Institut für Verbundwerkstoffe

Prozesskette zur Herstellung textilverstärkter Thermoplaste

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Technologietag 2011, 4a engineering GmbH
Leichtbau auf dem Prüfstand, 3. – 4. März 2011

The Institute on the Campus of the University of Kaiserslautern

Institut für Verbundwerkstoffe

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

12 100 Students

- Architecture / Regional and Environmental Planning / Civil Engineering
- Biology
- Chemistry
- Computer Science
- Electrical and Computer Engineering
- Mechanical and Process Engineering
- Mathematics
- Physics
- Social and Economic Studies

Mission:
Research and Knowledge Transfer

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- IVW develops technical applications of composites and provides material, process, and product development up to the support of pilot series

- IVW transfers its findings and expertise into industry and scientific public, and, in particular, into the education of engineers at the University of Kaiserslautern.

IVW 2010 at a Glance

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Employees		100
Budget	Mio. €	7.8
Third Party Funds	Mio. €	4.5
Projects		150
Bilateral Industrial Cooperations		85
Funded Third Party Projects		65
Publications		100
Doctoral Degrees (total s. 1990)		125
Lectures		13
Equipment	Mio. €	21
Laboratory and Office Space	m^2	7200

Fields of Research

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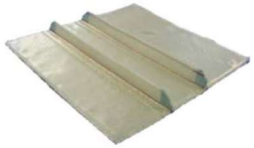


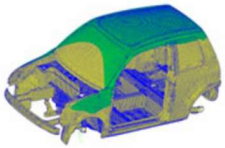
Processing of Textile Reinforced Thermoset FRPC

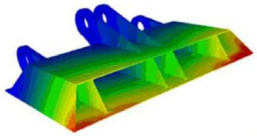
Processing of Textile Reinforced Thermoplastic FRPC

Processing of Unidirectional FRPC

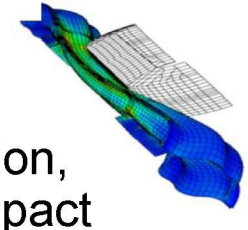
Compression Molding

Design of Composite Structures

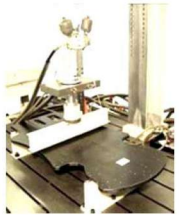




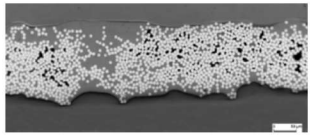
Process Simulation



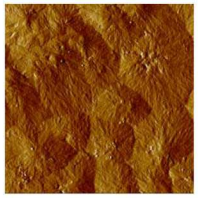
Modeling, Simulation, and Testing of Impact and Crash Behavior



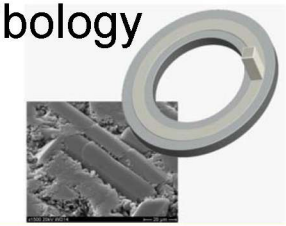
Fatigue and Fatigue Life Analysis



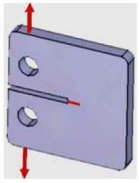
Process-Structure-Property Relations



Nanocomposites



Tribology



Material Characterization

From scientific basics to engineered components

Gliederung

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- Prozesskette zur Verarbeitung thermoplastischer Faser-Kunststoff-Verbunde
- Neue Prozessansätze
- Zusammenfassung

Examples of thermoplastic FRC components

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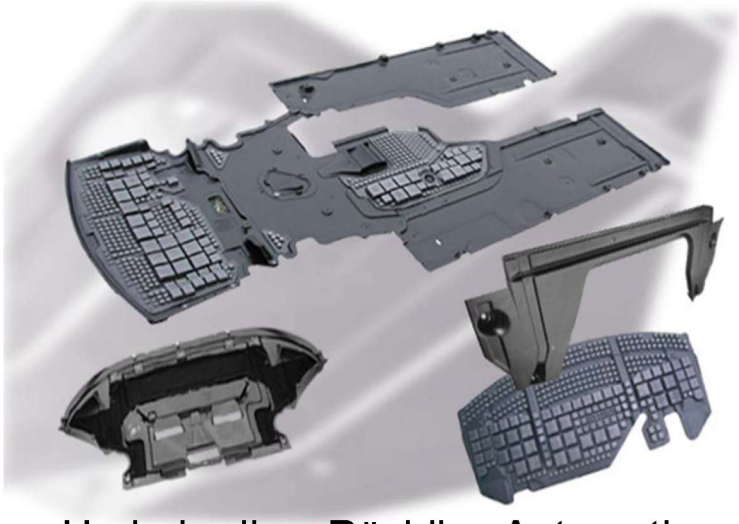
Bumper support, Jacob Composite GmbH

