IFUM
Institut für Umformtechnik
und Umformmaschinen
Prof. Dr.-Ing. Bernd-Arno Behrens

Thermomechanical processing of friction welded steel-aluminum billets to improve joining zone properties

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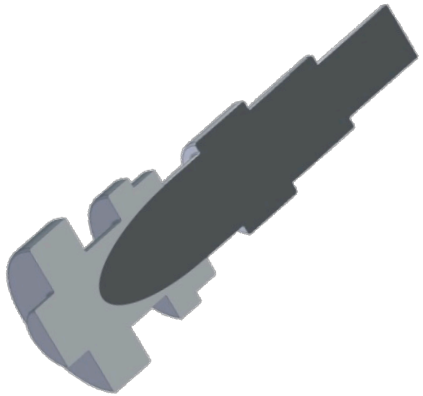
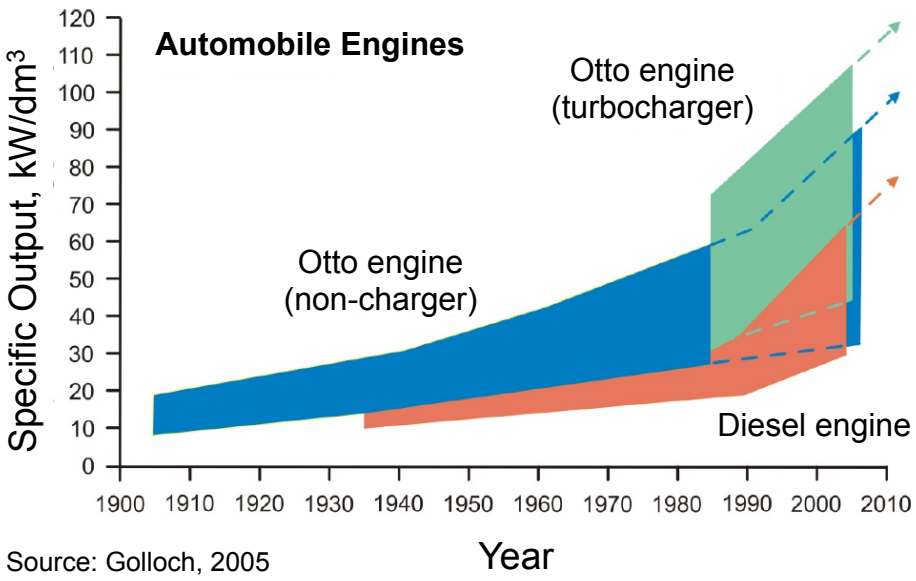


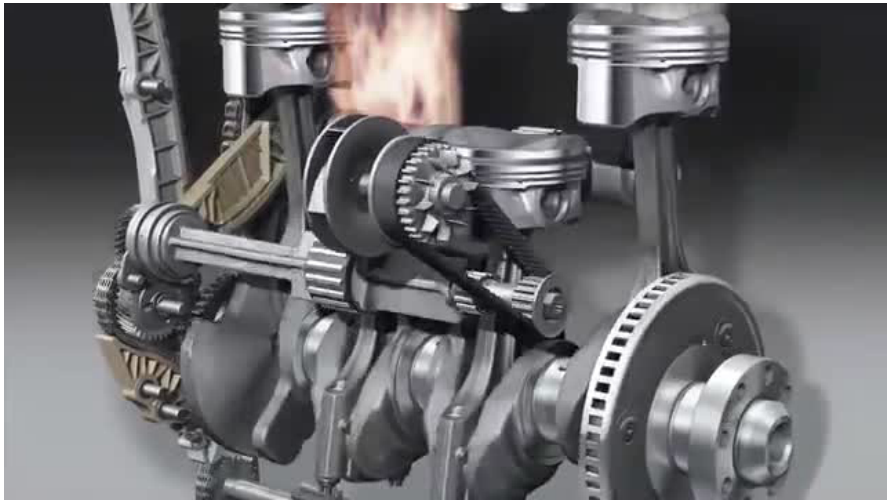
Thermal Processing in Motion
Spartanburg, South Carolina, June 5-7, 2018

Quality Associates Metallurgical Services QA
FLUXTROL Centre for Induction Technology
Leibniz Universität Hannover
Produktionstechnisches Zentrum Hannover

Introduction (1)



Source: Golloch, 2005
Downsizing bei Verbrennungsmotorren



Source: Audi AG 1.8 TFSI Engine

Current Trends

- Rising power density
- Locally varying loads

- Conservation of resources
- Energy efficiency

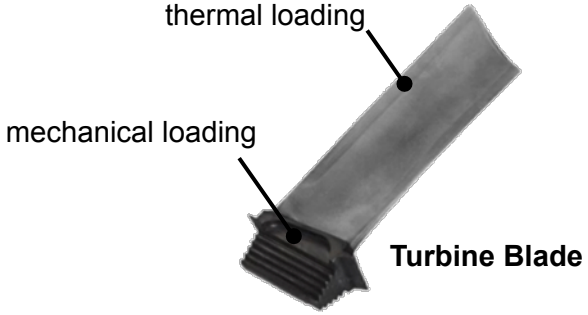
Motivation

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

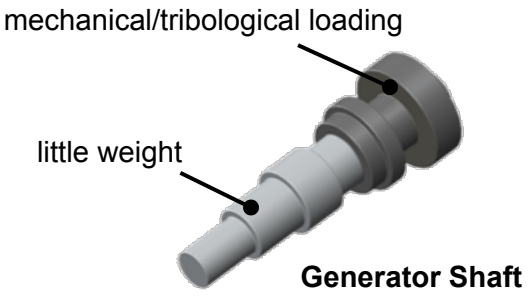
Appropriate Material at the Appropriate Location

- Extended functionality of components
- Lightweight construction

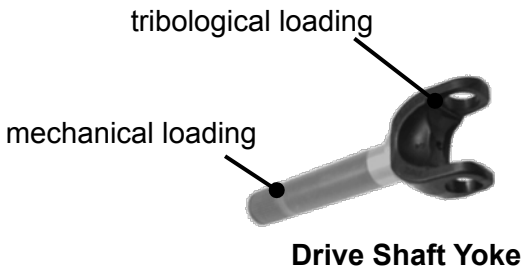
Automative Engineering



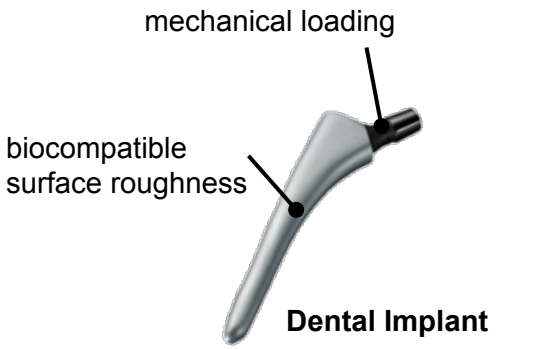
Aerospace Engineering



Energy Technology



Automative Engineering

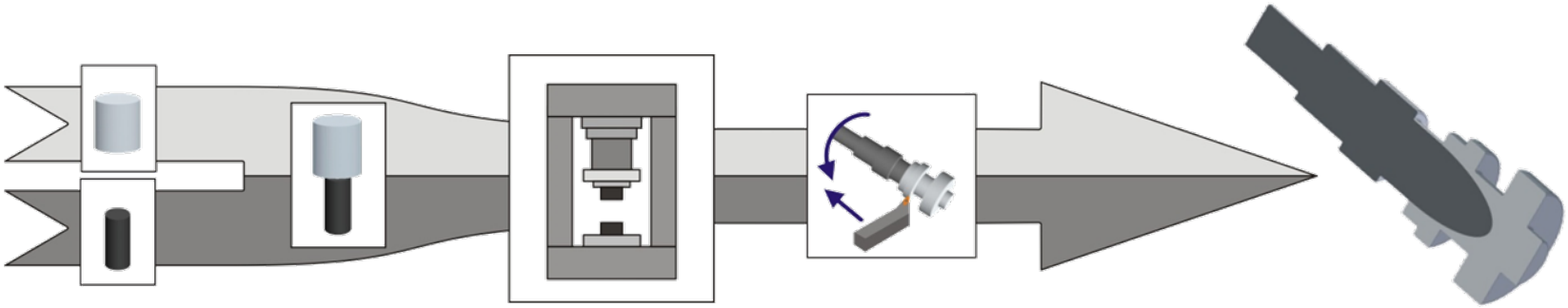


Medical Engineering

Research Overview (1)

