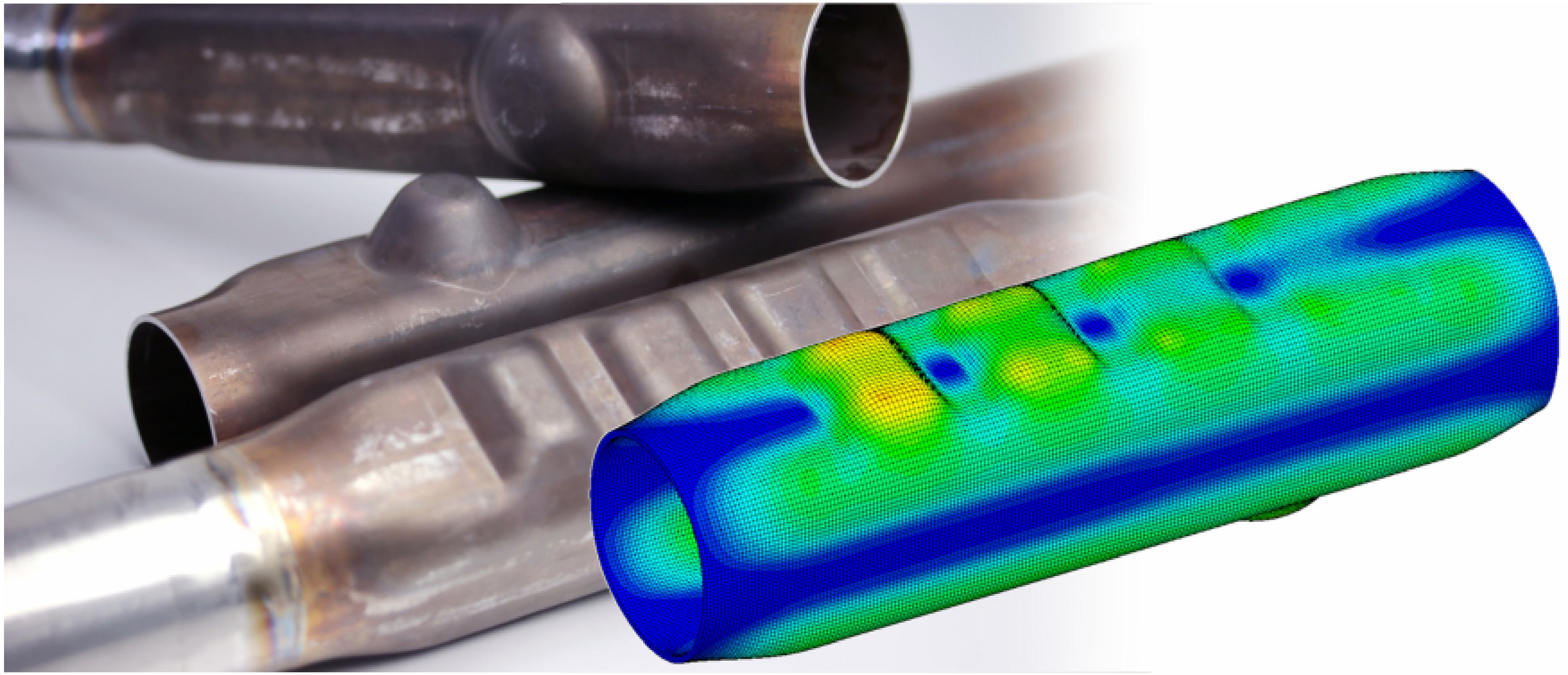
NUMERICAL AND EXPERIMENTAL INVESTIGATIONS FOR HOT METAL GAS FORMING OF STAINLESS STEEL X2CrTiNb18

ICAFT/SFU/AutoMetForm 2018, 07 November 2018, Chemnitz



SALZGITTER HYDROFORMING
Ein Unternehmen der Salzgitter Gruppe

Fraunhofer IWU

OUTLINE

- 1 Motivation and objective
- 2 Process
- 3 FE modeling
- 4 FE results
- 5 Comparison with experimental data
- 6 Excursus Hot Metal Gas Forming-Press Hardening
- 7 Conclusion

Funding

The presented research work originates from the MANUNET ERA-NET collaboration project

"Temperature supported hydroforming of stainless steel tubes"

which was funded

- by the **German Federal Ministry of Education and Research (BMBF)** within the Framework Concept "Research for Tomorrow's Production" and managed by the **Project Management Agency Forschungszentrum Karlsruhe**, Production and Manufacturing Technologies Division (PTKA-PFT)
- and the **Department of Economic Development and Infrastructures of the Basque Country**, through the Gaitek/Hazitek program, coordinated by project management agency **Innobasque**.

