ATLAS - Innovation

March, 2020

Institute of Manufacturing Technology
Prof. Dr.-Ing. habil. Marion Merklein

FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Shaping ideas into solutions – research at FAU´s Institute of Manufacturing Technology

Prof. Dr.-Ing. habil. Marion Merklein, Julia Degner, M.Sc., Matthias Graser, M.Sc., Niko Rigas, M.Sc., Sebastian Wiesenmayer, M.Sc., Dipl.-Ing. (FH) Manfred Vogel

Agenda

- Introduction of FAU and LFT
- Flexibilisation of process chains by tailoring material properties

Friedrich-Alexander-Universität Erlangen-Nürnberg

The Founders

1743 Founded by Markgrave **Friedrich** von Bayreuth

1769 Expanded and substantially supported by Markgrave **Alexander** von Ansbach und Bayreuth

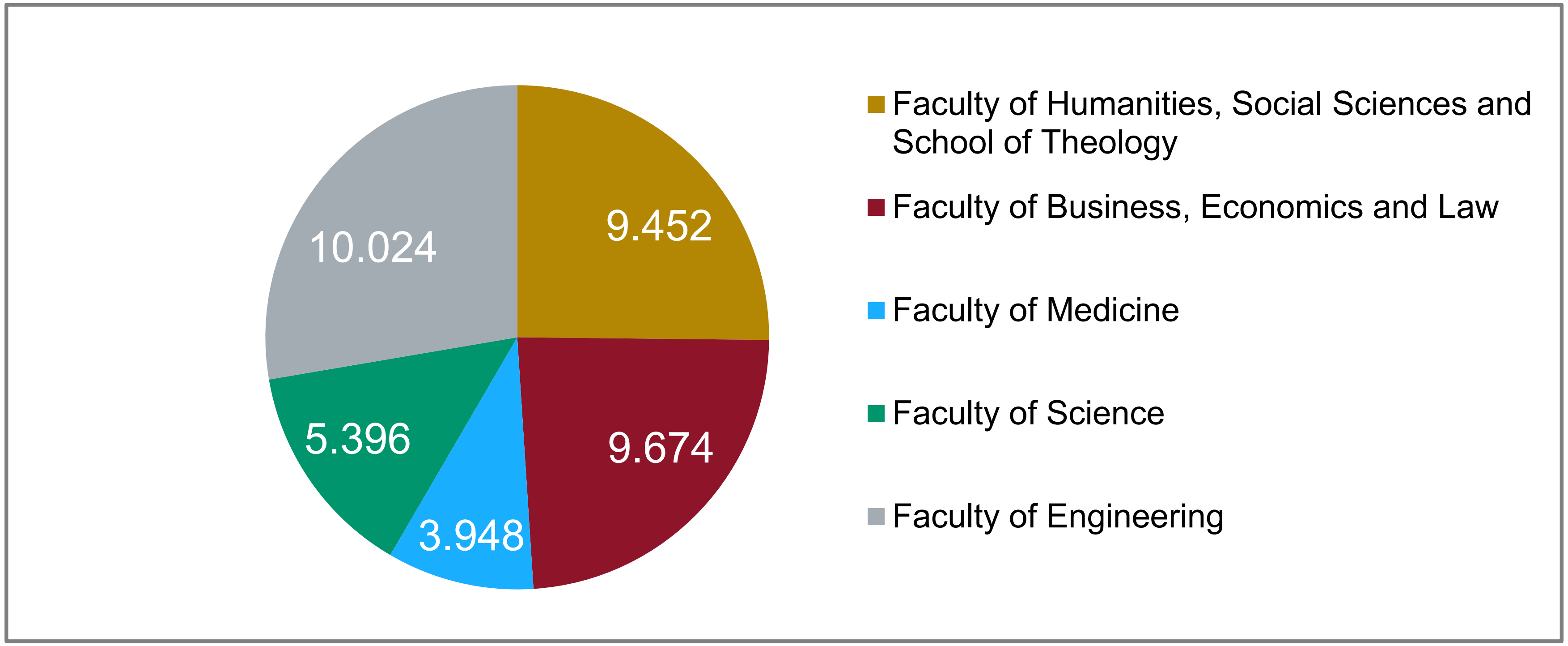
Friedrich-Alexander-Universität
Erlangen-Nürnberg

Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) – at the heart of Europe

Source: FAU

- **Main sites**
  - Erlangen [>100,000 inhabitants]
  - Nürnberg [> 500,000 inhabitants]
- **Other sites**
  - Bamberg — Astronomical Institute of the FAU
  - Fürth — Institute of Advanced Materials and Processes
  - Pleinfeld — Water sports centre
  - Ingolstadt — INI.FAU Ingolstadt Institute
- **Affiliated institutes**
  - Max-Planck Institute [in Erlangen]
  - Fraunhofer Institutes [two in Erlangen]

Students at FAU, Wintersemester 2019/2020



FAU total	**38.494**	students
Faculty of Engineering:	**~ 26%**	of all students of the FAU

Institute of manufacturing technology

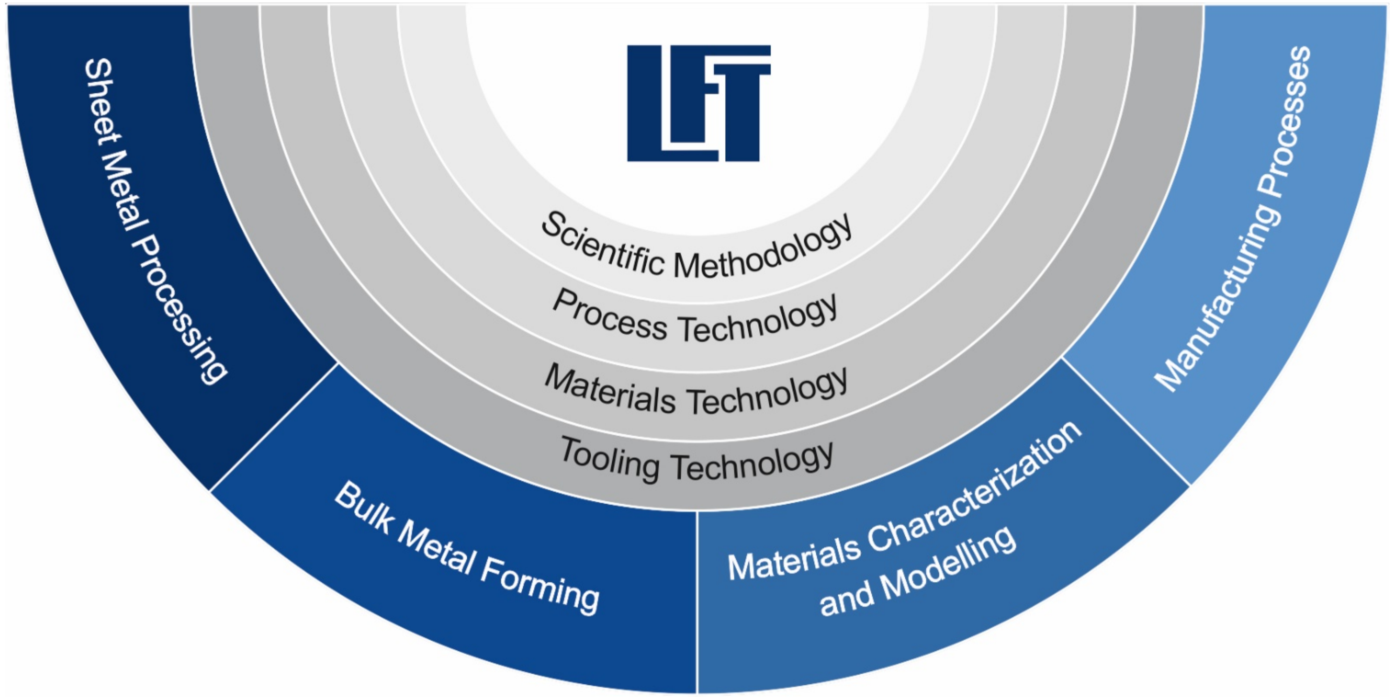
Ordinaria

Prof. Dr.-Ing. habil.
Marion Merklein

Member of CIRP
Member of WGP and AGU
Member of acatech and BBAW
Member of Leopoldina
Leibniz price winner (2013)

