Role of Thermal Processing in Tailored Forming Technology for Manufacturing Multi-Material Components

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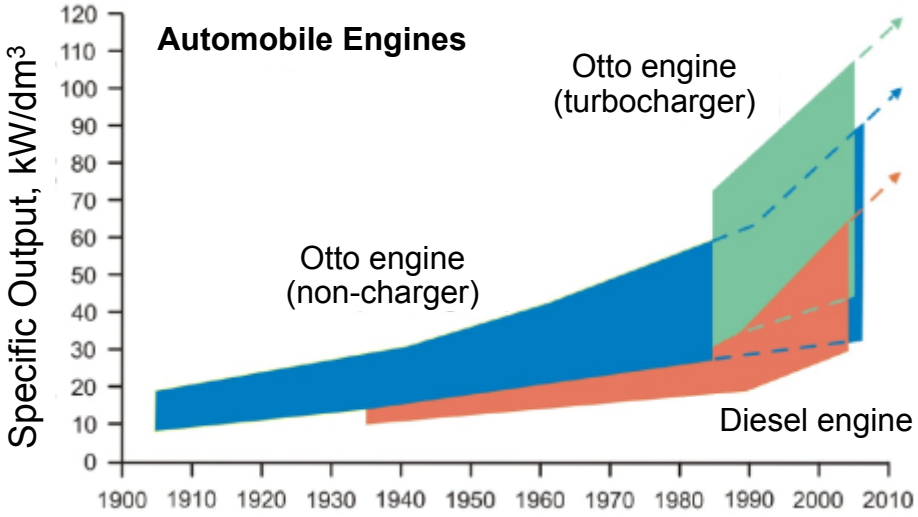
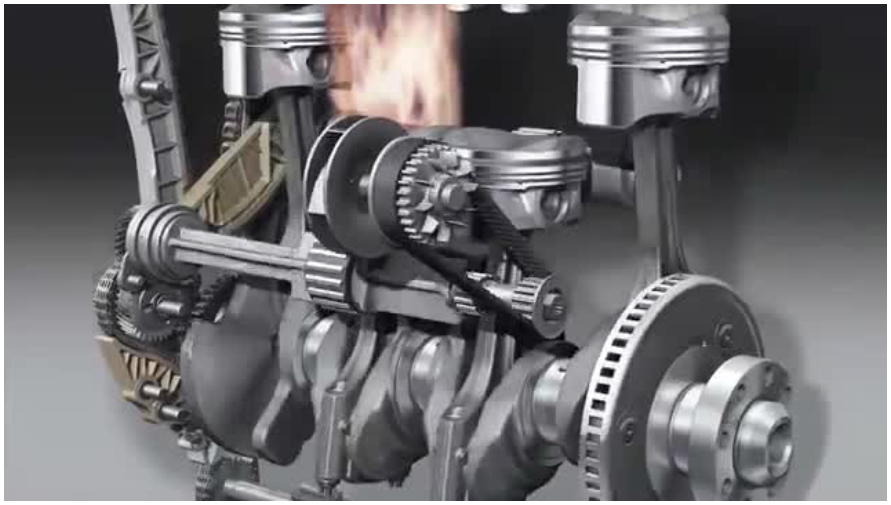


Source: Golloch, 2005
Downsizing bei Verbrennungsmotorren



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

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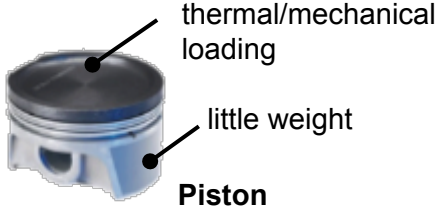
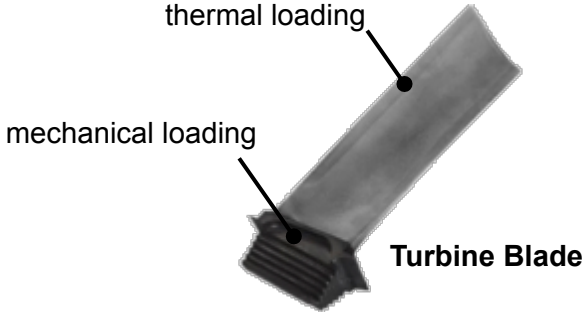
Appropriate Material at the Appropriate Location

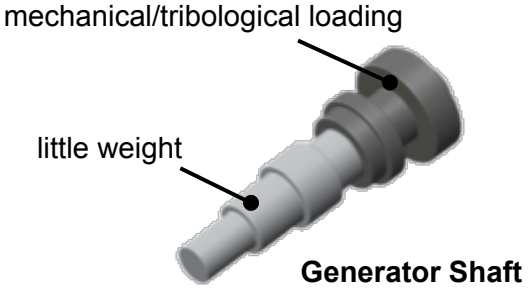
- Extended functionality of components
- Lightweight construction



