Hydroforming at Elevated Temperatures

International Seminar on Forming Technology 20 January, 2010, Bangalore, India

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Fraunhofer IWU

CONTENT

- The Fraunhofer-Gesellschaft
- The Fraunhofer IWU
- Hydroforming at Elevated Temperatures
  - Introduction, Motivation
  - Technological Base
  - Hydroforming with fluid media
  - Gas forming, Hydroforming with gaseous media
  - Press Hardening of Tubes via Gas forming
  - Summary

THE FRAUNHOFER-GESELLSCHAFT

Fraunhofer IWU

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society.

- 60 Institutes in Germany
- 17 000 employees, in majority scientists and engineers

Our Customers:

- Industry
- Service sector
- Public administration

Fraunhofer IWU

Joseph von Fraunhofer

The Fraunhofer-Gesellschaft

Discovery of “Fraunhofer Lines“ in the sun spectrum	**Researcher**	Research and development by order of industry and state
New methods of lens processing	**Inventor**	Music format MP3, white LED, high-resolution infrared camera
Head of Royal Glass Factory	**Entrepreneur**	Research Volume: ~ 1.4 billion euro per year

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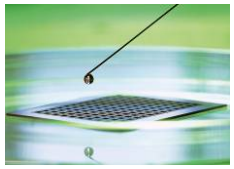
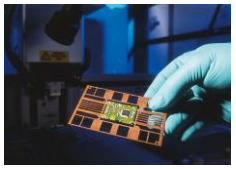
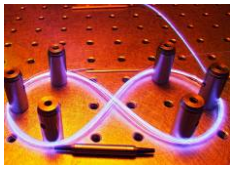
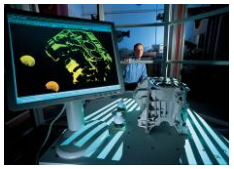
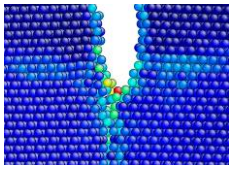
The Fraunhofer-Gesellschaft in Profile


7 Alliances:

- Information and Communication Technology
- Life Sciences
- Microelectronics
- Light & Surfaces
- Production
- MATERIALS - Materials and Components
- Defense and Security

Alliance: Production
(founded 1998)

- IFF Magdeburg
- IML Dortmund
- IPA Stuttgart
- IPK Berlin
- IPT Aachen
- IWU Chemnitz / Dresden / Augsburg
- UMSICHT Oberhausen

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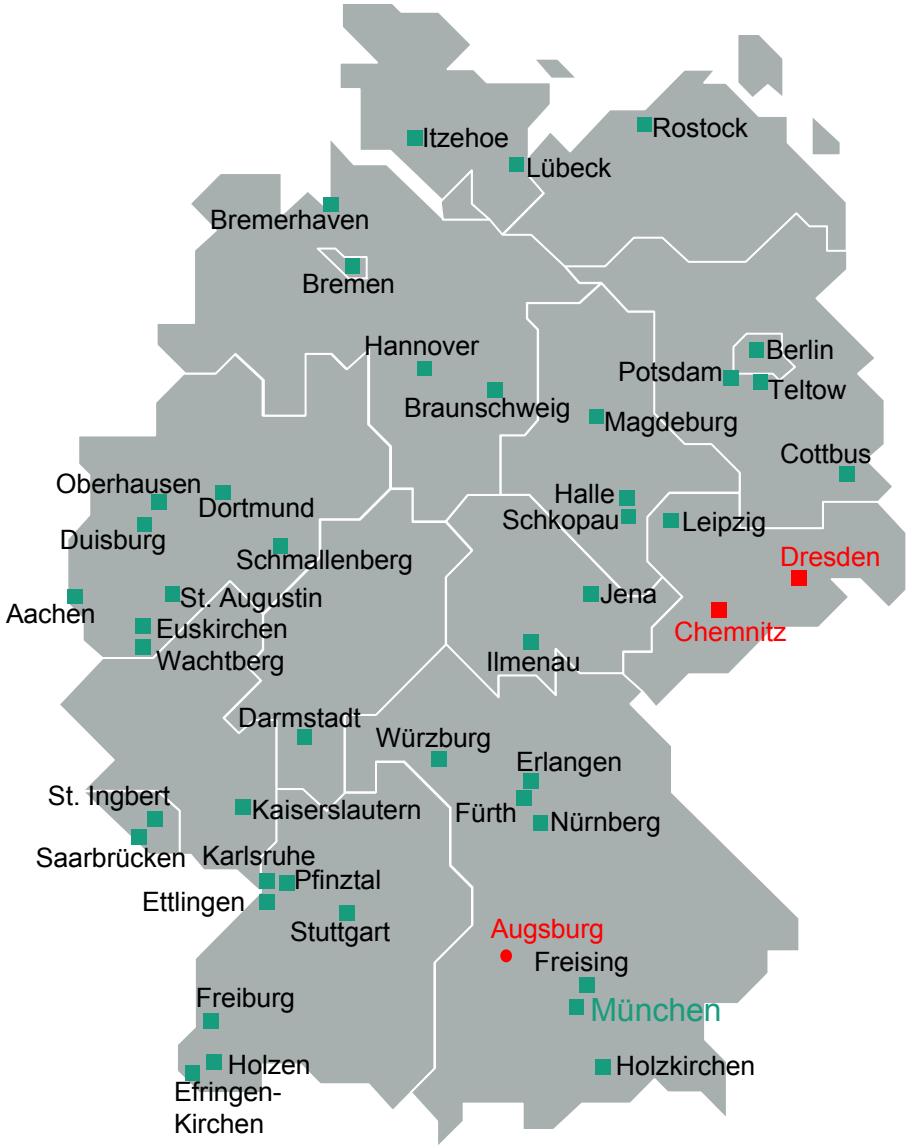
THE FRAUNHOFER IWU
Profile

Fraunhofer IWU

The Fraunhofer IWU
Locations in Germany

- founded on July 1st, 1991
- about 380 employees
- > 23 million euro budget
- 7 000 m² area in Chemnitz und Dresden, thereof 4 000 m² test area
- Project group in Augsburg since January 2009



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The Fraunhofer IWU in Profile

Fields of expertise

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

in close cooperation with

- Chemnitz University of Technology
- Fraunhofer-Gesellschaft
- Machine tool industry
- German and international automobile industry
- Ancillary industry (forming, cutting, tool and die making)