Rear seat back support, Jacob Composite GmbH

Crash tubes, IVW

Backseat backrest , Weber Fibertech



Underbodies, Röchling Automotive

Process chain for manufacturing of continuous fiber reinforced thermoplastics

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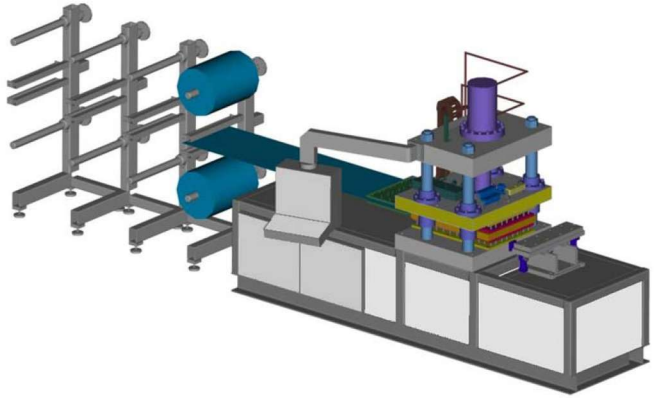
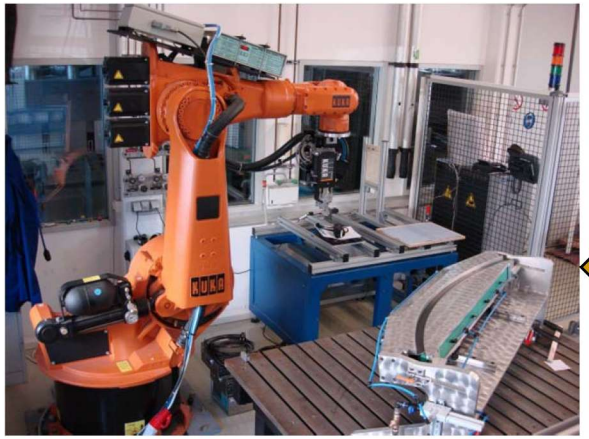


Semi-finished material manufacturing

Laminates

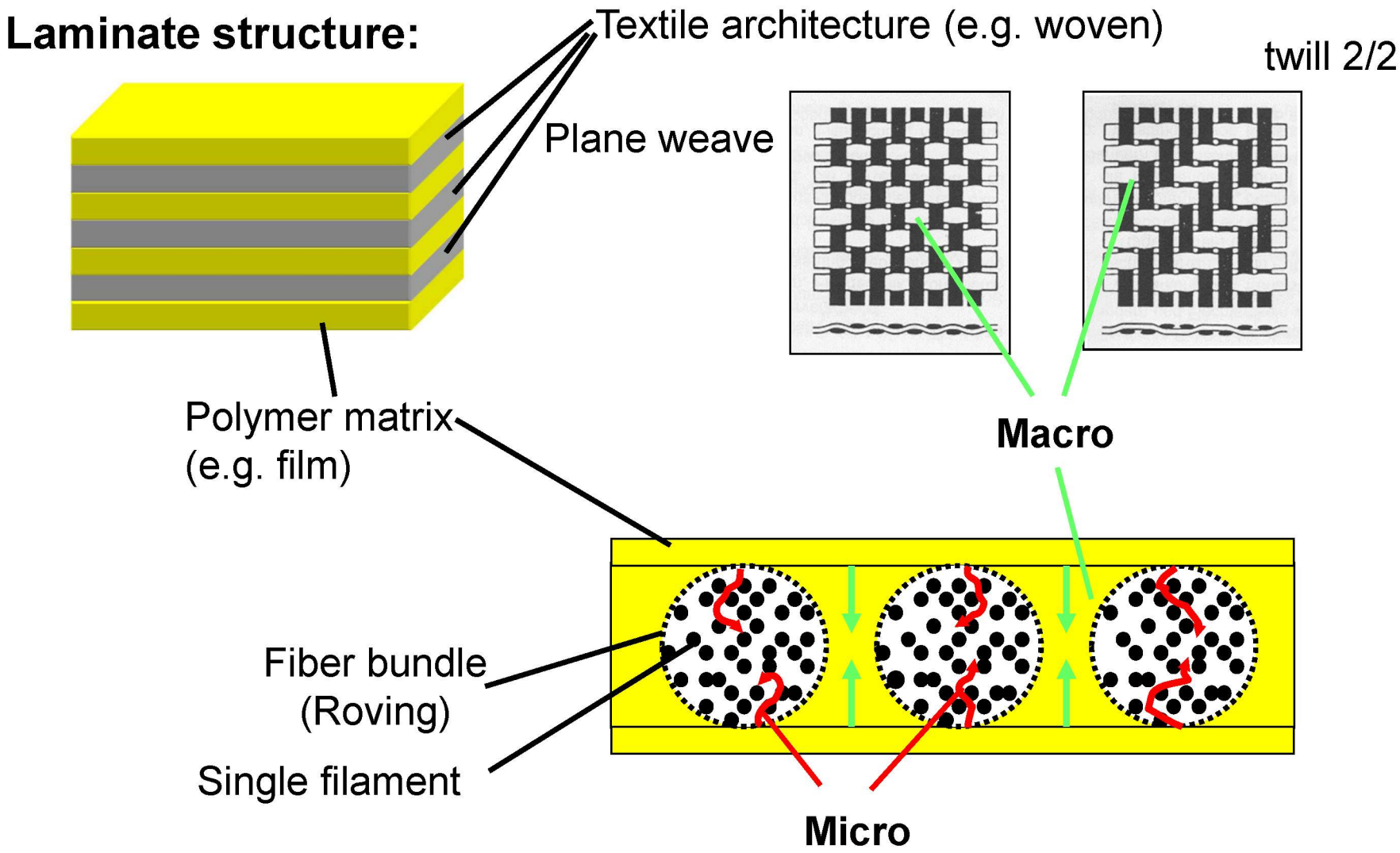
Thermoforming

Parts of components



Joining
(e.g. welding)