Collaborative Research Centre “SFB 1153”

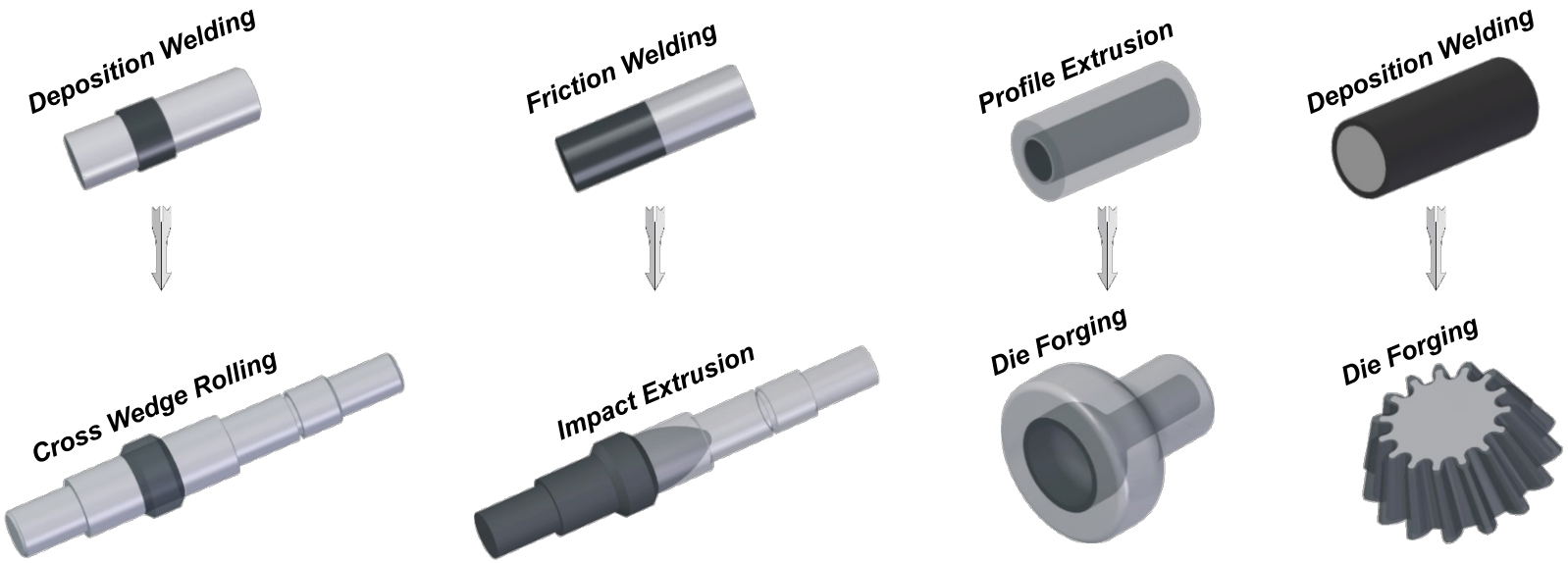
Use of **combined semi-finished workpieces** and **thermo-mechanical manufacturing processes** to produce hybrid components with locally-adapted properties



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

Research Overview (2)

Bi-Material Automotive Parts of SFB 1153



Stepped Shaft 1
Coaxial Arrangement of Materials

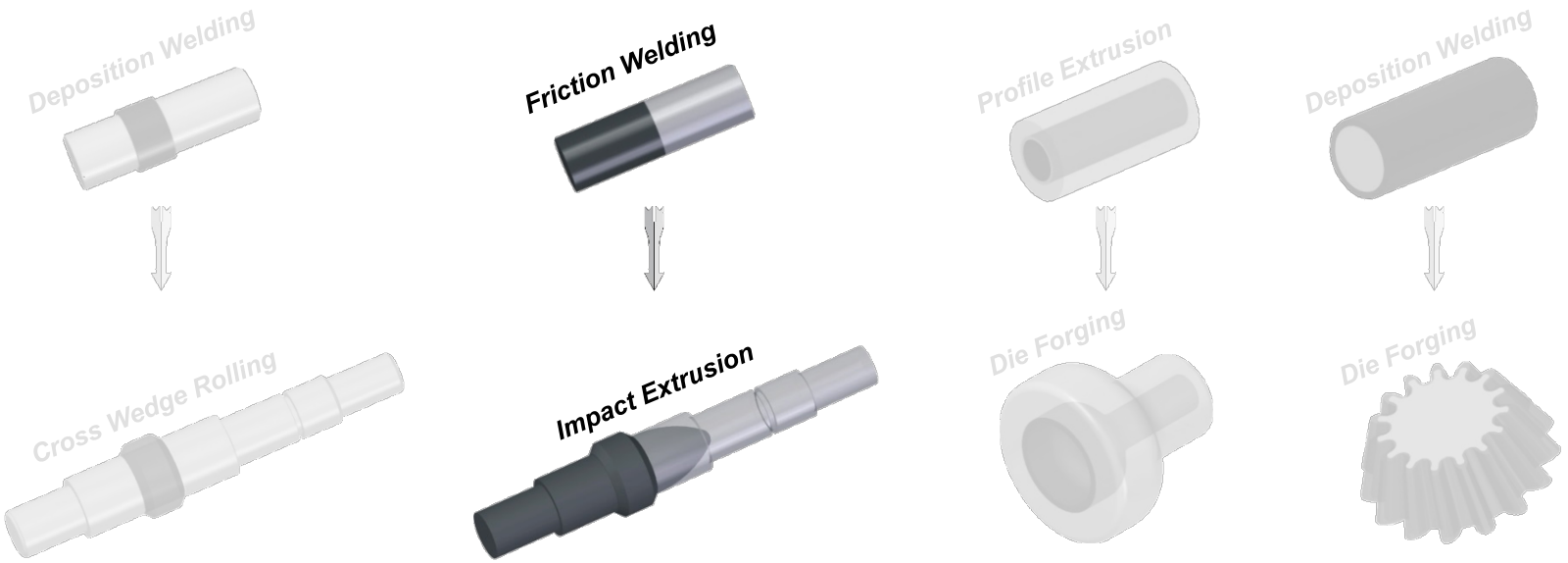
Stepped Shaft 2
Sequential Arrangement of Materials

Bearing Bushing

Bevel Gear

Research Overview (3)