Fraunhofer IWU

Research Activities in Europe

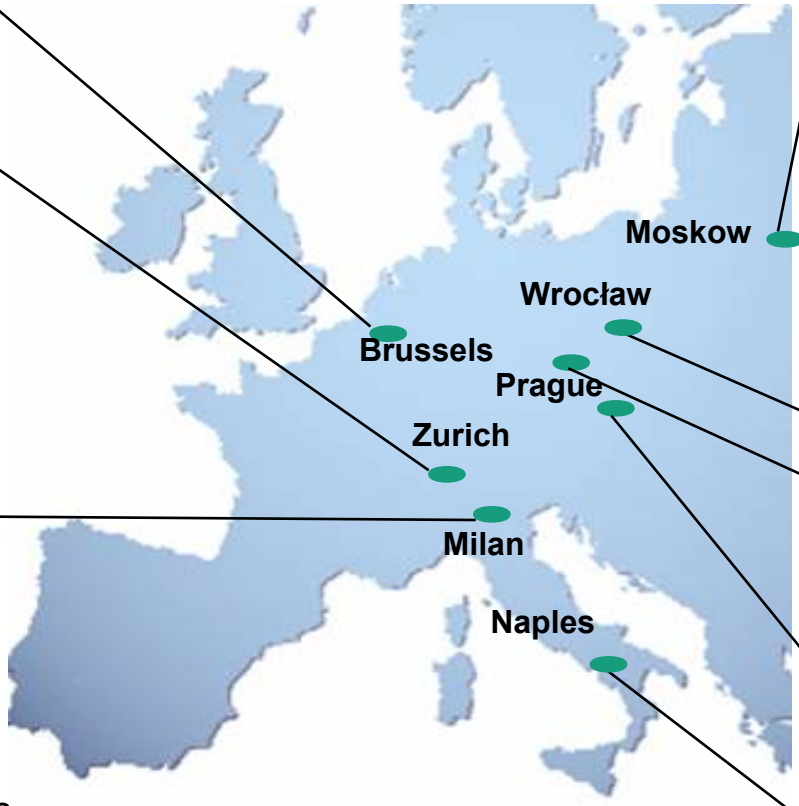
European Commission

Swiss Federal Institute of Technology Zurich (ETH)

SWISSMEM (Association of the Swiss Mechanical and Electrical Engineering Industries)

ITIA-CNR (Institute of Industrial Technology and Automation of the Italian National Research Council)

UCIMU (Association of Italian Manufacturers of Machine Tools, Robots, Automation Systems and ancillary products)



STANKIN (Moscow State Technological Institute)

NIAT (National Institute of Aviation Technologies)

Wrocław University of Technology

Czech Technical University in Prague (CTU)

Brno University of Technology

University Naples „Federico II“

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Hydroforming at Elevated Temperatures

Introduction, Motivation

Hydroforming at Elevated Temperatures - Requirements

- Market trends
  - Individualism ➔ increasing variety of parts
  - higher part and shape complexity
  - reducing structural weight
- Lightweight design
  - Increasing formability of lightweight materials (Al, Mg, Ti)
  - Implementing heat treatment of high performance steel

Hydroforming at Elevated Temperatures
Technological Base, Overview

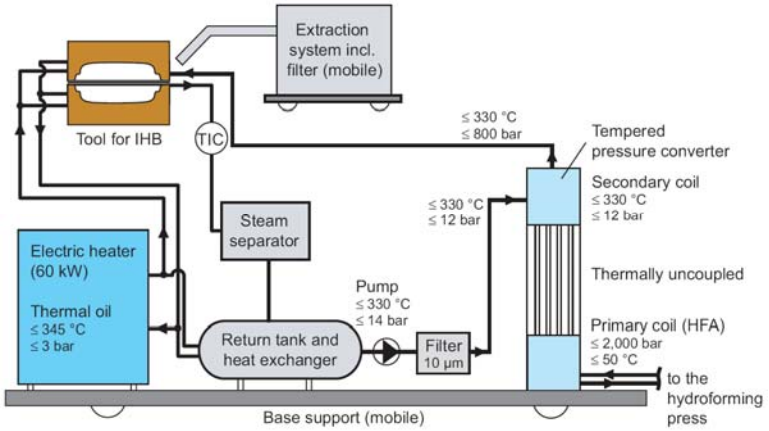
	Media	*Technology*	*Available Technique*
Hydro-forming	Fluid	Hydroforming of tubes and profiles	- at RT up to 700 MPa - at 300°C up to 80 MPa
		Sheet metal hydroforming	- at RT up to 700 MPa - at 300°C up to 80 MPa
	Gas	Gas-Forming	- at RT up to 80 MPa
		Hot-Gas-Forming	- at 1200°C, up to 80 MPa
Electro-magnetic Forming (EMF)	Magnetic Field	Flat Forming Compression of tubes Expansion of tubes	- at 100kJ up to 21 kV RT= room temperature

Hydroforming at Elevated Temperatures
Technological Base

mobile heat treatment system

Mobile heat treatment system for thermal fluids

- System with two separated circuits
- pressure up to 80MPa (800 bar)
- max. temperature of thermal fluid up to 300°C
- steam separator, mobile exhaust ventilation



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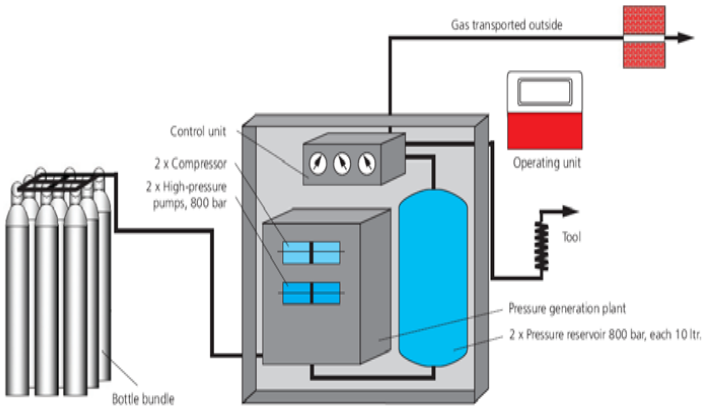
Hydroforming at Elevated Temperatures
Technological Base

mobile heat treatment system

Gas pressure generator unit

- gas bottle bunch 30MPa (nitrogen)
- 2 x pre-compressors
- 2 x high pressure compressors up to 80MPa
- 2 x pressure accumulators 80MPa, 10 liter each



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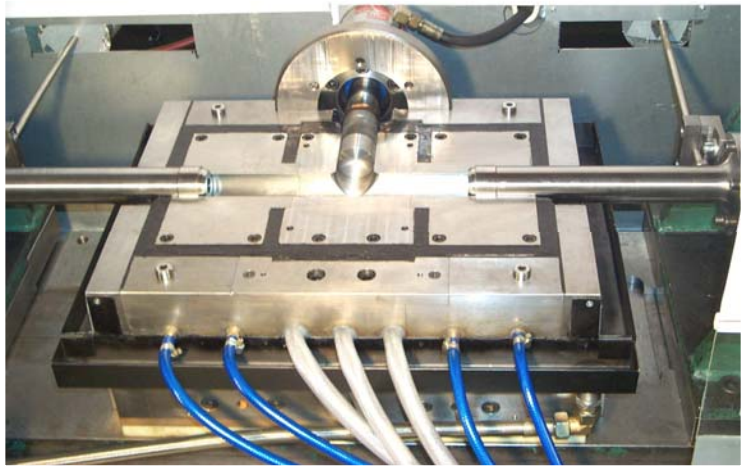
Hydroforming at Elevated Temperatures
Hydroforming with fluid media

AZ61 at room temp.