Macro and Micro flow



Macro and Micro Impregnation (CF-PEEK)

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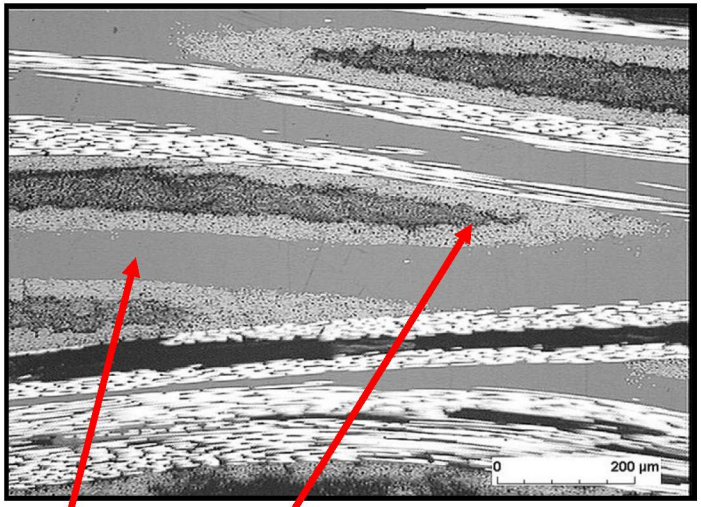

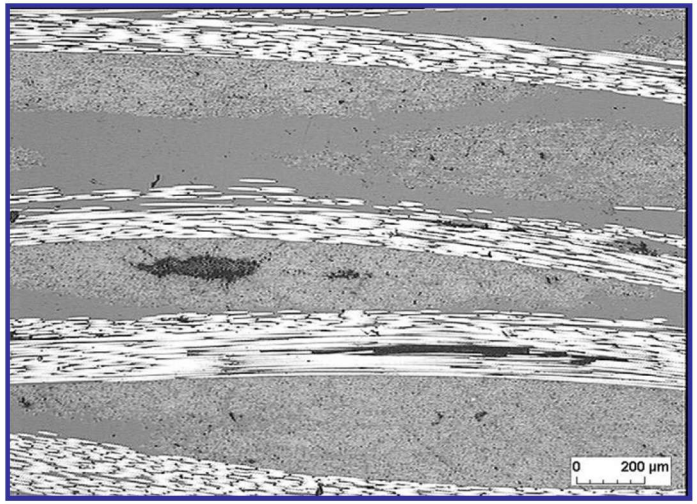

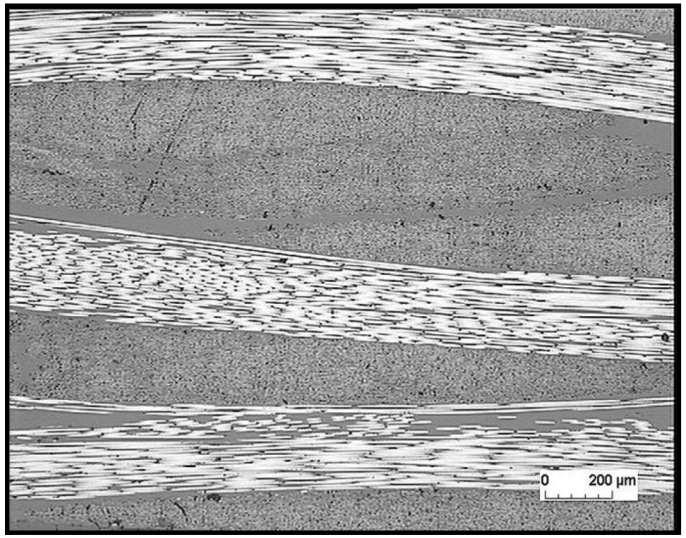

matrix

Fibres and bundles

Systems Engineering: Overview

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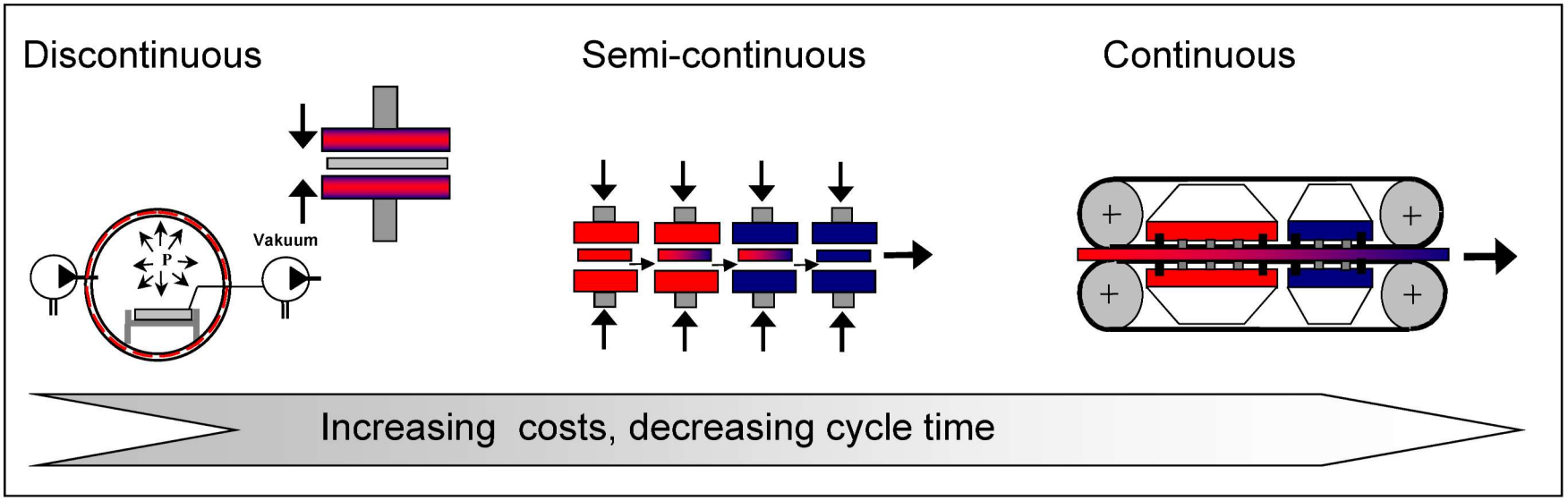

