IFUM

Institut für Umformtechnik
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Thermomechanical Processing for Creating Bi-Metal Bearing Bushings

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Thermal Processing in Motion

Spartanburg, South Carolina, June 5-7, 2018

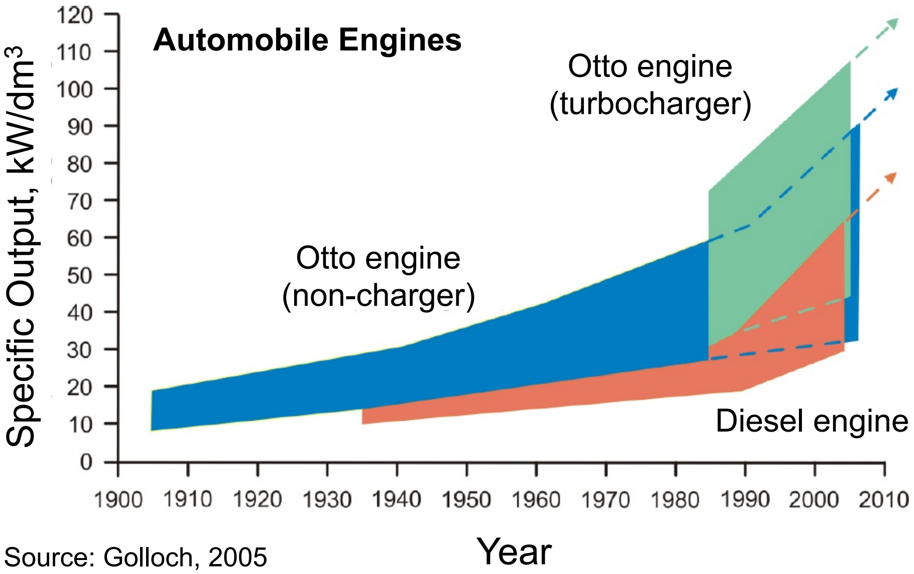
FLUXTROL
Centre for Induction Technology

Leibniz
Universität
Hannover

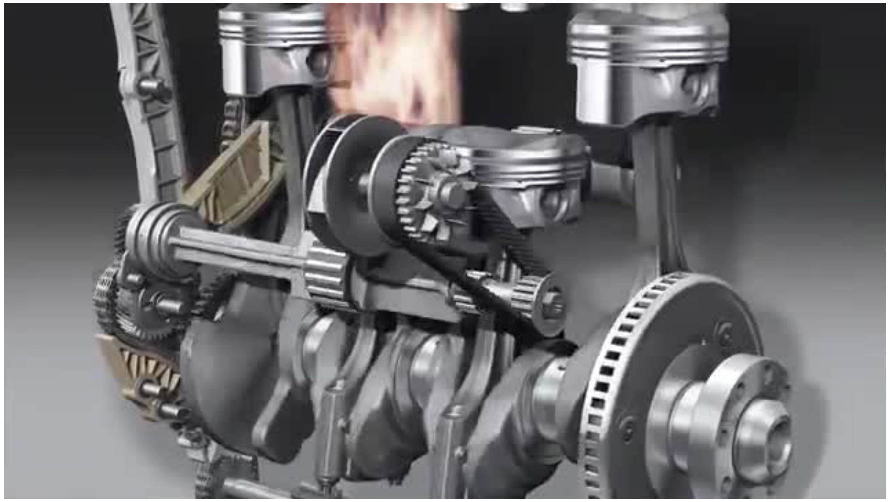
Produktionstechnisches
Zentrum Hannover

Outline

Introduction and Motivation



Source: Golloch, 2005



Source: Audi AG 1.8 TFSI Engine

Current Trends

- Rising output density
- Locally varying loads
- Conservation of resources
- Energy efficiency

Solution approaches

- Integrate different materials into one single **bi-material** component
- Take advantage of specific characteristics of different materials