Consortium

OUTLINE

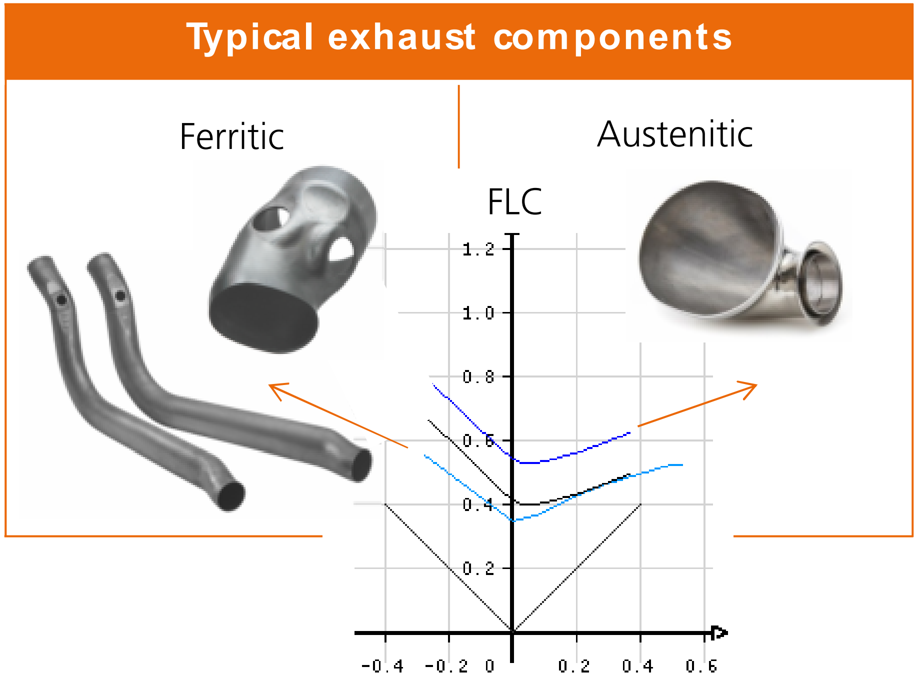
1 Motivation and objective

Motivation

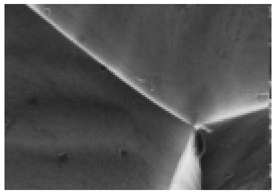
- Replacement of austenitic steel grades with ferritic grades for exhaust gas components
  - ➢ Price advantage due to alloy composition
  - ➢ Significantly lower thermal expansion

Objective

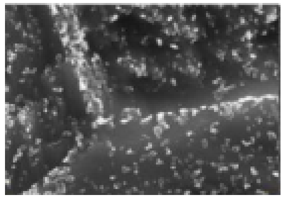
- Increase of the degree of forming at forming temperatures of 850°C
- Avoidance of multi-stage hydroforming process at 20°C and thus annealing steps between



Multi-stage IHU processes require annealing steps between, which leads to the formation of precipitates at the grain boundaries and thus to reduced formability.



