PARAMETER MEASUREMENT AND CONDUCTIVE HEATING DURING PRESS HARDENING BY HOT METAL GAS FORMING

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M. Bach, L. Degenkolb, F. Reuther, V. Psyk, R. Mauermann and M. Werner

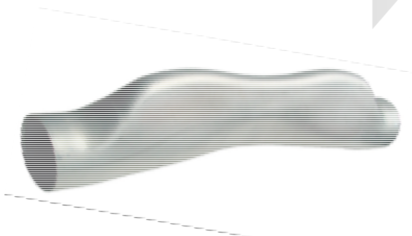
AGENDA

- Media based forming at Fraunhofer IWU
- Process principle of hot metal gas forming (HMGF)
- Motivation and Objectives
- Measurement Technique
- Process analyses
- Tool integrated heating by conduction
- Summary and outlook

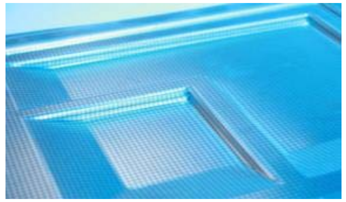
Media based forming at Fraunhofer IWU

Hybrid processes for hybrid parts

Hydroforming with heated oil



Hot Metal Gas Forming (HMGF) / press hardening (HMGF-PH)



Hydroforming at room temperature with water

Over 20 years of expertise in hydroforming at the Fraunhofer IWU

1995 2001 2006 2011 2019

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Media based forming at Fraunhofer IWU

Equipment for media based forming

- 2 Hydroforming presses
- 2 Gas pressure units from Maximator
- Control units for electrical tool heating and cooling
- Automated handling system with robot
- Heating devices

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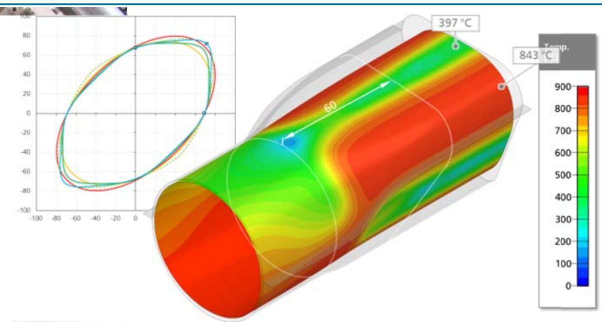
Possible media based forming processes

- Hydroforming
- Superplastic forming
- Hybrid forming
- **Hot Metal Gas Forming (HMGF)**

Simulation-based process design

- Different software for forming simulation
- Facilities for thermal and mechanical material testing (strain-rate and temperature effects)
- Metallographic laboratory
- Optical measurement systems



Principle of HMGF-PH and Motivation

Principle and known advantages of hydro forming

- high variety of possible geometric designs by forming tubes or closed profiles with various media under inner pressure against tool cavities
- integration of functions
- avoidance of joining operations
- high profile stiffness

Principle and known advantages of press hardening

- martensite generation for increasing tensile strength by cooling of heated blanks at a rate of min. 30 K/s with tools
- very common for manufacturing of automotive components with high geometric complexity
- high strength and ductility of blanks with low sheet thicknesses

combination of both principles

- HMGF-PH is more complex but:
  - utilization of advantages of both process routes
  - decreasing number of process steps

Efficient use of HMGF-PH requires reliable FEM-models and robust process design!

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Initial situation and Objectives

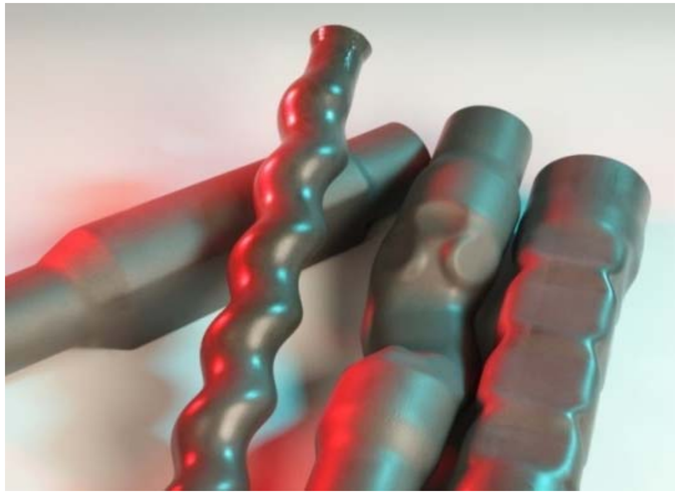
Initial situation

- New tool steels **HTCS®-23xx** and **HTCS®-26-EP by Rovalma** with improved thermal conductivity properties available
- HMGF parameters **currently** analysed separately ➔ no detailed conclusions regarding the mapping of deformation stages and temperature distribution