Staff

33 Researchers
10 Extern researchers
20 Technical staff members
4 Administration secretaries
94 Student assistants (2019)
90 Student theses (2019)



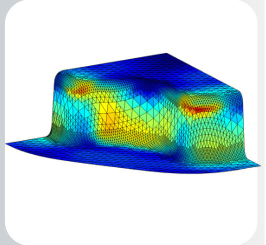
Research portfolio

Targeting the complete process chain

Rolling

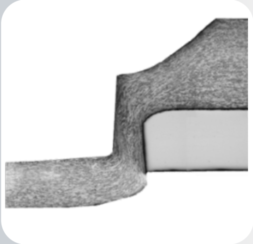
Material characterization

Simulation



Manufacturing real parts

Joining



Quality control

Research portfolio

Targeting the complete process chain

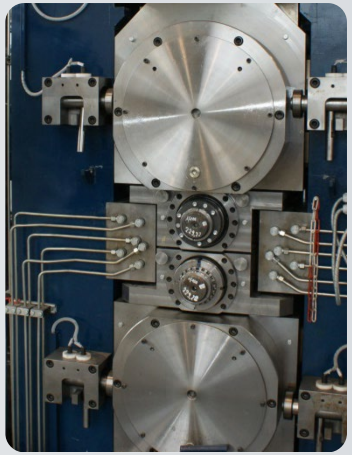
Rolling

Material characterization

Simulation

Manufacturing real parts

- Cold rolling
- Hot rolling
- Accumulative roll bonding (ARB)
- …



Research portfolio

Targeting the complete process chain

Rolling

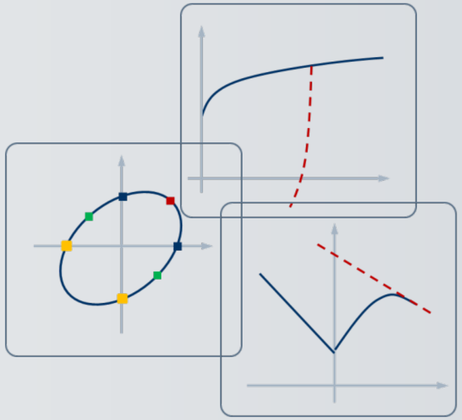
Material characterization

Simulation

Manufacturing real parts

Joining

- Tensile test
- Tensile compression test
- Crossed tensile test
- Layer crush test
- Bulge test
- Compression test
- Simple shear test
- Nakajima test
- Bending test
- Hole expansion test
- …



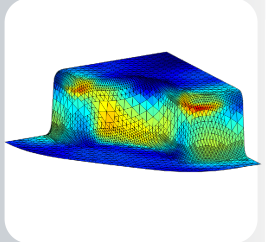
Research portfolio

Targeting the complete process chain

Rolling

Material characterization

Simulation



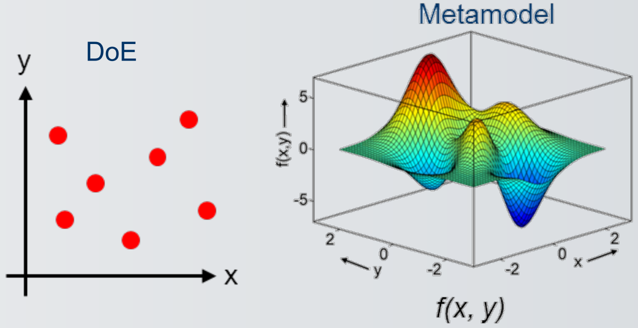
Manufacturing real parts

Joining

Quality control

- Abaqus
- Autoform
- Ls Dyna
- Simufact
- PamStamp
- Comsol

- Matlab
- Minitab
- Creo / ProE
- Solid Edge
- AutoCAD
- …



Research portfolio

Targeting the complete process chain

Rolling

Material characterization

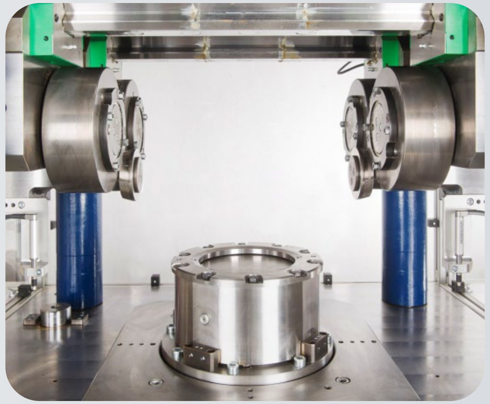
Simulation

Manufacturing real parts

Joining

Quality control

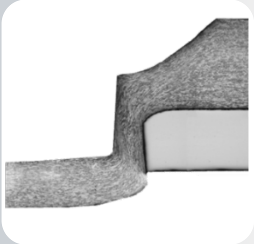
- Conventional sheet metal forming
- Conventional bulk metal forming
- Sheet bulk metal forming
- Hot stamping
- Hydroforming
- Tailored Heat Treated Blanks
- …



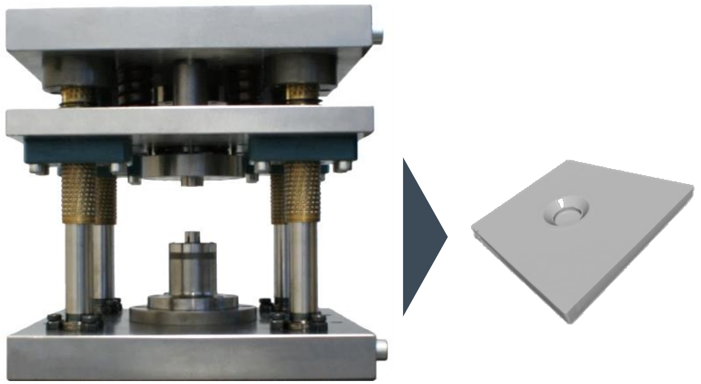
Research portfolio

Targeting the complete process chain

Rolling | Material characterization | Simulation | Manufacturing real parts | Joining | Quality control



- Shear clinching
- Joining by hydroforming
- Additive manufacturing
- …

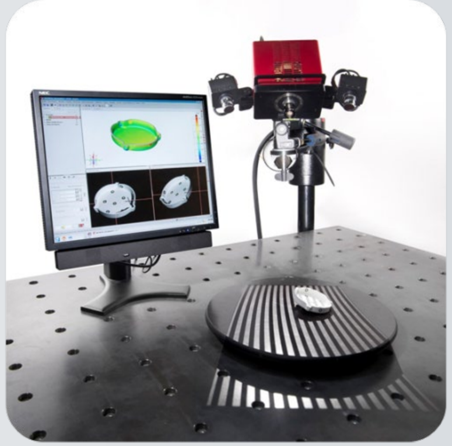


Research portfolio

Targeting the complete process chain

- Rolling
- Material characterization
- Simulation
- Manufacturing real parts
- Joining
- Quality control

- Strain measurement
- Coordinate measuring
- Roughness and topographie measurments
- Hardness measurement
- …



Project partners

Premium Aerotec, +GF+ AgieCharmilles, AIT Austrian Institute of Technology – Tomorrow Today, Alcoa, Aleris, Audi – Vorsprung durch Technik

AutoForm – Forming Reality, Bang & Olufsen, Bechem Lubrication Technology, Benteler, BFFT Gesellschaft für Fahrzeugtechnik mbH, Bilstein – Ein Name für Kaltband, Biotronik – excellence for life

blz Bayerisches Laserzentrum, BMW, Bosch, Brose – Technik für Automobile, Braun CarTec, Bruderer, Crippa, Daimler