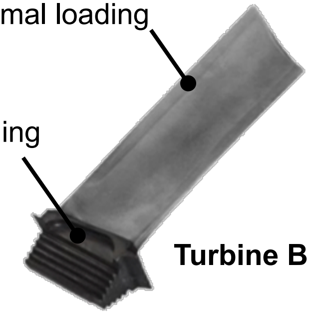
Introduction and Motivation

Appropriate Material at the Appropriate Location

- Extended functionality of components
- Lightweight construction

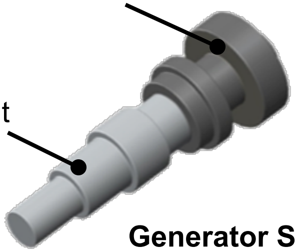
Piston

Automative Engineering



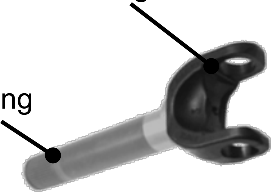
Turbine Blade

Aerospace Engineering



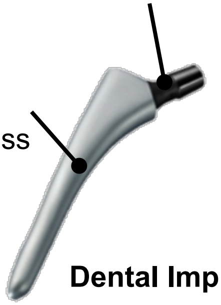
Generator Shaft

Energy Technology



Drive Shaft Yoke

Automative Engineering



Dental Implant

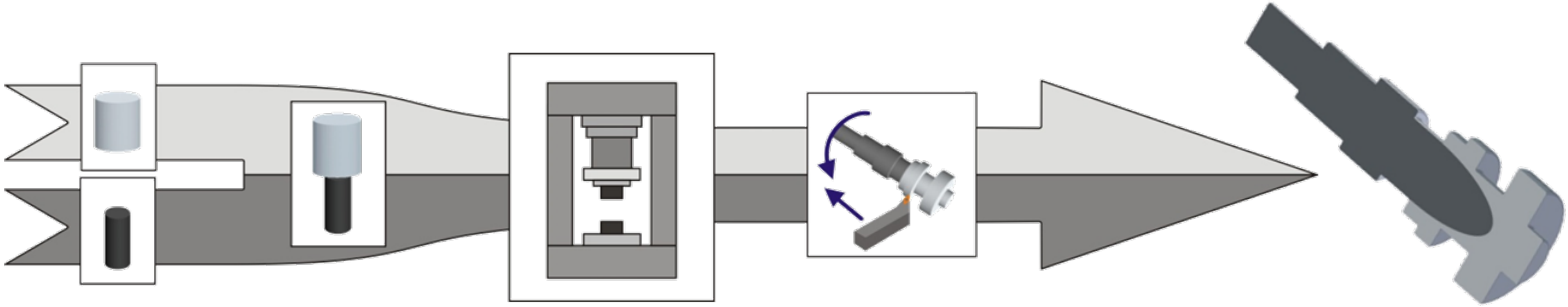
Medical Engineering

Outline

- Introduction and Motivation
- SFB 1153 Tailored Forming
- Forming Process Design
- Results
- Summary and Outlook

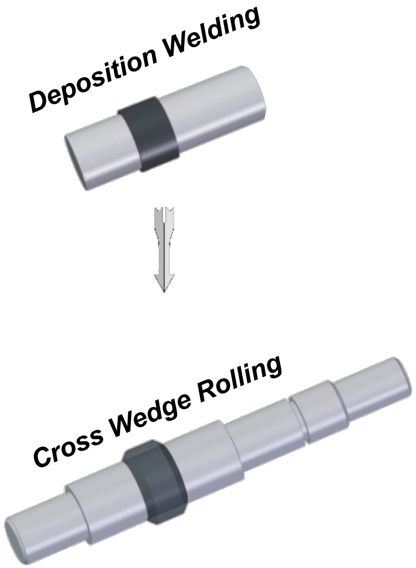
General Process Chain within the Collaborative Research Centre SFB 1153

Use of **combined semi-finished workpieces** and **thermo-mechanical manufacturing processes** to produce hybrid components with locally-adapted properties

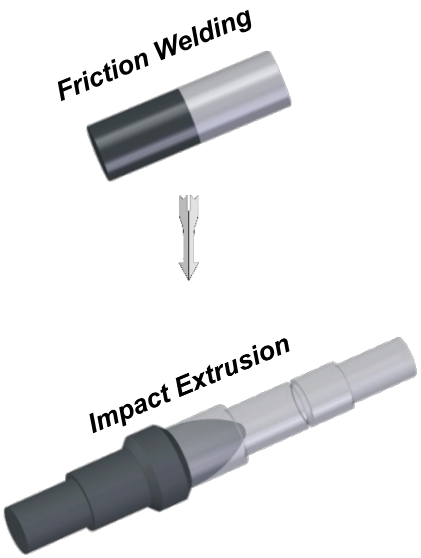


Joining	**Forming**	**Finishing**	**High-performance components with locally-adapted properties**
Profile extrusion Deposition welding Friction welding	Die forging Impact extrusion Cross wedge rolling	Machining Heat treatment Finishing	Service life evaluation Geometrical inspection Damage prediction Multiscale modelling

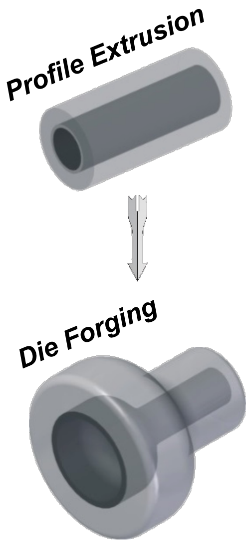
Bi-Material Automotive Parts



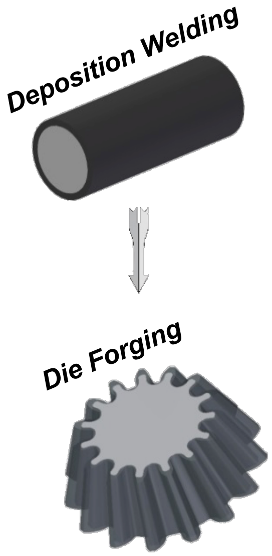
Stepped Shaft 1
Coaxial Arrangement
of Materials