Bi-Material Automotive Parts of SFB 1153



Stepped Shaft 1
Coaxial Arrangement
of Materials

Stepped Shaft 2
Sequential Arrangement
of Materials

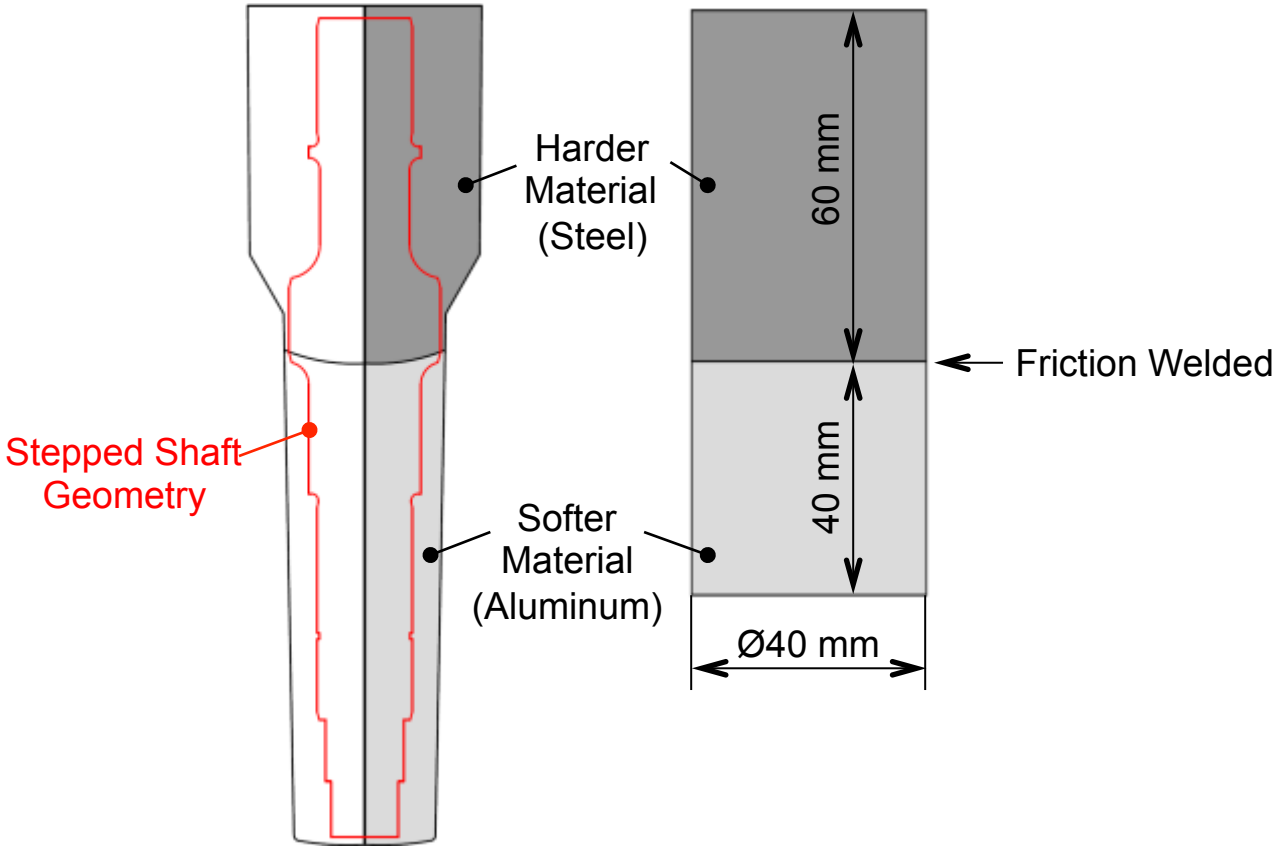
Bearing Bushing

Bevel Gear

SFB 1153

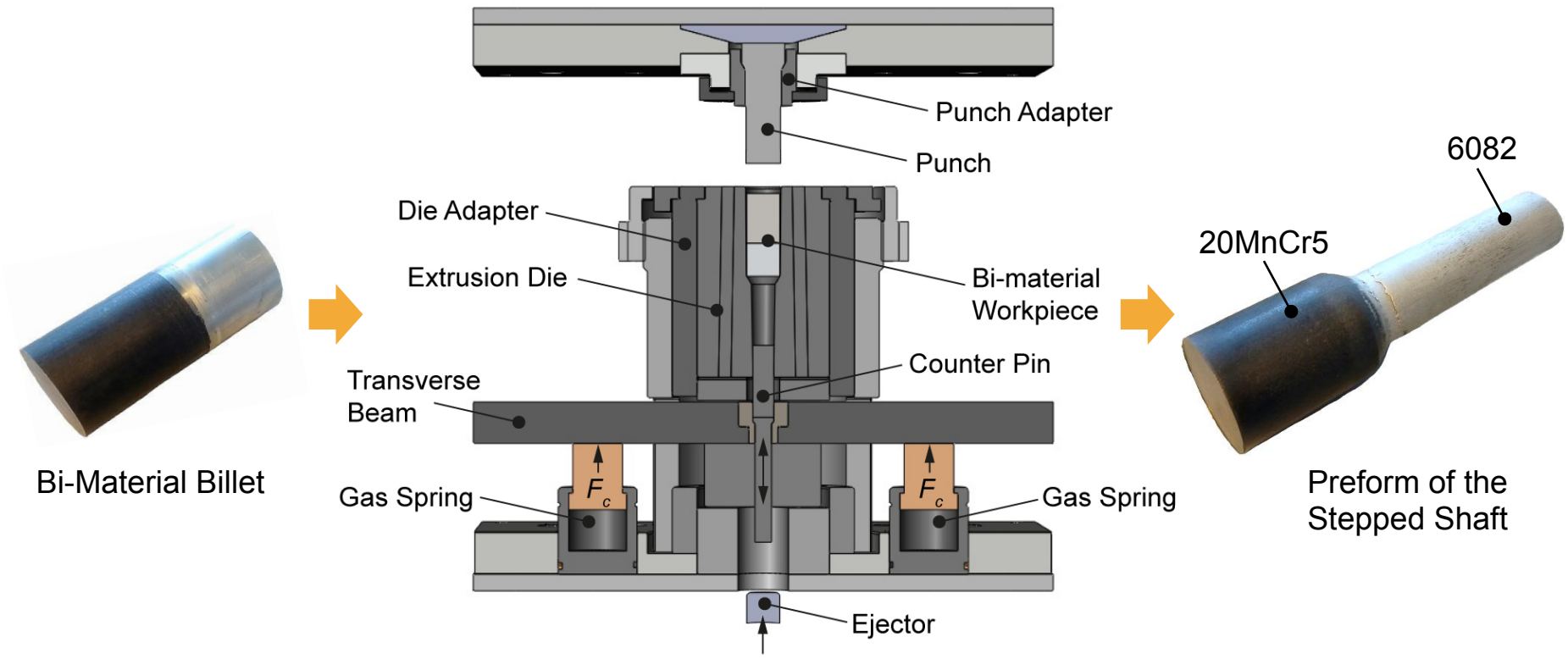
www.sfb1153.uni-hannover.de

Geometry Description



Material and Method (2)

Tooling for the Impact Extrusion



- Combination of a wrought aluminum alloy (6082) and a case hardening steel (20MnCr5)
- Counter force application by two gas springs to control stress-state by the joining zone
- Inhomogeneous temperature distribution in the bi-material billet by induction heating

Material and Method (3)

Thermal Processing Prior to Forming

Motivation

Quality of the joining decisive in the final product quality

Faulty microstructure at the joining zone as a result of the preceding welding process

Treatment of joining zone properties possible by deformation processing at elevated temperatures

Challenges

Vast difference of flow behaviors of aluminum and steel at a given temperature

Homogeneous temperature distribution leads to insufficient plastic straining at the joining zone

Aluminum melts away ca. above 550 °C

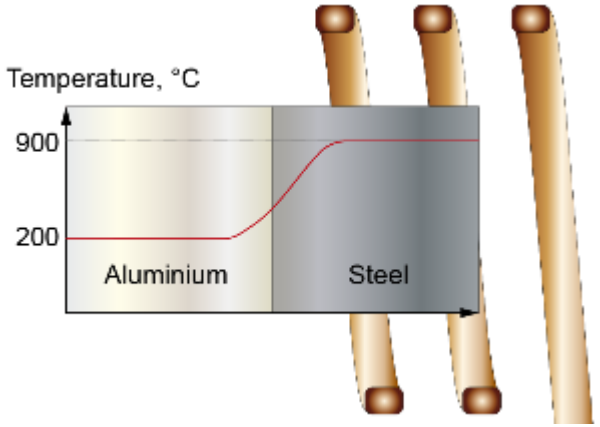
Solution approach

Tailored temperature distribution using induction heating

Analysis of materials‘ responses to deformation

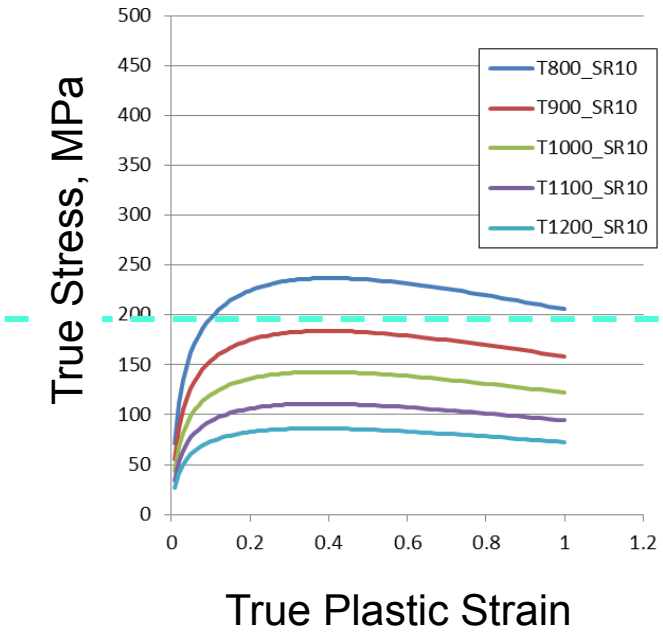
Choosing individual target forming temperatures

