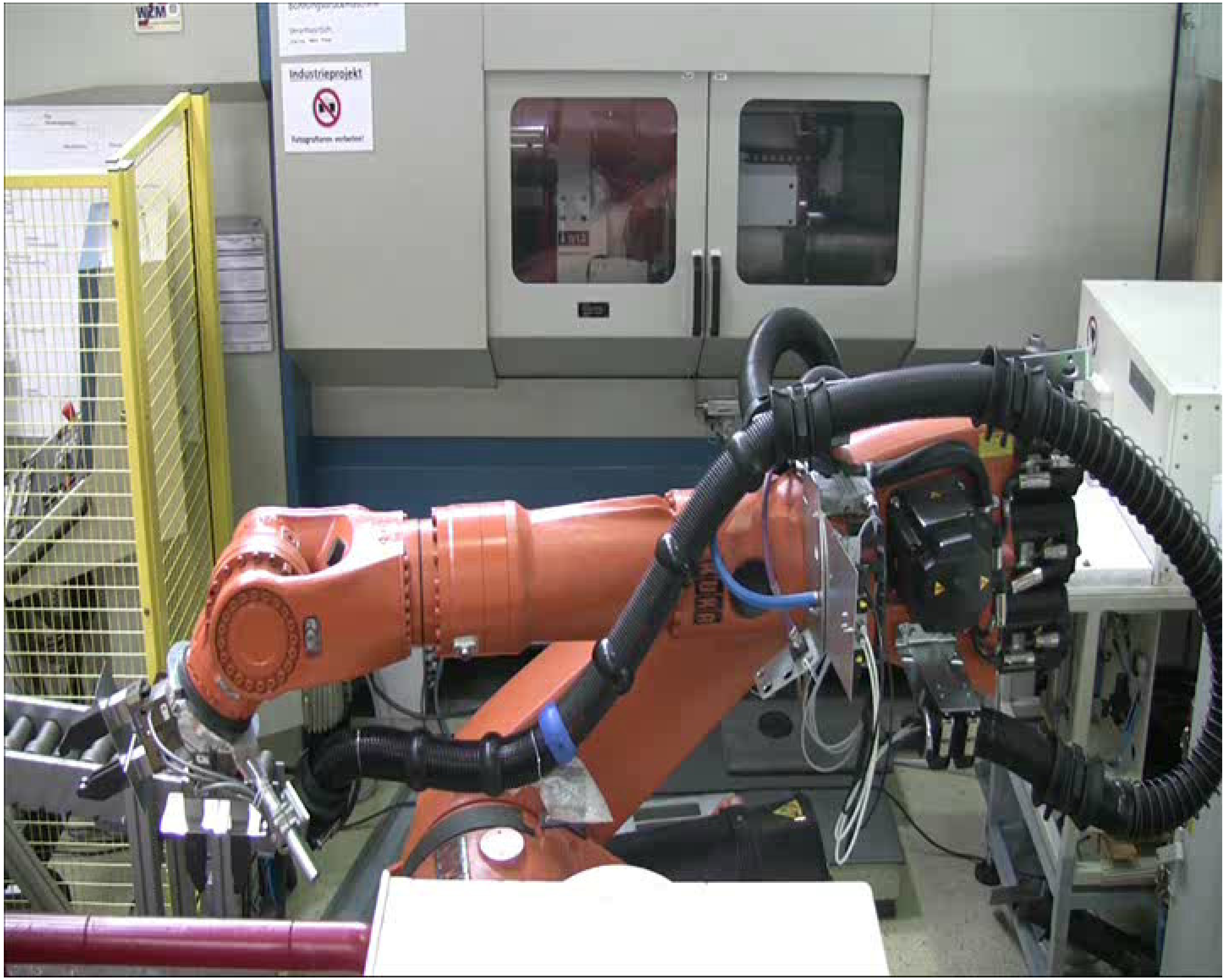
# Spin Extrusion (hot forming)





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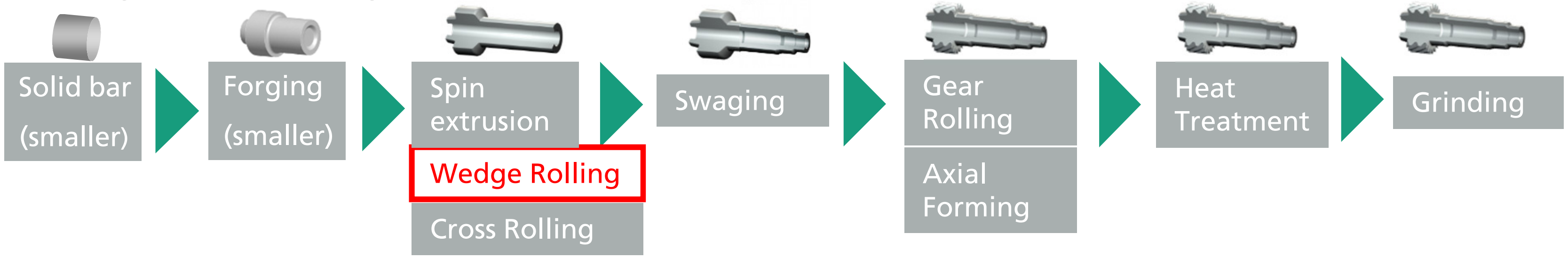
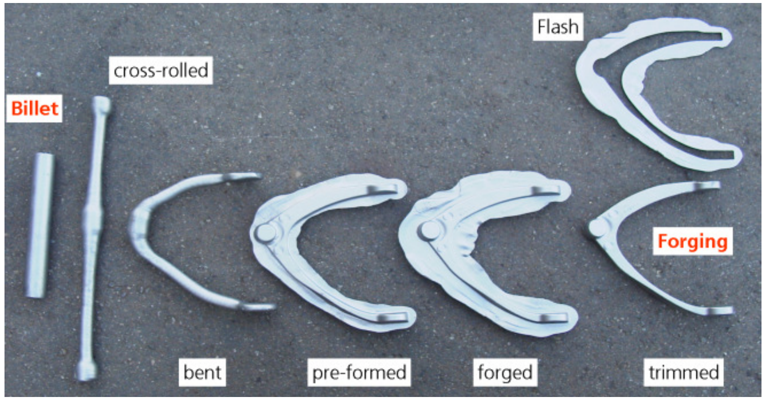
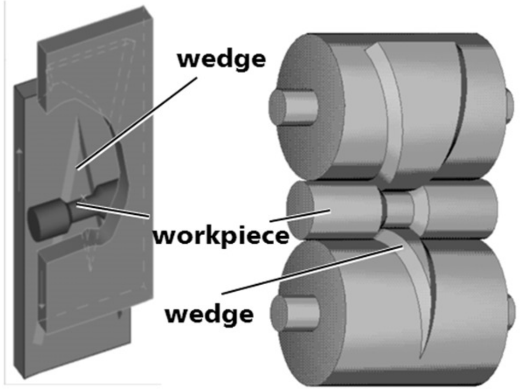
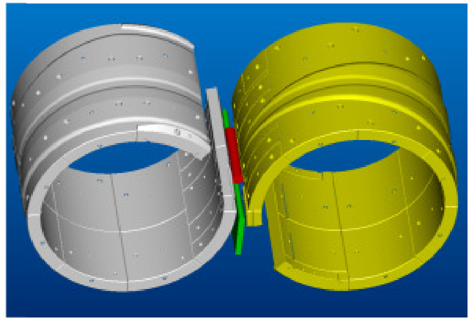
# Wedge Rolling (hot forming)