Diehl, Dyna More, eifeler, ElringKlinger, Energietechnik Essen GmbH · seit 1811, esi – get it right®

faurecia, F:K, Frank Präzision, Gedia, freud – The sharpest woodworking tools, gom – Gesellschaft für Optische Messtechnik, Hirschvogel Umformtechnik

H-O-T Härte- und Oberflächentechnik, Hydro, inpro, Kennametal, Keyence, Kobelco – Kobe Steel Group, LMS Engineering Innovation

Magna, mall//herlan, Matfem, data M Sheet Metal Solutions, MT Aerospace, Mubea, Novelis

Project partners

noesis
obru
oerlikon balzers
OPEL
PHILIPS
posco
PRECITEC
P+Z Engineering
E. Rihs

RIBE
RUAG Aerospace Defence Technology
SACHS
SAG Salzburger Aluminium AG
SALZGITTER MANNESMANN FORSCHUNG Ein Unternehmen der Salzgitter Gruppe
LUK INA FAG SCHAEFFLER GRUPPE
SCHEUERMANN + HEILIG Metall in Bestform

SCHLETTER GmbH
schwartz WÄRMEBEHANDLUNGSANLAGEN
SEALING PRODUCTS VICTOR REINZ
seidel living design
Severstal
SIEMENS
simufact

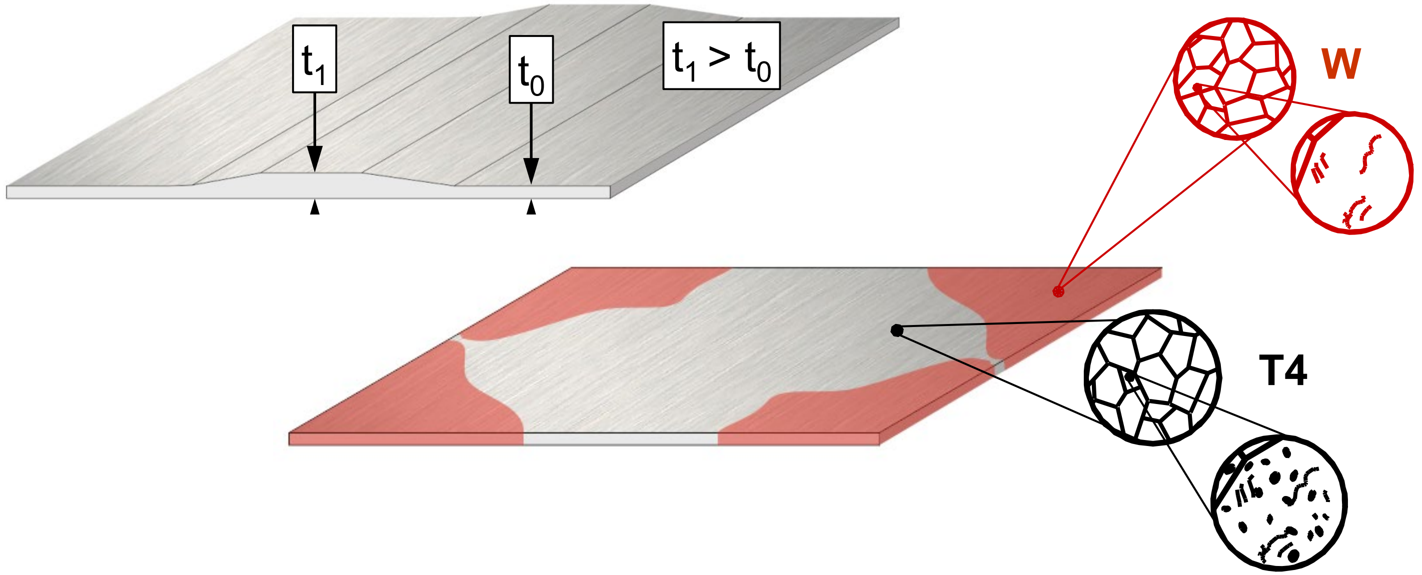
sommer wind Reiseagentur
SSF Verbindungsteile
s[&]t dependable solutions
TATA
TNO innovation for life
TREBANTEC innovation in steel
TRUMPF

VEW DIE ENTWICKLER Vereinigte Elektronikwerkstätten GmbH
virtual vehicle
viseon your bus
voestalpine
VSL Dutch Metrology Institute
VOLVO
weiler WERKZEUGBAU STANZEREI

weiss
Wieland
ewe Wezel GmbH Kaltumform - Technik
Zwick / Roell

Flexibilisation of process chains by tailoring material properties

- Motivation
- Definition of “Tailoring”
- Tailored Processes
    - Tailored Blanks
    - Tailor Heat Treated Blanks
- Summary and outlook



Motivation

Decentralized production

/pixabay.com/

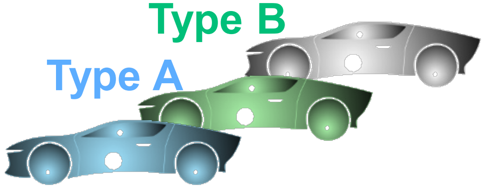
Shorter production cycles

2000 - 2005

2010 - 2015

/nokia.com/ /apple.com/

Vehicle derivates



Ressource efficiency

/mesanusa.com/

Trends in automotive industry

- Lightweight/multi-material design
- Functional integration
- Shorter process chains

➡ Flexible processes mandatory for competitive ability

➡ Tailoring of material's properties as promising approach

Tailoring

Tailored - definition

"Specially made for a particular purpose."
(Cambridge Dictionary)

/The Thelegraph/

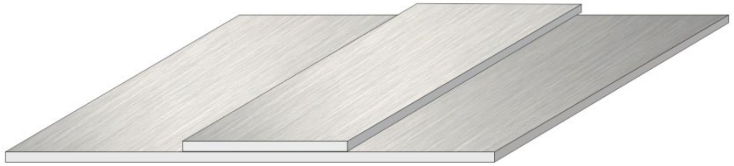
Tailoring in the context of forming processes

- Adapting the material's properties for enabling specific forming operations and thereby flexibilize process chains
- "Tailoring" can include for instance the change of geometrical or mechanical properties by means of
  - Local adjustment of blank thickness
  - Locally defined heat treatment