A sharp gradient necessary by the joining zone

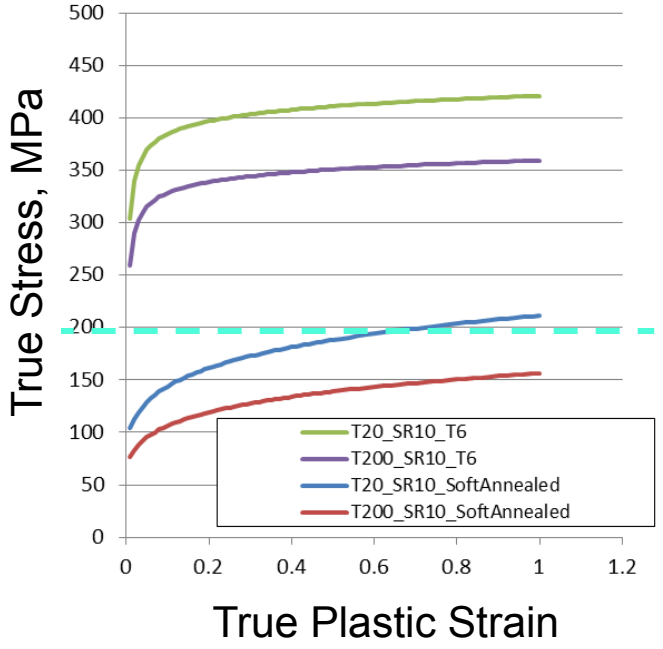


Flow Curves for Aluminum and Steel

20MnCr5 Steel



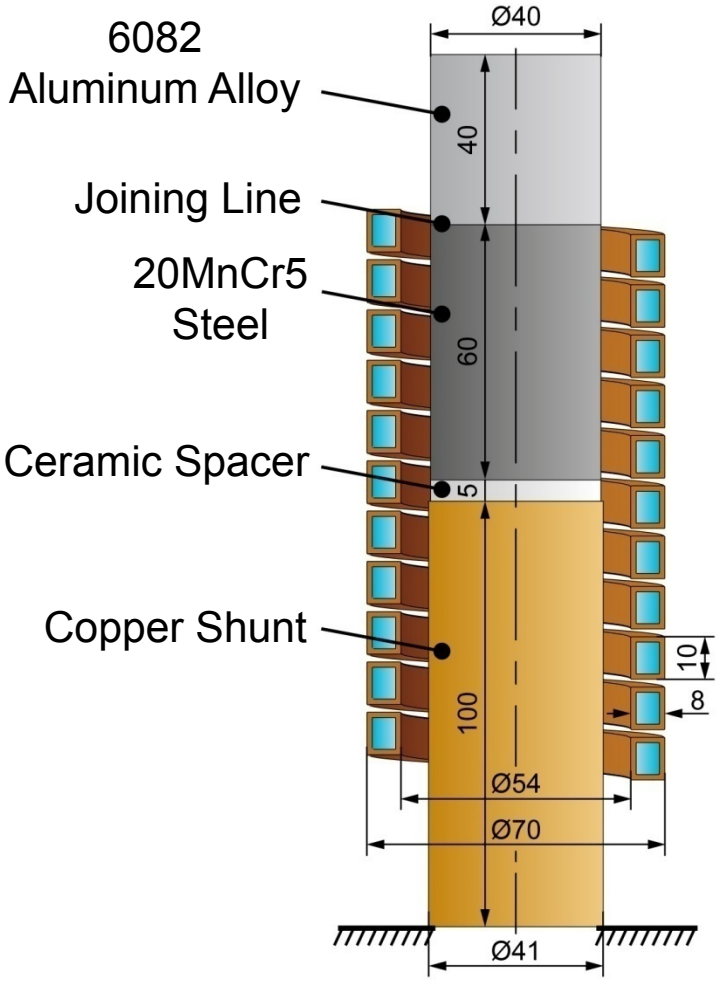
6082 Aluminum

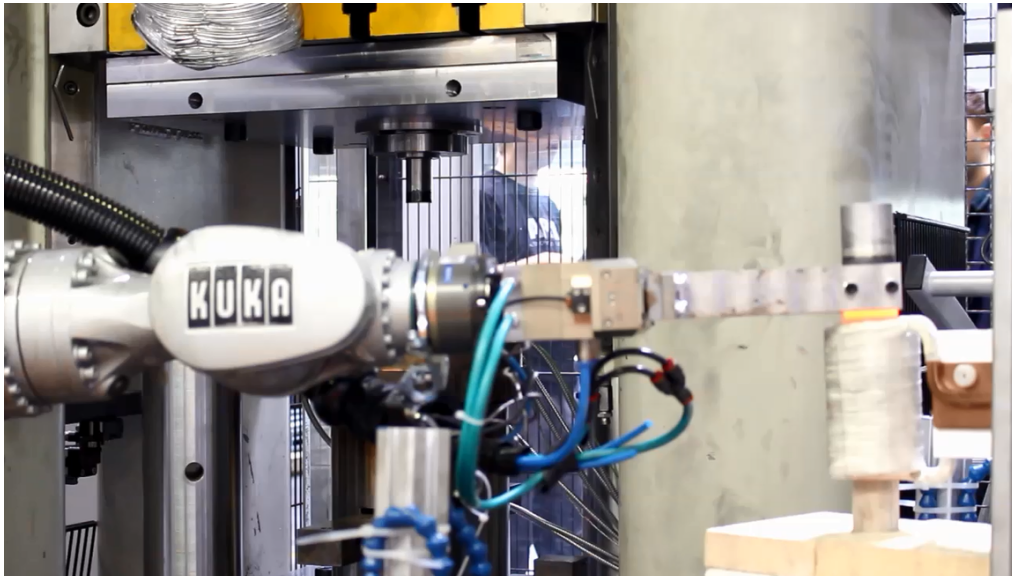


- 800-900 °C in steel matches to 20 C in aluminum
- Target is a step function of temperature

Material and Method (5)