Steps to form a control arm



## Advantages of Cross Wedge Rolling

- High productivity (average process time 4 sec/part)
- Excellent material utilization
- Wide range of rotation-symmetrical geometries
- Long tool life of the production dies

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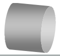
# Cross Rolling (hot forming)


Solid bar (smaller)


Forging (smaller)

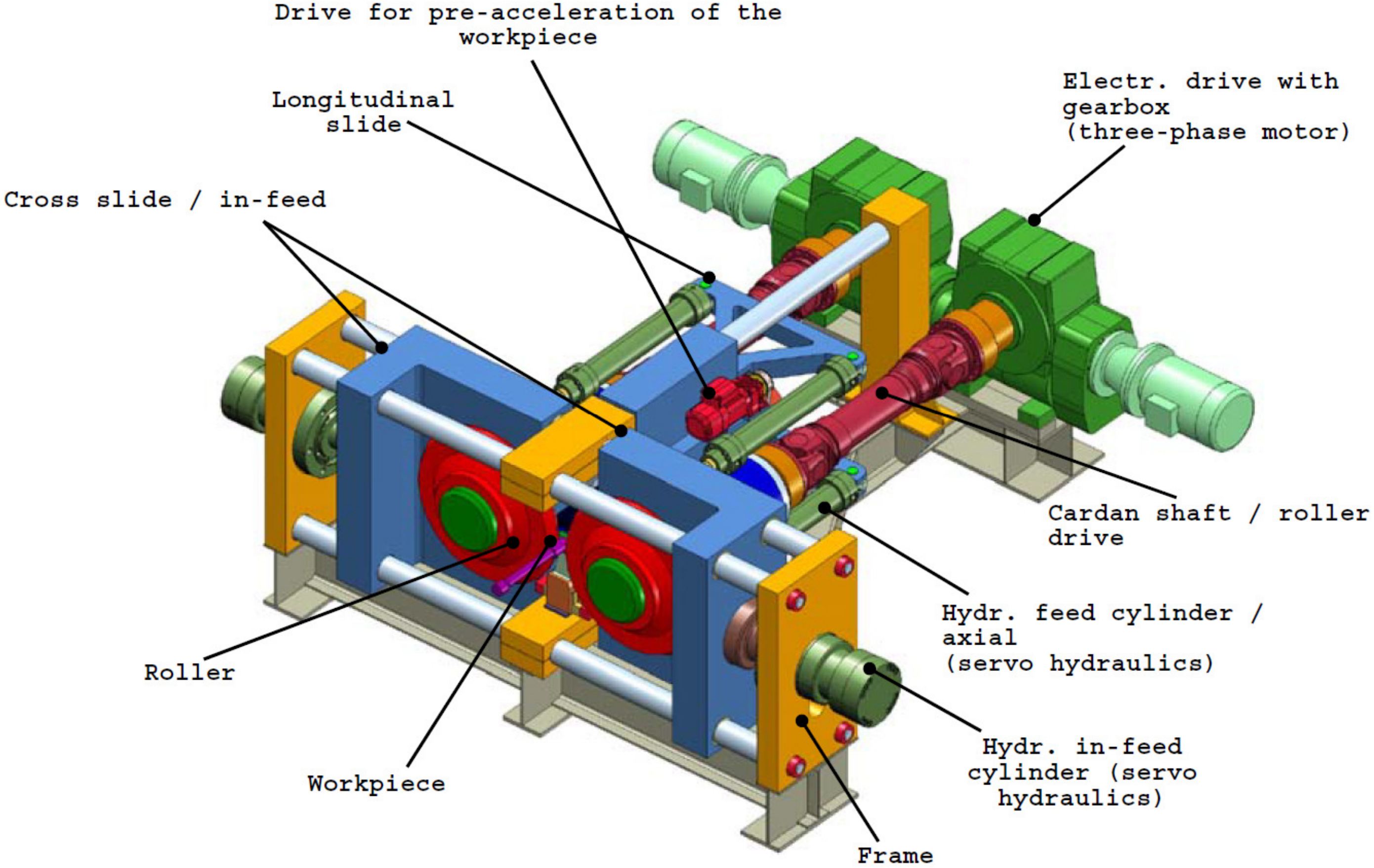

Spin extrusion
Wedge Rolling
Cross Rolling

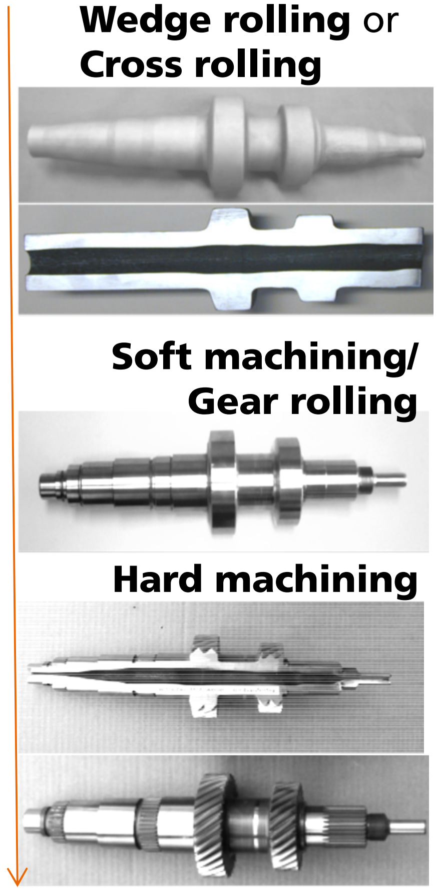

Swaging


Gear Rolling
Axial Forming


Heat Treatment


Grinding



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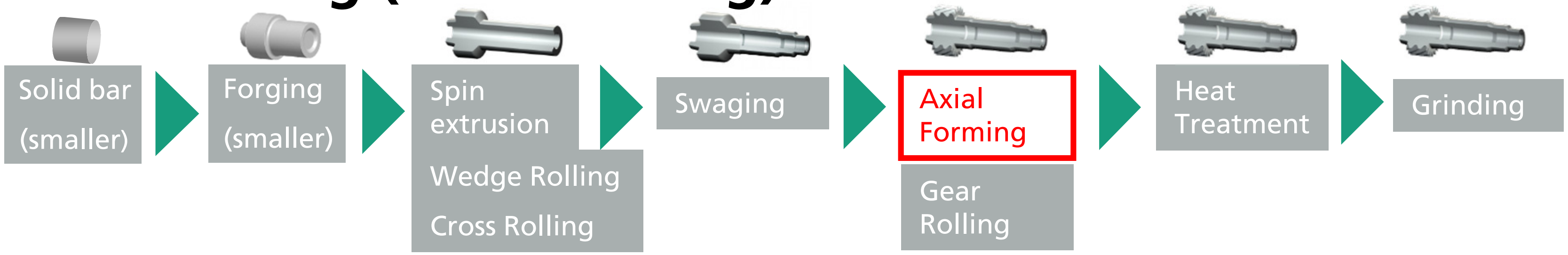
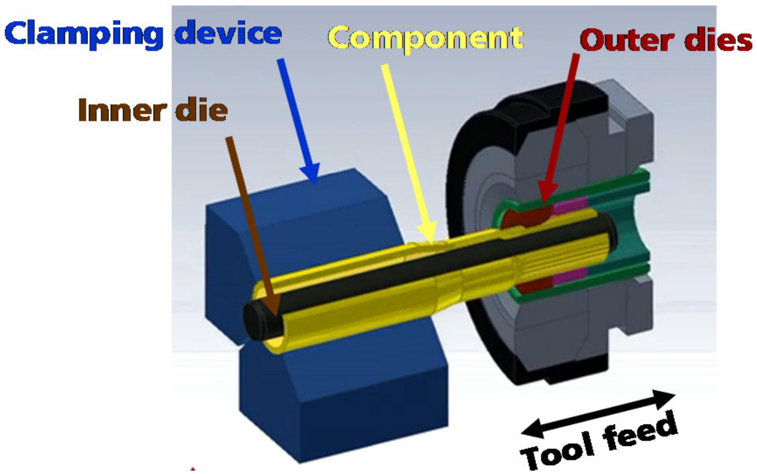