Objectives

- practical tests and numerical simulations of HMGF with a new and innovative forming demonstrator tool DP3
- improved measurement technology enabling **simultaneous measurement** of **part temperature** and the **movement of the component wall**
- cyclic and close-to-serial-production tests for characterising the **temperature distribution in the tools**
- design of a complex near-series demonstrator DP4 and demonstrator manufacturing using **conductive component heating** in combination **with HMGF**
- application the newly developed tool steel **HTCS®-23xx and HTCS®-26-EP** of Rovalma for the active tool parts

conductive heated tube & demonstrators



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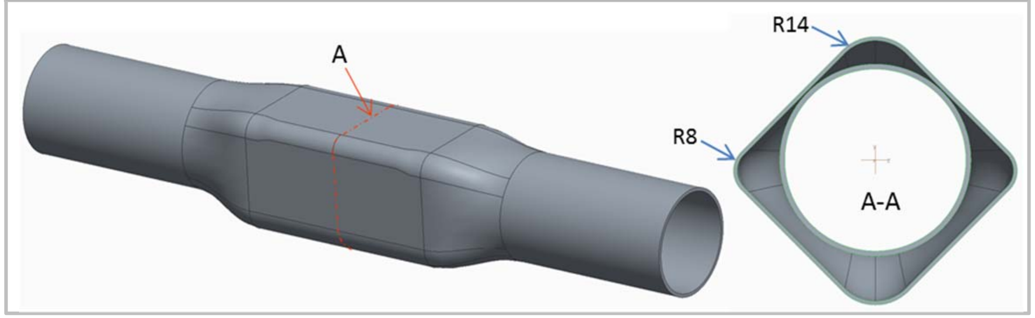
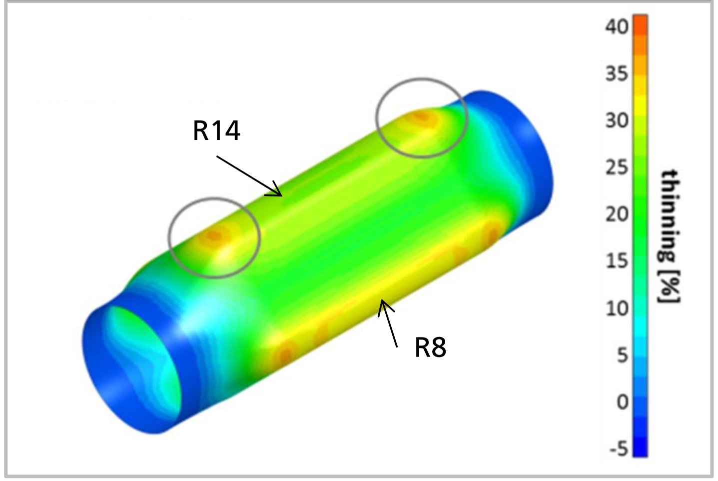
Analysis of material displacement during HMGF
component design and simulation

- Component geometry DP3
  - different corner radii (R8, R14)
  - eccentric shape
- initial tube material
  - diameter 57 mm
  - wall thickness1.5 mm
- flow curve data
  - tensile tests at different temperatures (950 °C, 900 °C, 850 °C, 800 °C, 750 °C, 680 °C, 600 °C) and strain rates (0.5, 5, 50 s-1)
  - extrapolated flow curves for quasi-static strain rates approximated according to Swift/ Hockett-Sherby
- static coefficient of friction μ = 0.35
- tube mesh: Belytschko-Tsay shell elements (initial length of 0.75mm)