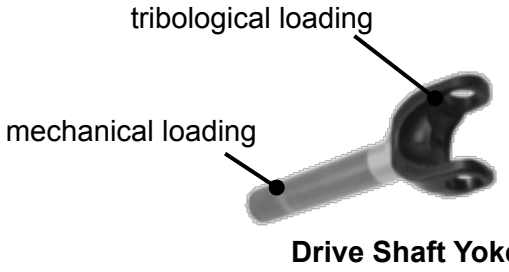
Automative Engineering



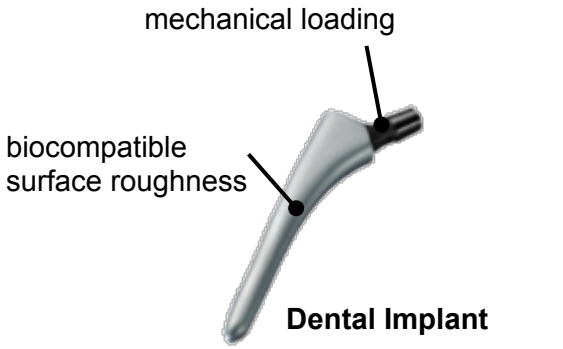
Aerospace Engineering



Energy Technology



Automative Engineering



Medical Engineering

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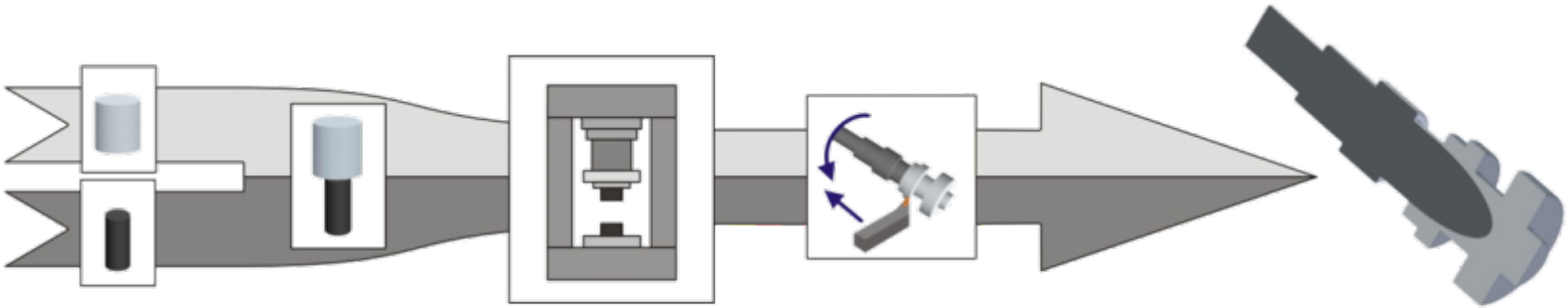
Collaborative Research Centre “SFB 1153”

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



Joining

- Laser welding
- Friction welding
- Profile extrusion

Forming

- Die forging
- Impact extrusion
- Cross wedge rolling

Finishing

- Machining
- Heat treatment
- Finishing

High-performance components with locally-adapted properties

- Service life evaluation
- Geometrical inspection
- Damage prediction
- Multiscale modelling

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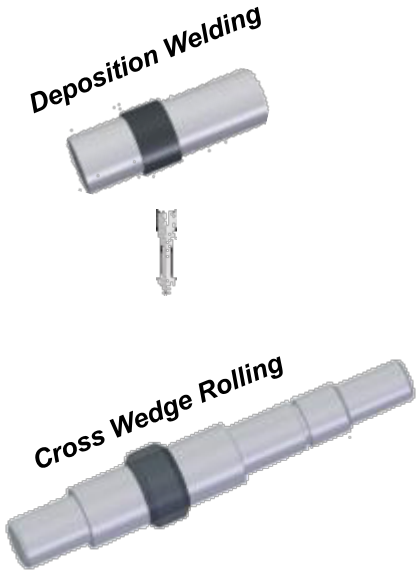
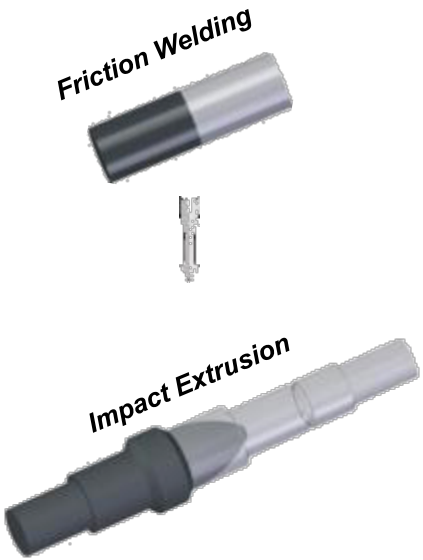
Bi-Material Automotive Parts of SFB 1153