Tailored Blanks

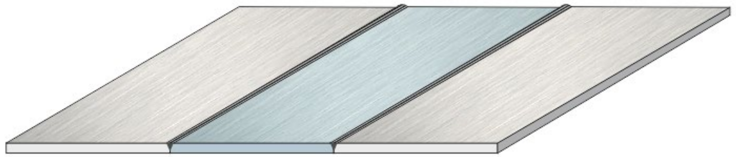
Patchwork Blanks

Local reinforcement of the blank



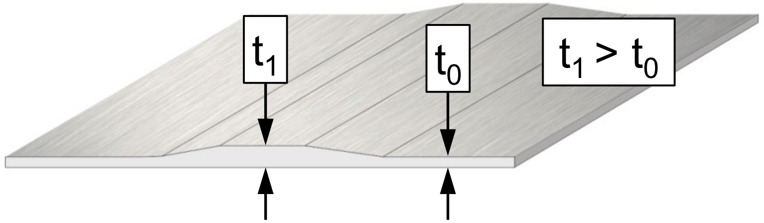
Tailor Welded Blanks

Joining of dissimilar material



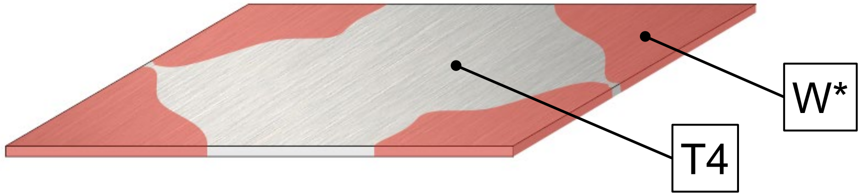
Tailor Rolled Blanks

Locally adjusted blank thickness



Tailor Heat Treated Blanks

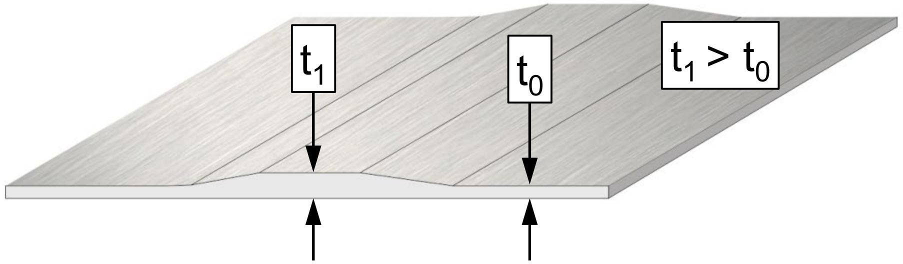
Locally adjusted mechanical properties



➡ Process-optimized semi-finished products

Tailored Processes

- Tailored Blanks
- Tailor Heat Treated Blanks



Motivation

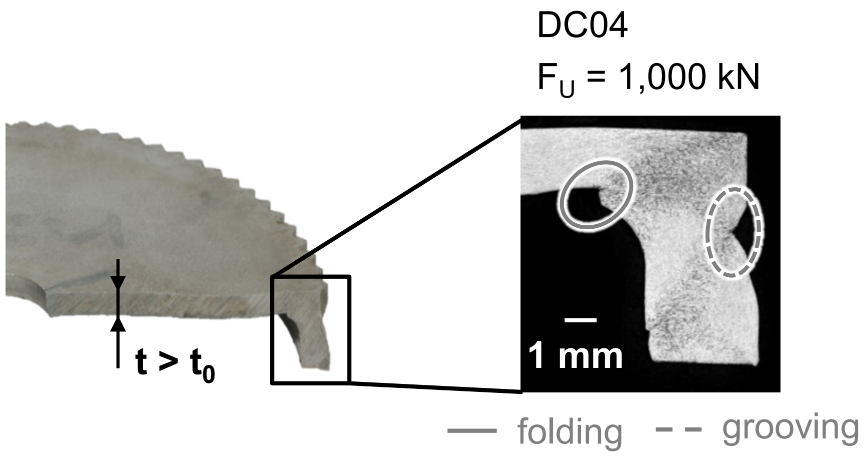
Demands

[Diehl]

[Feintool]

- High accuracy
- Functional integration
- Lightweight design
- Enhanced load-bearing capacity

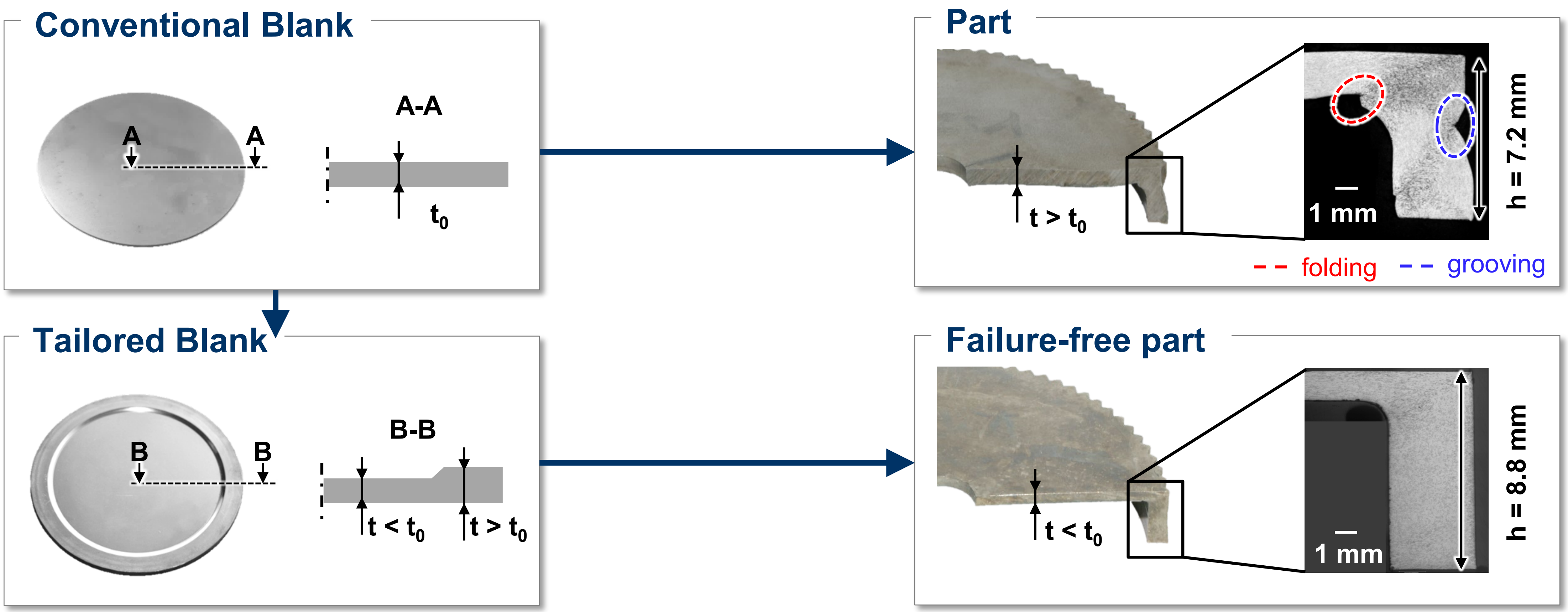
Challenges



- Extension of process understanding
- Prevention of process failures
  - Folding
  - Grooving

→ Tailored approach required to ensure sufficient material flow control

Tailored Blanks

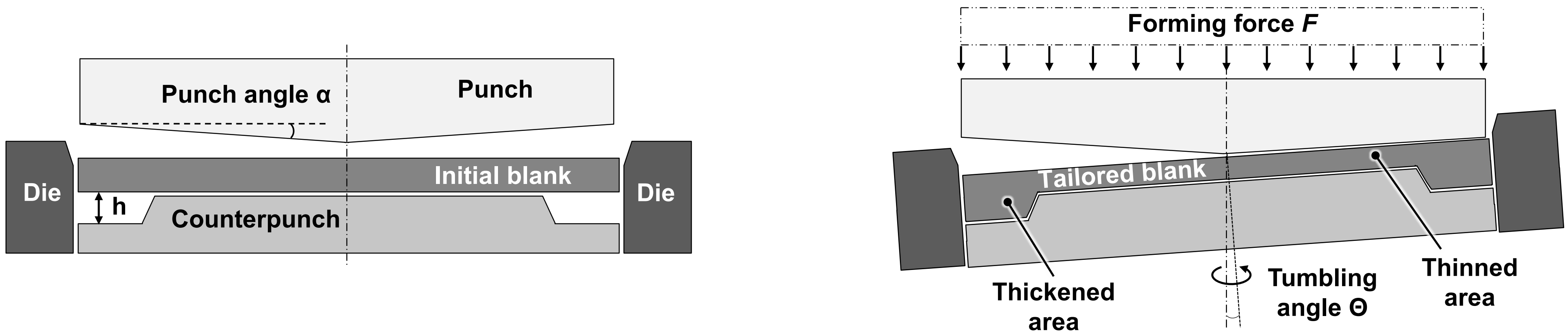


- Geometrical tailoring of the blank
- Process-adapted thickness profile

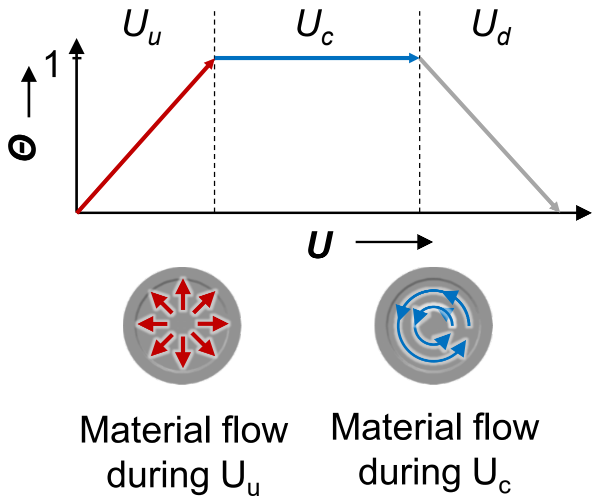
- Enhanced die filling of the functional elements
- Significant reduction of process failures
- Increase of the cup height due to a process adapted thickness profile of the tailored blank