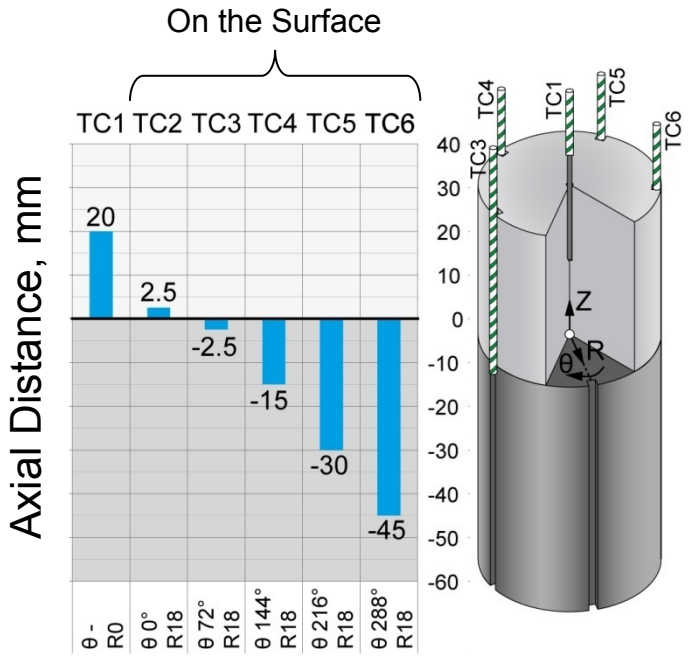
Thermal Process Design

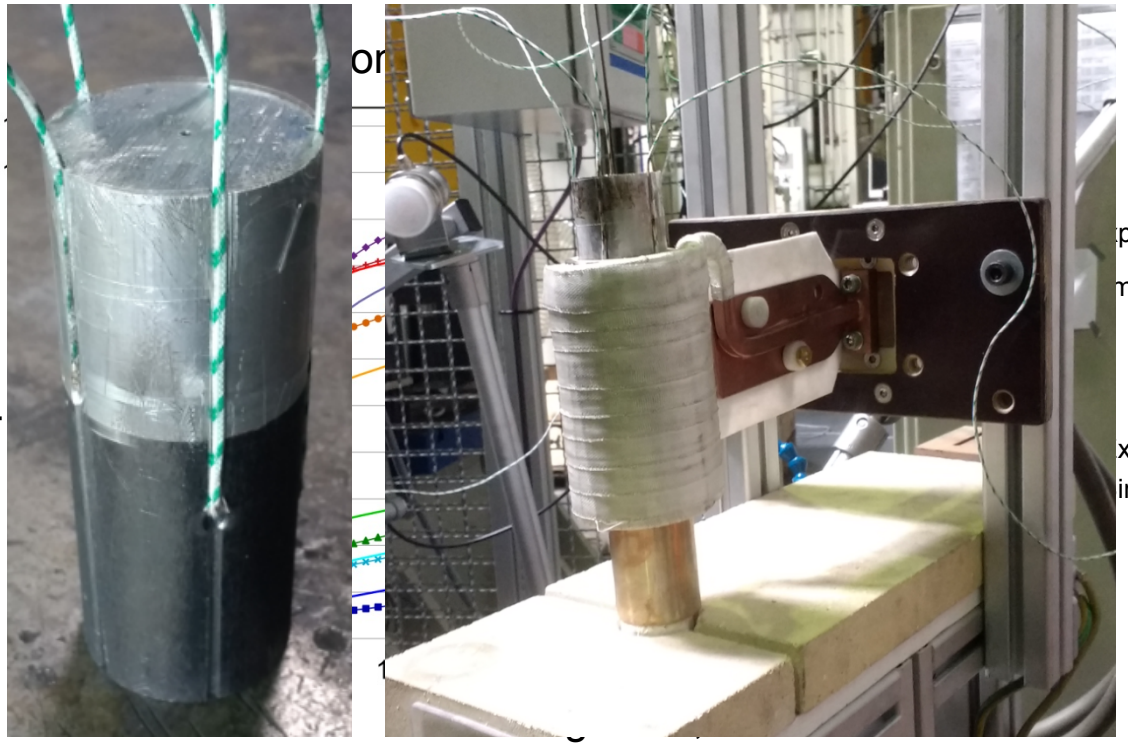




Due to project budget, it was necessary to utilize an induction coil that was designed for another process, hence the copper shunt was introduced to control the electromagnetic end effect.

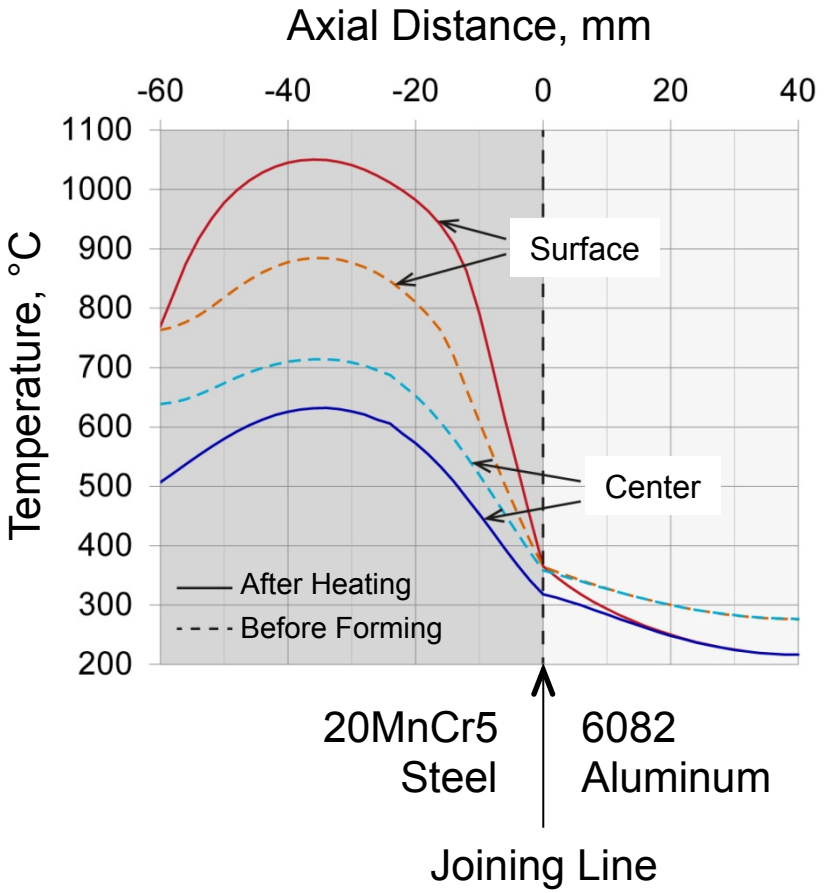
Comparison Between Models and Experiments

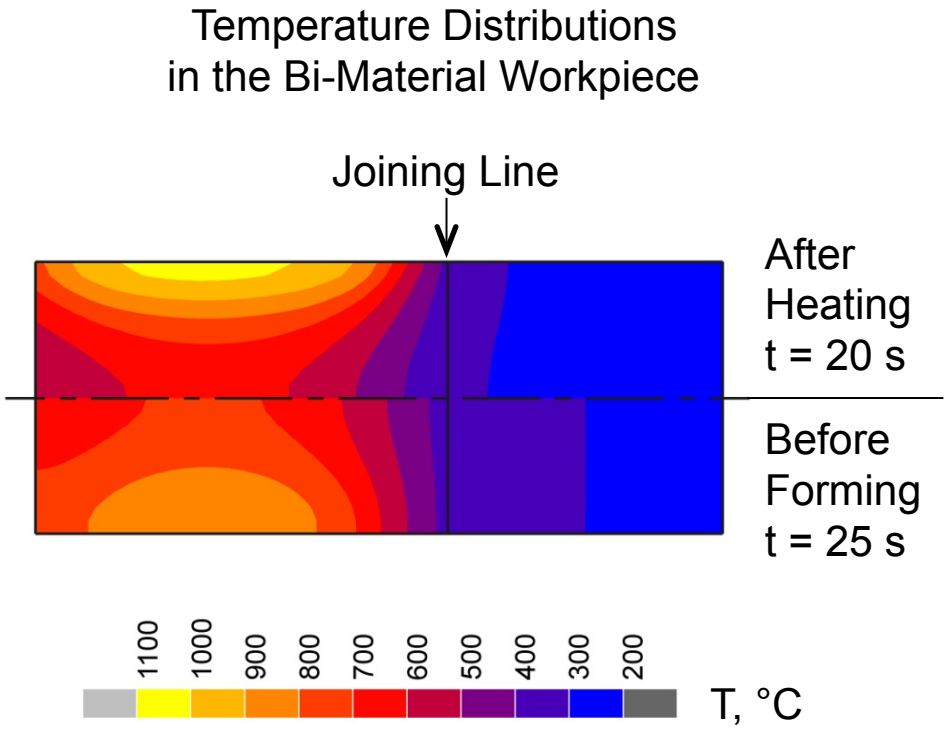




- Relatively good agreement for the results
- Further refinement could be made with better material property description