AZ61 at 280°C

Fundamental research

- tool design for thermal hydroforming
- process design using coupled FEA
- material behavior depending on temperature
- suitable process parameter sets



hydroforming die set with heating and cooling segments

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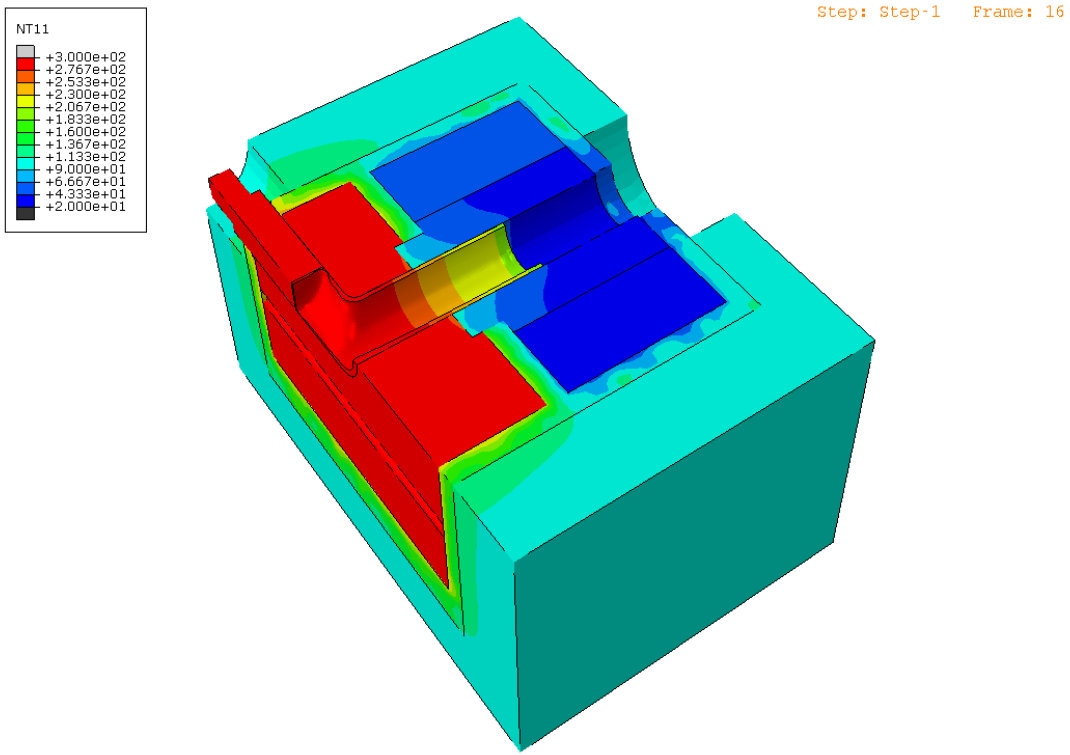
Hydroforming at Elevated Temperatures

Hydroforming with fluid media

Thermo-mechanical coupled simulation



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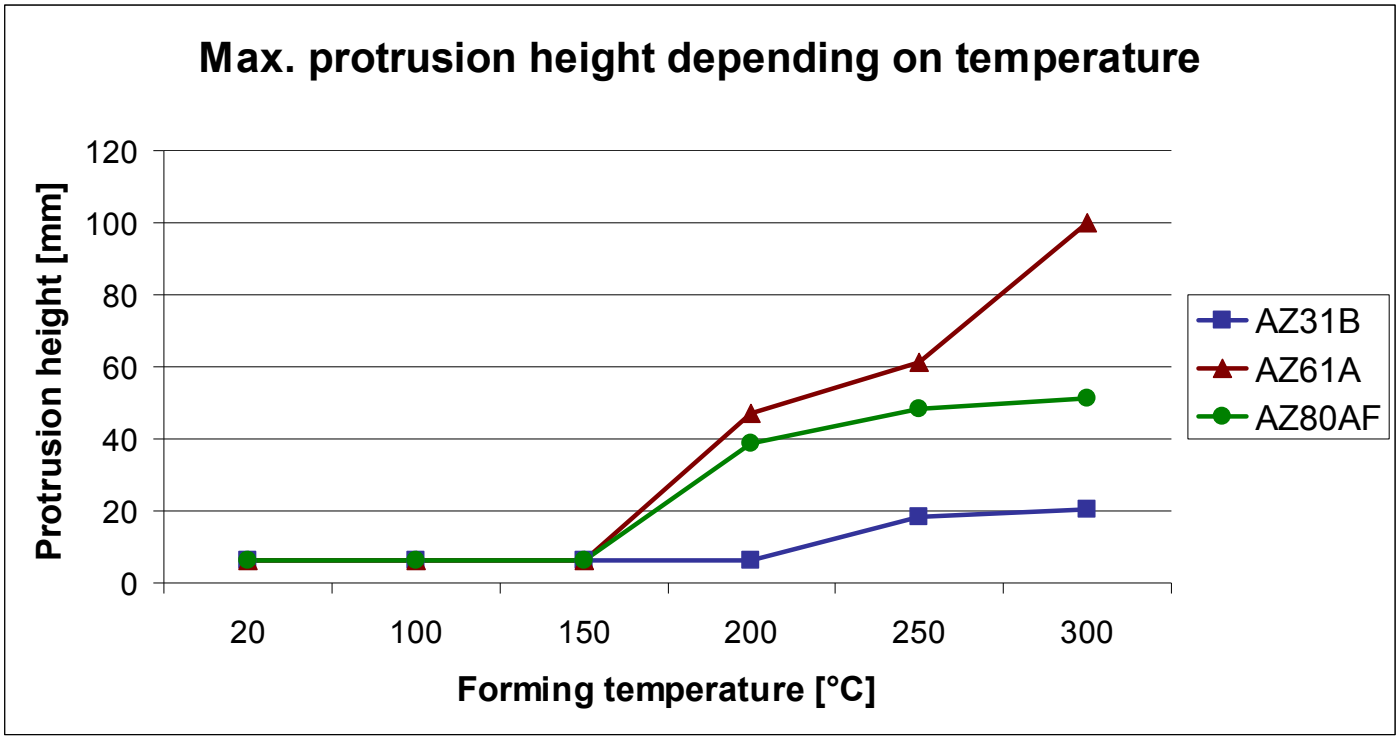
Hydroforming at Elevated Temperatures

Hydroforming with fluid media

Results of fundamental research



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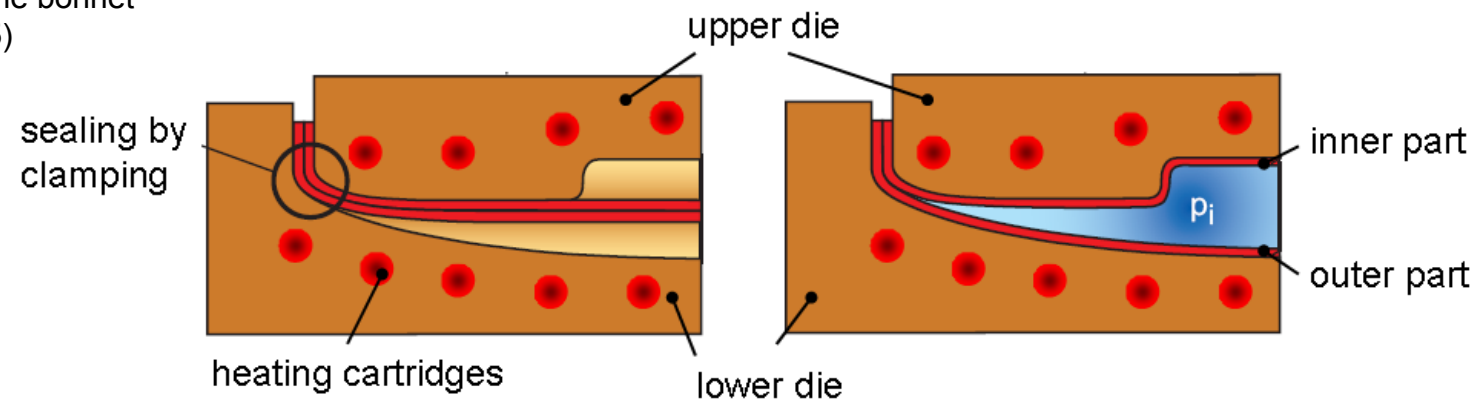
Hydroforming at Elevated Temperatures