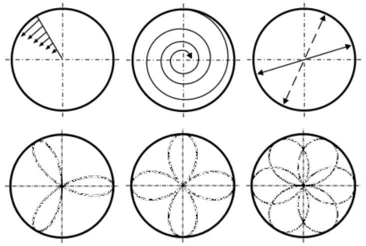
Tailored Blanks – Orbital forming

Orbital forming process



- Forming force F is applied by the upper punch
- Geometry is defined by a die cavity in the counter punch
- Orbital forming plate applies the kintematics by four phase-shifted hydraulic cylinders



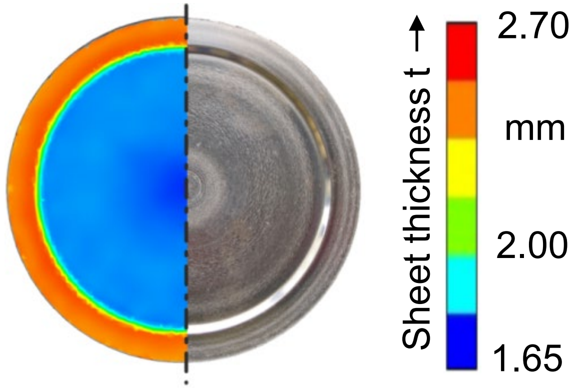


Kinematics

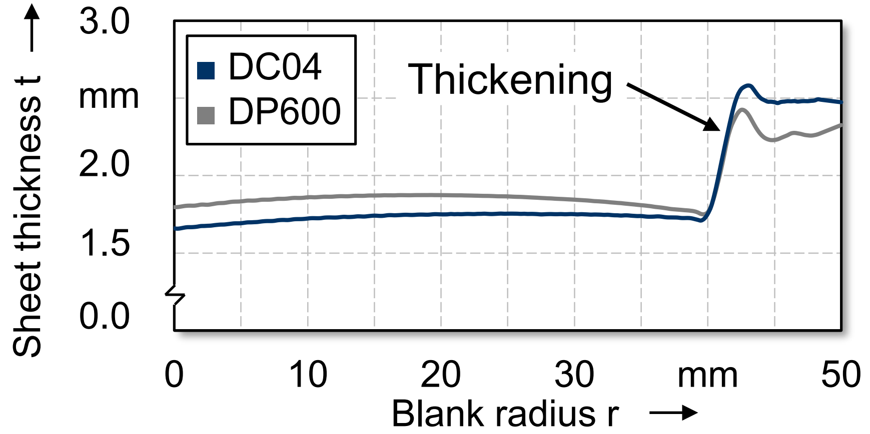
Potential of Tailored Blanks

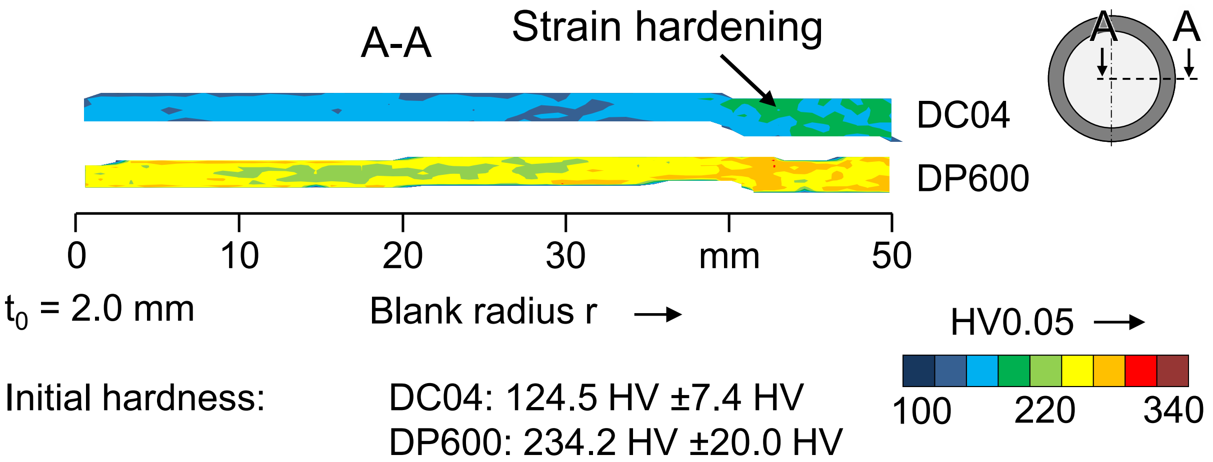
Semi-finished product

- Local material thickening up to 30 % of the initial sheet thickness
- Process adapted material pre-distribution
- Strain hardening leads to a specific adjustment of the mechanical properties of functional components



Properties of semi-finished products





Tailored Blanks – Process flexibility

One-sided thickness profile

Rotational-symmetric

Cyclic-symmetric

Rotational-symmetric
(reduced diameter)

Asymmetric

- One-sided material supply for shaping of different functional elements
- Adapted process strategy for targeted application of direction-dependent material flow to ensure a proper die filling

Functional components

Open carriers

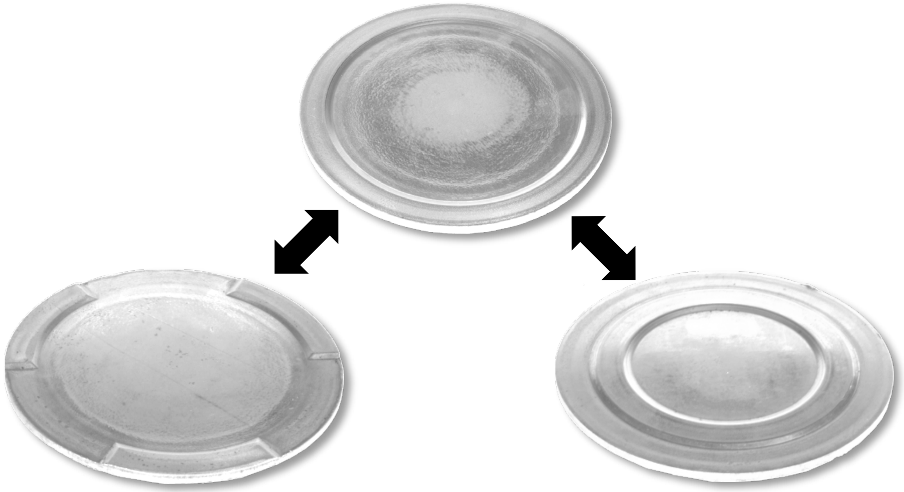
Circumferential toothing

Combined toothing and open carriers

- Application of the tailored blanks in a combined deep-drawing and upsettin process
- Targeted material pre-distribution depending on subsequent requirements

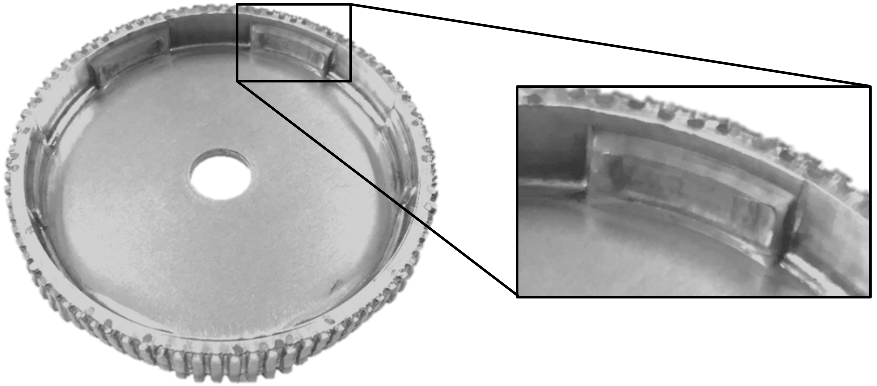
Tailored Blanks – Process flexibility

Two-sided thickness profile



- Increased component complexity by combining different thickening geometries on the top and bottom sides
- Design of the tailored blanks depending on the target geometry of the functional components possible