component design DP3



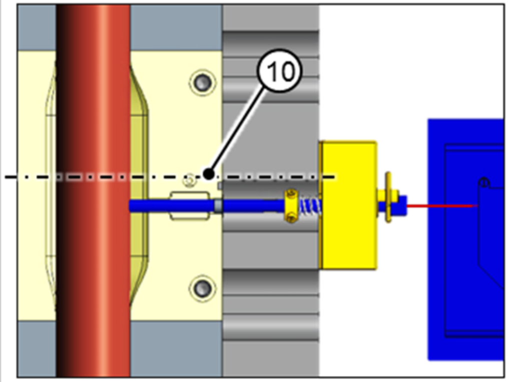
FEM-simulated forming result

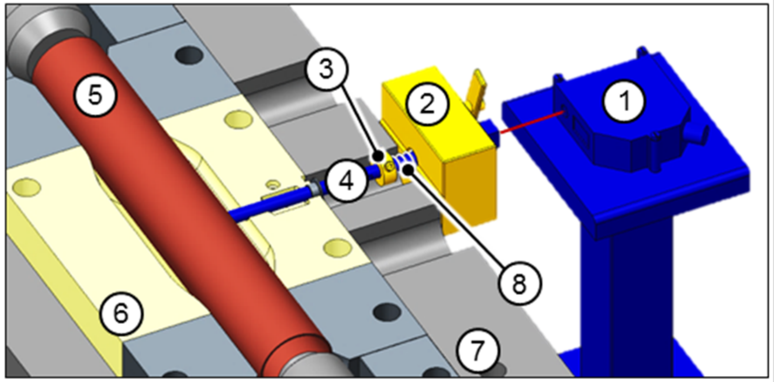


Measurement techniques: Displacement

- spring loaded tactile pin (4) is pressed against surface of heated part (5)
- during deformation traversed path is tracked by a laser (1)
- fixing (3) limits the pin movement
- position of the pin near R14 gives information about complete forming of component
- results serve as validation data for simulation

HMGF tool DP3 with tactile measurement equipment, view from top



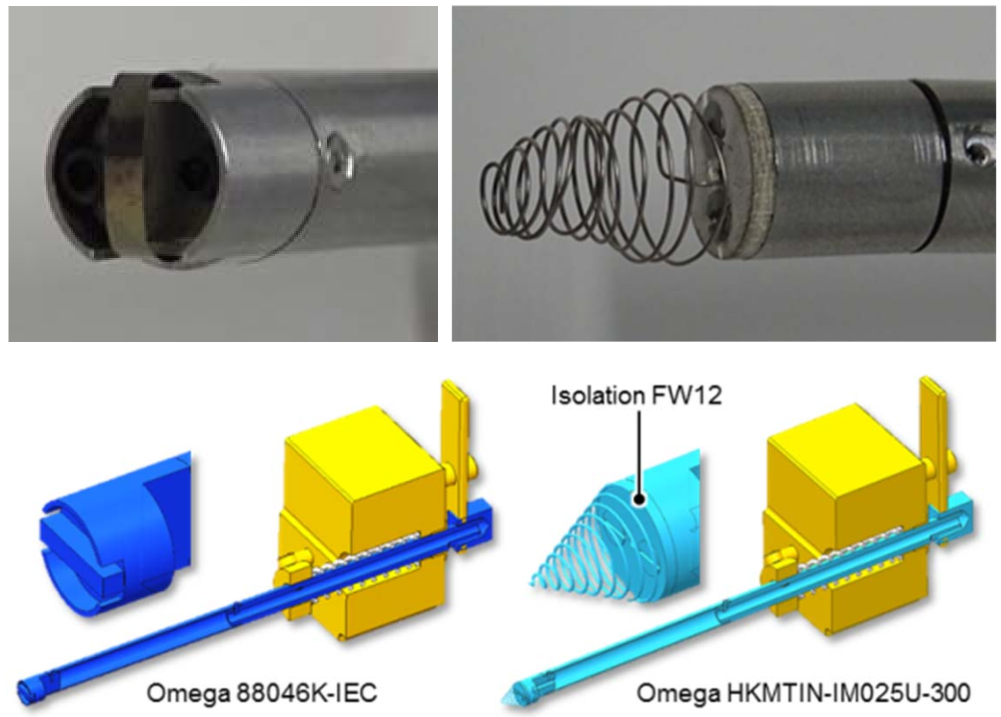


1 - MicroEpsilon optoNCDT ILD 1700-100
2 - cover with lever
3 - aiming position
4 - tactile pin
5 - initial tube ø 57 mm hot
6 - active tool part
7 - monoblock
8 - spring
9 - tool middle

Measurement techniques: Temperature

- testing of two thermal sensors
  - *88046K IEC*
  - *HKMTIN-IM 025U-300 "helix"* by OMEGA
- mounted onto tip of tactile pin
  - measuring the temperature of the displaced component surface during forming
- allows conclusions interpretation regarding material ductility during the process
- limited sensor lifetime due to high workpiece temperatures