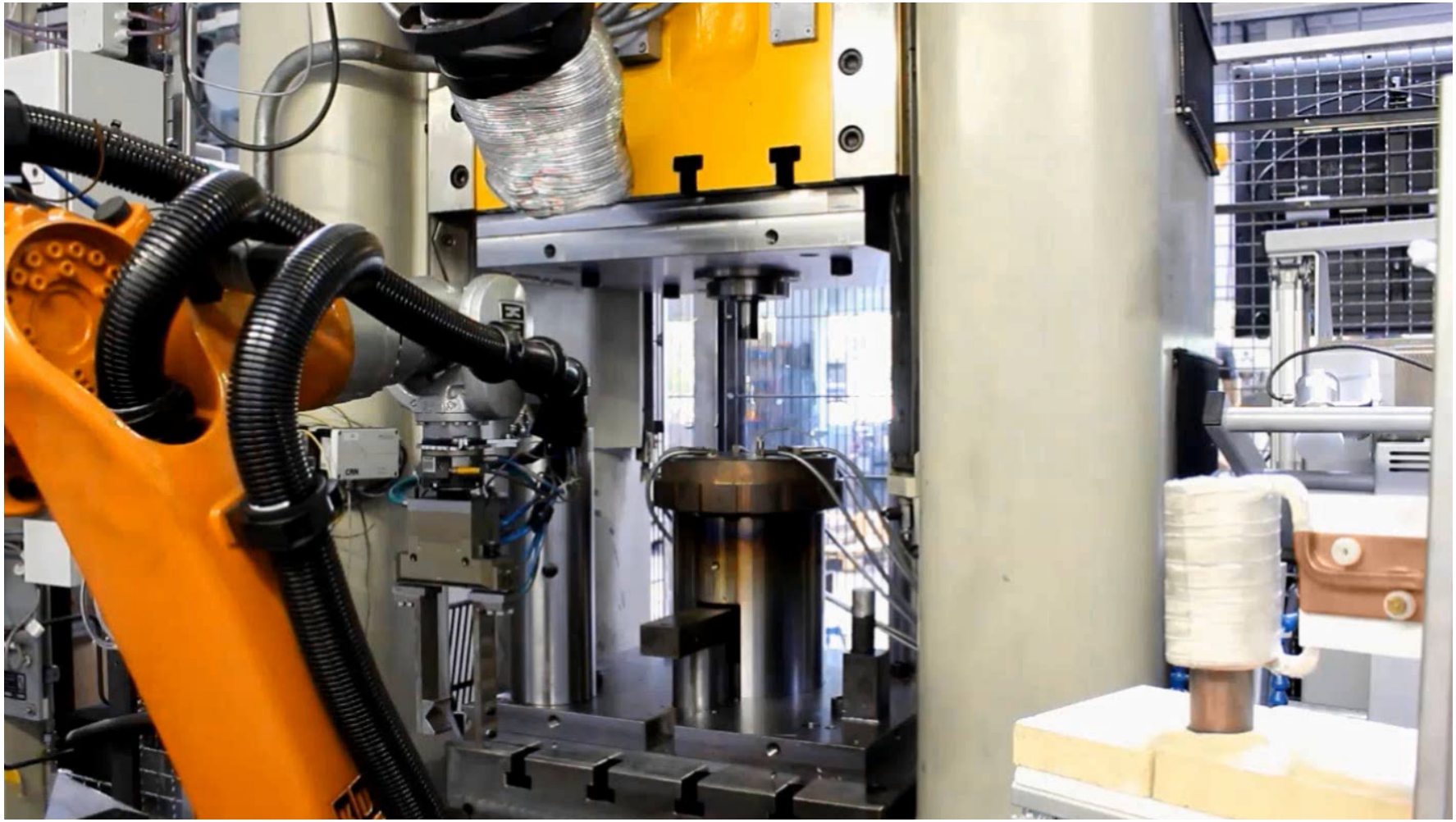
Induction Heating Simulation



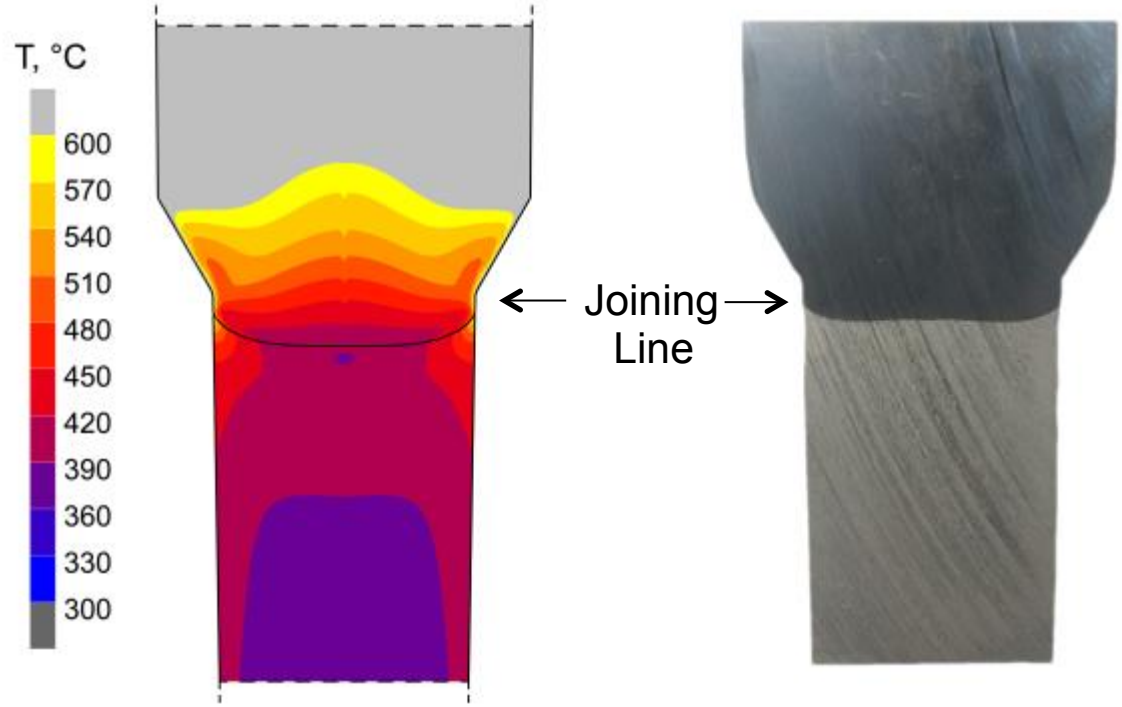


Results (3)