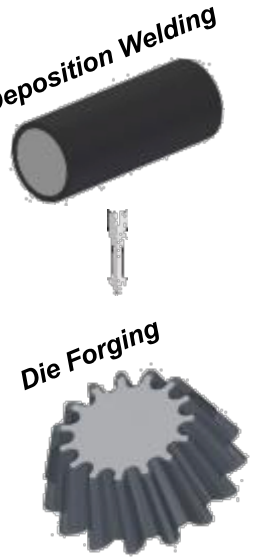


Stepped Shaft 1
Coaxial Arrangement of Materials



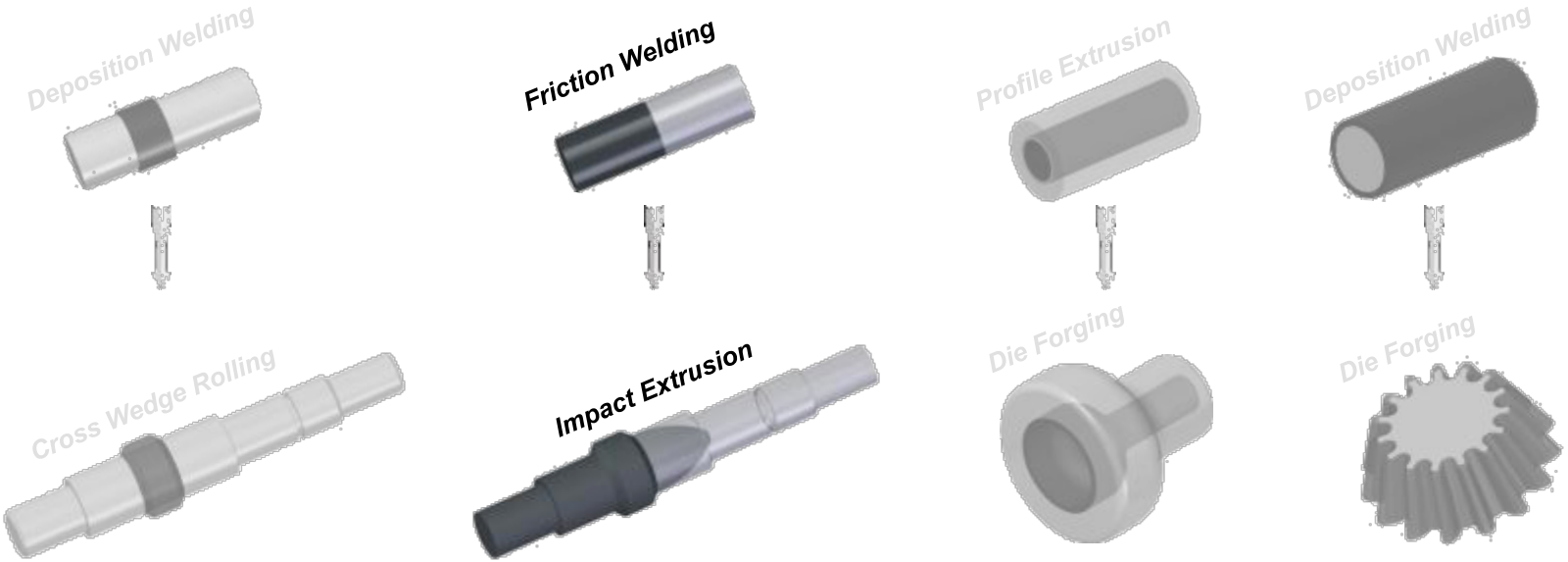
Stepped Shaft
Sequential Arrangement of Materials