Hydroforming with fluid media

model engine bonnet
(scale 1:2.5)

Demonstrator to prove several concepts

- combination of deep drawing a double blank and hydroforming process in one stroke (steel)
- tool re-design for thermal hydroforming for aluminum and magnesium alloys (up to 250°C)



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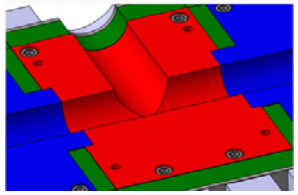
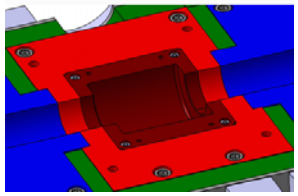
Hydroforming at Elevated Temperatures

Gas forming, Hydroforming with gaseous media

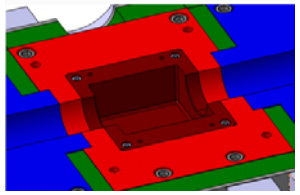
T-fitting



barrel

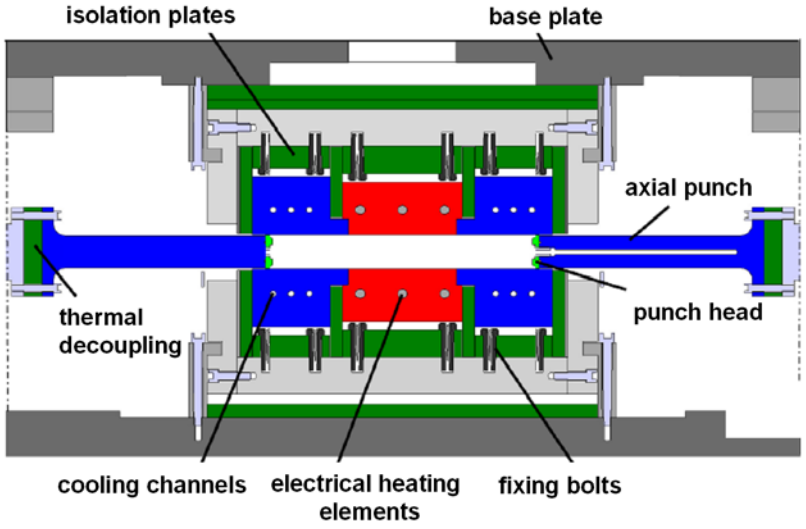


cube



Fundamental research

- tool and process design for thermal hydroforming
- formability depending on temperature
- suitable process parameter sets



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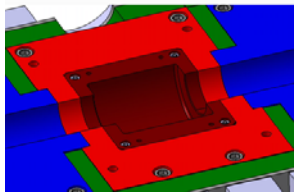
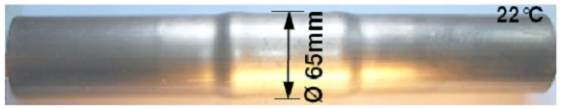
Hydroforming at Elevated Temperatures

Gas forming, Fundamental research - results

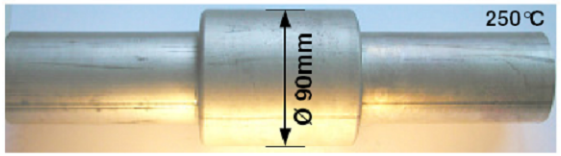
barrel



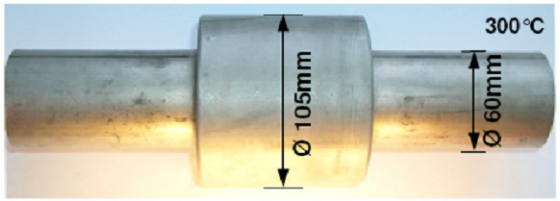
AZ 61 A



ϑ_U = 22 °C; Δu_{max} = 5,6%



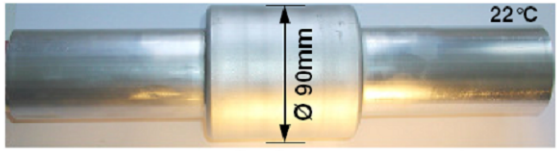
ϑ_U = 250 °C; Δu_{max} = 59,2%



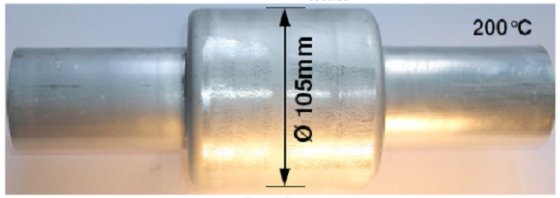
ϑ_U = 300 °C; Δu_{max} = 73,3%

Increasing Δu_{max} by 67,7%

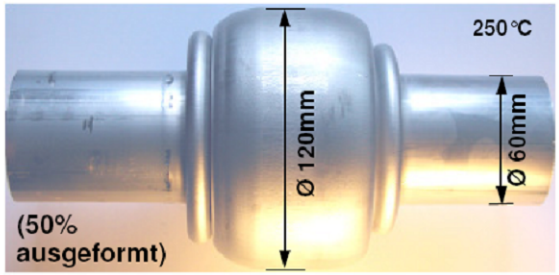
AlMgSi0,5



ϑ_U = 22 °C; Δu_{max} = 56,6%



ϑ_U = 200 °C; Δu_{max} = 80,0%



ϑ_U = 250 °C; Δu_{max} = 93,3%

Increasing Δu_{max} by 36,7%

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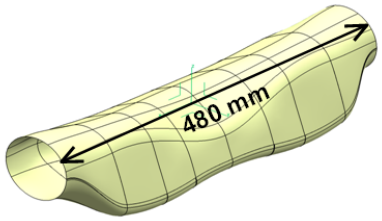
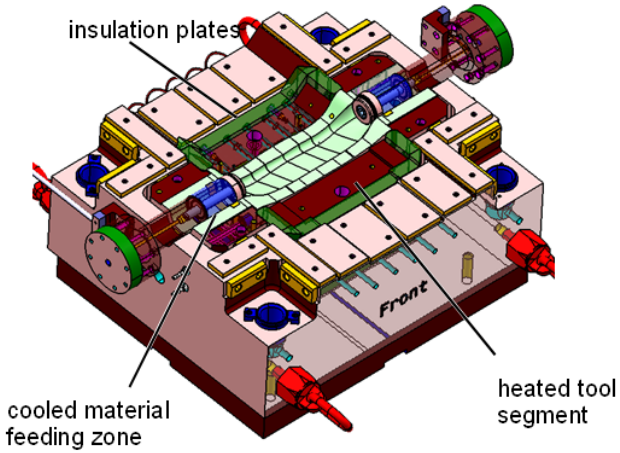
Hydroforming at Elevated Temperatures
Gas forming, industrial parts