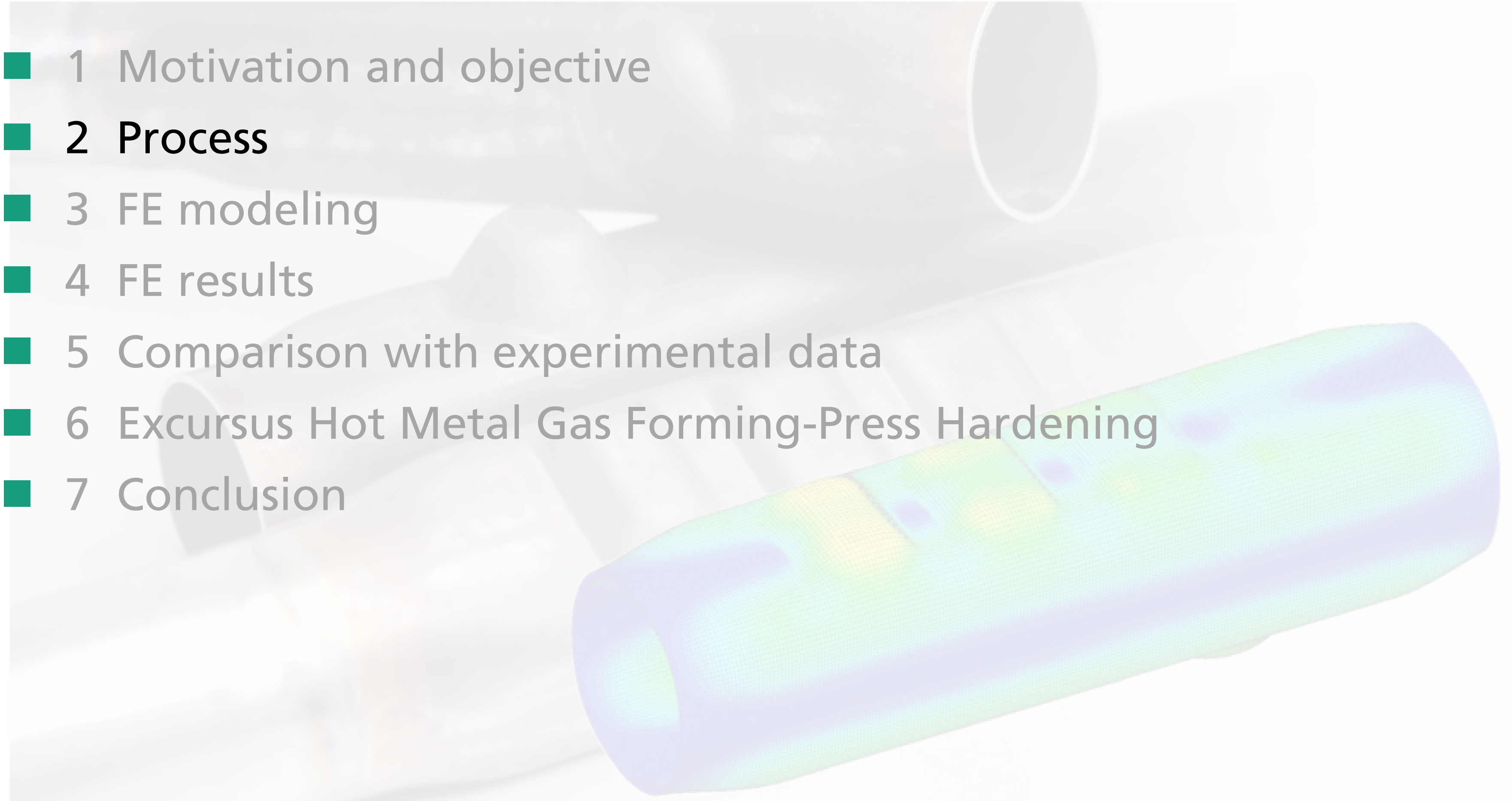
Without annealing



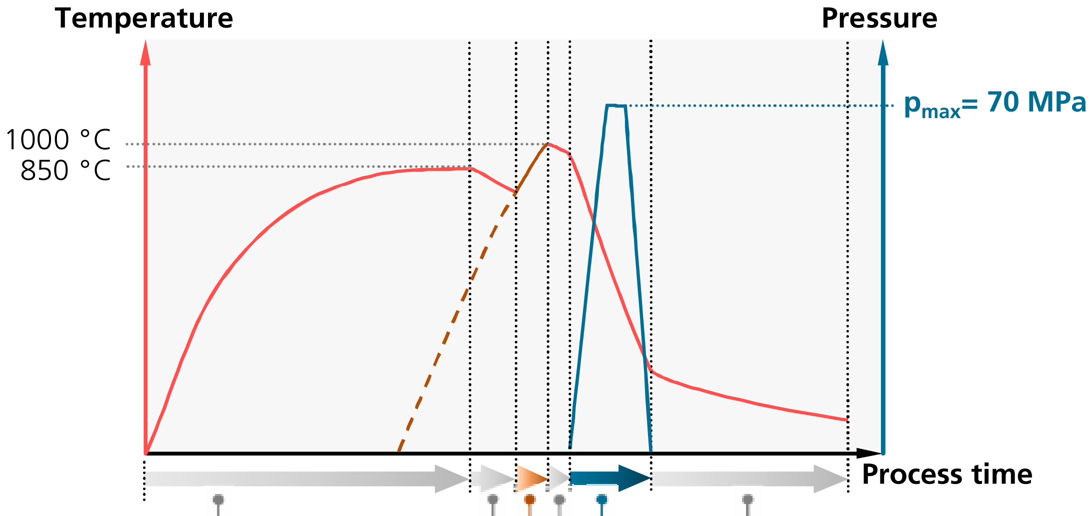
Multi annealed

Archivierungsangaben

OUTLINE



2 Process



Pre-heating

- Pre-heating in chamber furnace within recrystallization temperature

Transfer phase

- Transfer of the tube into the tool, press closing until position for resistance heating

Resistance heating

- 8 s from 740 to 1000 °C
- 30 s from 20 to 1000 °C

Press closing

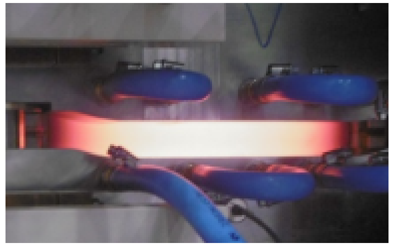
- Final press closing and sealing

HMGF

- Hot Metal Gas Forming by pressure built up (1.4 s to 70 MPa), holding and pressure release