# Axial Forming (cold forming)

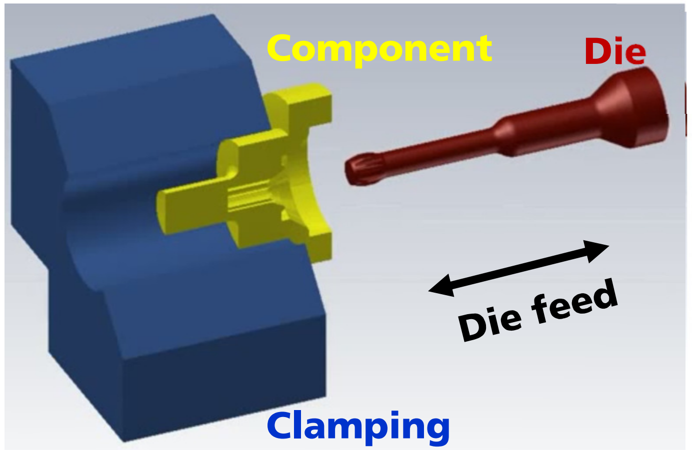


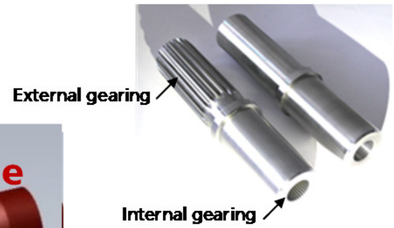

- Modular cold forming technology for hollow and massive components
- Incremental precision forming of complex parts
- Max. force in alternating machine operation: 400kN at a frequency 10-30 Hz
- Axial feed 30mm/s (main axis), 300mm work area (workpiece length)
- Cold forming of inner and outer geometries

## Axial forming principle
**(external geometries)**

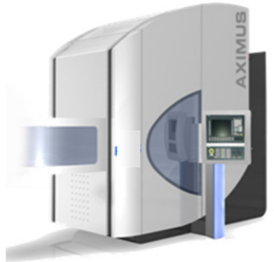



## Axial forming principle
**(internal geometries)**




# Axial Forming (cold forming)

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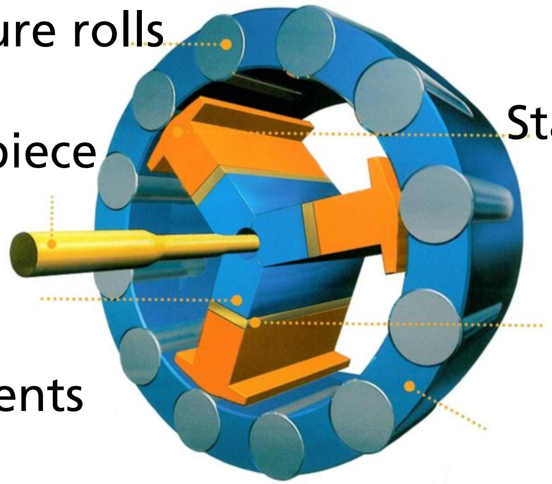
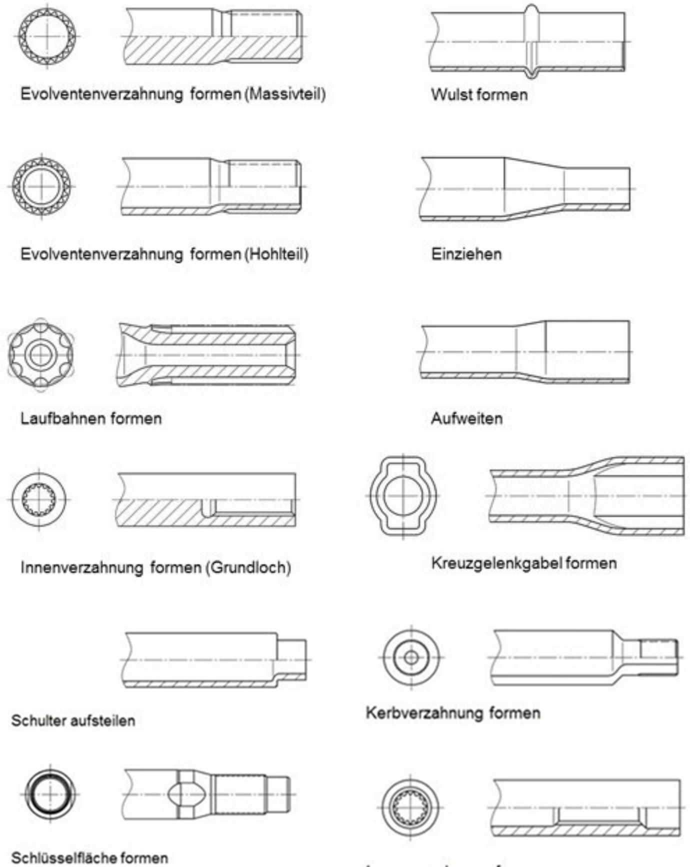
# Swaging (cold forming)