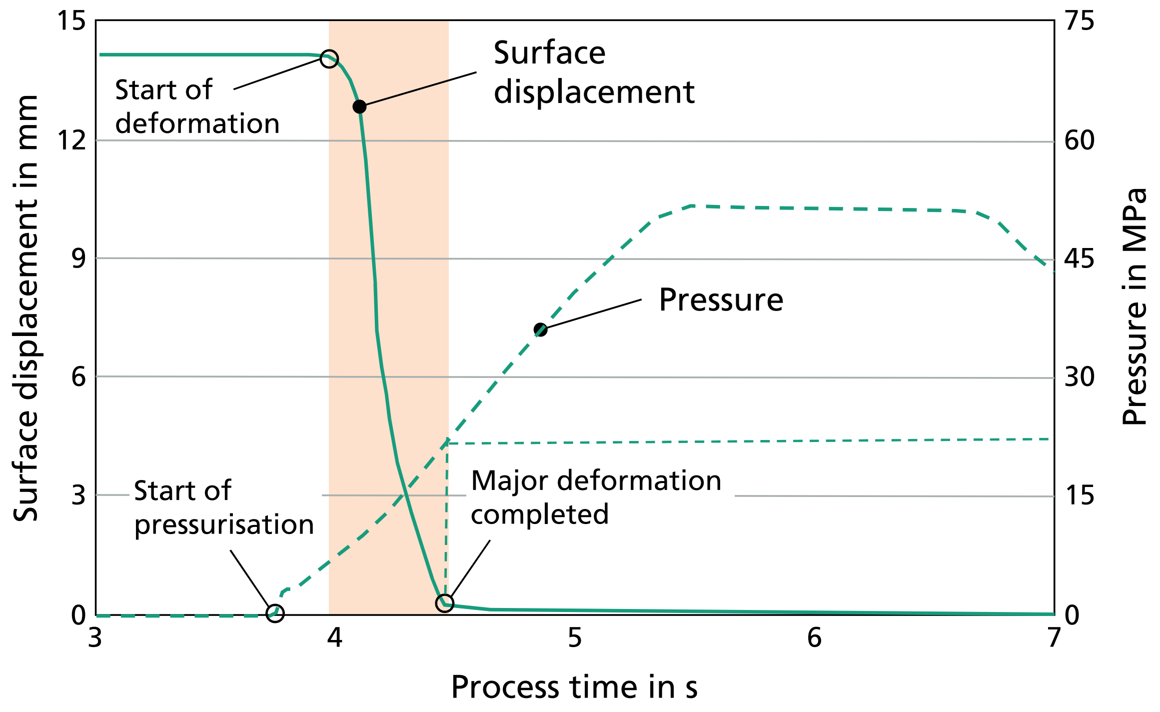
thermal sensors on the tip of tactile sensors and setup



Analysis of material displacement during HMGF

- matching measurement of internal pressure and displacement of the component wall as a function of time
- major deformation completed within 0.5 s
  - pressure at this time: <25 Mpa
  - full pressure: 50 Mpa
- successful validation of simulation
  - reaching of yield strength lead to aprupt material flow

displacement R14 vs. inner pressure 113 (ok-part)