Part removal

- Part removal, cooling on air

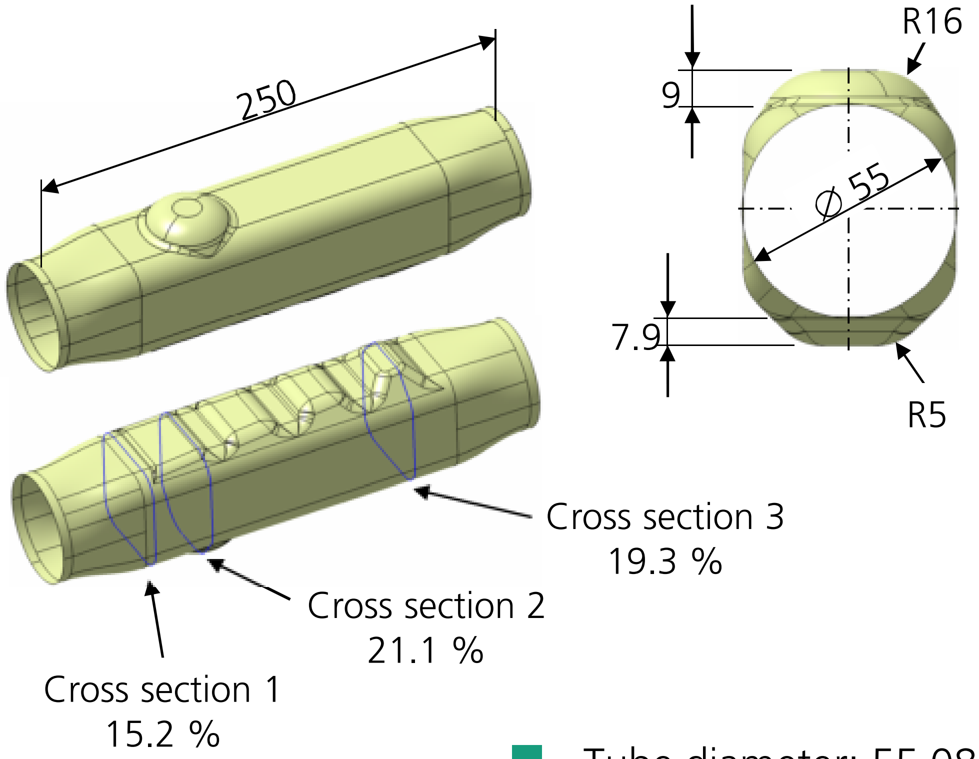


SALZGITTER HYDROFORMING
Ein Unternehmen der Salzgitter Gruppe

Fraunhofer IWU

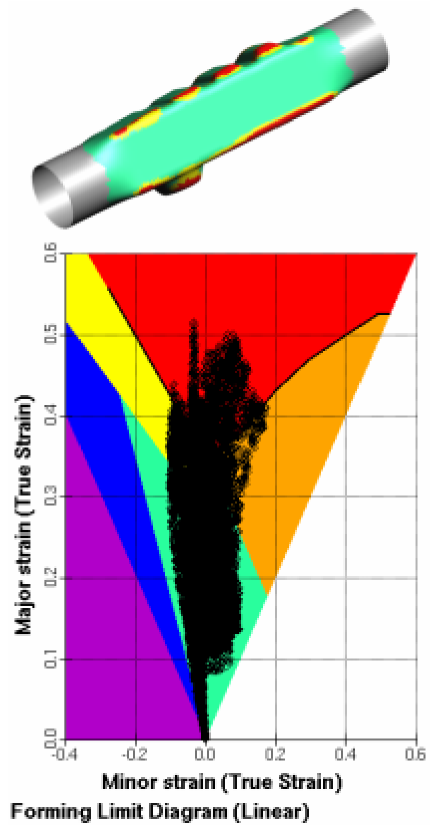
2 Process

- Technologically challenging geometry with local high plastic strains (65 %) in radius areas and hardly any free forming