Solid bar (smaller) ▶ Forging (smaller) ▶ Spin extrusion / Wedge Rolling / Cross Rolling ▶ **Swaging** ▶ Axial Forming / Gear Rolling ▶ Heat Treatment ▶ Grinding




- **Different geometries feasible, flexible**
- **Weight reduction by overall constant wall thickness**
- **Tolerances IT 8-9 (<0,1mm)**
- **high surface quality, minimized notch effect**
- **strain hardening effects**
- **nealy all steels / alloys feasible**
- **available by end of 2013 at Fraunhofer IWU**

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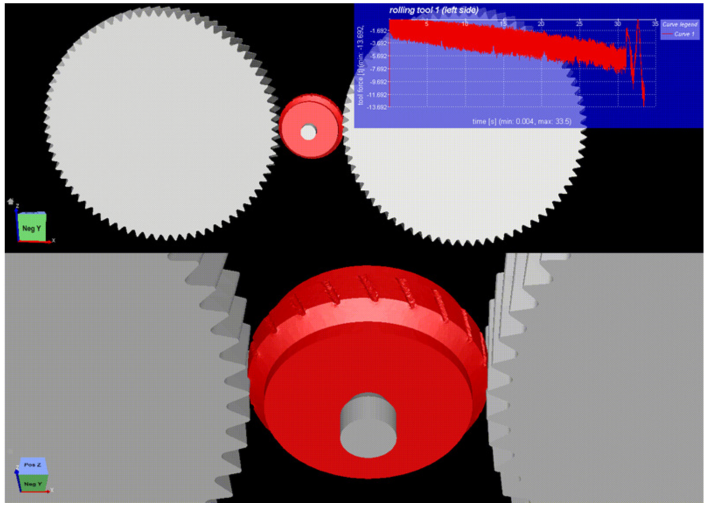
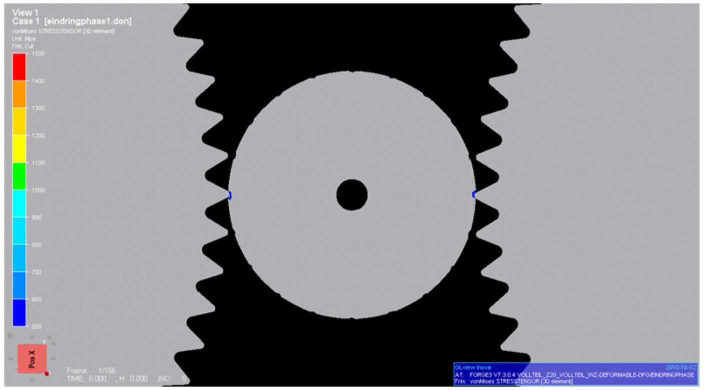
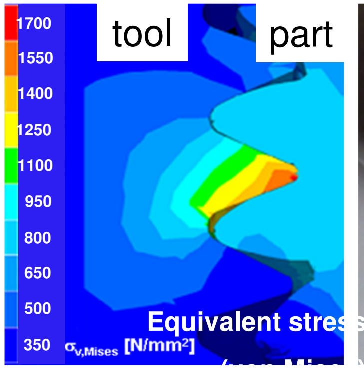
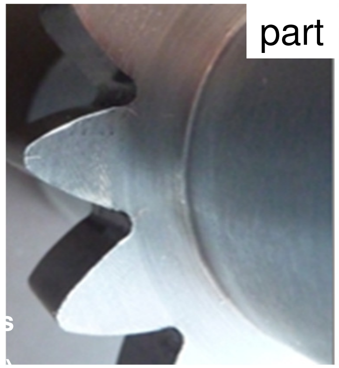
# Gear Rolling (cold forming)

Solid bar (smaller) → Forging (smaller) → Spin extrusion / Wedge Rolling / Cross Rolling → Swaging → Axial Forming / Gear Rolling → Heat Treatment → Grinding








- Material flow analysis
- Optimization of tool and blank design
- Tool load optimization
- Choice of optimal tool steel
- Excellent compliance of simulation and reality





Funded by the DFG

DFG Deutsche Forschungsgemeinschaft

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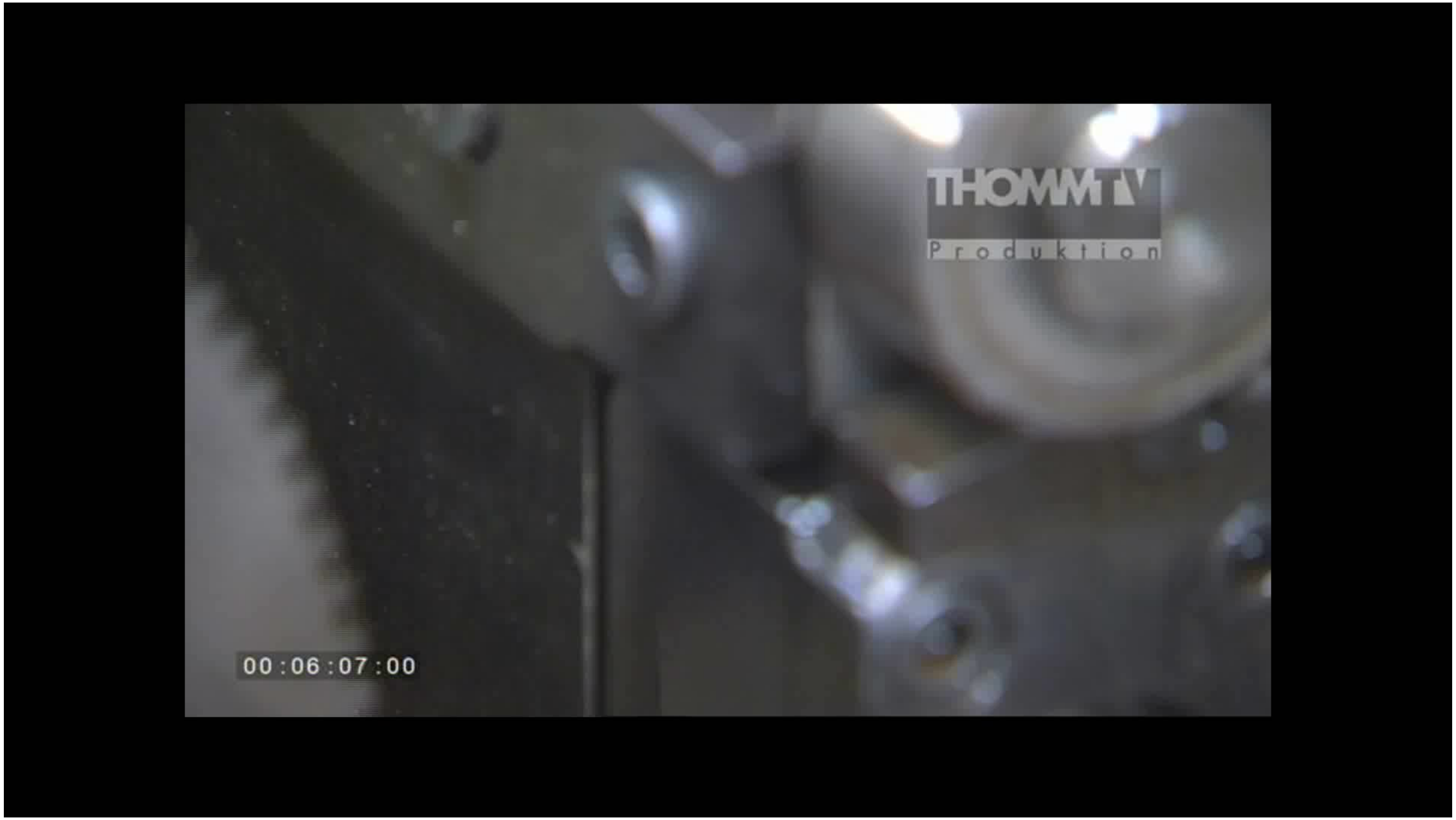
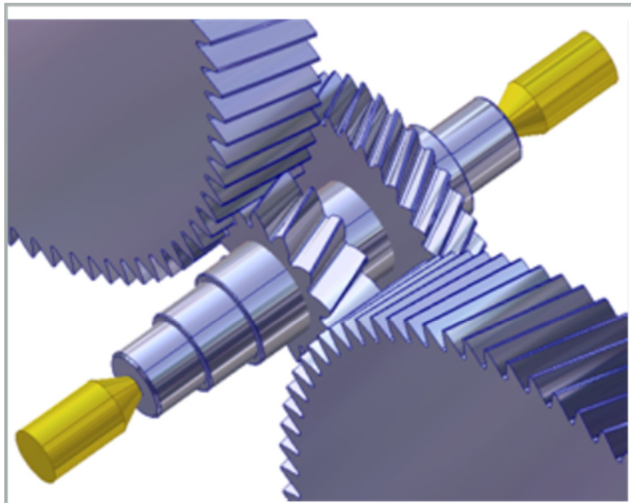
# Gear Rolling (cold forming)