Stepped Shaft 2
Sequential Arrangement
of Materials

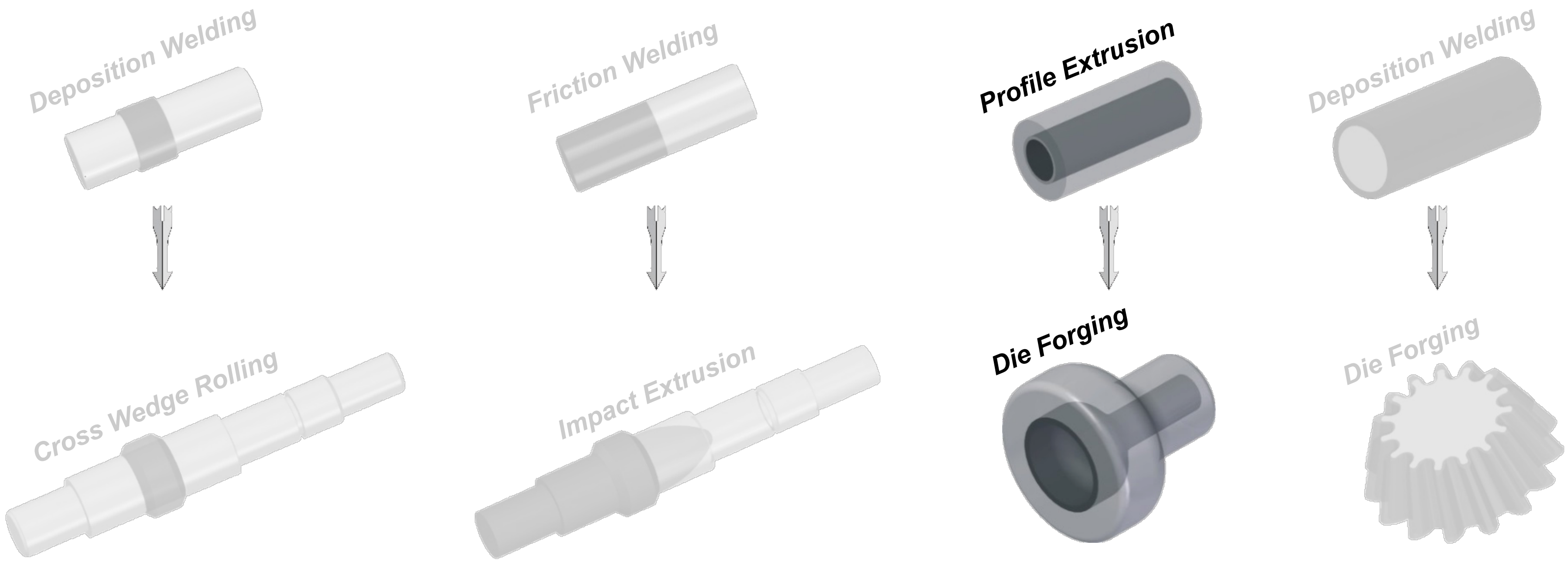


Bearing Bushing



Bevel Gear

Bi-Material Automotive Parts



Stepped Shaft 1
Coaxial Arrangement
of Materials

Stepped Shaft 2
Sequential Arrangement
of Materials

Bearing Bushing

Bevel Gear

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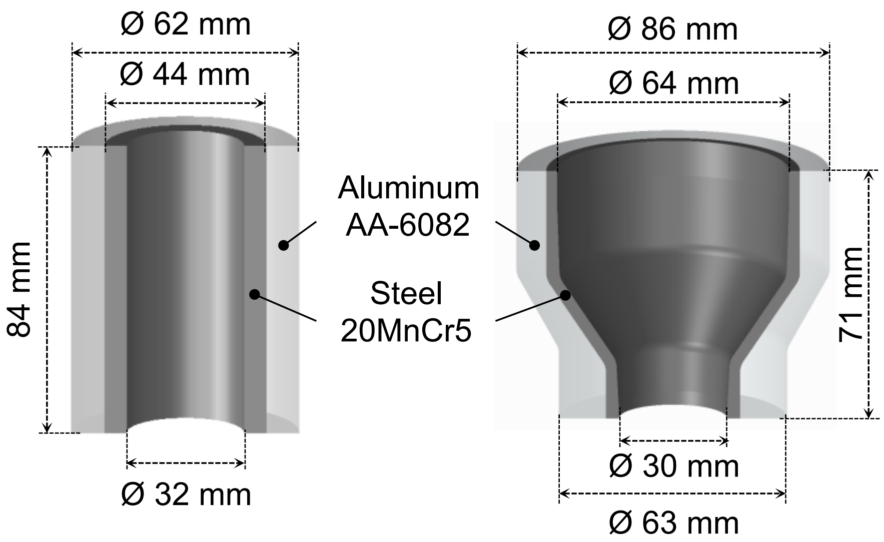
Forming Process Design

Initial and Final Geometry

The bi-metal bearing bushing represents a lightweight concept:

- Combination of steel 20MnCr5 and aluminum 6082
- Coaxially arranged workpieces were designed in accordance with the final geometry
- High performance and wear resistant material on the high loaded bearing surface
- Light aluminum in the structure areas
- Low weight while maintaining high durability and performance