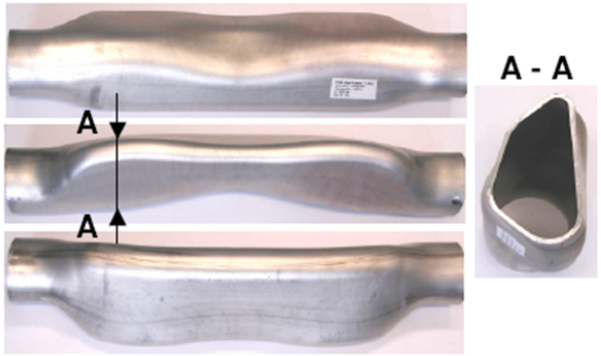


Lightweight Rear Axle Cross Member

- materials
  - magnesium: AZ 31 B / AZ 61 A / AZ 80 A-F
  - aluminum: AlMgSi0,5 / AlMg3Mn
- tube dimensions: 85 x 650 x 4,0



Δu_{max} = 42 %



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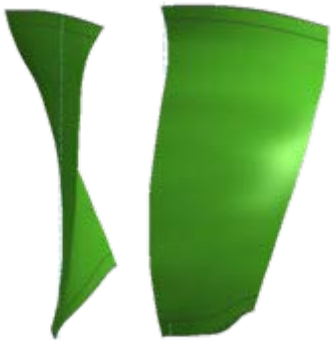
Hydroforming at Elevated Temperatures

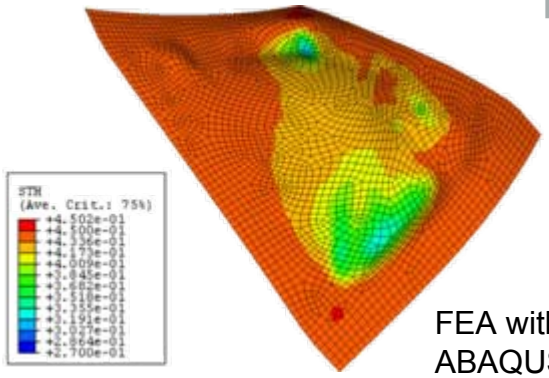
Gas forming, industrial study, Titanium blanks



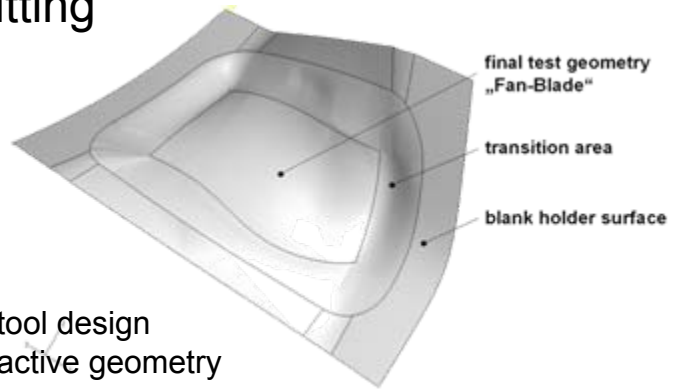
part geometry

Part & process design

- material: Titanium (Ti3Al2.5V), wall thickness 0,4mm
- method planning
  - OP 10: blanking (right angular)
  - OP 20: drilling (angle 70°)
  - OP 30: gas forming
  - OP 40: laser cutting



FEA with
ABAQUS



tool design
active geometry

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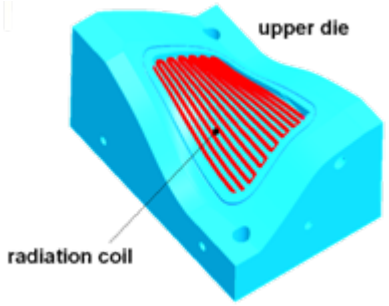
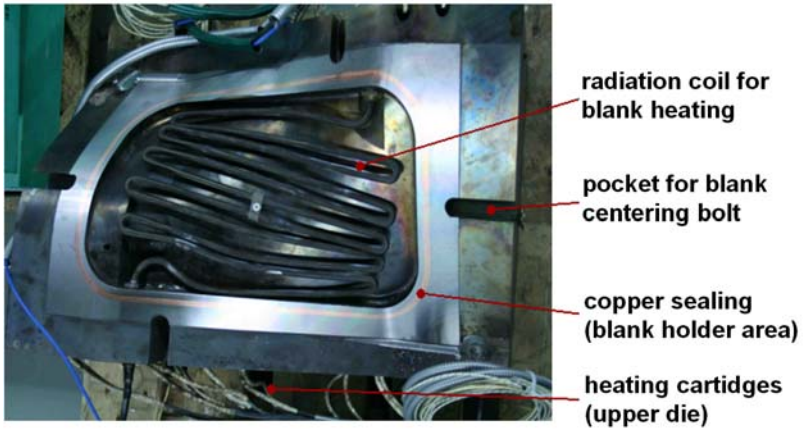
Hydroforming at Elevated Temperatures
Gas forming, industrial study, Titanium blanks



Tool design and prototyping

- electrical heated tool (heating cartridges, radiator)
- thermal control of upper and lower die
- gas forming at 650°C and 35MPa gas pressure



prototyped part

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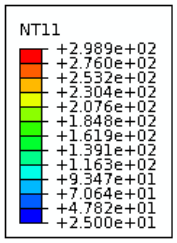
Hydroforming at Elevated Temperatures

Gas forming of Magnesium with local heat treatment

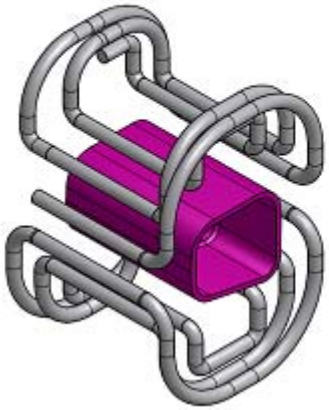


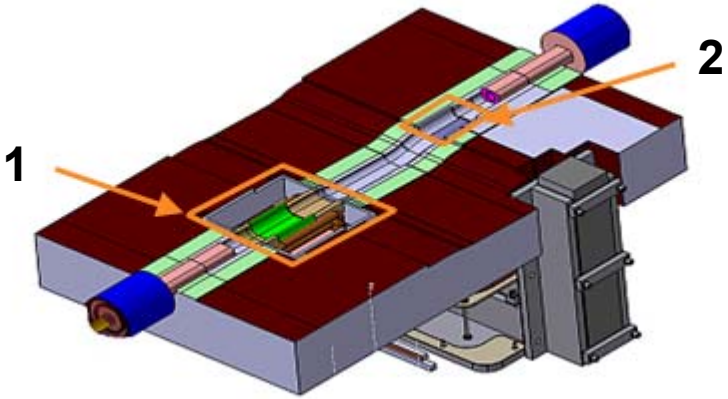
Integration of heat treatment into die set