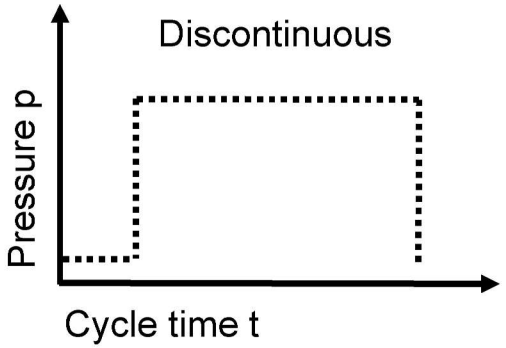

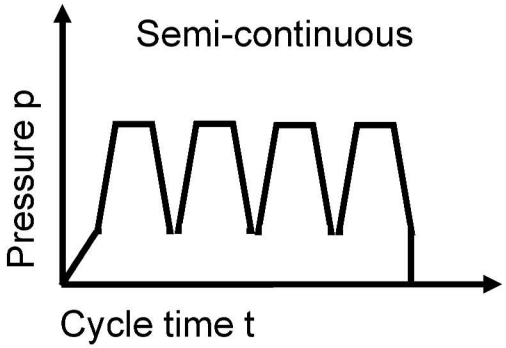

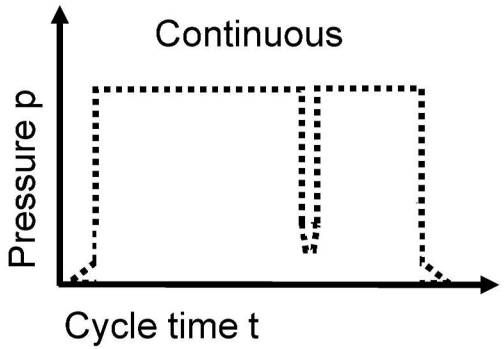

Semi-continuous manufacturing process: Continuous Compression Molding at IVW

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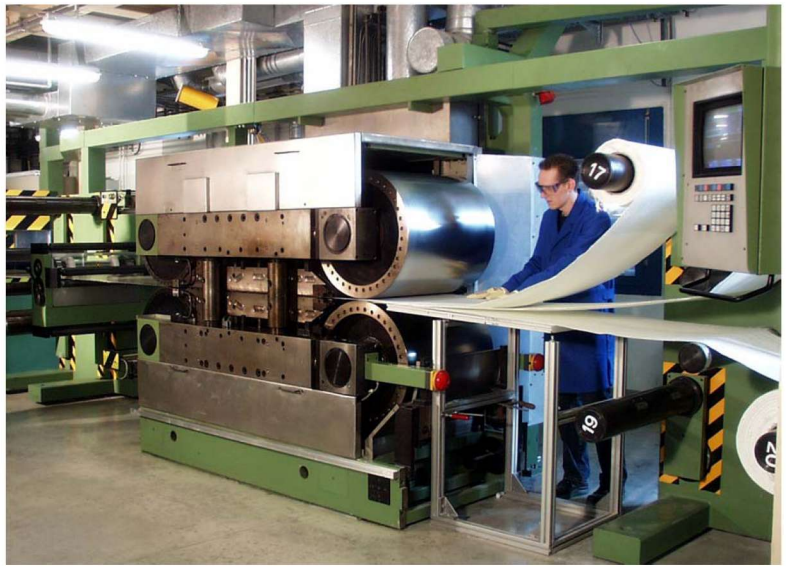
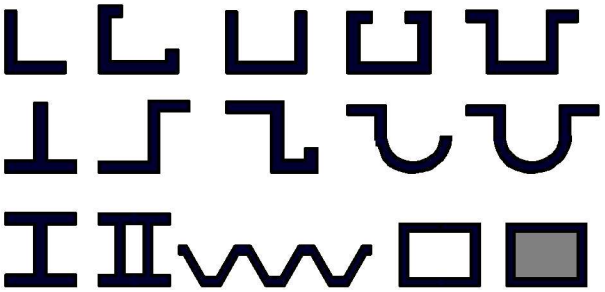
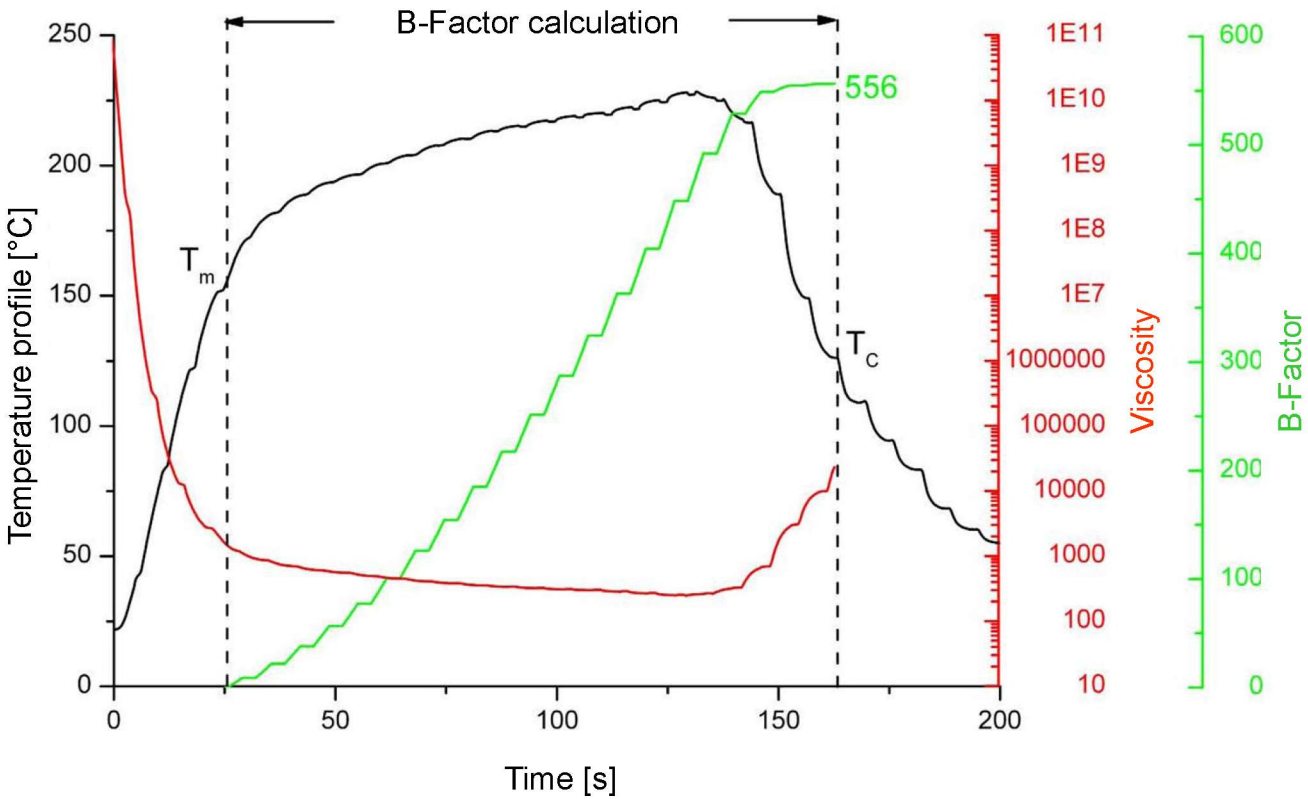


Profiles and flat semi-finished components



Process Modelling II



Calculation of the viscosity profile