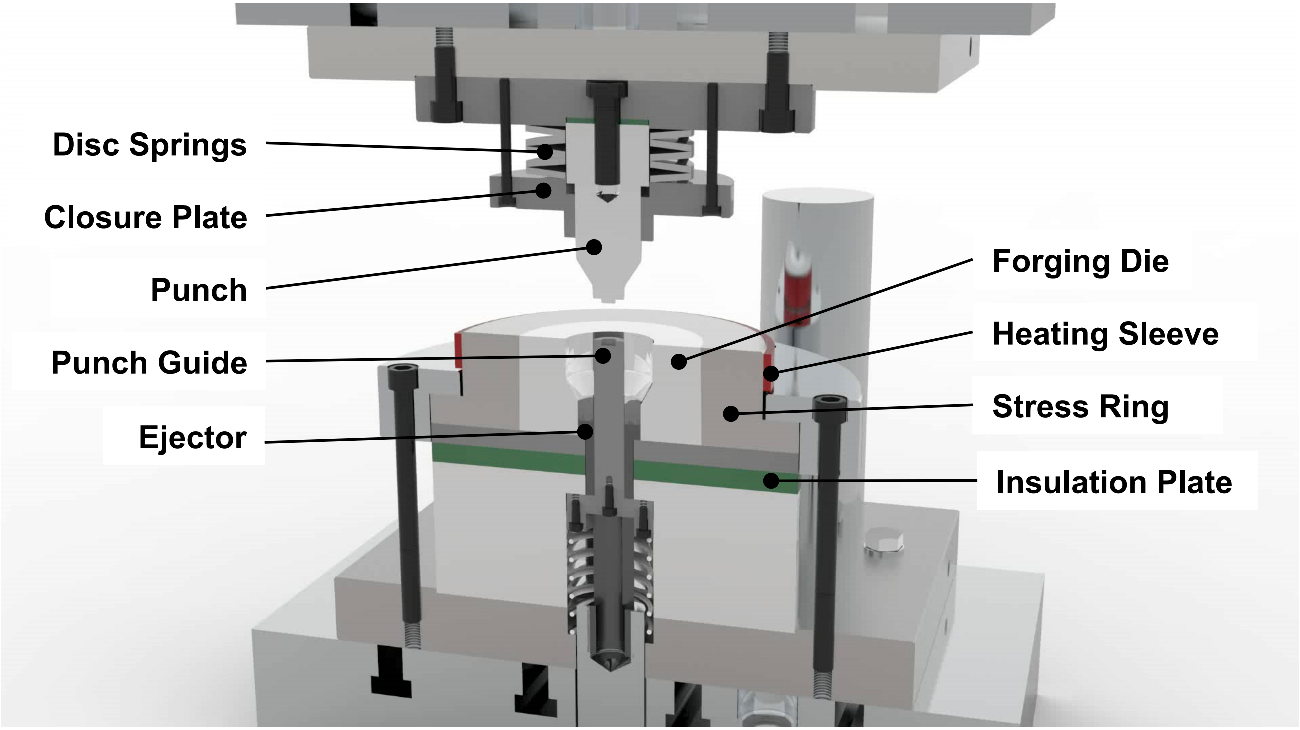


Bi-Material Workpiece

Bearing Bushing

Forming Process Design

Forming Tool System

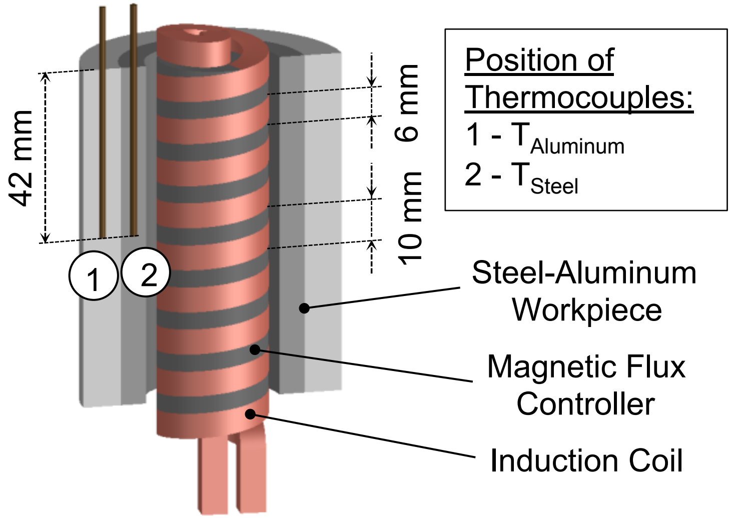


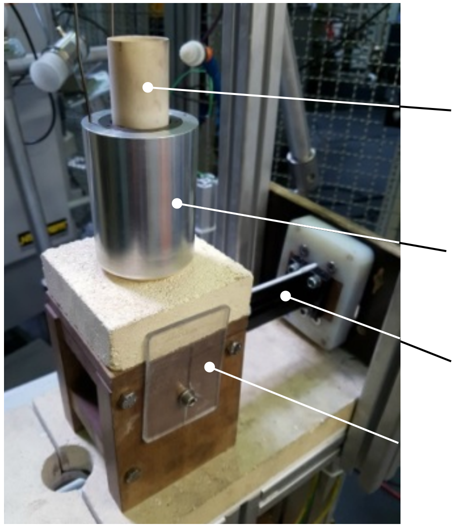
- Precise positioning of the workpiece by an integrated punch guide
- Near-net-shape forging
- Automatic detaching of the forged parts with disc springs’ force
- Inhomogeneous forming temperature (Steel/Aluminium)