- local heating to increase formability

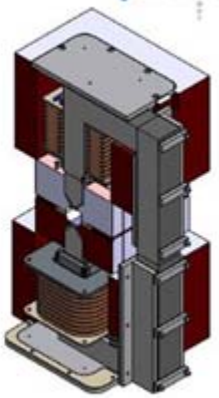
- inductive heat treatment (1)
- magnetic heat treatment (2)

EMA-TEC





pro beam



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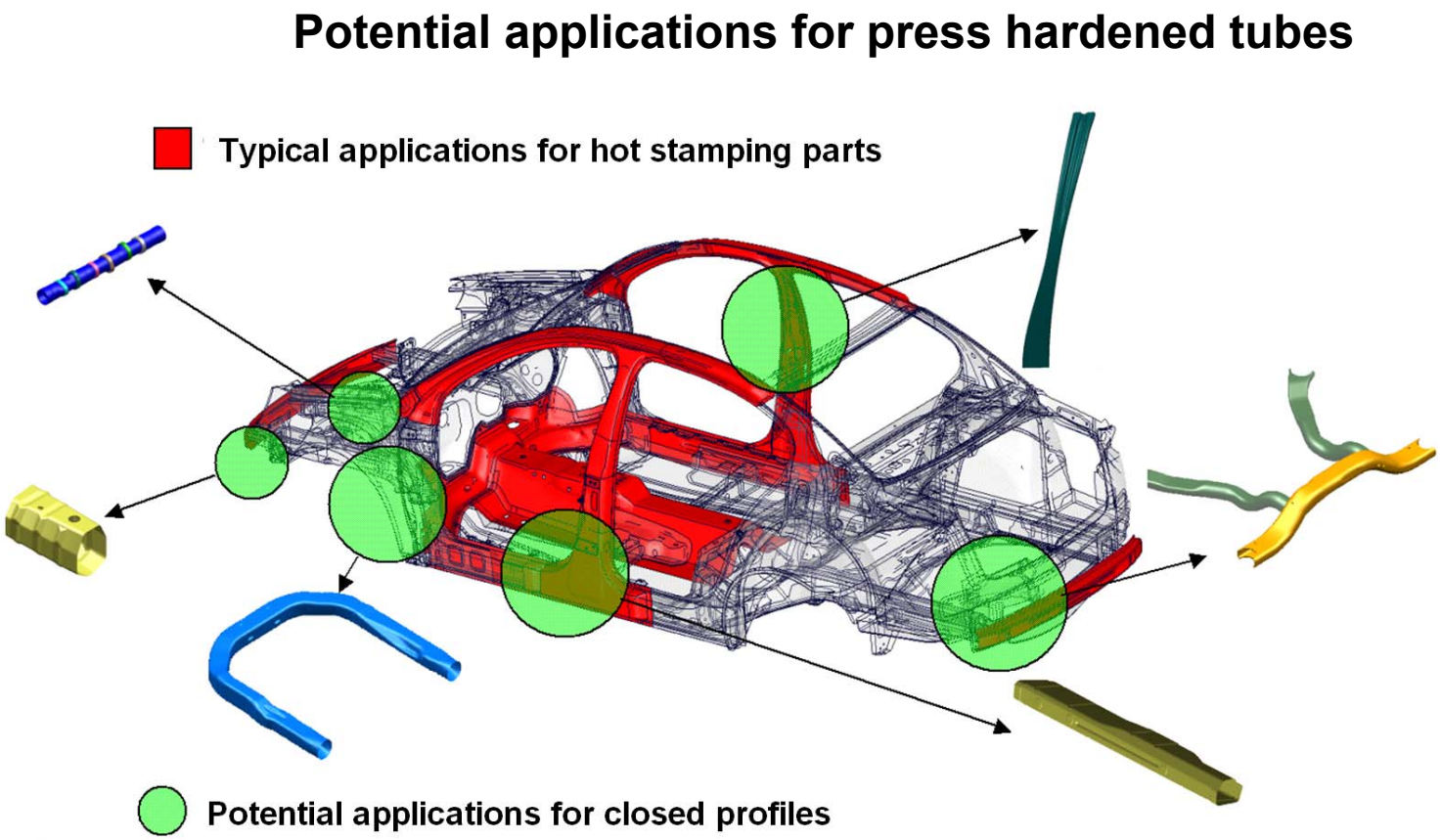
Hydroforming at Elevated Temperatures

Press Hardening of Tubes via Gas forming



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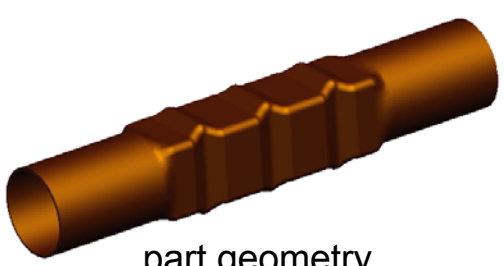
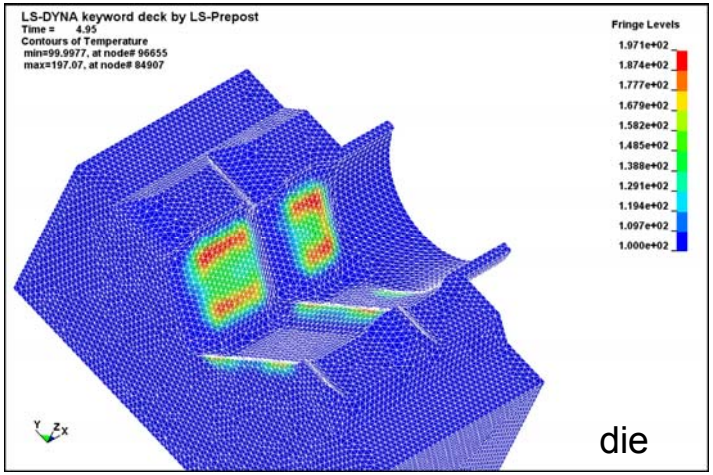
Hydroforming at Elevated Temperatures
Press Hardening of Tubes via Gas forming



part geometry

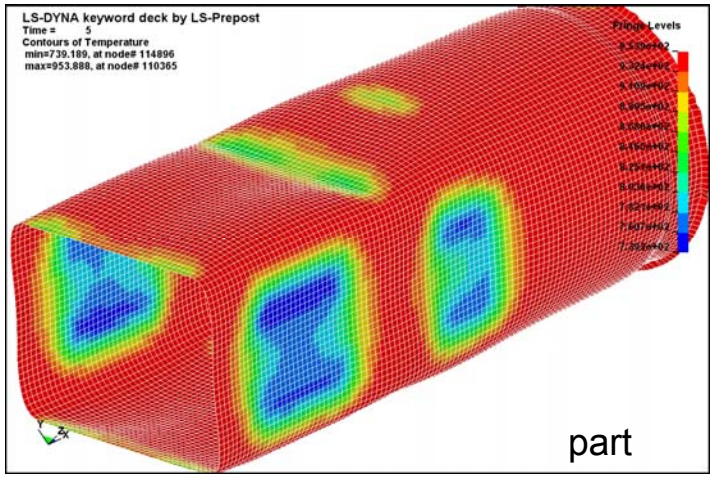
Part & process design

- 3 rows of bulges with corner radius of 8mm
- tube 70 x 2, 22MnB5, coating x-tec^{R} CO 4020
- FEA with LS-DYNA