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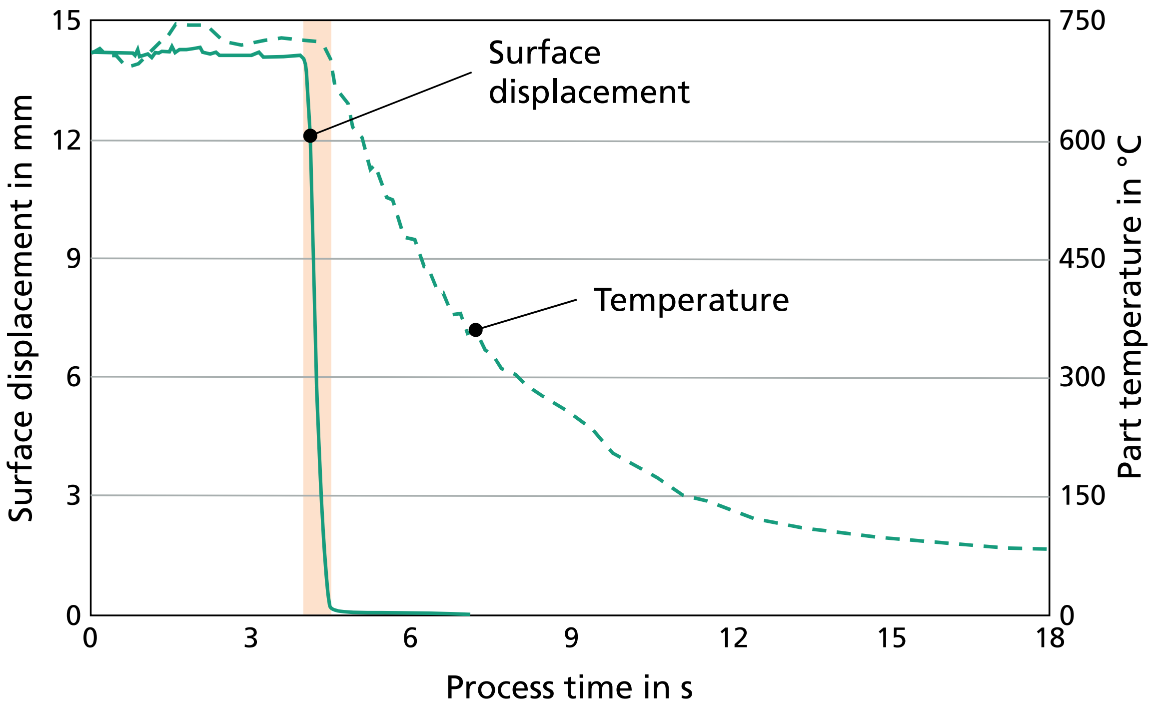
Analysis of temperature development during HMGF

temperature of the part

- matching measurement of temperature and displacement of the component wall as a function of time
- starting temperature of component: 950°C
- manual workpiece transfer (furnace ➔ tool)
- temperature ~600°C when major deformation is completed
- cooling rate of 100 K/s is far above the usual 27 K/s

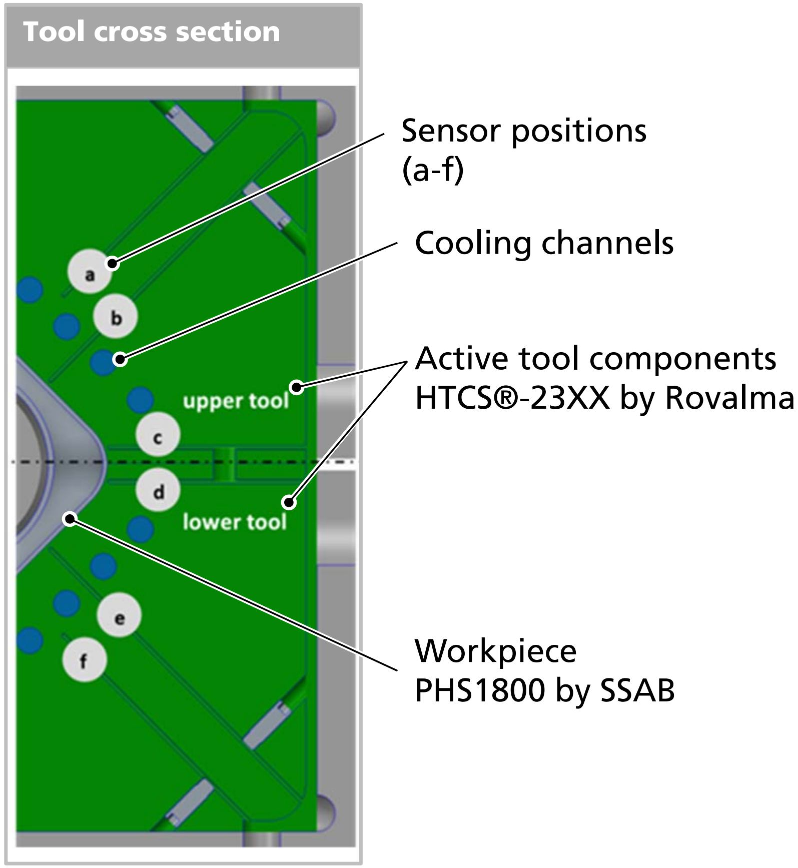
  ➔ sufficient for reliable martensite formation during contact and cooling of the component