Bearing Bushing



Bevel Gear

Bi-Material Automotive Parts of SFB 1153



Stepped Shaft 1
Coaxial Arrangement
of Materials

Stepped Shaft
Sequential Arrangement
of Materials

Bearing Bushing

Bevel Gear

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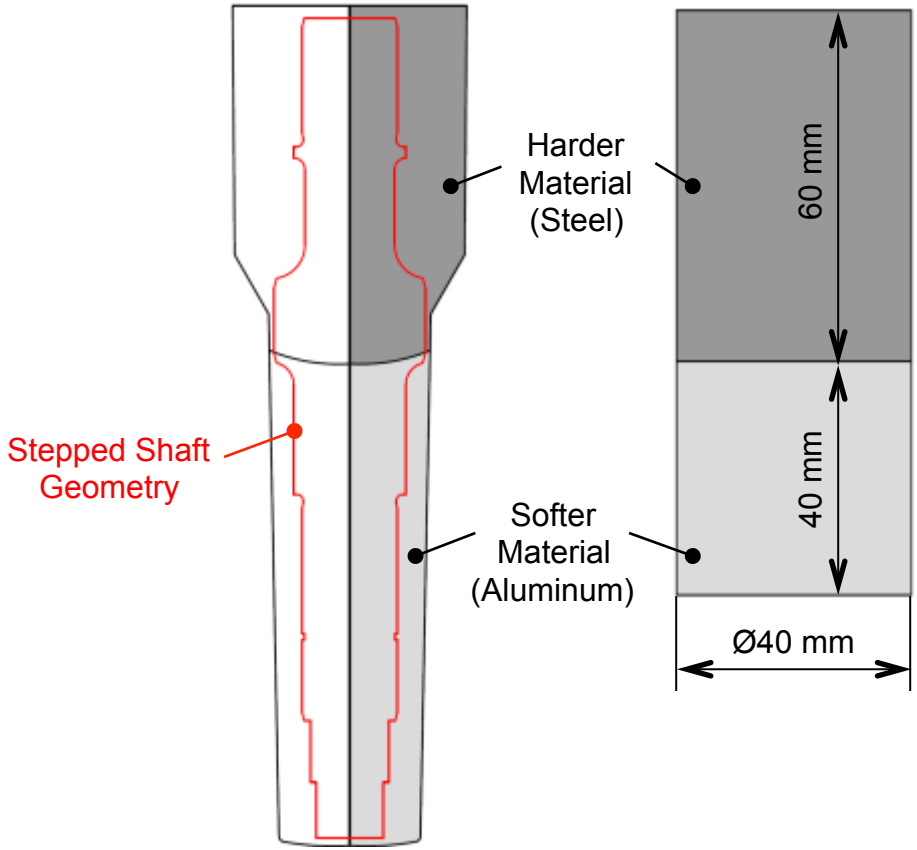
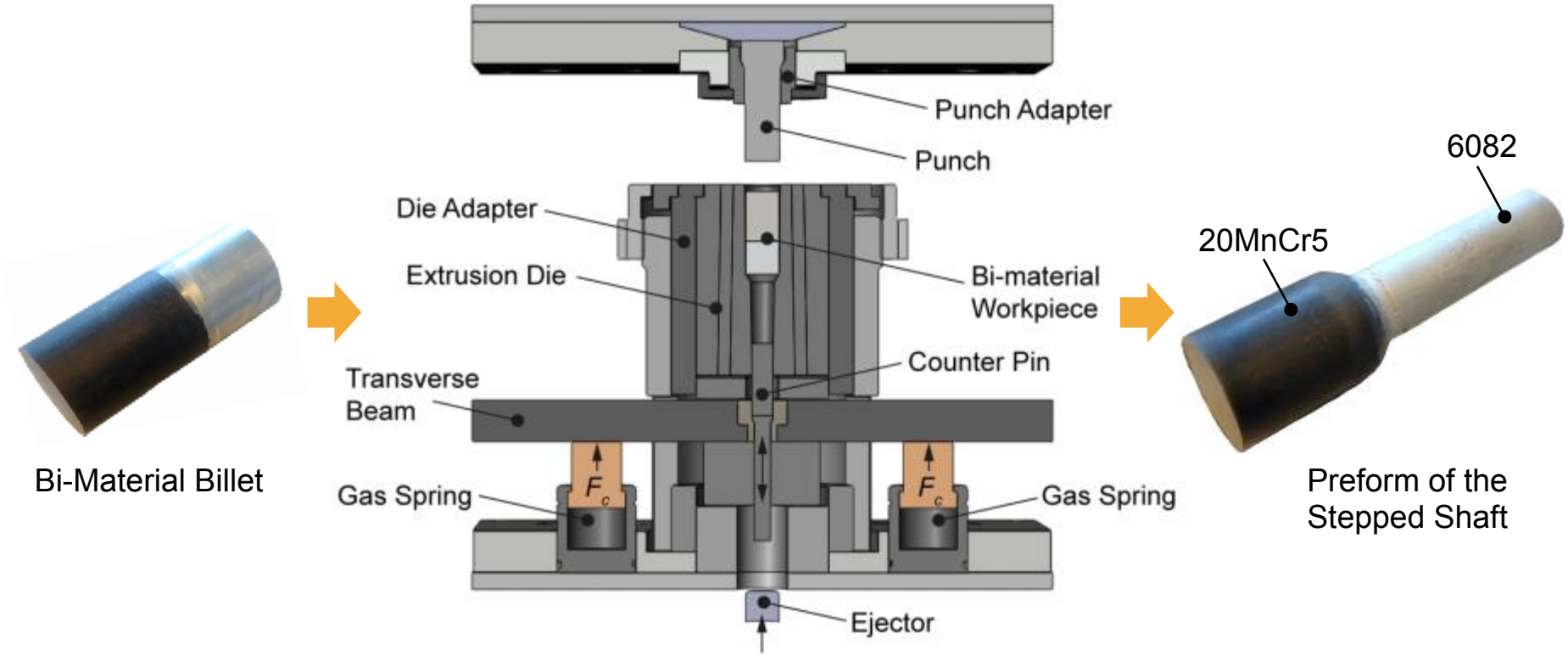
Geometry Description



Tooling for the Impact Extrusion



- Combination of a wrought aluminum alloy (6082) and a case hardening steel (20MnCr5) by friction welding
- 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

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

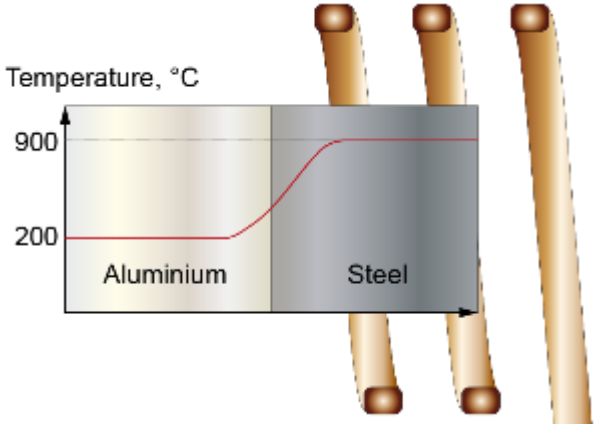
Solution approach

Tailored temperature distribution using induction heating

Analysis of materials‘ responses to deformation

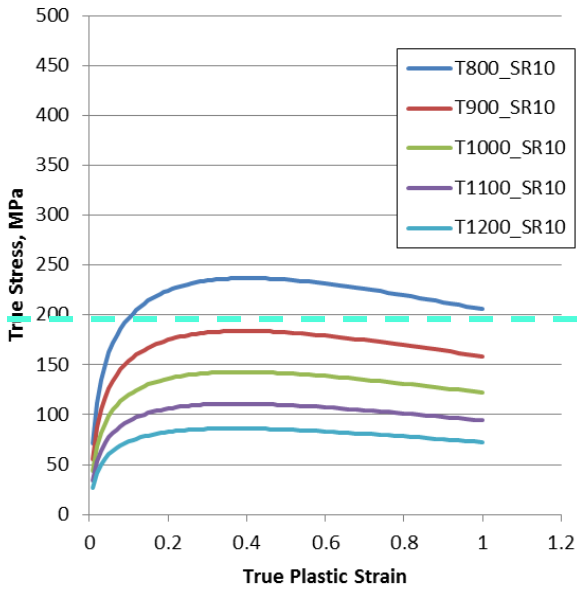
Choosing individual target forming temperatures