Forming Process Design

Heating Concept – Induction Coil

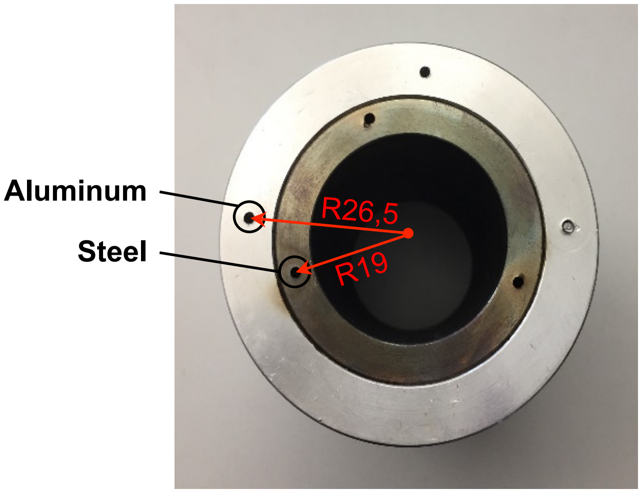
- Dissimilar thermal, physical and mechanical properties of steel and aluminum
- Reaching of material specific forming temperatures for both material is required
- Targeted presetting of temperature gradients by induction heating in order to increase the formability
- Maximum temperature of steel is limited due to the melting temperature of aluminum
- Improvement of the heating efficiency by magnetic flux controller



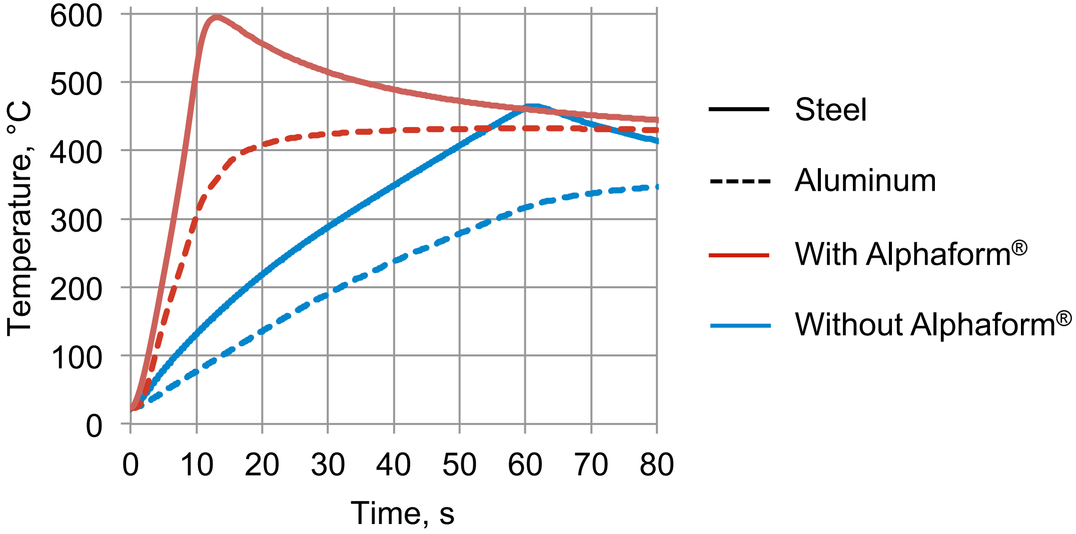


Heating Concept – Effect of Magnetic Flux Controller

Measurement Points



Temperature Curves



Dimensions	mm
Outer Diameter Aluminum	62
Outer Diameter Steel	44
Inner Diameter Steel	32

Heating Parameter	Without Alphaform®	With Alphaform®
Output Voltage, V	600	300
Set Voltage, %	60	100
Heating Time, s	60	10

- Using of magnetic flux controller lead to shorter heating time with less power

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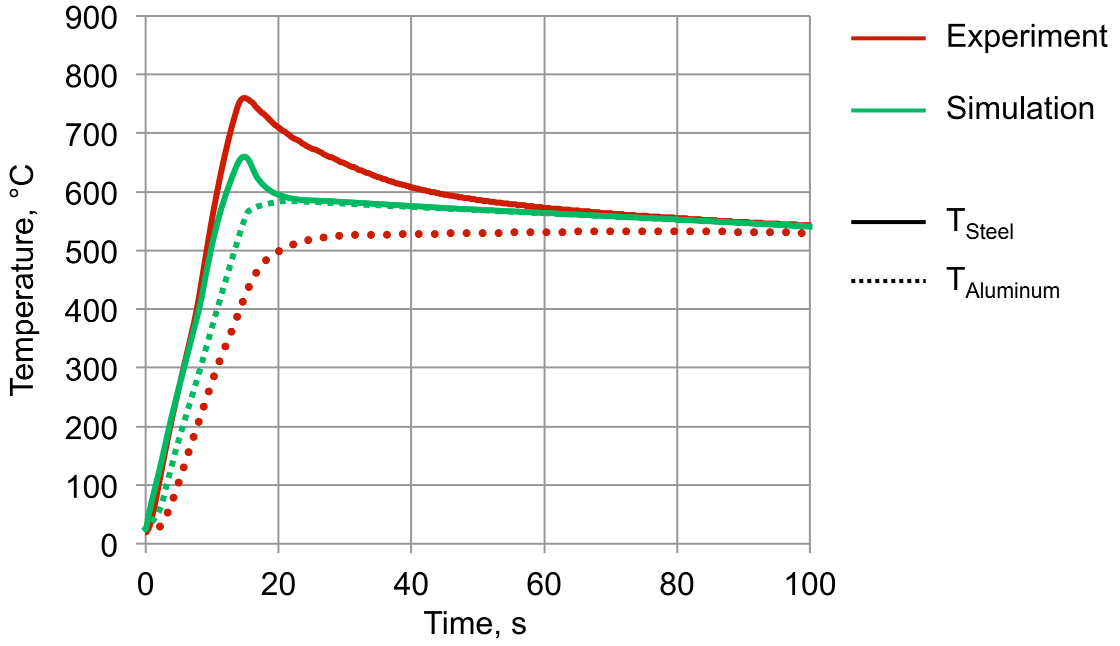
Numerical Modelling of the Heating Process