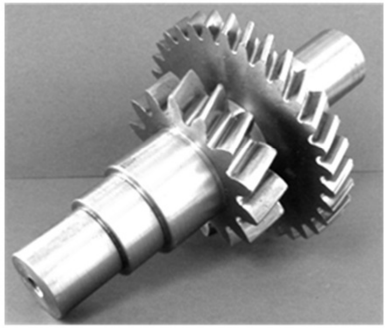


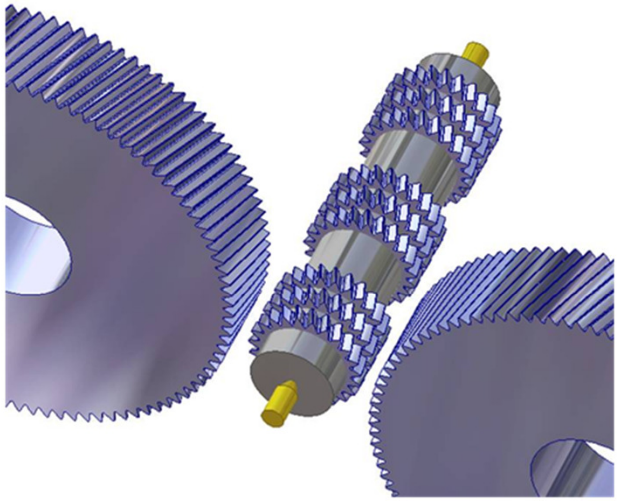
# **Gear Rolling** - Advantages regarding machine and process

- **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 gear & tools)
- Rolling of **narrow located gears** on shafts (no joining of gears on the shaft necessary)
- **Rolling of multiple gears in one cycle**



Narrow located gears on shafts





Single gears with distance rings and clamping

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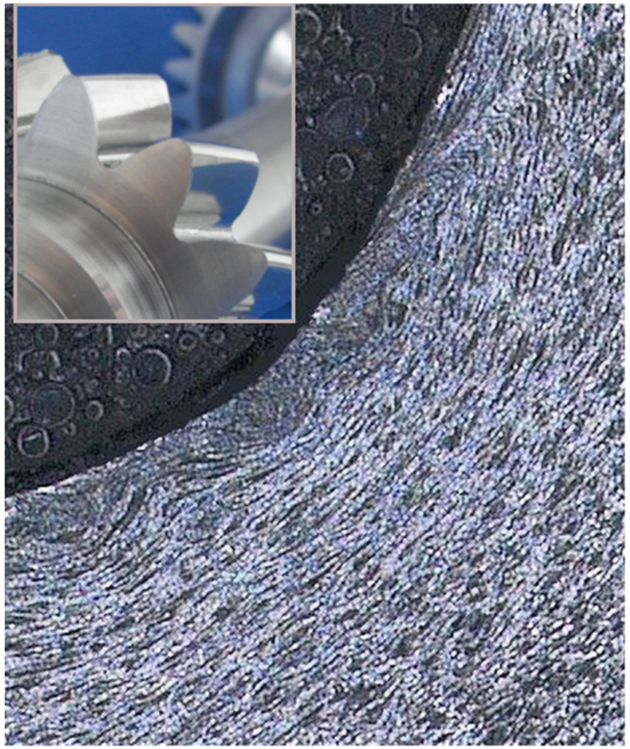
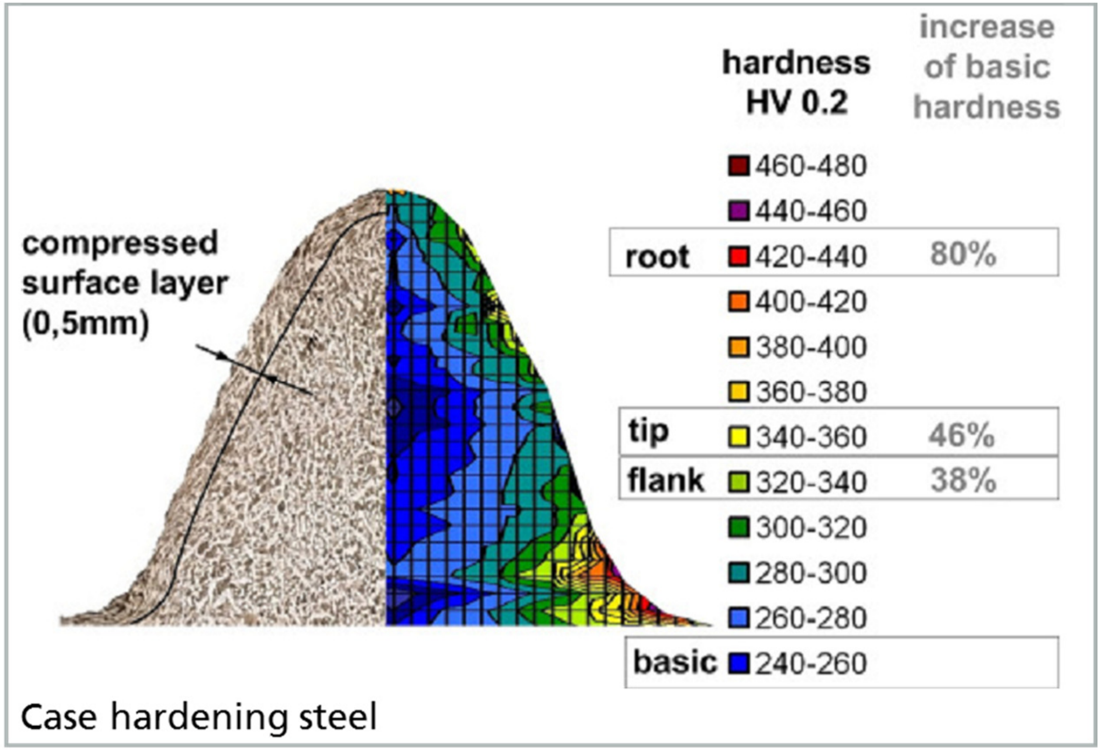
# **Gear Rolling** - Advantages regarding components