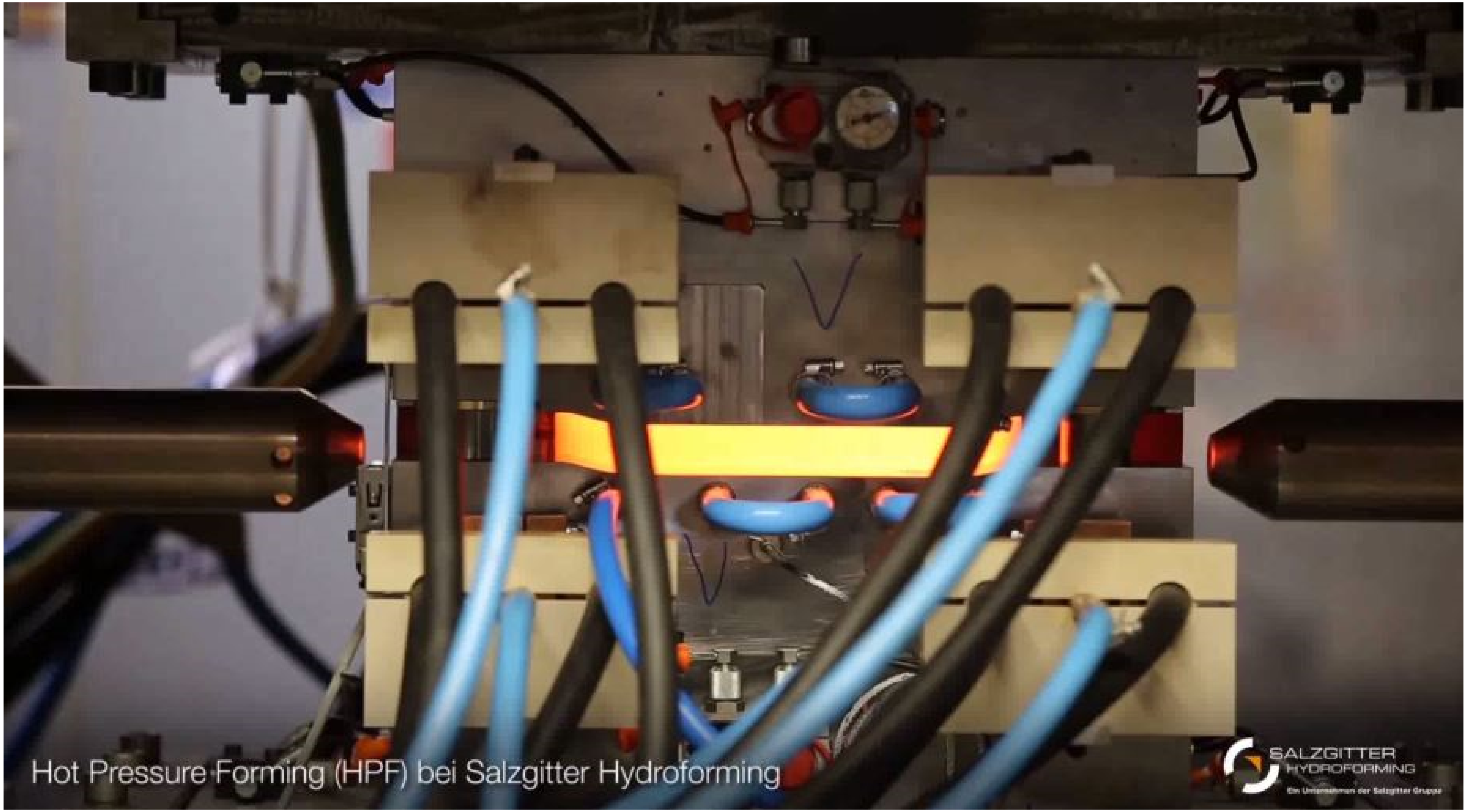


- Tube diameter: 55.08 mm
- Wall thickness: 1.84 mm

Component failure with single-stage hydroforming at 20°C



2 Process


Hot Pressure Forming (HPF) bei Salzgitter Hydroforming
SALZGITTER
HYDROFORMING

OUTLINE

SALZGITTER HYDROFORMING

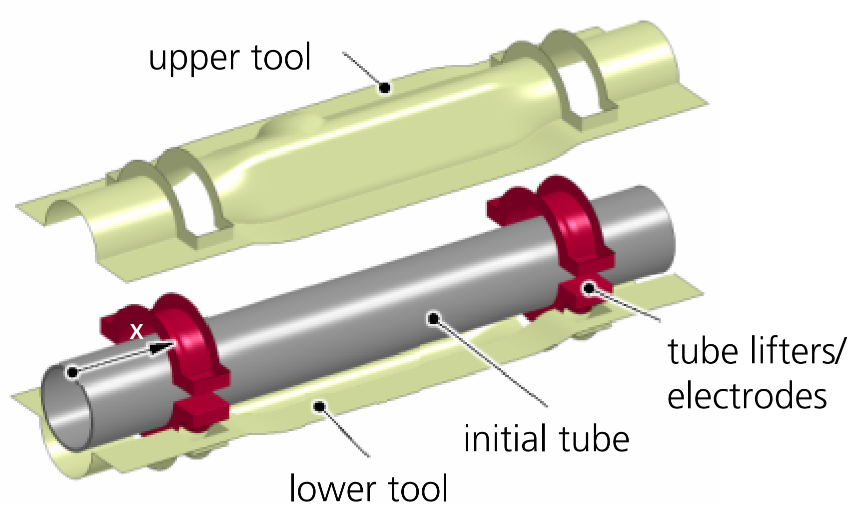
Ein Unternehmen der Salzgitter Gruppe

Fraunhofer IWU

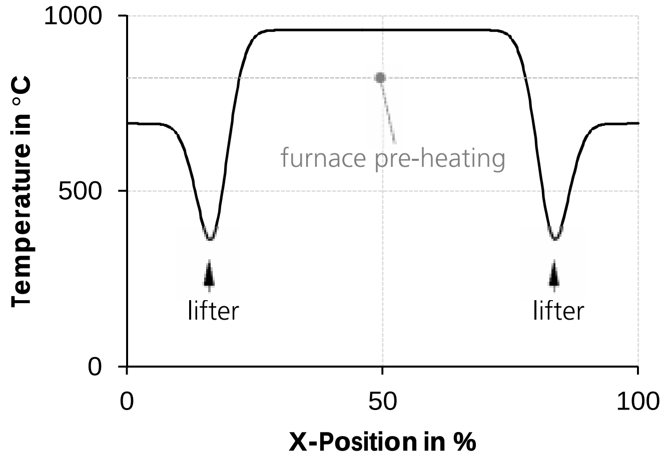
3 FE modeling

FE model setup

- Tools: rigid active surfaces
- Tube: elastic-plastic shell, 1 mm element length
- Input from Comsol simulation: axial temperature distribution of tube
  → result mapping
- Local tube diameter scaled according to local temperature
- Thermal boundary conditions are considered (pressure dependent contact heat transfer, heat radiation and convection, initial tool temperature of 25 °C)



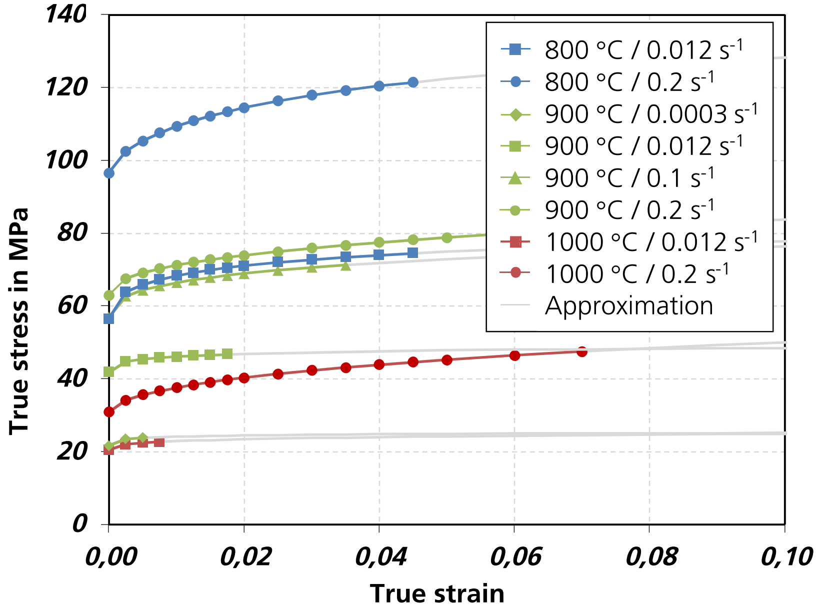
Axial temperature distribution of tube at beginning of pressure build-up

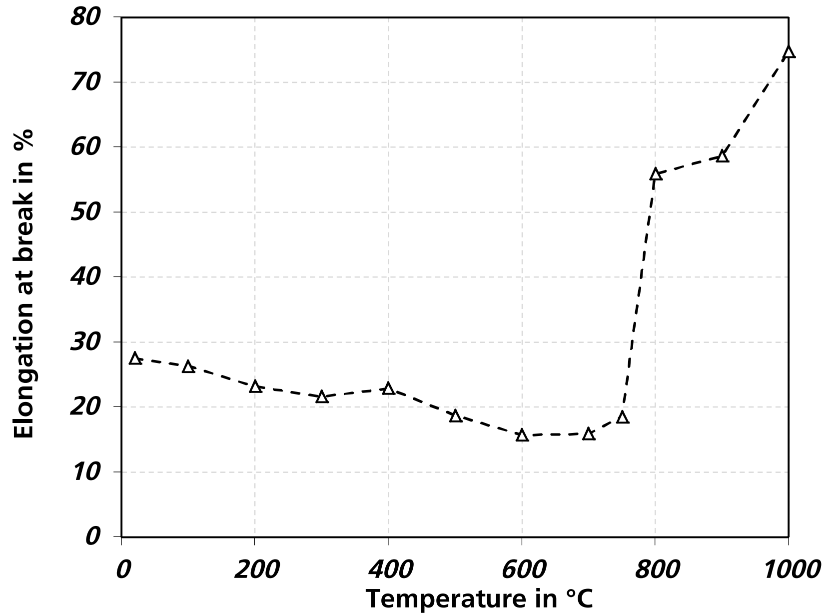


3 FE modeling

Material modeling

- Uniaxial tensile tests with specimens milled lengthwise from tubes





▶ Flow curve approximation and transfer into material model (elastic-plastic)