thermal behavior of part



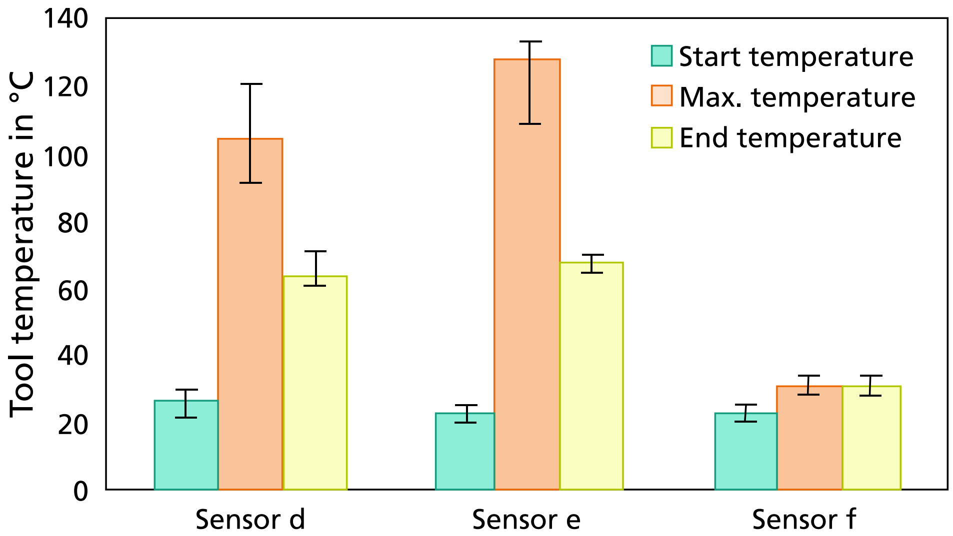
Analysis of temperature development during HMGF

temperature of the tool



furnace temperature: 950 °C manual transfer (furnace ➔ tool)

maximum internal pressure: 70 Mpa

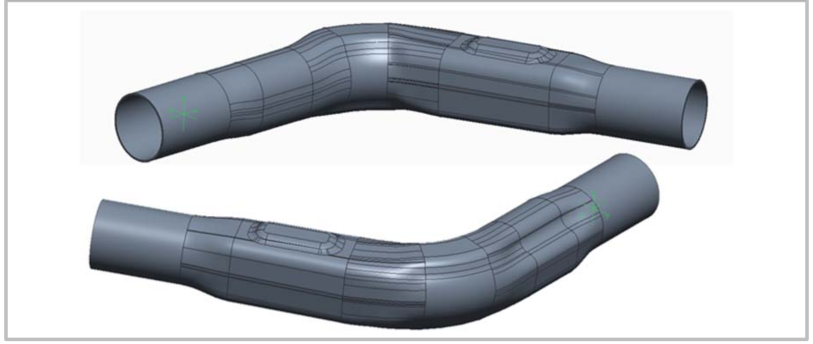


constant starting temperature in the range of 20°C
➔ stable process conditions
➔ repeatability of component properties

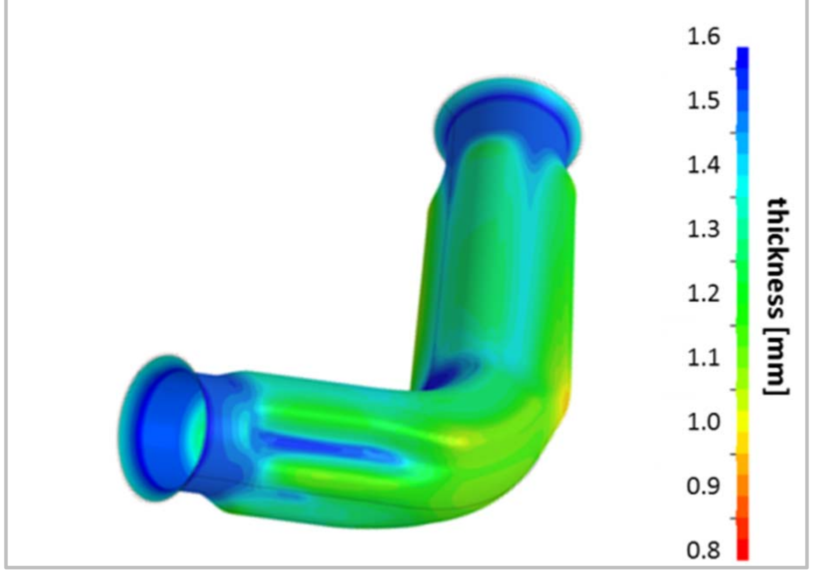
Tool integrated heating by conduction
component design and simulation