A sharp gradient necessary by the joining zone

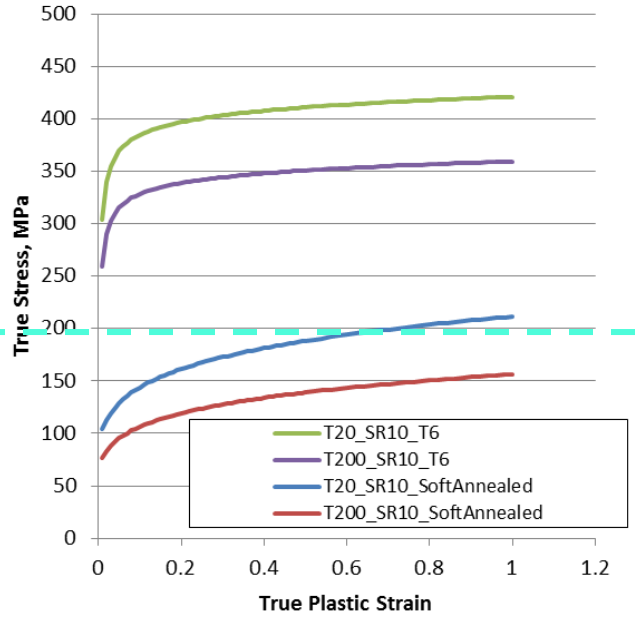


Flow Curves for Aluminum and Steel Used for initial Trials

20MnCr5 Steel



6082 Aluminum



800-900 C in steel matches to 20 C in aluminum, so target is a step function of temperature

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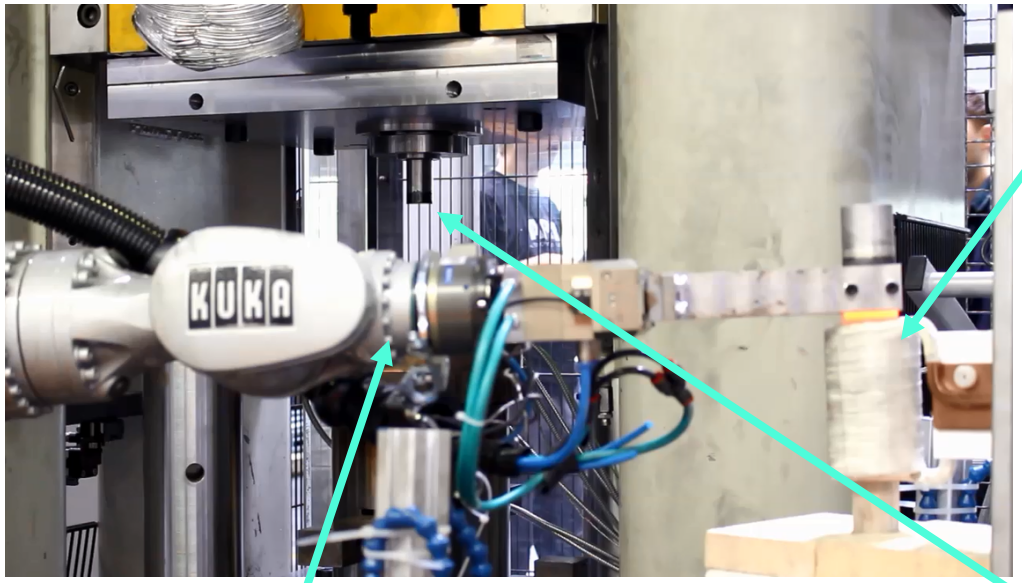
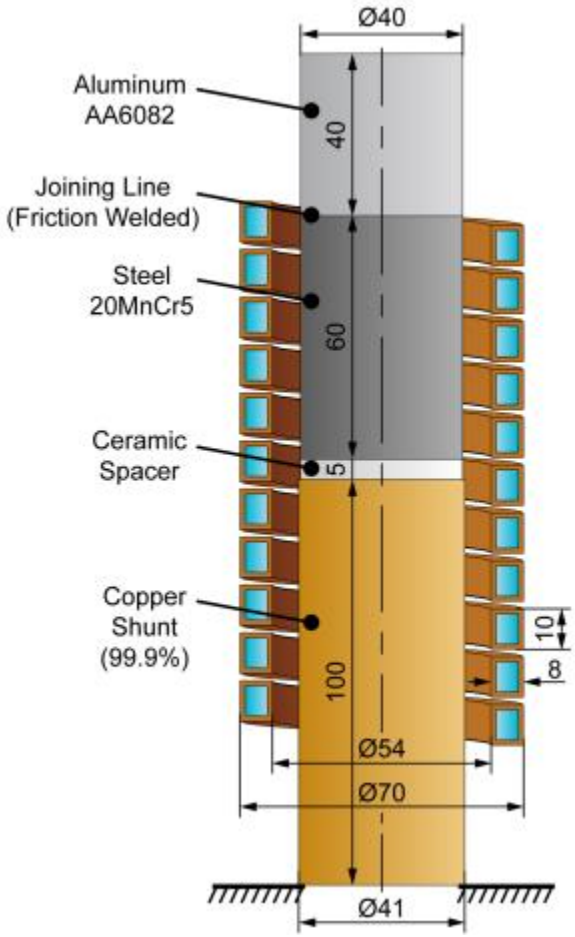
Testing Description