- **Strain hardened surface layer** (for low loaded components, elimination of hardening)
- **Contour related and not cutted material texture**
- **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

# Component examples

## Special profiles *cold rolled into „solid material“*

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

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# Component examples

## High gears *cold rolled into „solid material"*

- 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 treatable steels

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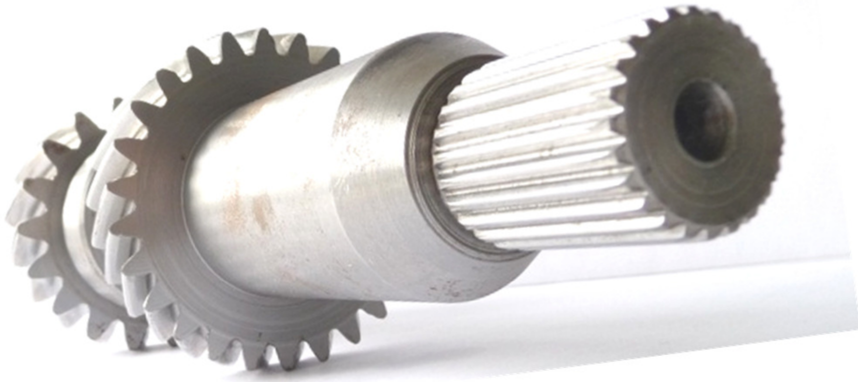
# Component examples

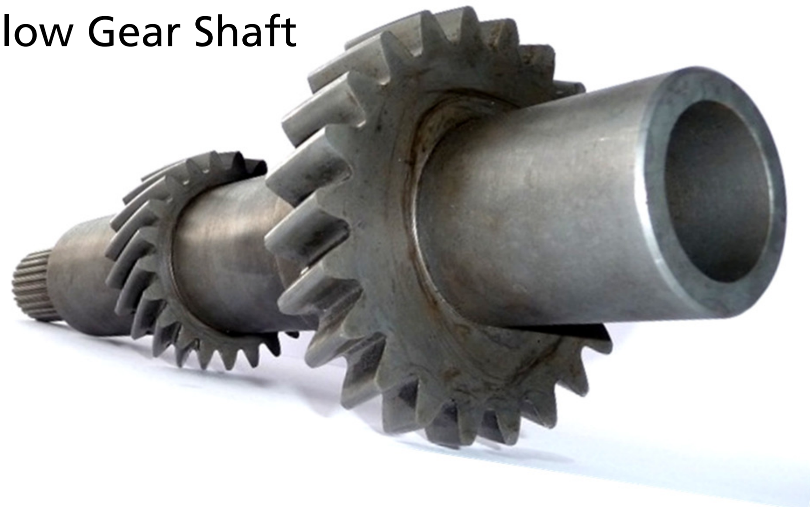
## Gears *cold rolled directly on the shaft (no assembly of gear and shaft)*

- Reverse Gear Shaft

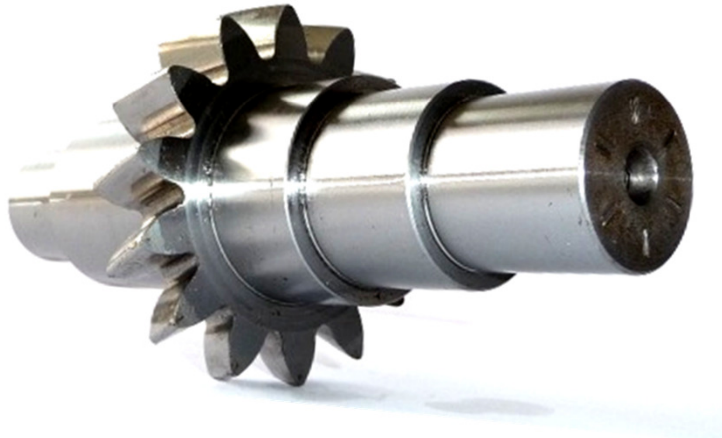
- Transmission Gear Shaft



- Hollow Gear Shaft



- Reverse Gear Shaft



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# Component examples

bar → Forged prefrom → Spin extrusion → swaging cutting → Gear rolling → Heat treatment → grinding

**Funded by BMWi**

Bundesministerium für Wirtschaft und Technologie

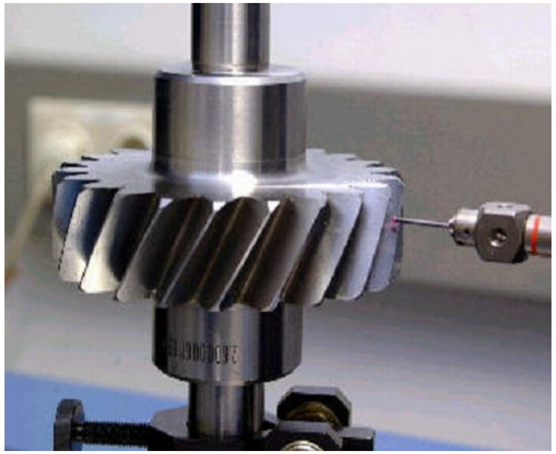
**(German Federal Ministry of Economics & Technology)**