$$\eta_0(T) = \eta_0(T_0)\exp\left[\frac{E_0}{R}\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$$

Determination of the impregnation performance

$$b = \int_{t_1(T_m)}^{t_2(T_c)} \frac{1}{\eta_0(T(t))}\,dt \approx \sum_{k=0}^{n} t_k \cdot \frac{1}{\eta_0(T_k)}$$

Implementation of process pressure

$$B = b \cdot p$$

Thermoforming of Continuous Fiber Reinforced Polymer Composites

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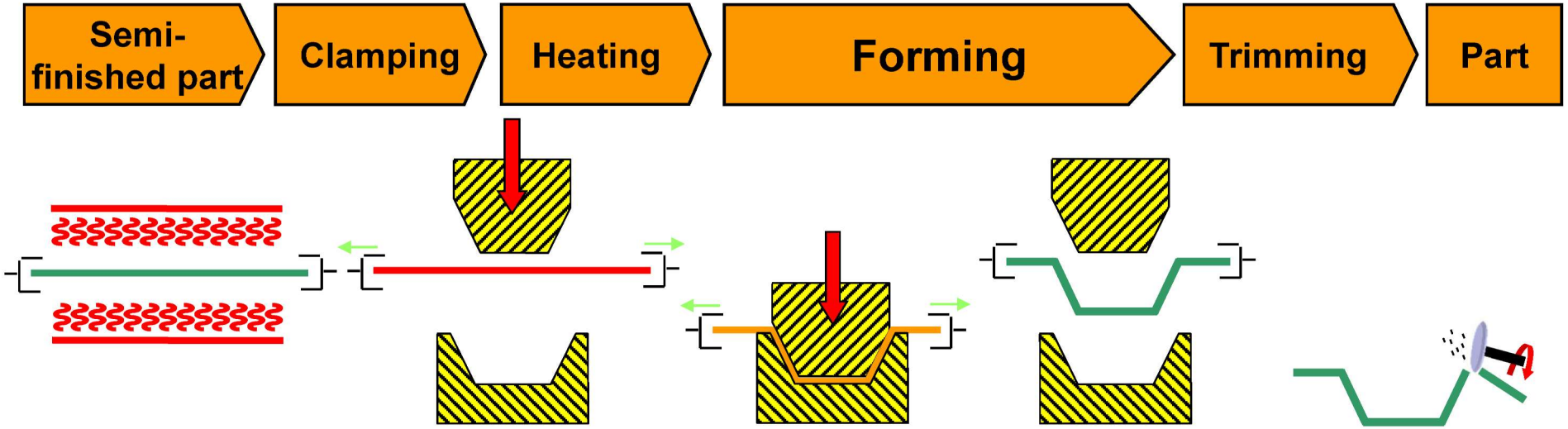