Comparison between Experiment and Simulation with ideal contact

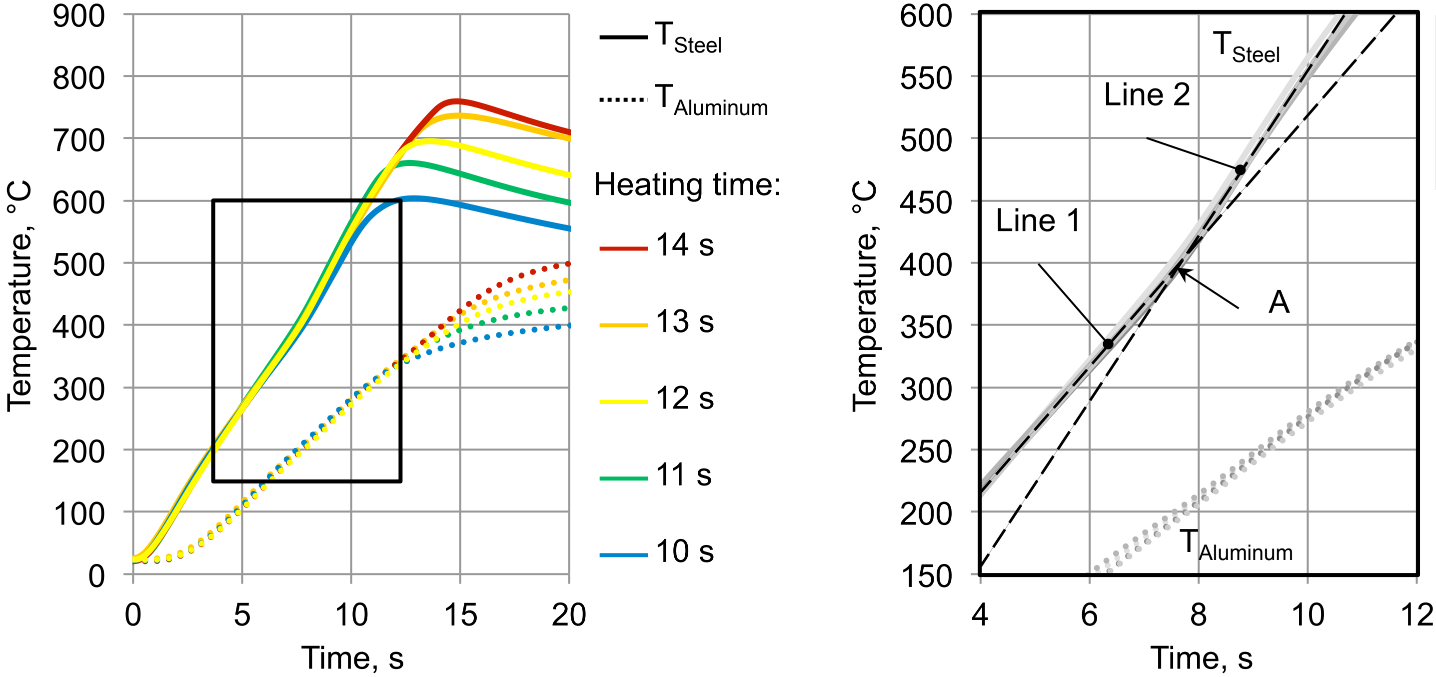


- Both curves equalize at the same temperature
- The total energy input was the same for both cases
- The shrink-fitted workpieces have not perfect contact → higher temperature gradients possible