Process Video

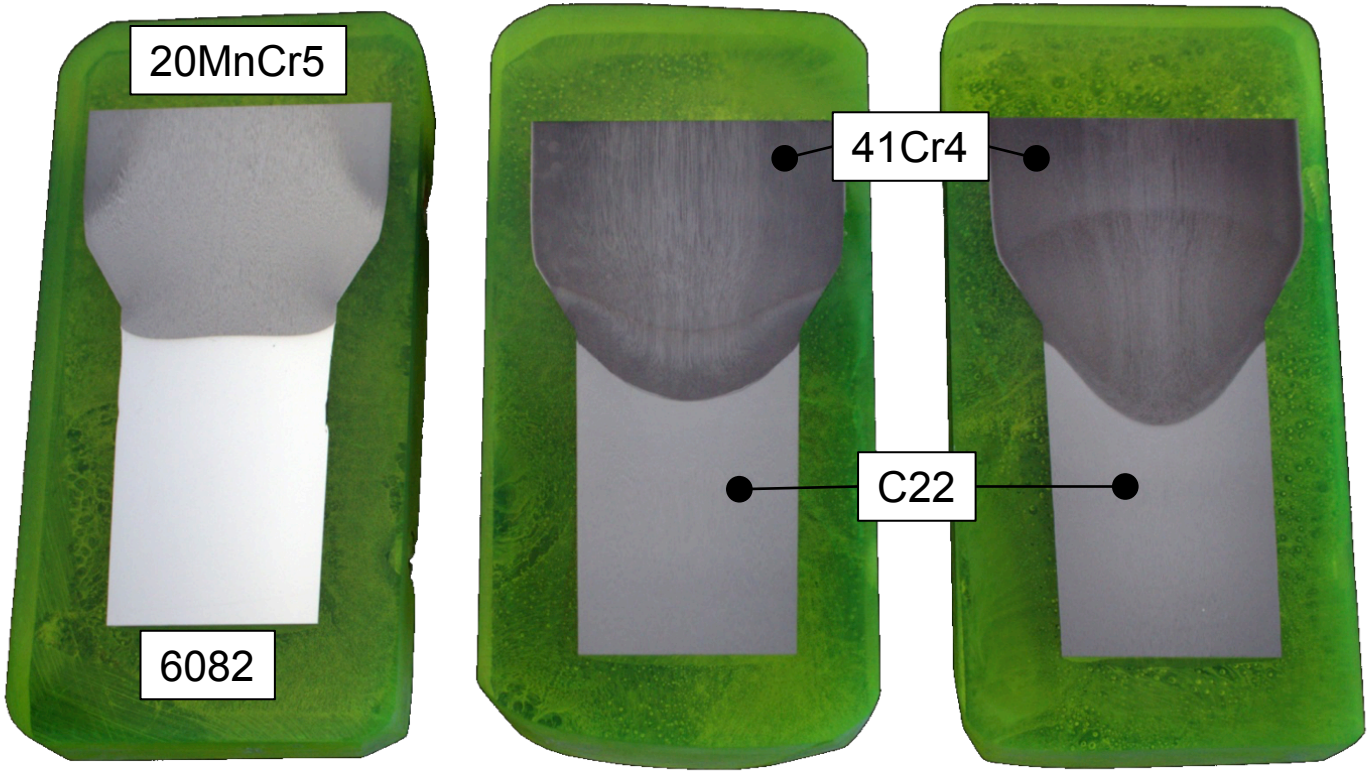


Extrusion Simulations and Experiments



- Successful Prediction of Joining Line Geometry
- Transfer of Temperature History to Forming Simulation (Flux 2D → Marc Mentat)

Development of the Joining Lines



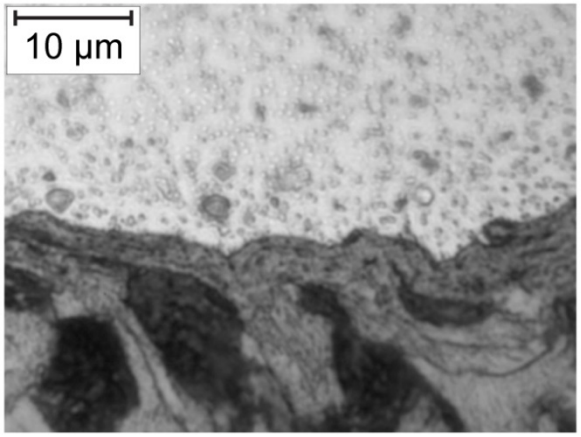
Steel-Aluminum with the applied heating strategy

Steel-Steel formed at 700 °C

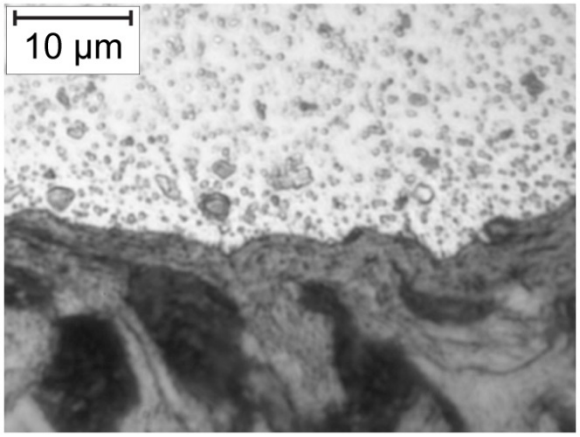
Steel-Steel formed at 900 °C

Results (6)

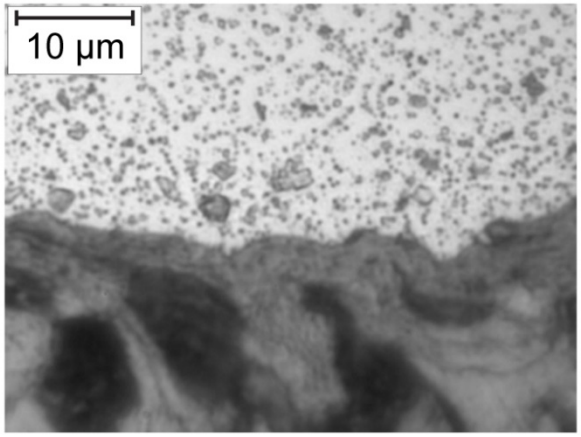
Metallography



Steel in focus



Joining line in focus

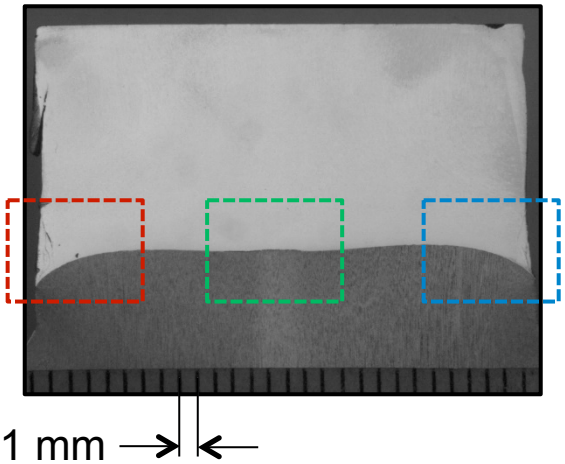


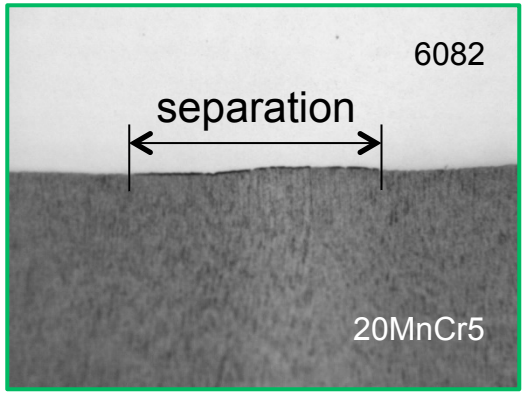
Aluminum in focus

- Focusing problem due to different responses to grinding/polishing
- 2% Nital for etching steel and 0.5% Hydrofluoric for aluminum
- No distinct intermetallic phase observed at the joining interface

Results (7)