Advantages	Disadvantages
• Short cycle time • Forming with low pressure • Cost-efficient aluminum tools with long tool life • Lower investment costs • High formability	• High energy consumption for heating • Relative expensive semi-finished products • Labor-intensive trimming • „New Technology“

CageSystem®-Technology for New Tooling Concepts

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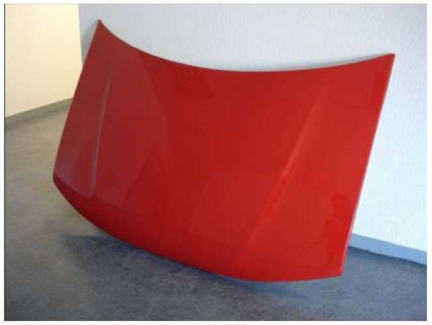
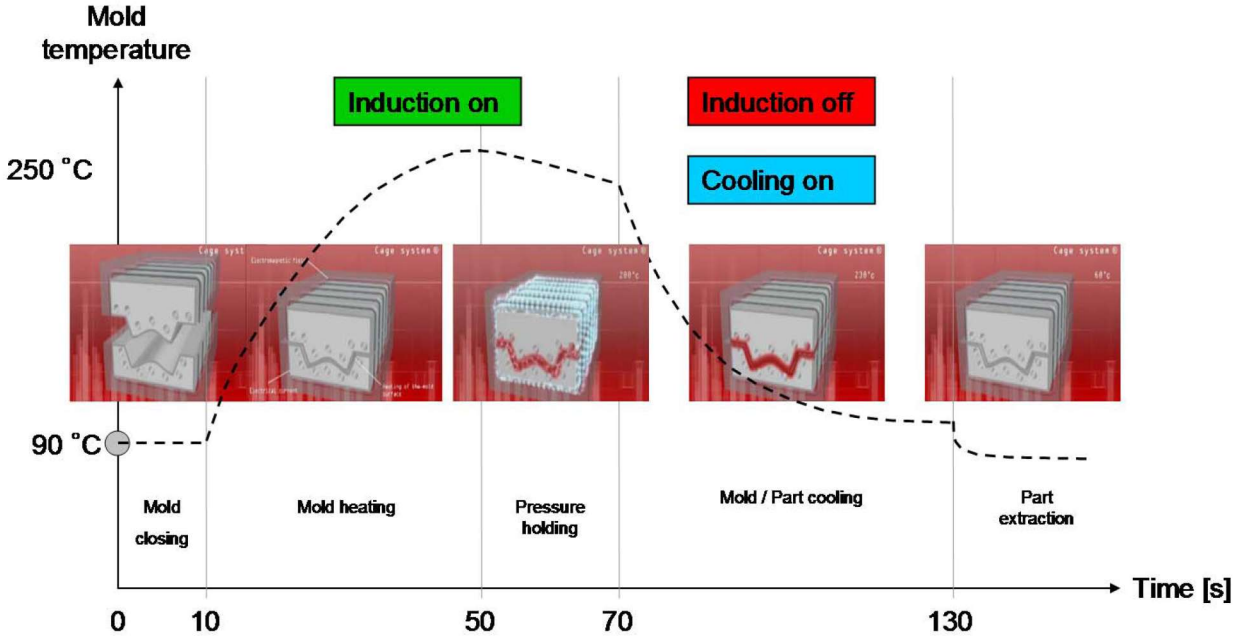
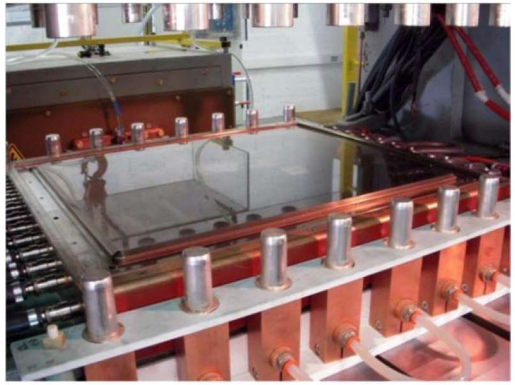
Picture supplied by RocTool