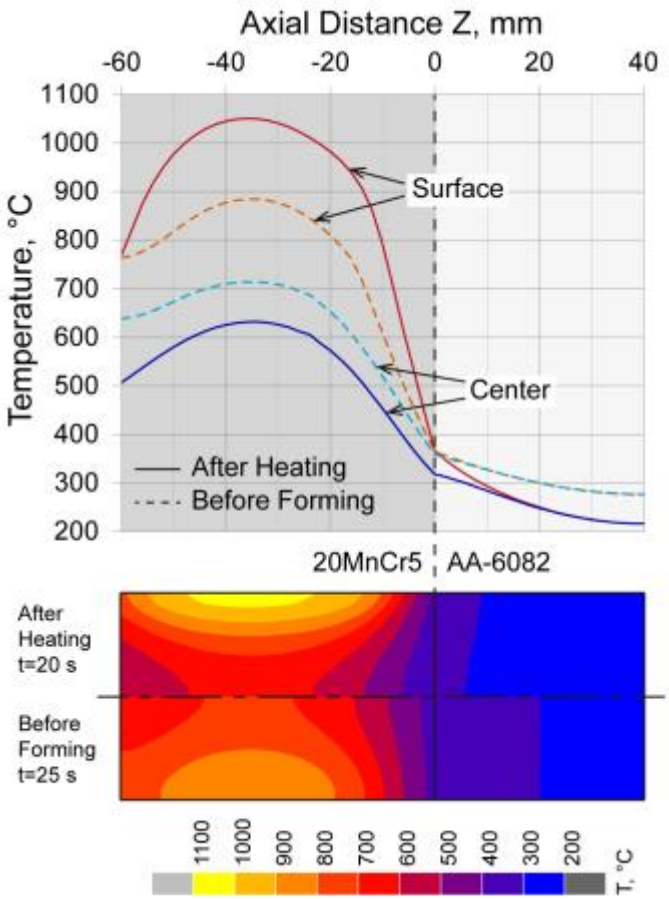


Robot

- Heating in Induction Coil
- Lift Billet out of Coil
- Robot moves billet from coil to press
  - Estimated time from end of heating to forming 5-10 s
- Press forms billet
- Manual removal from press

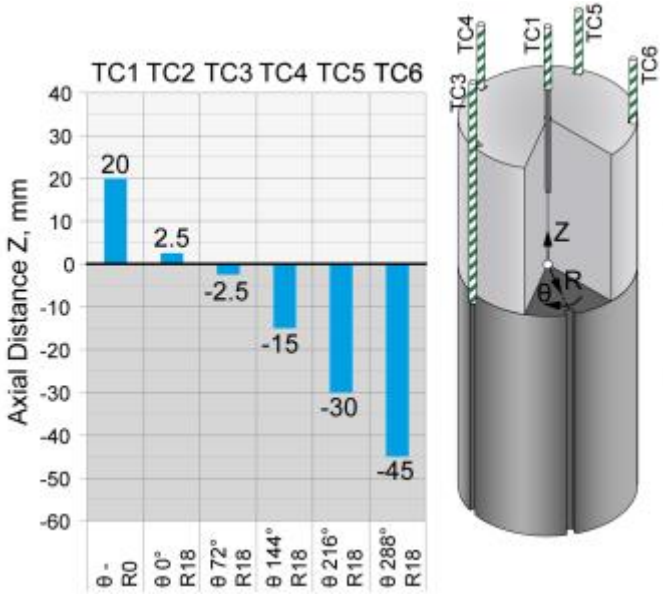
Thermal Process Design

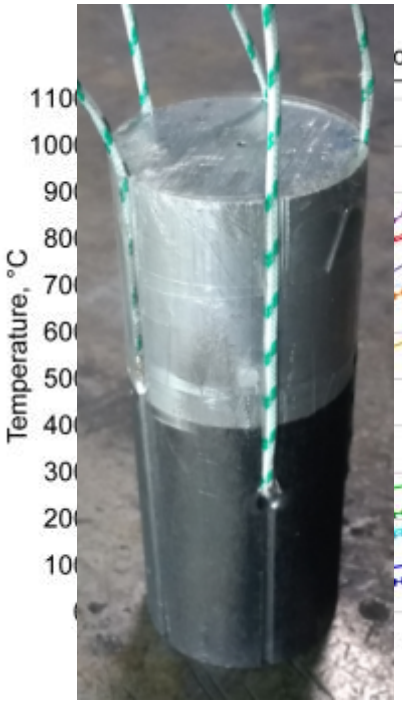




Due to project budget, it was necessary to utilize an induction coil that was designed for another process, hence the copper shunt was introduced to control the electromagnetic end effect

Comparison Between Models and Experiments



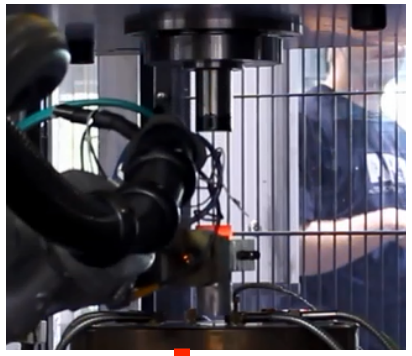


Relatively good agreement for the results. Further refinement could be made with better material property description