High strain rate sensitivity → strain rate dependent flow curves

▶ 20 °C → 800 °C: increase of elongation at break from 27.6 to 74.8 % (2.7 times)

SALZGITTER HYDROFORMING Ein Unternehmen der Salzgitter Gruppe

Fraunhofer IWU

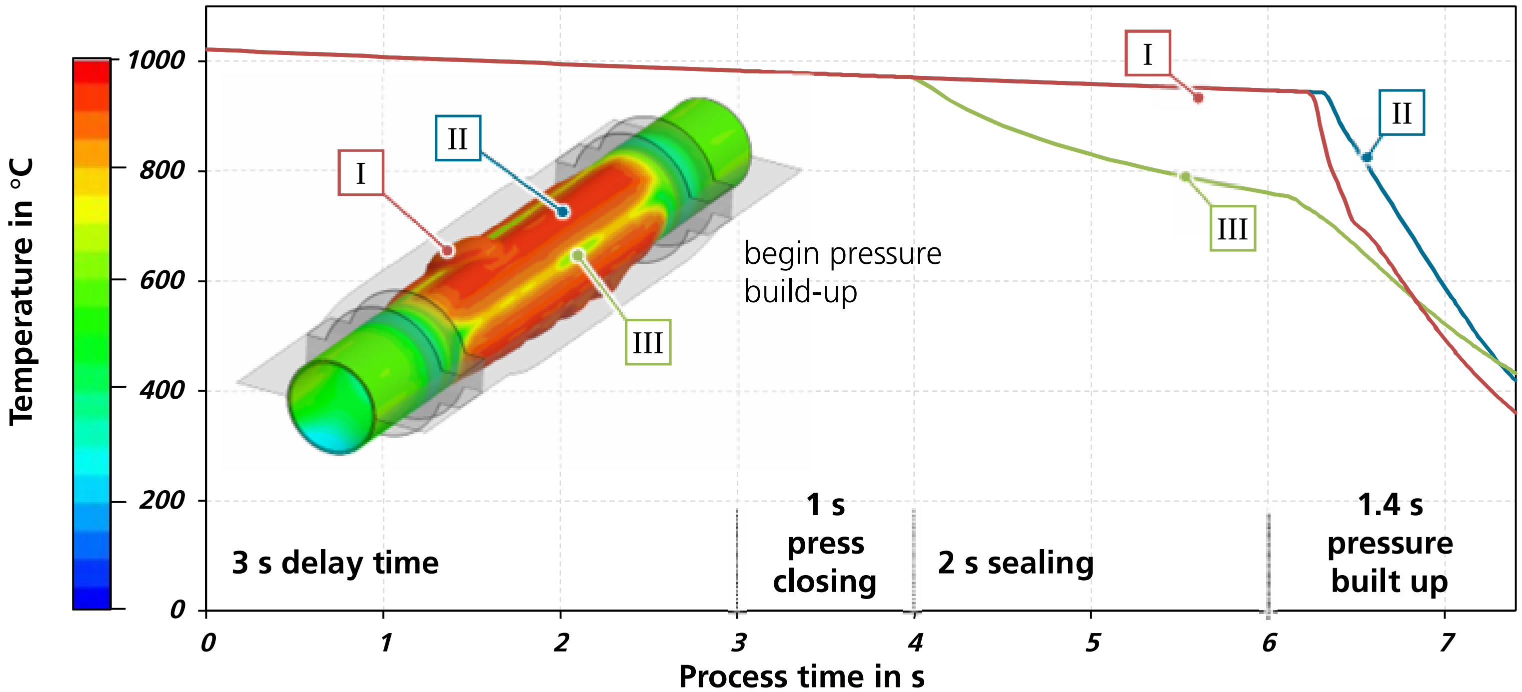
OUTLINE

- 1 Motivation and objective
- 2 Process
- 3 FE modeling
- **4 FE results**
- 5 Comparison with experimental data
- 6 Excursus Hot Metal Gas Forming-Press Hardening
- 7 Conclusion