Results

Numerical Modelling of the Heating Process

Experimentally measured temperature curves



Line 1:
$y = 52{,}56x – 0{,}5202$

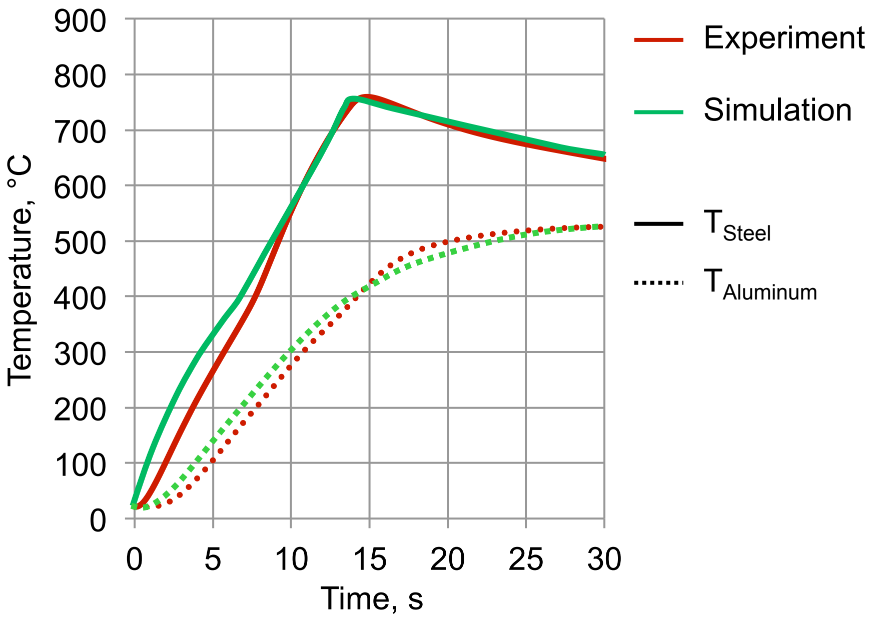
Line 2:
$y = 60{,}157x – 427{,}22$

A: Point of contact conditions change

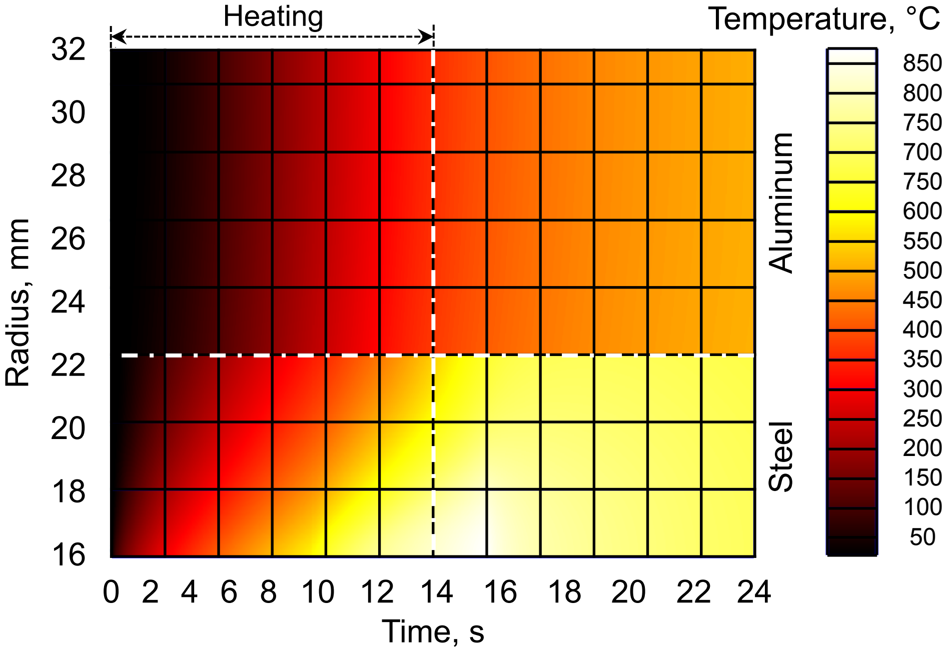
- The aluminum has a higher thermal expansion coefficient compared with steel
- The gap between steel and aluminum grows with increasing temperature
- The heat exchange decreases due to less contact

Numerical Modelling of the Heating Process

Comparison between Experiment and Simulation with variable power and conductivity of the gap



Radial temperature distribution dependent on heating time

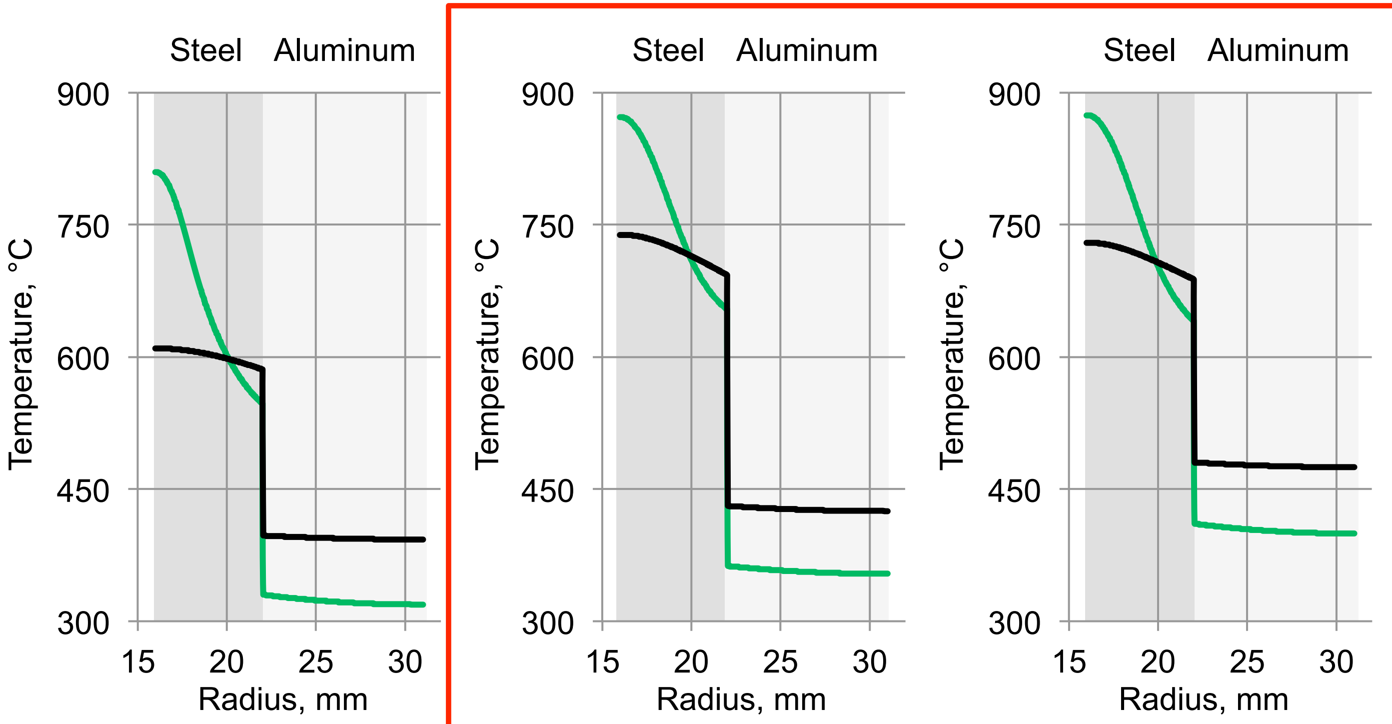


- Integration of a thin layer with temperature dependent conduction properties between steel and aluminum in simulation model
- Slight deviations at the beginning and the end of the heating process are caused by thermal lag of the thermocouples