Functional components

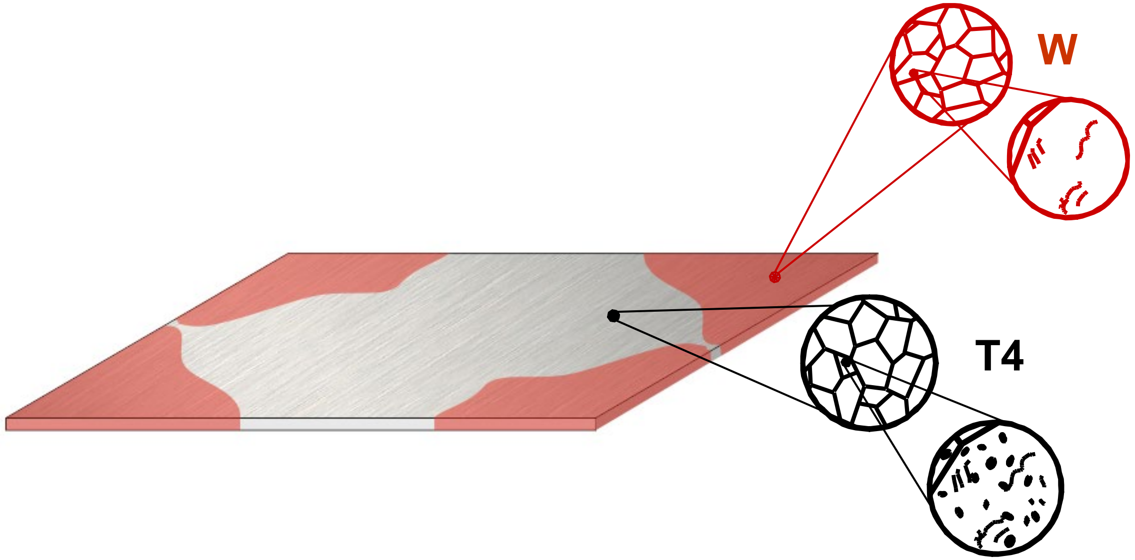


Circumferential toothing outside with carriers inside

- Manufacturing of components with combined toothing and carriers on both sides of the frame
- Targeted material flow control in the further processing due to defined adaption of the material pre-distribution

Tailored Processes

- Tailored Blanks
- Tailor Heat Treated Blanks



History of Tailor Heat Treated Blanks

1941 | 1953 | 1960 | 1998 | 2009 | 2012 | 2015

Material softening (1941)

Short-term heat treatment allows **softening** of age hardenable aluminum alloys.

/Haase, C.; Wurst, H.

Formability extension (1953)

Significant **enhancement** of the **formability** by local heat treatment.

/Siebel, E.; Beisswänger, H.

Laser invention (1960)

Local softening (1998)

Local adaption of the mechanical properties of aluminum blanks by **laser heat treatment**.

/Vollertsen, F.; Lange, K.

Design principles (2009)

Transfer of the THTB-technology to geometrically advanced deep-drawn parts.

/Geiger, M.; Merklein, M.; Vogt U.

Local hardening (2012)

Precipitation hardenable aluminum alloys can not only be softened, but also **hardened** by using artificial ageing effects.

/Nguyen, H.; Merklein, M.

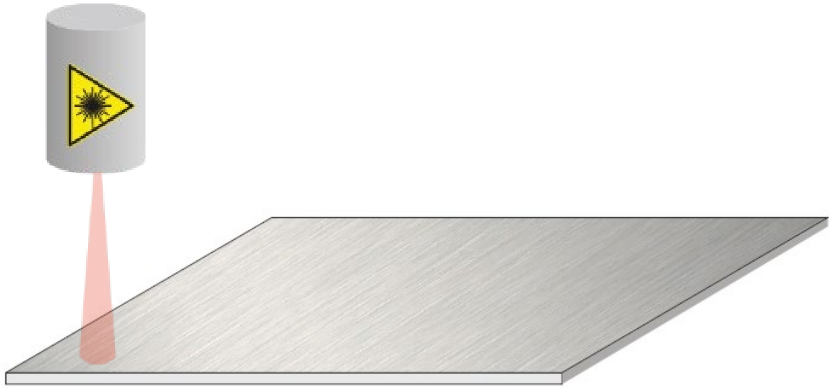
Industrial application (2015)

Use of THTB technology for manufacturing of a tailgate of a **series car**.

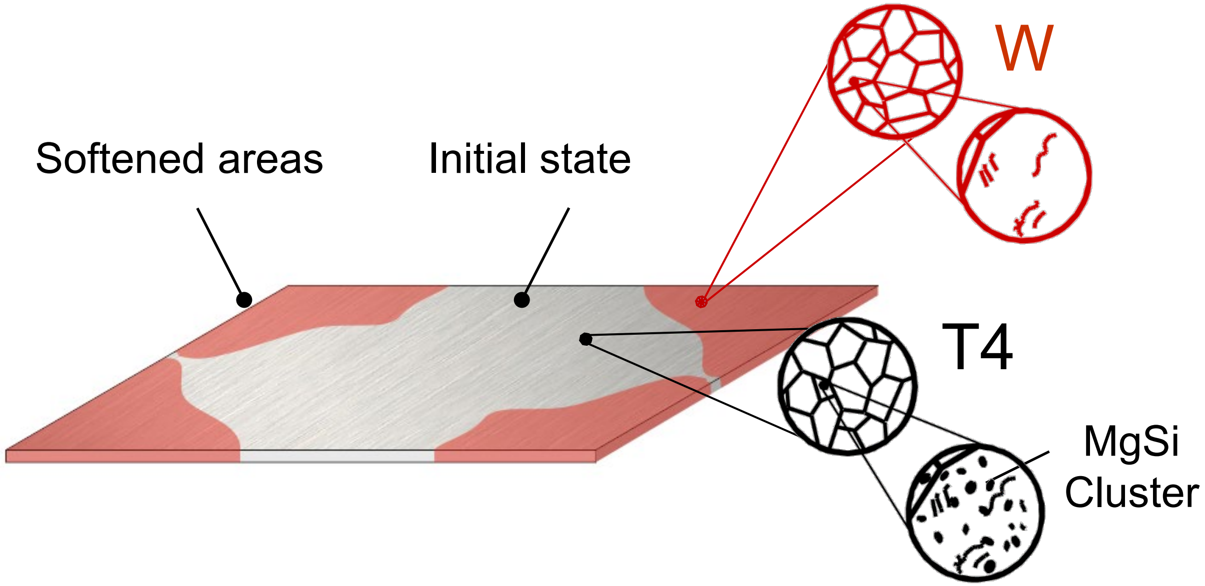
/Kahrimanidis, A.; Lechner, M.; Degner, J.; Wortberg, D.; Merklein, M.