die

temperature distribution after closing



part

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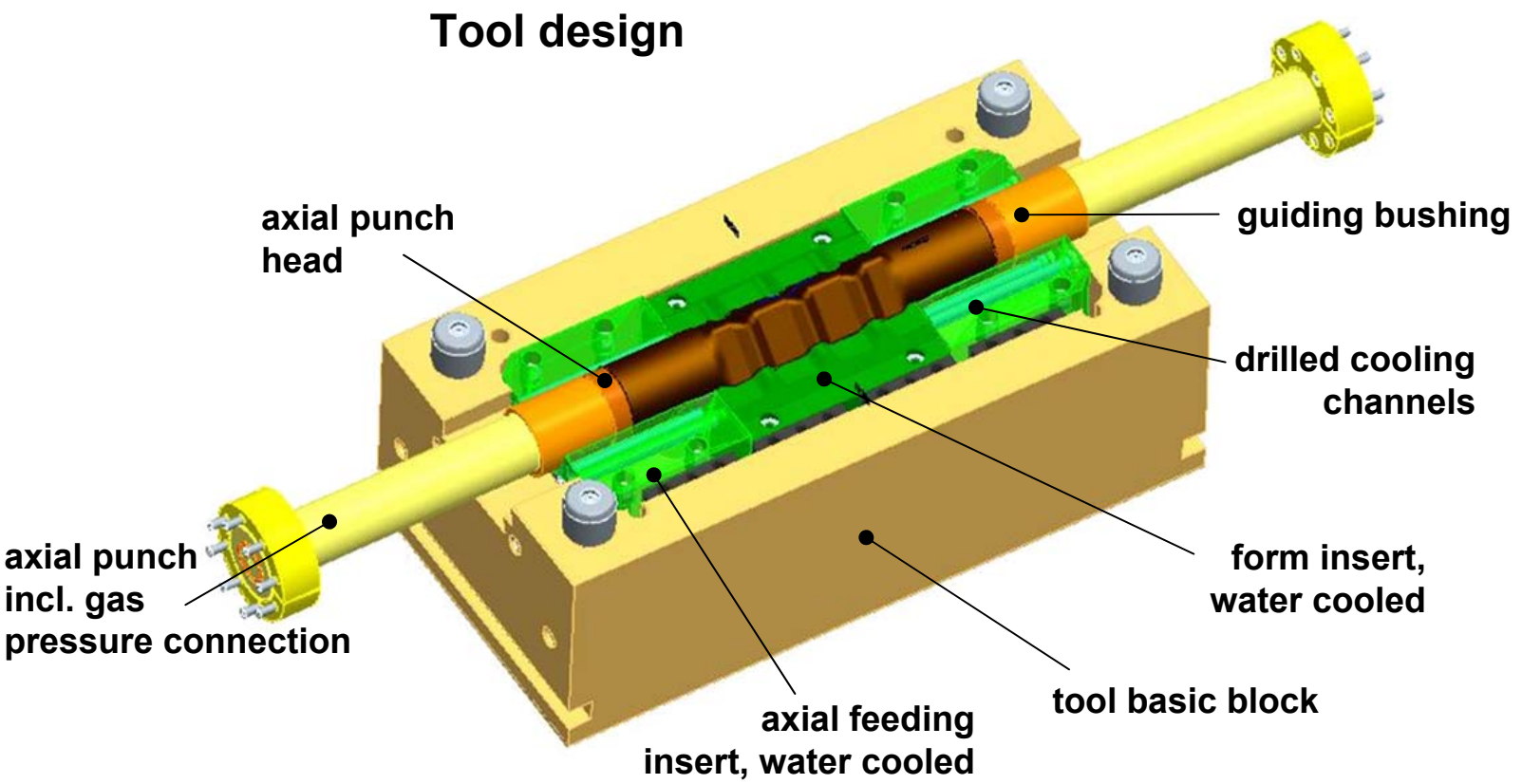
Hydroforming at Elevated Temperatures

Press Hardening of Tubes via Gas forming



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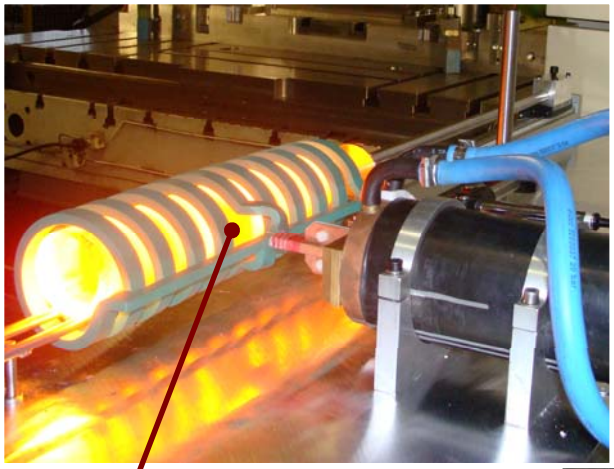
Hydroforming at Elevated Temperatures
Press Hardening of Tubes via Gas forming