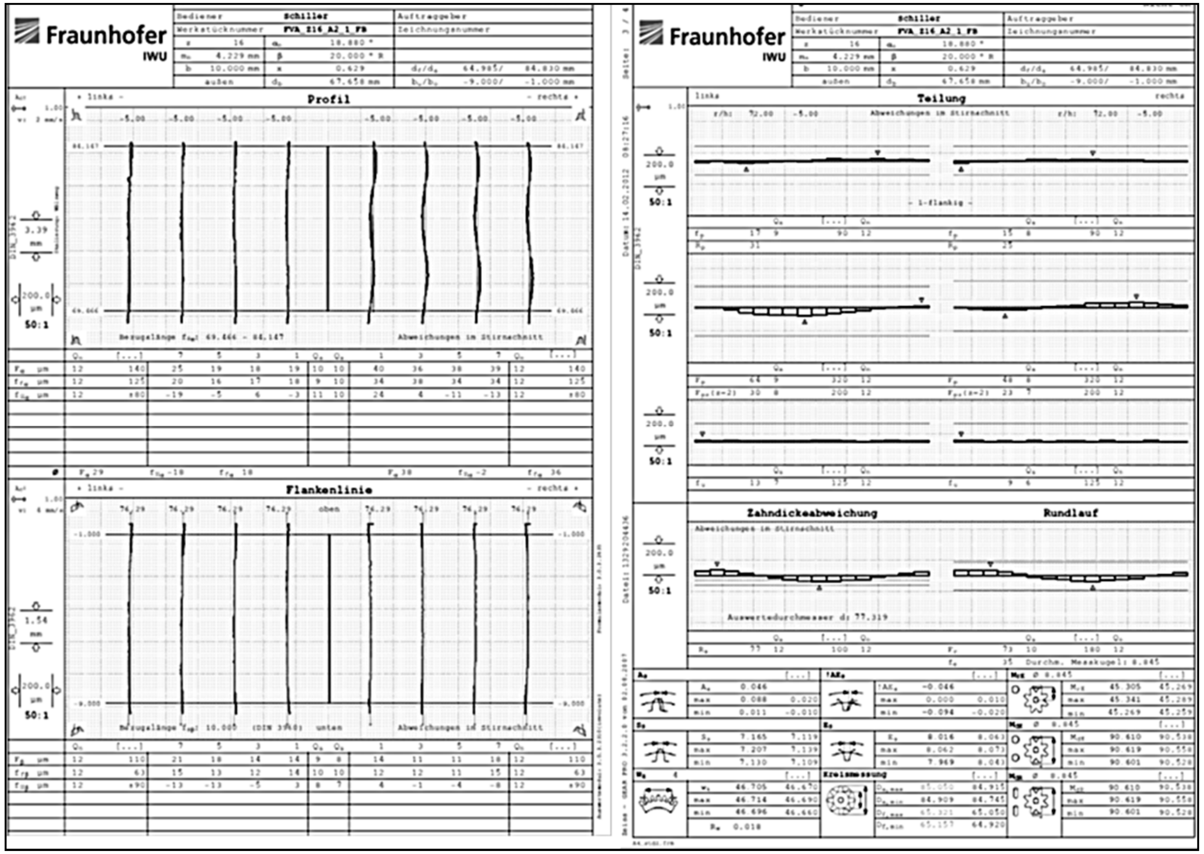
External gear axial formed

Internal gear axial formed

Diameter reduction, Internal and External gear swaged

# Gear testing at Fraunhofer IWU
## Gear measurements acc. to DIN standard 3960-3962



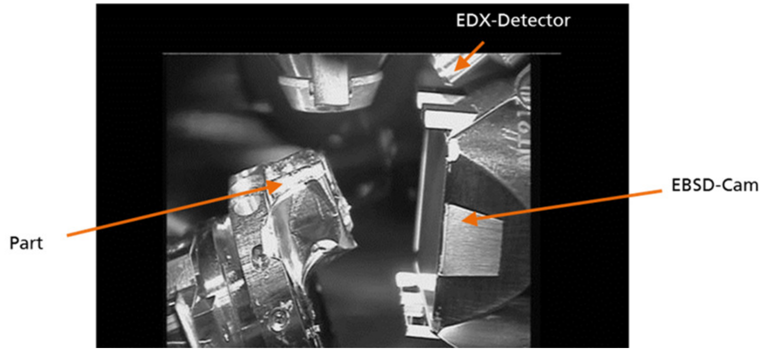


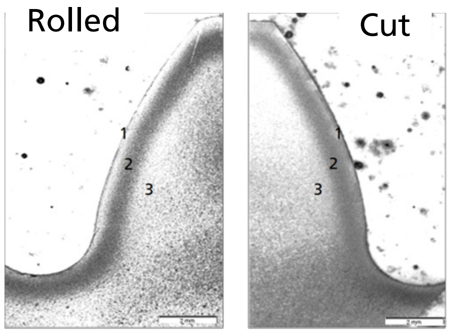

**Measurements acc. DIN 3960-3962**

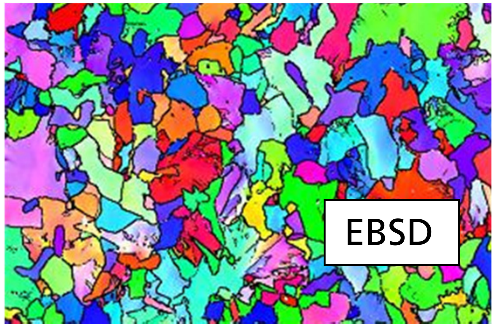
- **Profile**
- **Lead / Flank**
- **Pitch**
- **Concentricity**
- **Diameters, etc**

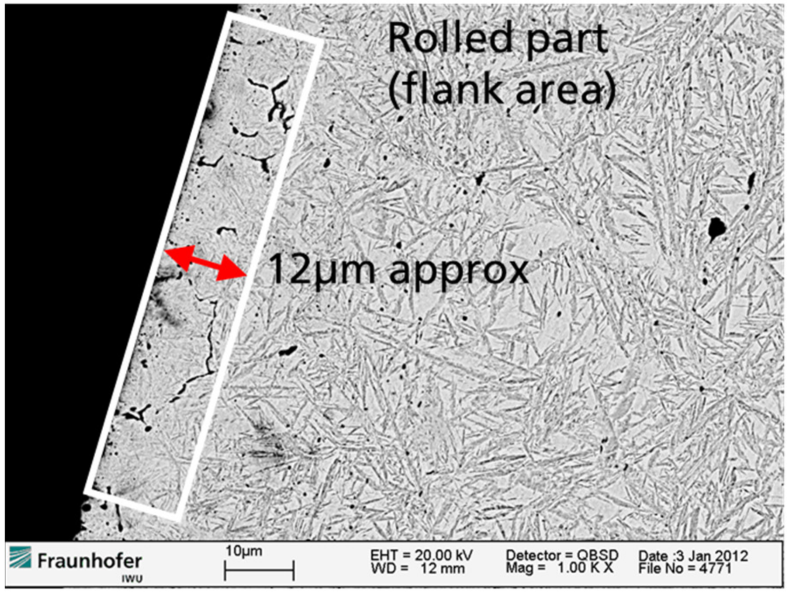
# Gear testing at Fraunhofer IWU
## Microstructure evaluation