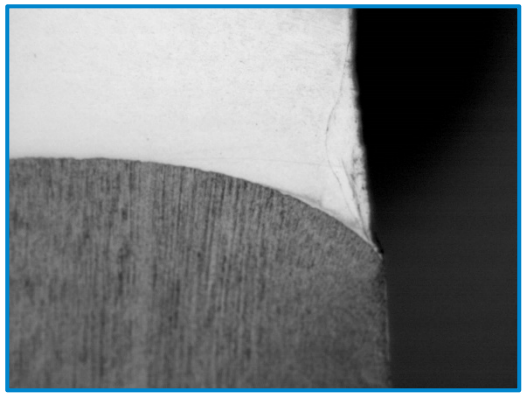
Metallography





center

left edge

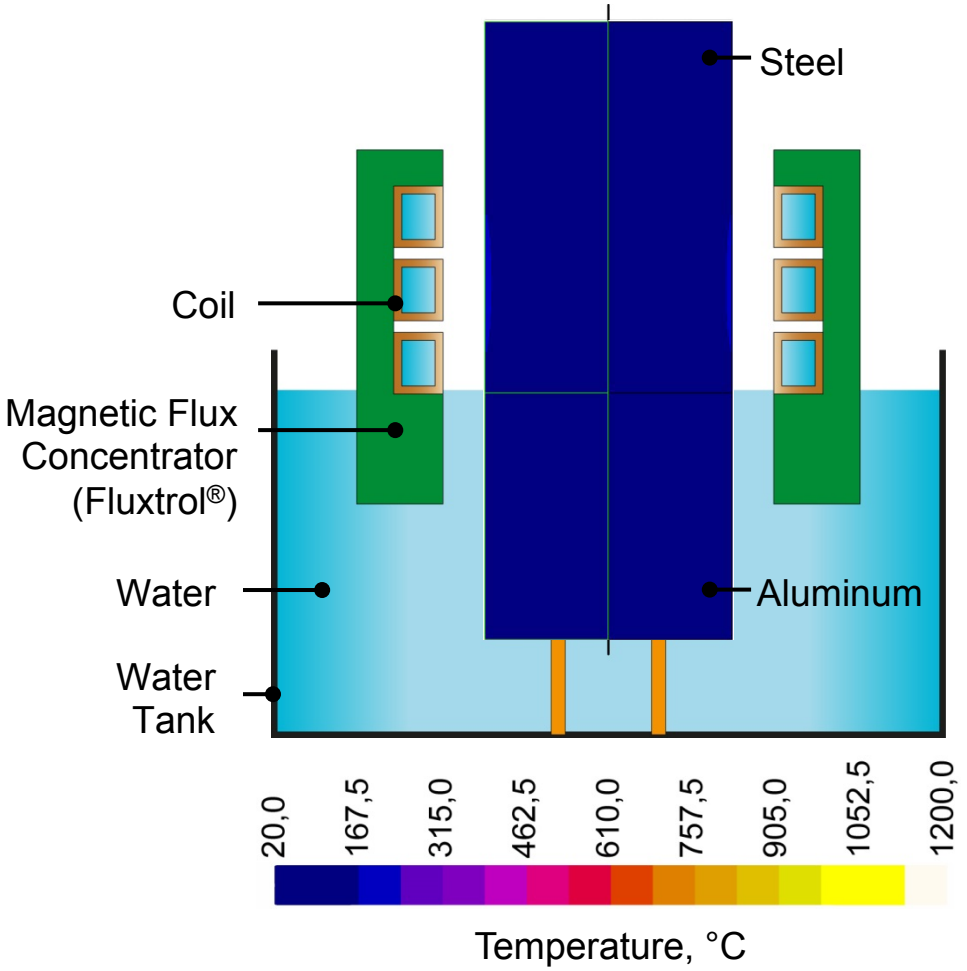


right edge

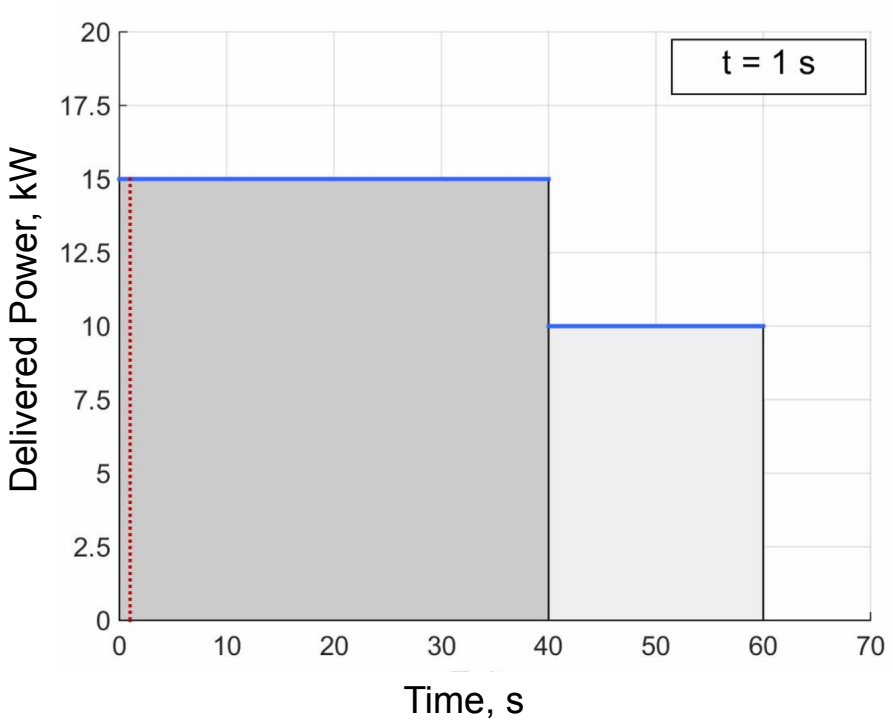
Outlook (1)

Semi-Submerged Induction Heating

Experimental Setup



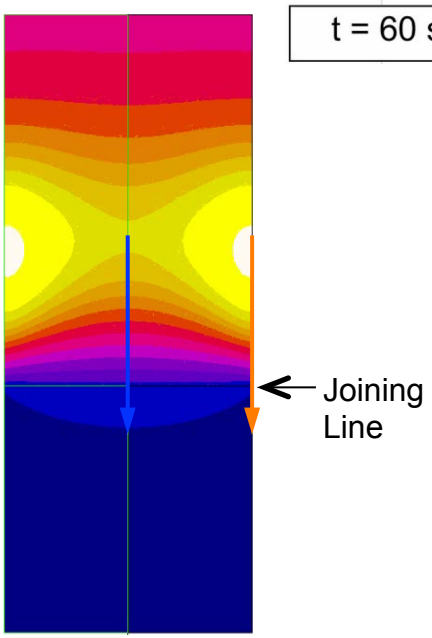
Delivered Power over Time

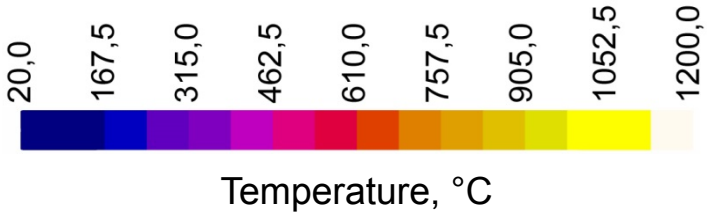


Semi-Submerged Induction Heating

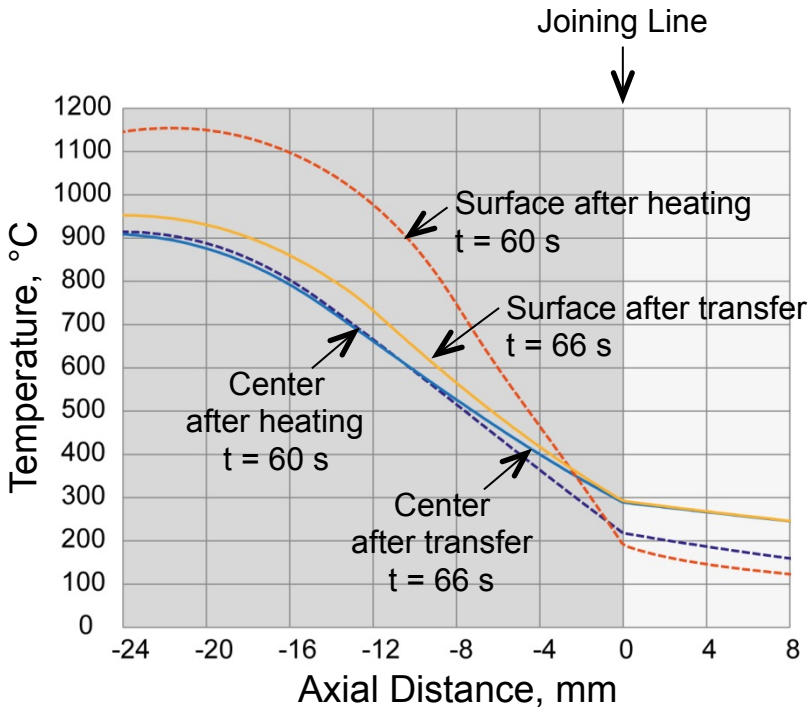
Transfer after Induction Heating

Transfer time
app. 6 s





Temperature Profiles



Thank you for your attention!

Contact us!

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