- new demonstrator DP4
  - prove of technological feasibility on the basis of a complex part geometry
- results close to series production
  - initially wall thickness of 1.5 mm
  - frequently occurring cross sections of vehicle components and a additional requirement for tool technology with a bendy
- FEM-results:
  - a minimum sheet thickness of the tube material of about 0.85 mm
  - maximum thinning of 43.3%

Geometry DP4



FEM-simulated forming result

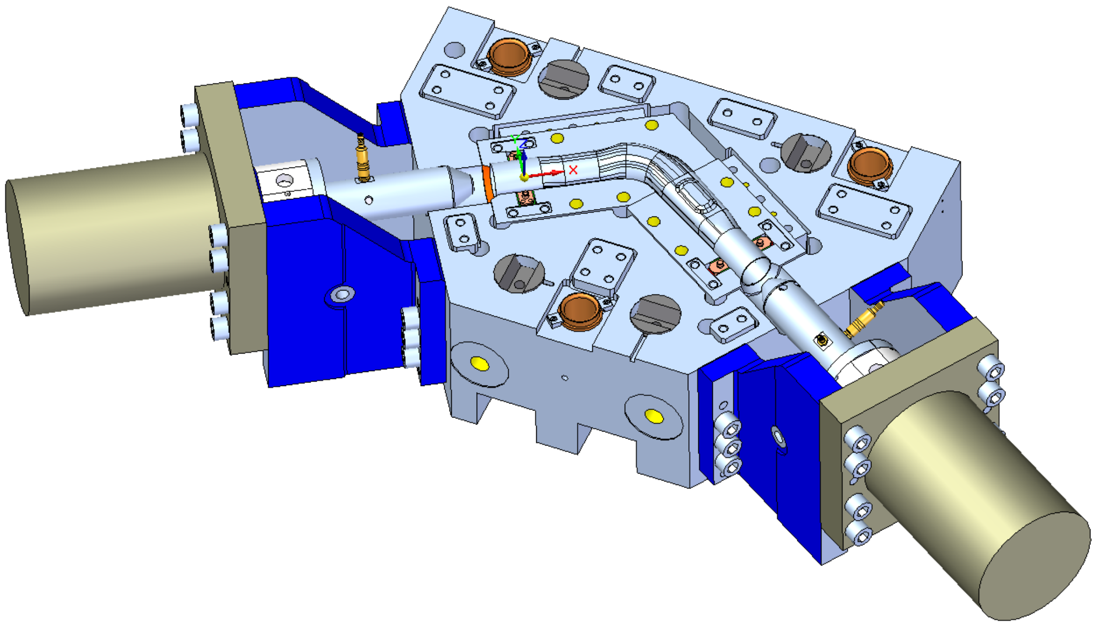


Tool integrated heating by conduction

tool concept

- complicated construction
  - devices for conduction,
  - tool guides/force absorption
  - and cooling channels are incorporated
  - spring loaded electrodes are raised with open tool
  - electrodes clamp component while heating
- newly developed tool material HTCS®-26-EP by Rovalma
  - improved thermal conductivity properties
- conduction system monitored by installed pyrometers

HMGF forming tool



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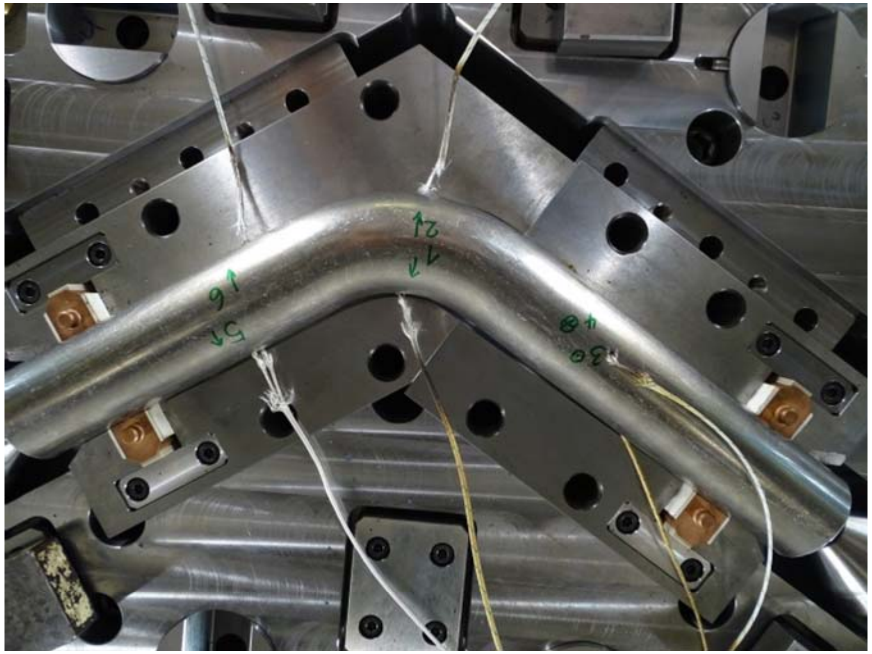
Tool integrated heating by conduction
tool concept