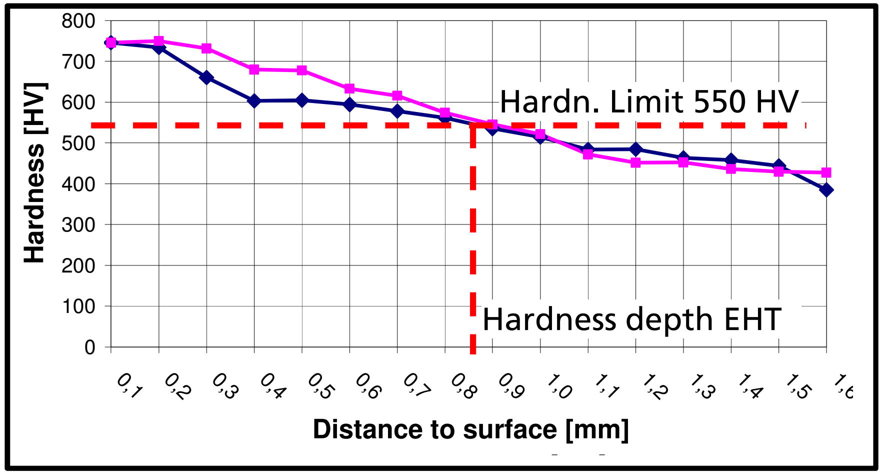
- **Microstructure**
- **Surface oxidation**
- **EDX / EBSD analyses**
- **Hardness**



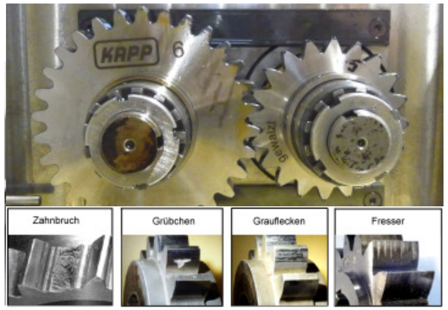




- **half tooth height:** Eht = 0,9mm
  → max. $0{,}2 \cdot m_n = 0{,}2 \cdot 4{,}5 = 0{,}9$mm

# Gear testing at Fraunhofer IWU

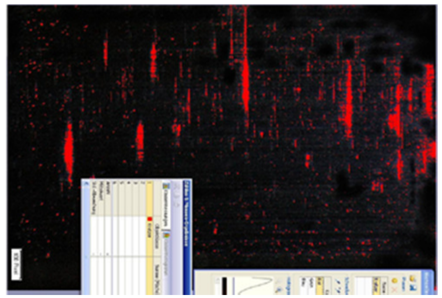
## Gear analyses

- **Scuffing / Pitting / Micropitting**

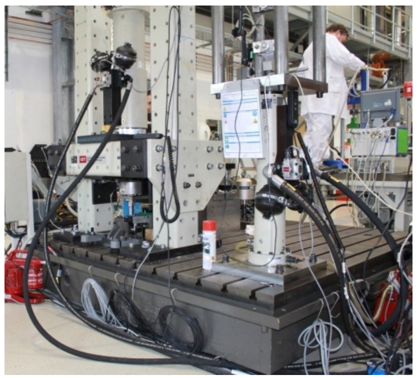



Scuffing failure

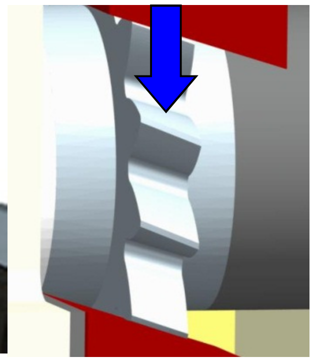
Greyscale correlation



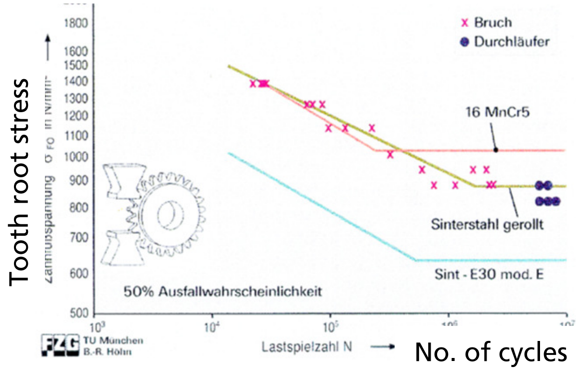
- **Tooth root strength / Tooth bending load**



Pulsator Force

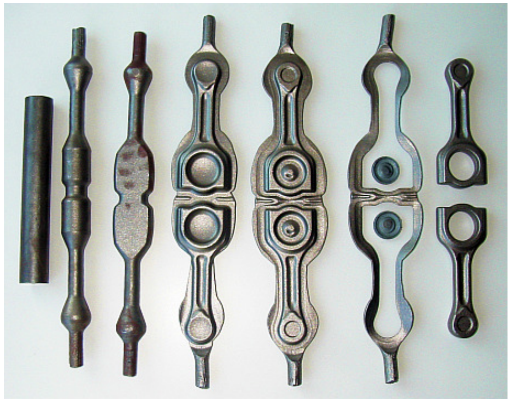


Wöhler life cycle diagram



# French business partners

Centre technique des industries mécaniques – St. Etienne
Ecole Nationale Supérieure d'Arts et Métiers – Metz
Ateliers des Janves – Bogny sur Meuse


process sequence

## CROSS-WEDGE ROLLING

### Research and Development

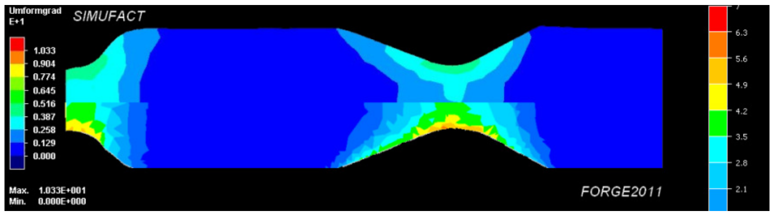
simulation of cross wedge rolling

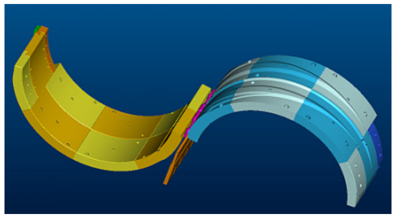
- making a test roll tooling
- comparison of parts and simulation
- doctoral thesis (Mr. MANGIN)
- diploma thesis (Mr. GHIDUCI)
- european net-work (F, ES, I, PL, BY, G)

### Automotive Industry

a set of roll tooling for cross wedge rolling

- hammer forging connecting rods
- preforming in a automated forging line
- training a group of employees
- initial operation together with machine tool supplier in France



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# Thank you very much for your attention!

## Fraunhofer IWU Chemnitz



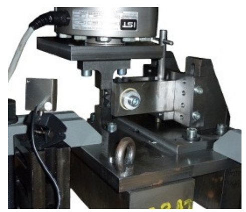
### Competences

- 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)
- Xstess 3000 test bench (x-ray residual stress analyses)
- Simulation software:  Forge 2009, Simufact



### Project cooperation (Industry, public research)

- Research from development studies to the serial production