Tailor Heat Treated Blanks

Local laser heat treatment



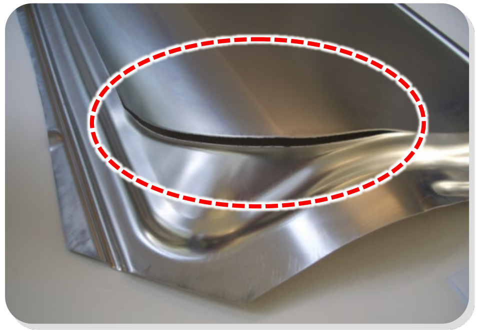
Tailor Heat Treated Blank



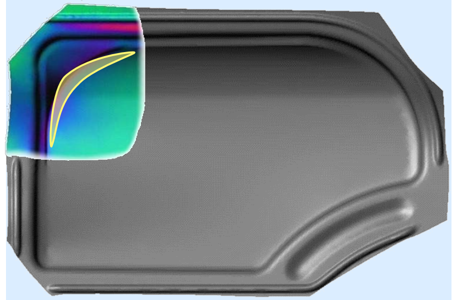
- Local short-term heat treatment by laser irradiation
- Aluminium blanks with locally adapted mechanical properties
- Reduced process forces and improved material flow into forming zone
- Due to the high flexibility of tailor heat treatment, transfer of the methodology to further processes

Potential of Tailor Heat Treated Blankas

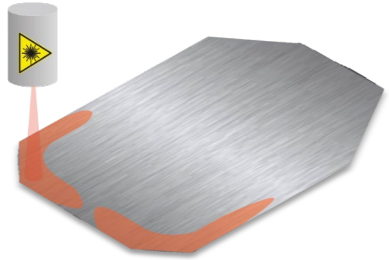
Front door



Process analysis



Heat treatment strategy



FE optimization

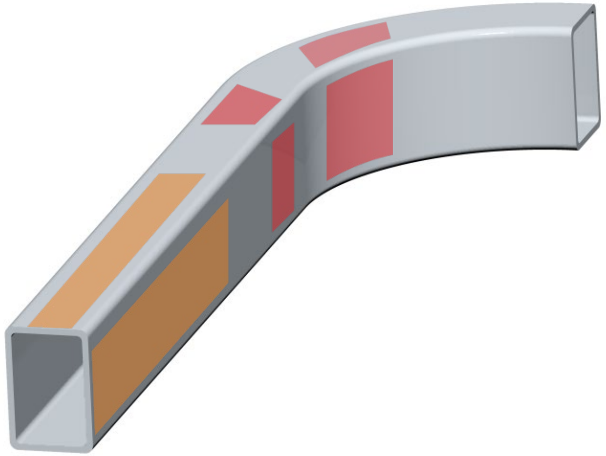
Deep drawing

Failure free front door

Enhanced range of applications for aluminium alloys

Transfer of the THTB-Technology

- Tailor Heat Treated Profiles

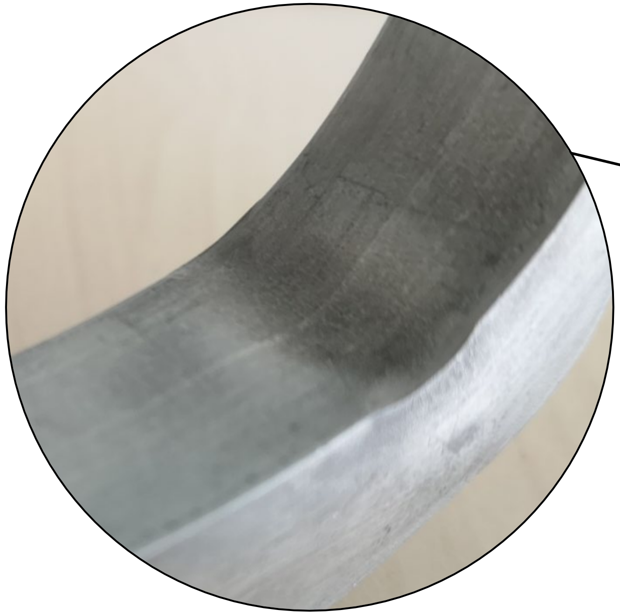


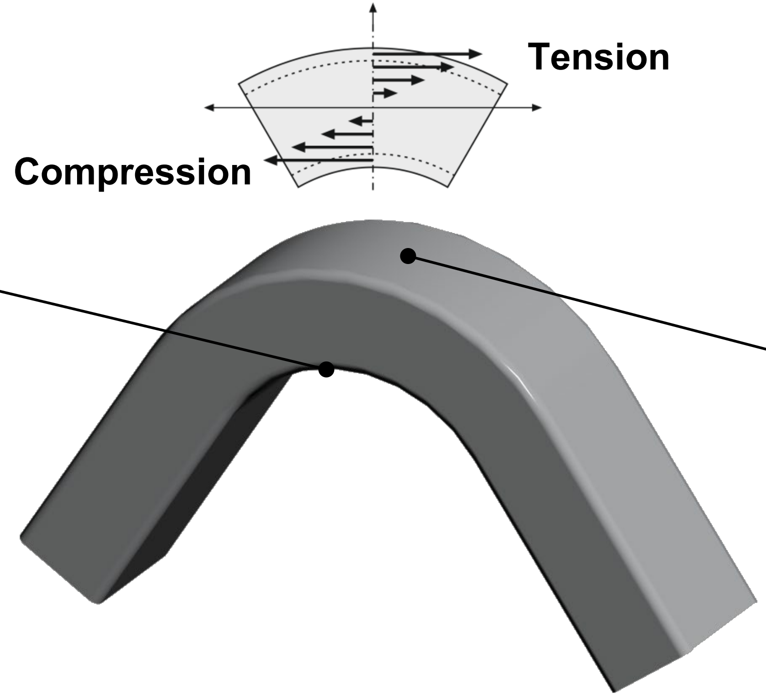
- Mechanical joining of high-strength dissimiliar materials

Tailor Heat Treated Profiles

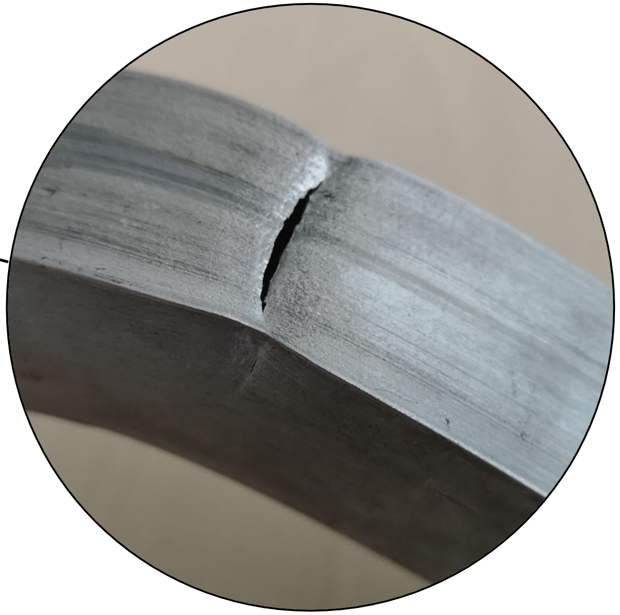
Challenges in the field of profile bending

Wrinkling / Deformations





Necking failure

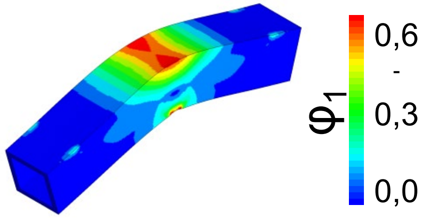


- Compressive stresses on the inner radius → Wrinkling
- Tensile stresses on the outer radius → Necking failure

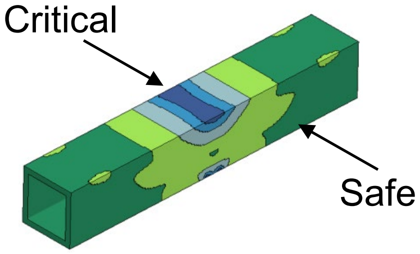
➡ Development of a methodology for a profile-adapted tailored heat treatment