GMT Application Bonnet





Advanced capabilities:
Local stiffening through FRPC inserts

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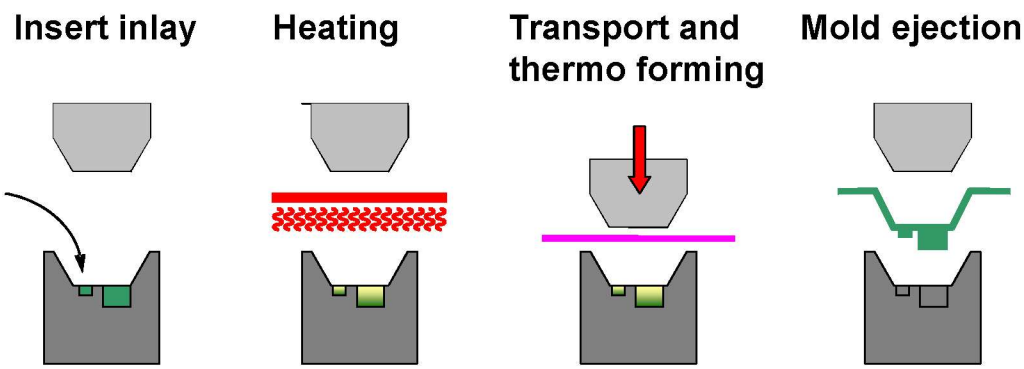
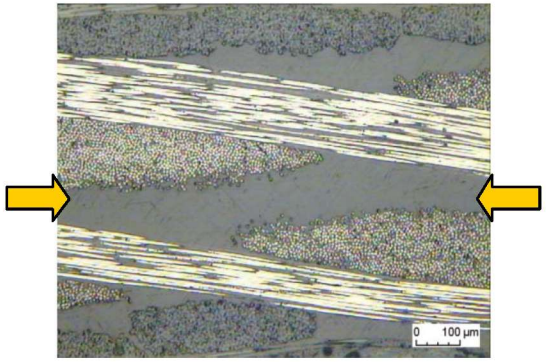


CF/GF/PA12



Welded joint

T_{Ob} = 222 °C, T_I = 234 °C

Applications

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Bumper beam, Jacob Composite GmbH

Back seat support, Jacob Composite GmbH

Airplane door, Eurocopter Deutschland GmbH

Demonstrator part (Porsche / IVW)

J-nose on wing, Airbus

Motivation for Welding Technology

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- Joining technology is essential for manufacturing large and complex parts

- For many applications welding, or fusion bonding, is a preferable process:
  - Short processing times, no curing
  - Low surface preparation requirements
  - Prevention of stress concentrations

- Various processes are available but lack of comparative data

Welding Processes for Thermoplastic Composites

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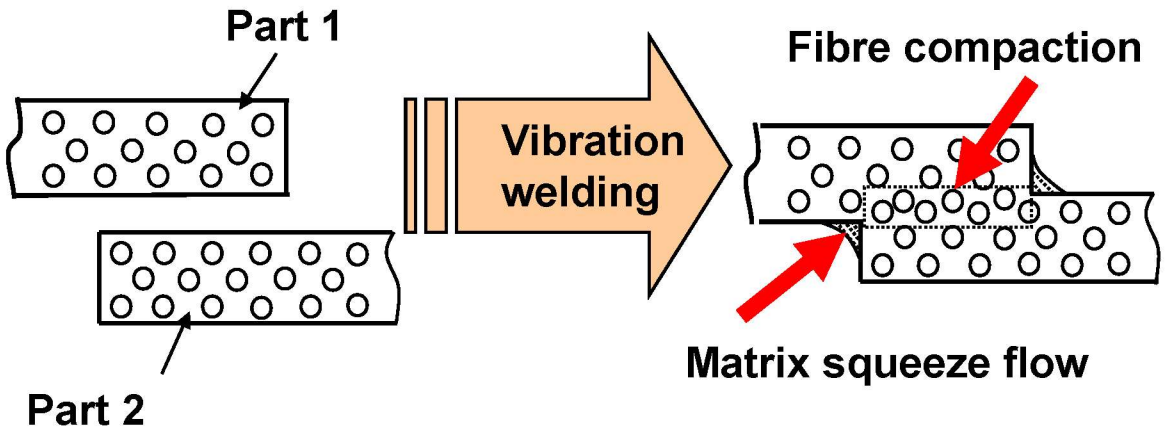
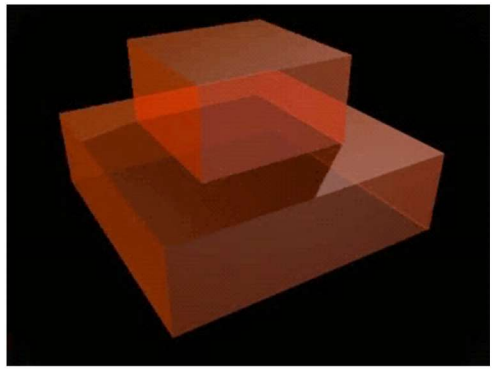
Fusion bonding

- **Bulk heating**
  - Co-consolidation
  - Hot-melt adhesives
  - Dual resin bonding
- **Frictional heating**
  - Spin welding
  - **Vibration**
  - Ultrasonic welding
- **Electromagnetic heating**
  - **Induction welding**
  - Microwave heating
  - Dielectric heating
  - Resistance welding
- **Two-stage techniques**
  - Hot plate welding
  - Hot gas welding
  - Radiant welding