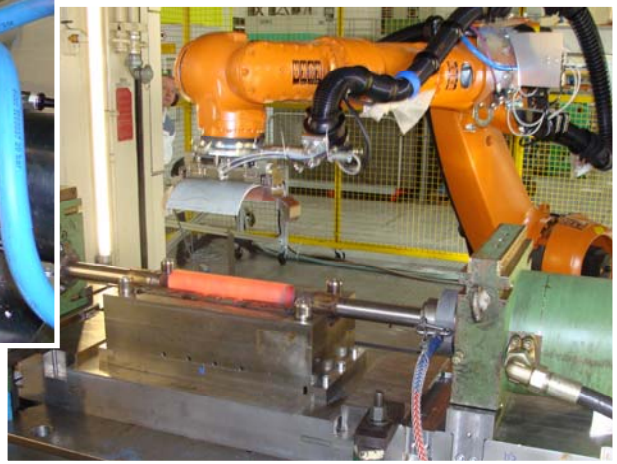
Process steps

inductive heat treatment

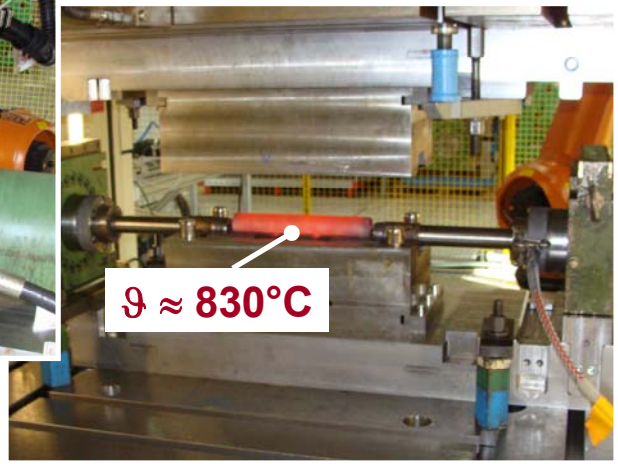


$\vartheta \approx 950°C$, 50 sek

part handling



die closing



$\vartheta \approx 830°C$

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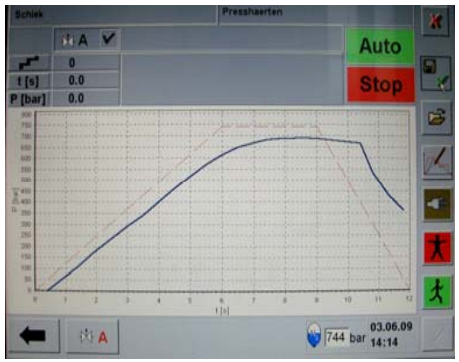
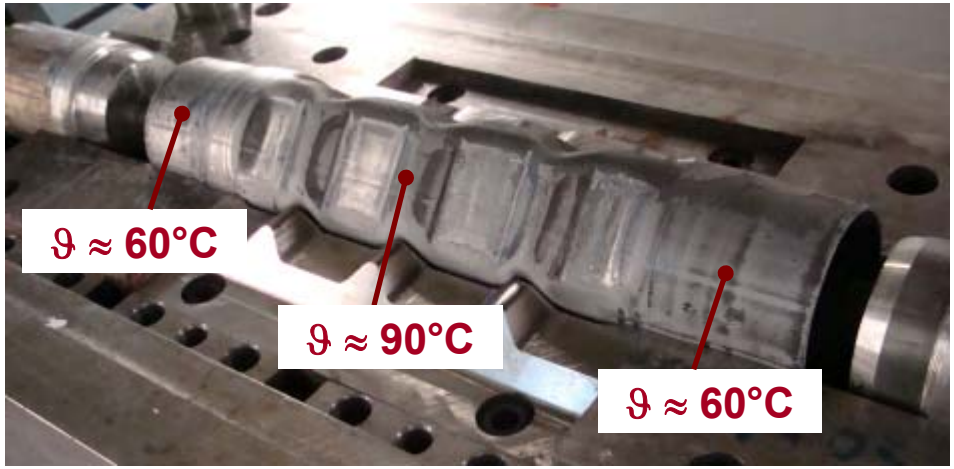
Hydroforming at Elevated Temperatures
Press Hardening of Tubes via Gas forming



Forming sequence

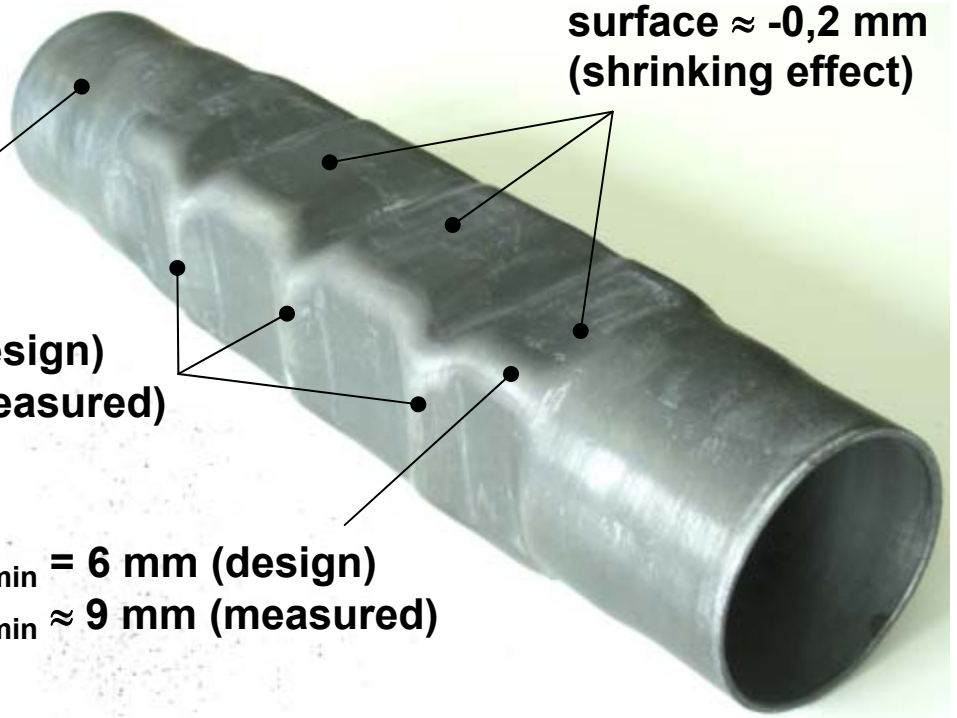
- forming, pressure 0 to 70 MPa — 6 sec
- calibration at 70 MPa — 3 sec
- pressure outlet, 70 to 0 MPa — 3 sec
- colling down at 0 MPa — 15 sec



Fraunhofer IWU

Press Hardening of Tubes via Gas forming

Results of CMM Measuring

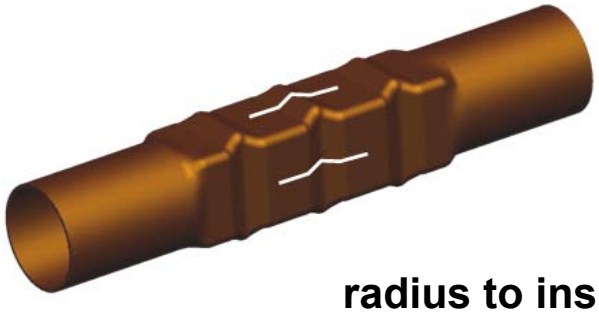


Hydroforming at Elevated Temperatures

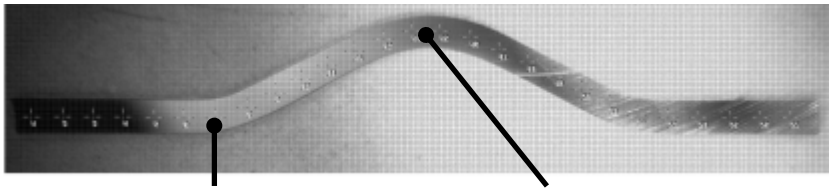
Press Hardening of Tubes via Gas forming

Results of Hardness Measuring

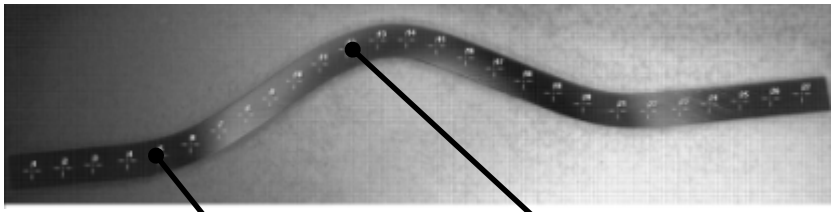
radius to outside



radius to inside



max. ≈ 1620 MPa **min. ≈ 1430 MPa**



max. ≈ 1610 MPa **min. ≈ 1450 MPa**

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Hydroforming at Elevated Temperatures
Summary

Realized effects

- increased formability of lightweight materials (Al, Mg, Ti) to form complex shapes
- local heat treatment to reduce cost (energy, die set)
- press hardening to increase strength of manganese-boron steel (500 to 1500 MPa)

Gained expertise

- suitable part, tool and process design
- thermo-mechanical coupled FEA

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