Tailor Heat Treated Profiles - Methodology

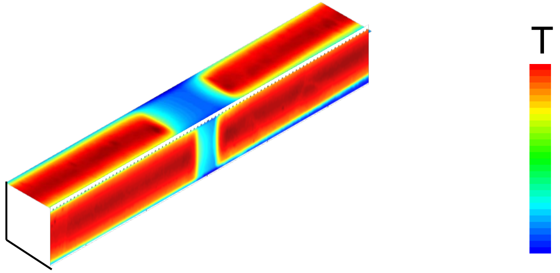
FE-Analysis



Zone-Identification

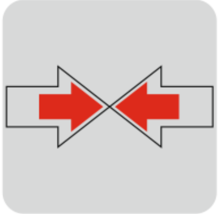


Deduction of heat treatment layout

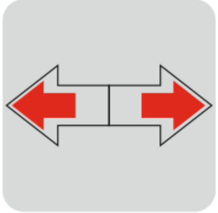


Mechanisms of tailored heat treatment layouts

Reduction of process forces → **Reduction of reactive stresses**



Reduction of compressive stresses → **Prevention of wrinkling on inner radius**

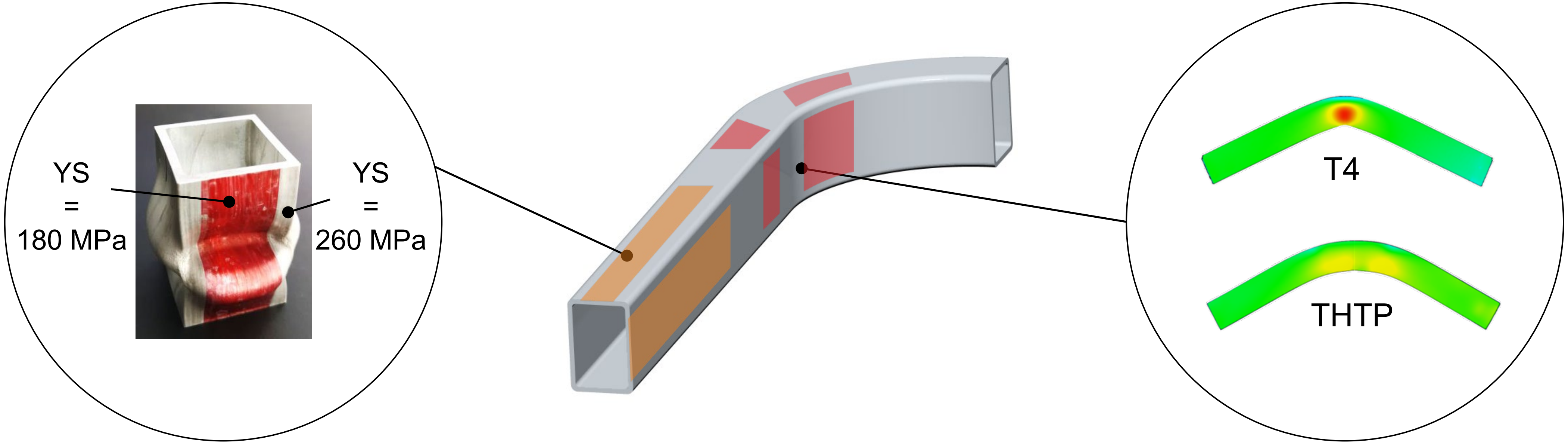


Reduction of tensile stresses → **Prevention of strain localisation on outer radius**

Tailor Heat Treated Profiles - Outlook

Example for Tailor Heat Treated Profile

Adapted crash performance | **Improved formability**

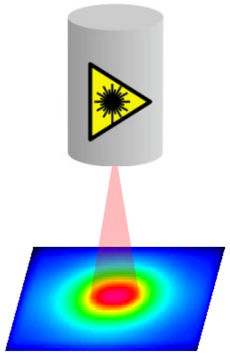


- Tailored artificial ageing behaviour by local laser heat treatment
- Improved material flow by numerically identified heat treatment layout

➡ Tailor Heat Treated Profiles open new possibilities for component design

Transfer of the THTB-Technology

- Profiles
- Mechanical joining of high-strength dissimiliar materials



Short-term heat treatment assisted shear-clinching

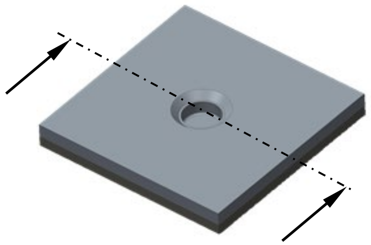
Developments in the automotive industry

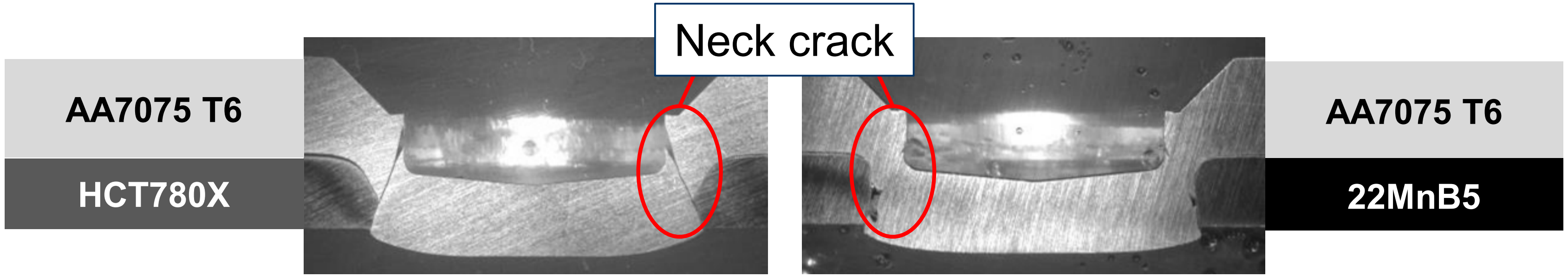
- Increasing application of high-strength materials in automotive applications
- Combination of various materials due to multimaterial design

New challenges for mechanical joining processes

- High strength of both joining partners → High process forces
- Low ductility of punch-sided joining partner → Appearance of joining failure

Mechnical joining



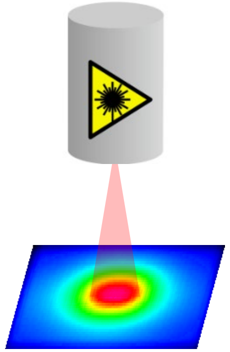


→ Innovative approach: Local softening of punch-sided high-strength aluminium alloy

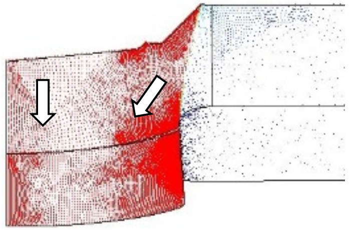
Combination of THTB with shear-clinching process

AA7075 T6

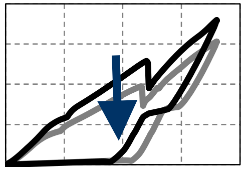
Local softening



22MnB5 / HCT780X

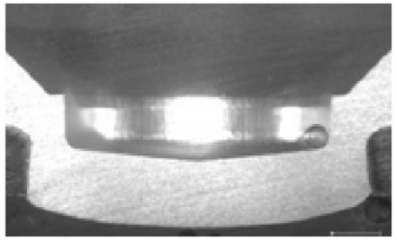


Improved material flow into joint area

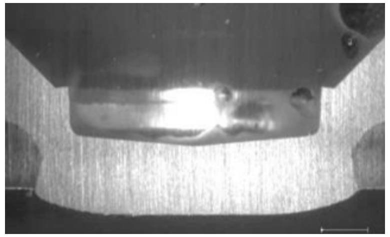


Force reduction due to softened joining area

AA7075 / 22MnB5



AA7075 / HCT780X



Successful joint formation

Possibility of joining parts out of dissimilar high-strength materials

Summary and outlook

Summary

- Flexible process chains mandatory for the competitive ability in automotive industry
- Tailoring of the material‘s properties as promising approach for the flexibilization of process chains
- Material can be adapted for the subsequent process step by changing the properties of the semi-finished products as for instance by geometrical or mechanical adaptions
- Tailored Blanks and Tailor heat treatment as effective methods for the enlargement of process limitations in terms of bulk and sheet metal forming as well as joining

Outlook

- Besides tailoring of the material‘s properties also tailoring of the whole processes as for instance by means of artificial intelligence
- Improvement of process robustness by data acquisition and flexible process control for improvement of part quality and reduction of rejection rates

Shaping ideas into solutions