Results

Numerical Modelling of the Heating Process

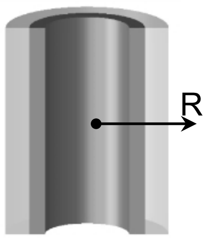
Radial temperature distribution in bi-metal workpieces



a) Heating time 11 s

b) Heating time 13 s

c) Heating time 14 s



Used for the Forming Tests

Results

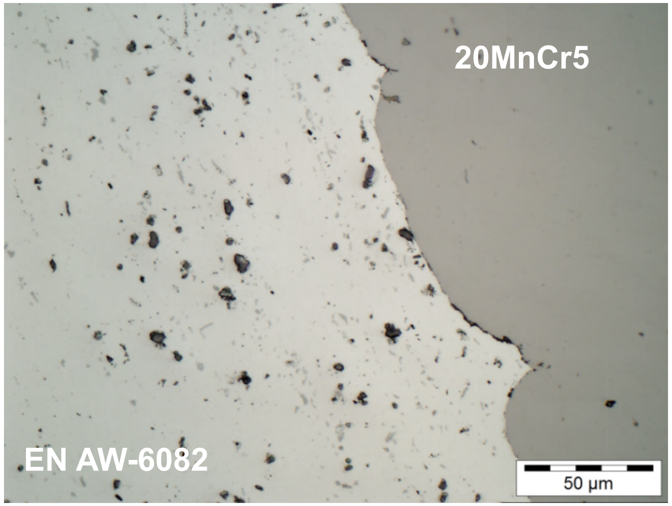
Experimental Forming Tests

Results

Experimental Forming Tests

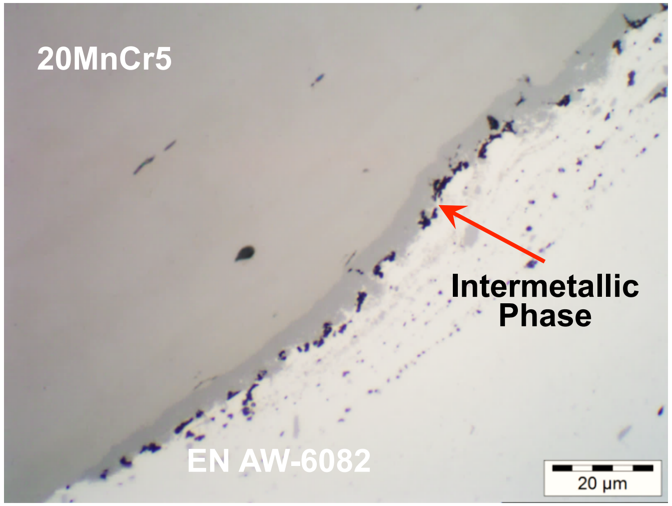
Heating strategy 1

Heating time	13 seconds
Transportation time	6 seconds
T_{Steel}	Approx. 717 °C
$T_{Aluminum}$	Approx. 458 °C
Bonding quality	Form-/ Force-closed joint



Heating strategy 2

Heating time	14 seconds
Transportation time	6 seconds
T_{Steel}	Approx. 719 °C
$T_{Aluminum}$	Approx. 492 °C
Bonding quality	Partially metallurgical bonding



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Summary and outlook

Summary

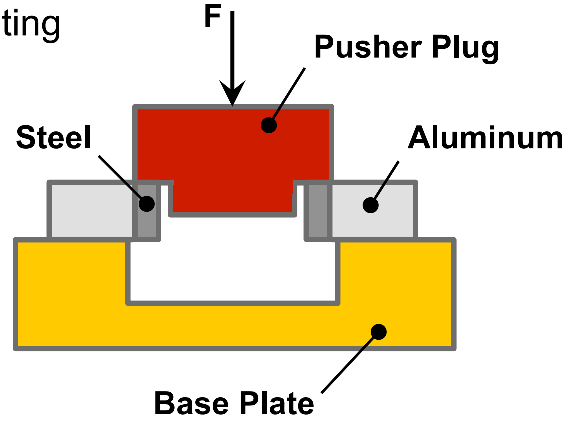
- Forming of dissimilar materials is challenging due to their different material-specific properties
- By using of tailored heating, high forming strains can be achieved in steel-aluminum workpieces
- The forming temperature have the most influence on the resulting bonding quality

Outlook

Mechanical characterization of the bonding quality by push-out test

For further improving of bonding quality, an optimization of the heating process is required:

- Targeted cooling of aluminum surface during the induction heating (water spray field, water-cooled robot gripper)
- Reduction of the transportation time
- Application of the induction generator with higher power



Cross section of push-out test arrangement

Thank you for your attention!

Contact us!

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