- real HMGF forming tool

HMGF forming tool with part, view from top



HMGF tool with conductive heated part

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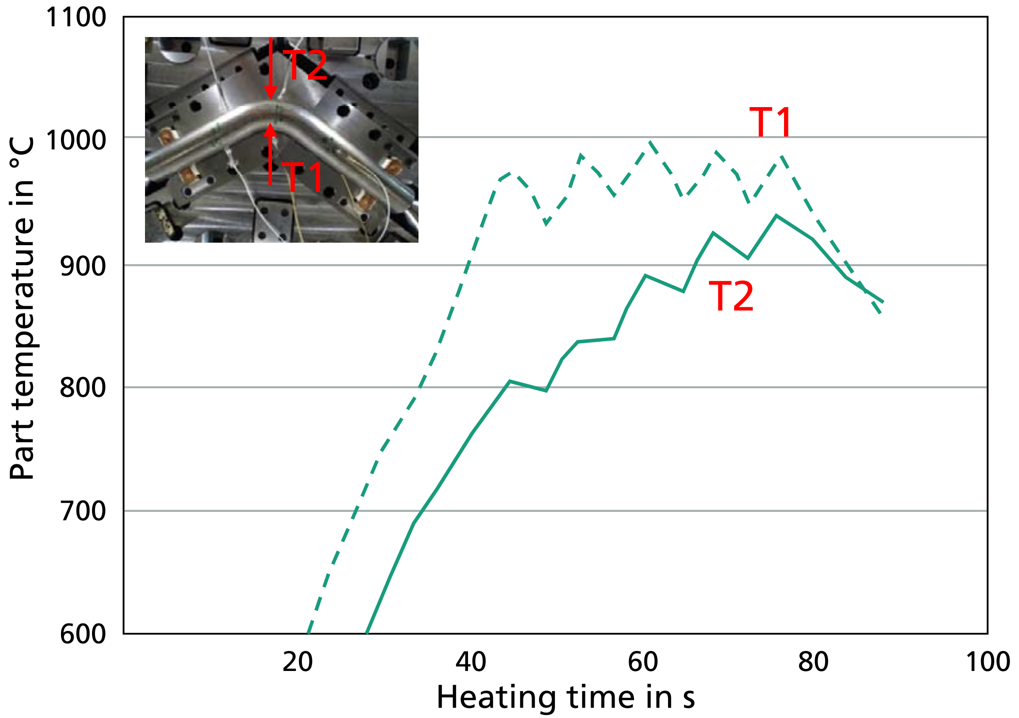
Tool integrated heating by conduction

results of forming tests

- bended component ➔ inhomogeneous heating
  - current flow follows the shortest possible route through the component →inner arc
- counteracting by pulsing of current
  - resulting short time window without power supply, heat transfer from hot to cooler areas
- overall almost homogenous heating of the component
  - targeted austenitisation temperature 911 °C
- constant starting temperature guaranteed by principle
- significantly reduced surface scaling
  - no transfer and less air contact

conductive heating, inner & outer arc of part



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Summary and outlook

- HTCS®-23xx evaluated as suitable for use in HMGF tool
- temperature, shape and internal pressure recorded and evaluated simultanously
  - discovered interrelationships lead to better understanding of the HMGF process
  - essential for future process design using FEM-simulation
- tests with tool-integrated component heating via conduction
  - important basis for the design of more complex production tools
  - additional technological expense of the integrated conduction device for medium quantities of components is justified
- HTCS®-26-EP with improved thermal conductivity properties used as tool material
  - suitable for use in HMGF tools due to its strength and high thermal conductivity

manufactured part

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References in hydroforming

Audi
Vorsprung durch Technik

Das Auto.

BMW

Opel

Rolls-Royce

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