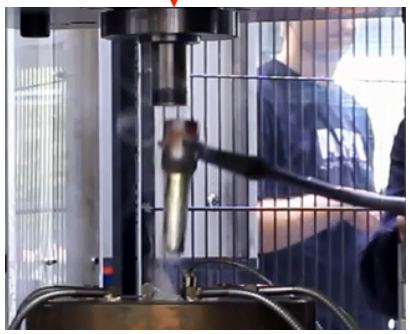
Process Images

End of Heating

Handling

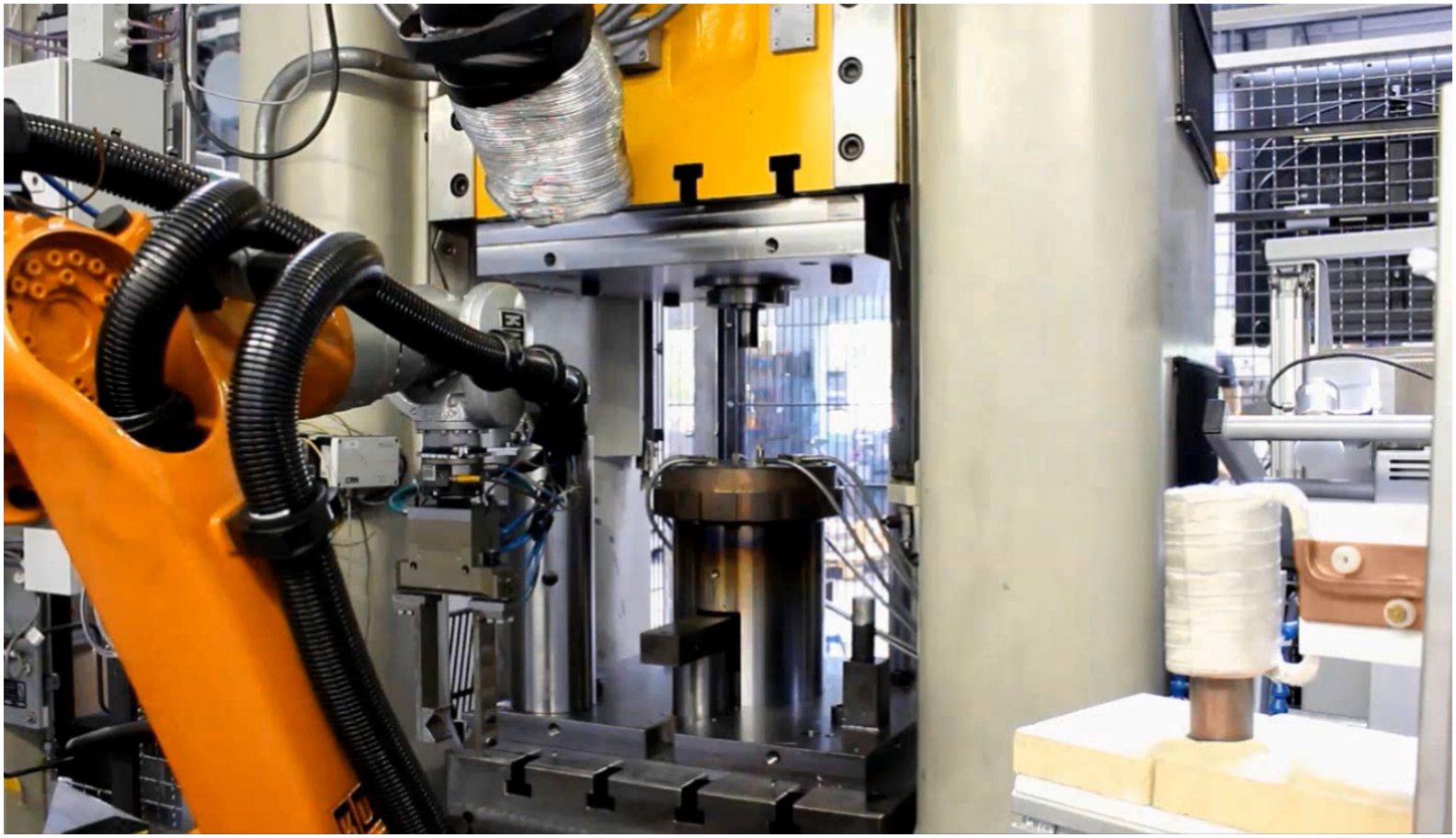


In Die



Removal

Process Video



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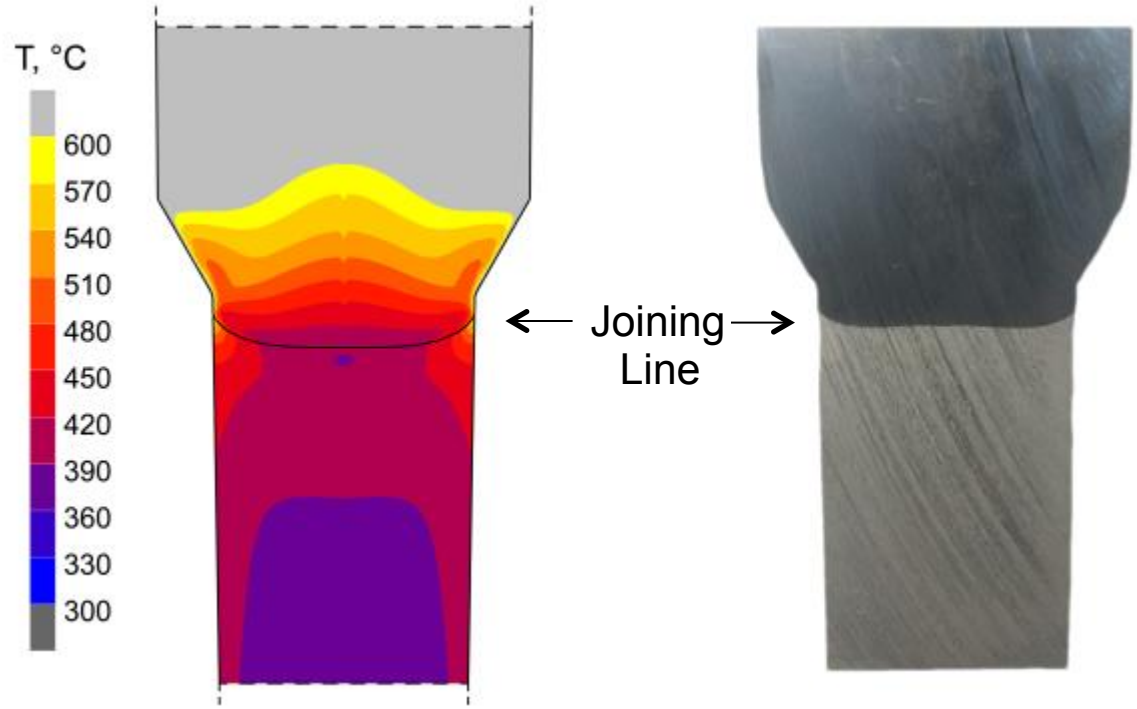
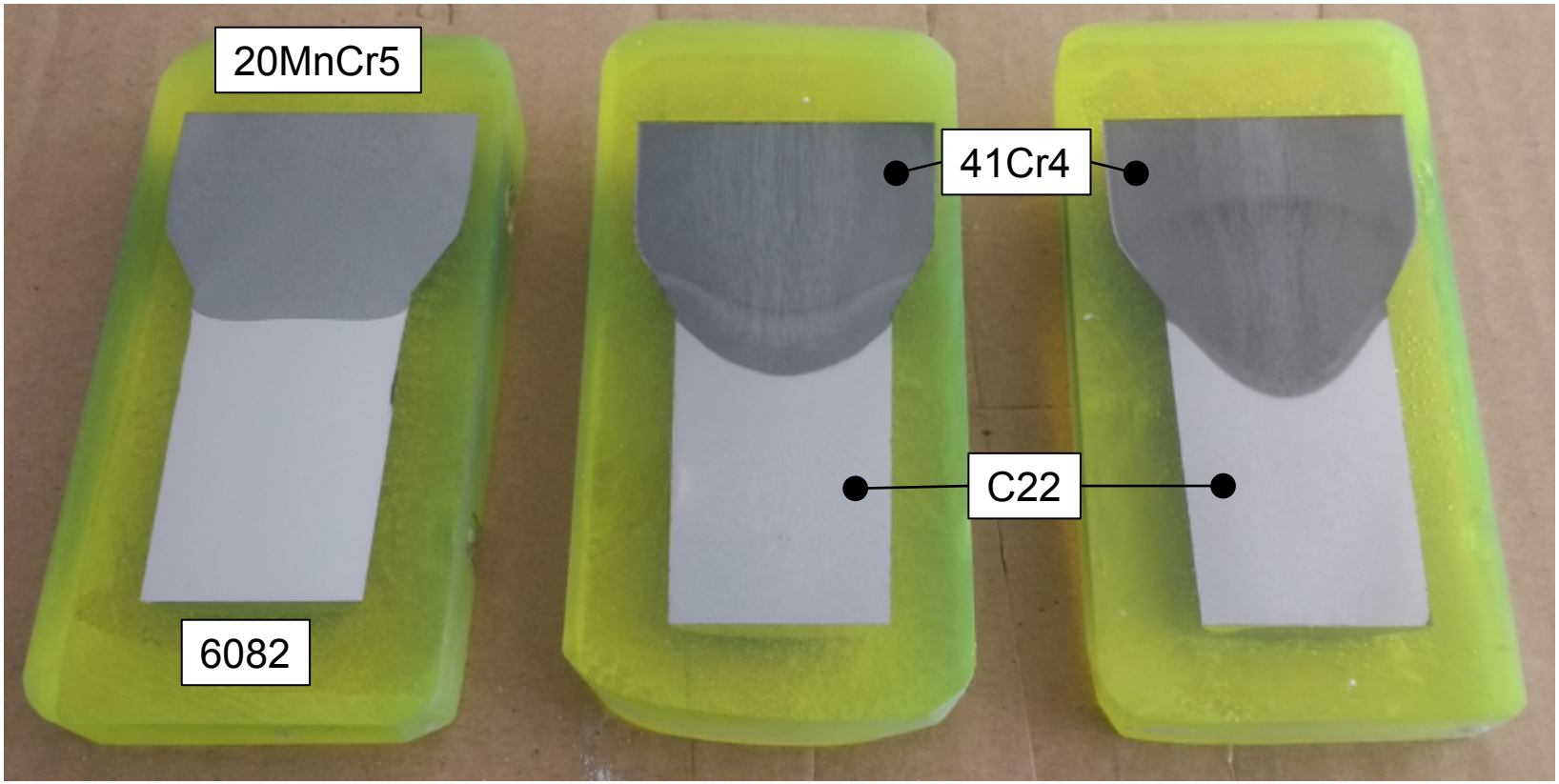
Extrusion Simulations and Experiments



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

Joining Lines



Steel-Aluminum
Applied Heating Strategy

Steel-Steel
formed at 700 C

Steel-Steel
formed at 900 C

Summary

- Successful heating and tailored forming of an aluminum-steel billet was performed.
- Additional modeling needs to be performed to optimize the induction coil in concert with the thermomechanical process in order to optimize the strength of the bond/component that is formed.
- Alternative materials should be explored that are more favorable for post forming thermal processing.

Acknowledgements

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