4 FE results

Temperature

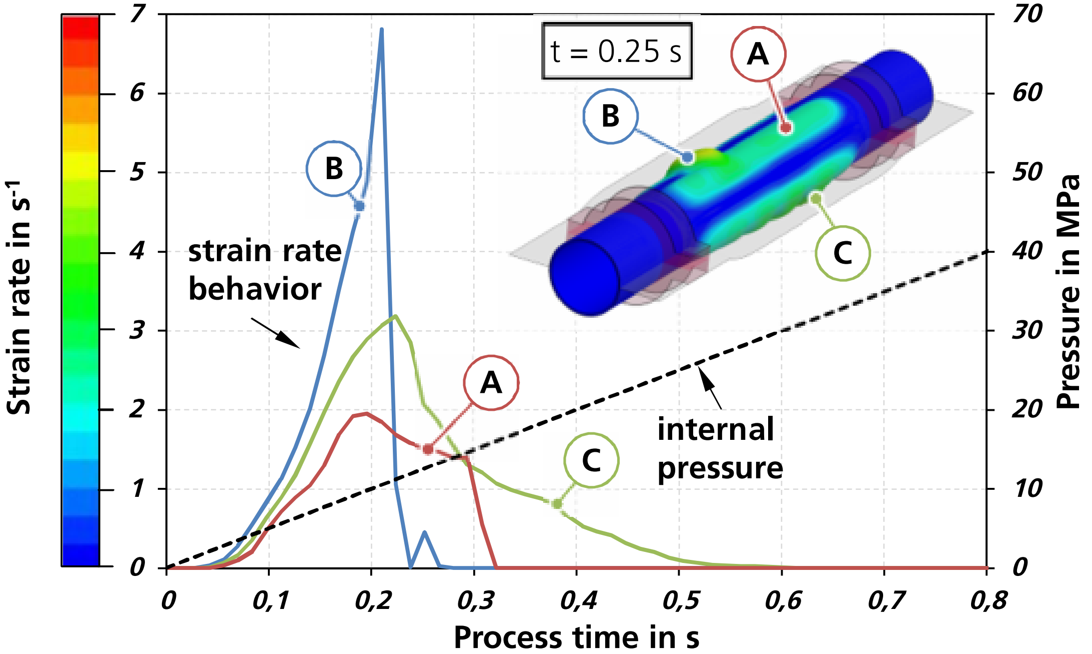
- First contact between workpiece and tool occurs in the region of point III
  → earlier cooling
- Significant cooling during pressure build-up when tube gets in contact with die
- Radius areas cool down more slowly than plane areas due to later tool contact



4 FE results

Plastic strain

- Different behavior depending on the position of the component area
- Larger, free expansions are initiated already at low pressures and at higher strain rates (point B)
- Forming of radii (points A, C) is only completed at higher pressures and lower strain rates



Need for a strain rate-dependent material model

→ Prevention of premature localization considered

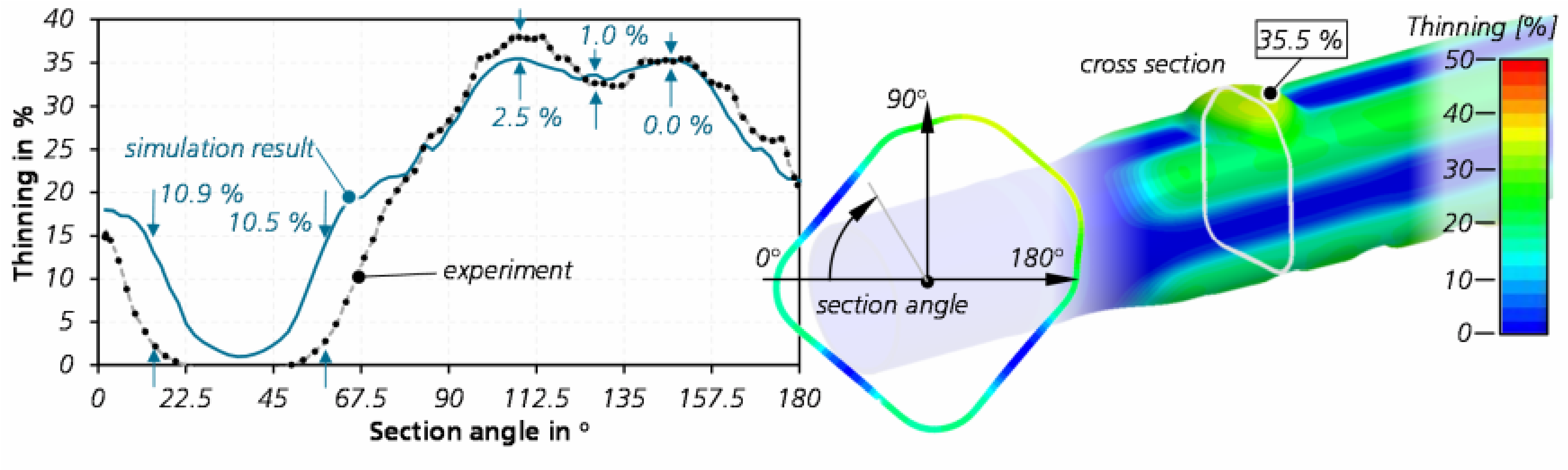
OUTLINE

- 1 Motivation and objective
- 2 Process
- 3 FE modeling
- 4 FE results
- 5 Comparison with experimental data
- 6 Excursus Hot Metal Gas Forming-Press Hardening
- 7 Conclusion

5 Comparison with experimental data

- Determination of remaining wall thickness with coordinate measuring machine

Cross section with dome



- Possible causes of larger deviations
  - Inhomogeneous initial circumferential wall thickness distribution not considered
  - Sealing not considered (axial compression / position deviation)
  - Material modeling, e.g. tensile test specimen axially cut from tubes

▶ **Need of more information out of experiment for precise verification of simulation**

SALZGITTER HYDROFORMING
Ein Unternehmen der Salzgitter Gruppe

Fraunhofer IWU

OUTLINE

- 1 Motivation and objective
- 2 Process
- 3 FE modeling
- 4 FE results
- 5 Comparison with experimental data
- **6 Excursus Hot Metal Gas Forming-Press Hardening**
- 7 Conclusion

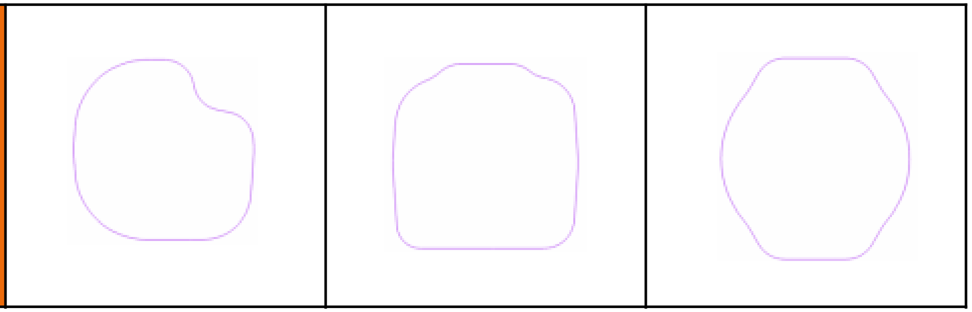
SALZGITTER HYDROFORMING
Ein Unternehmen der Salzgitter Gruppe

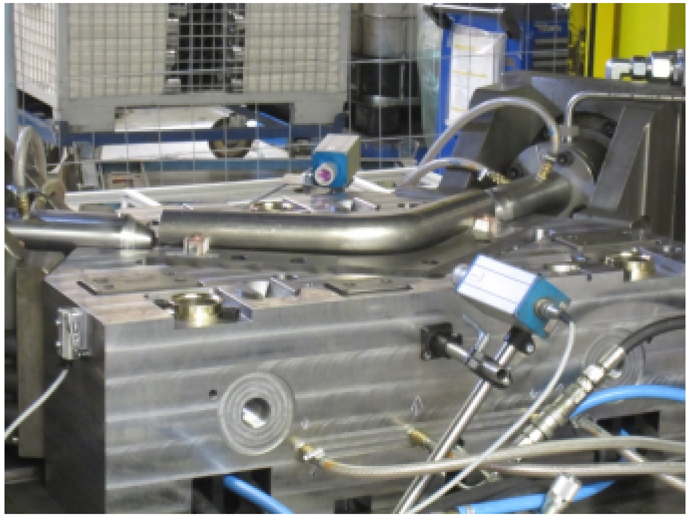
Fraunhofer IWU

6 Excursus Hot Metal Gas Forming-Press Hardening

- Demonstrator for chassis and body structure

Different cross sections

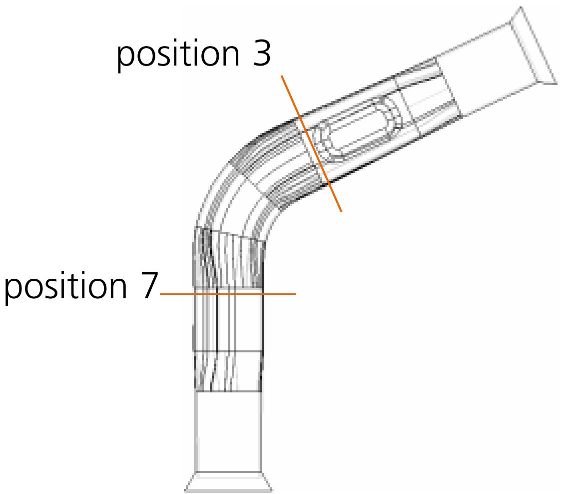




- Geometric and mechanical properties
  - Bent outlet tube
  - Boron-Steel (1800PHS)
  - Cross sections close to series production
- HMGF-tool
  - Tool with integrated conductive component heating
  - Component and electrode cooling

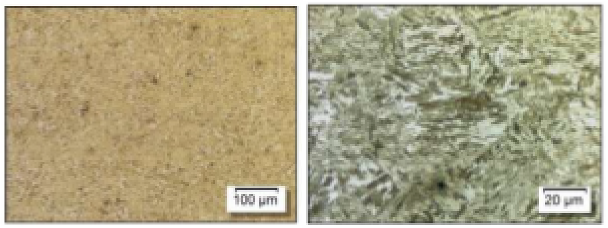
6 Excursus Hot Metal Gas Forming-Press Hardening

- Results



sample		hardness in HV0,2 measuring					
part	position / section	1	2	3	average	tensile strength	
11	3 outer fiber	594	638	623	618	2040	conversion with comparative table "ZAPP" material engineering
11	3 inner fiber	660	649	608	639	2140	
11	3 neutral area	538	558	522	539	1750	
11	7 preformed area	613	576	594	594	1970	
11	7 neutral area	567	576	585	576	1910	
15	3 neutral area	598	571	576	582	1950	
21	3 neutral area	554	571	542	556	1835	

- Geometrical properties
  - Wall thickness distribution
  - Shape accuracy
- Mechanical properties
  - Martensitic structure
  - Ultra-high strengths



Martensitic structure

OUTLINE

6 Conclusion

- New HMGF process for the material 1.4509
  - Two-stage heating, 2nd step by tool-integrated conduction
  - Improvement of process stability, dimensional accuracy and thinning

- Simulation of HMGF process
  - Simulation leads to a more critical evaluation of thinning
  - More information needed out of experiment for precise verification of simulation

- Hot Metal Gas Forming - Press Hardening
  - Successful forming of demonstrator for chassis and body structure
  - Martensitic structure with ultra-high strengths
  - Highly developed tool-technology

5 Comparison with experimental data

Possible causes of deviations

Material modeling	Tensile test specimen axially cut from tubes → Radial behavior not measured	Flow curve approximation → No experimental points for higher strain rates	Yield locus approach → Assumption due to missing data
Process modeling	Radial deviations of the tube position in the tool not considered	Sealing not considered → Possible axial compression and position deviation	
Semi-finished tube	Initial circumferential wall thickness distribution not considered (mean wall thickness)	Welding seam not considered	

Interactions between influencing variables currently unknown