Ageorges, C., Ye, L. & Hou M., *Composites Part A* 32(6) (2001): 839-857

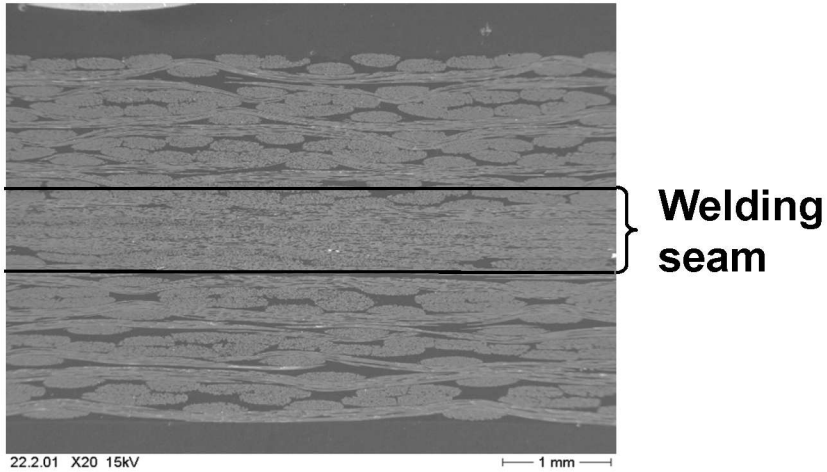
Vibration Welding Basics





Process steps during vibration welding:

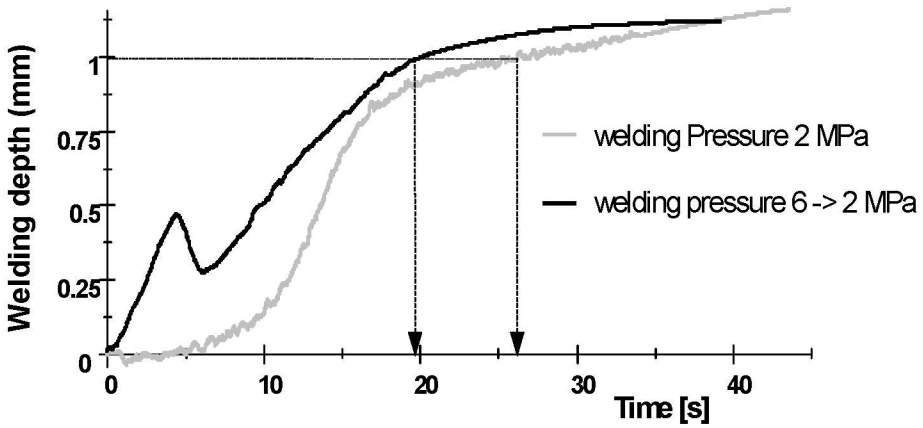
1. Sold friction (V1)
2. Beginning of melting (V2)
3. Friction in melting stage (V3)
4. Cooling and solidification (H1, H2)

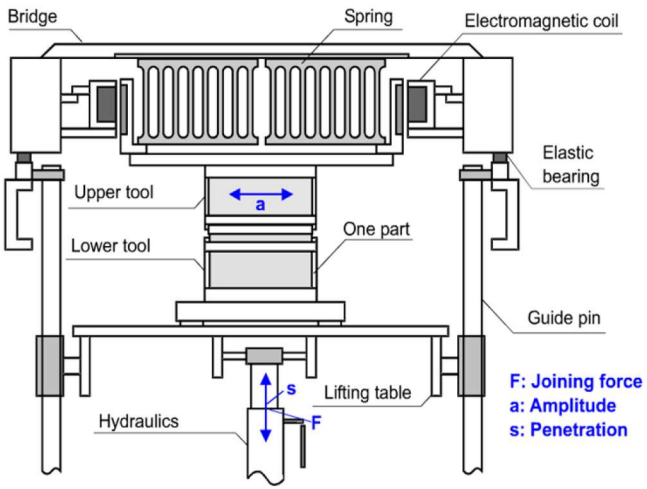


Process Parameters and Equipment for Vibration Welding

- Process parameters
  - Processing or welding time
  - Holding time
  - Welding depth
  - Pressure constant / variable
  - Amplitude
  - Frequency

Process optimisation by controlled pressure-profile





Vibration Welding Machine (Branson)

Induction Welding Basic Principle

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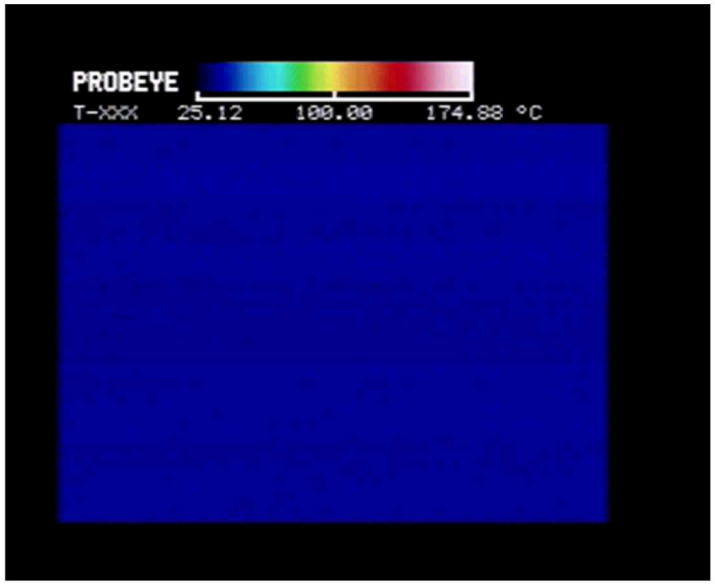
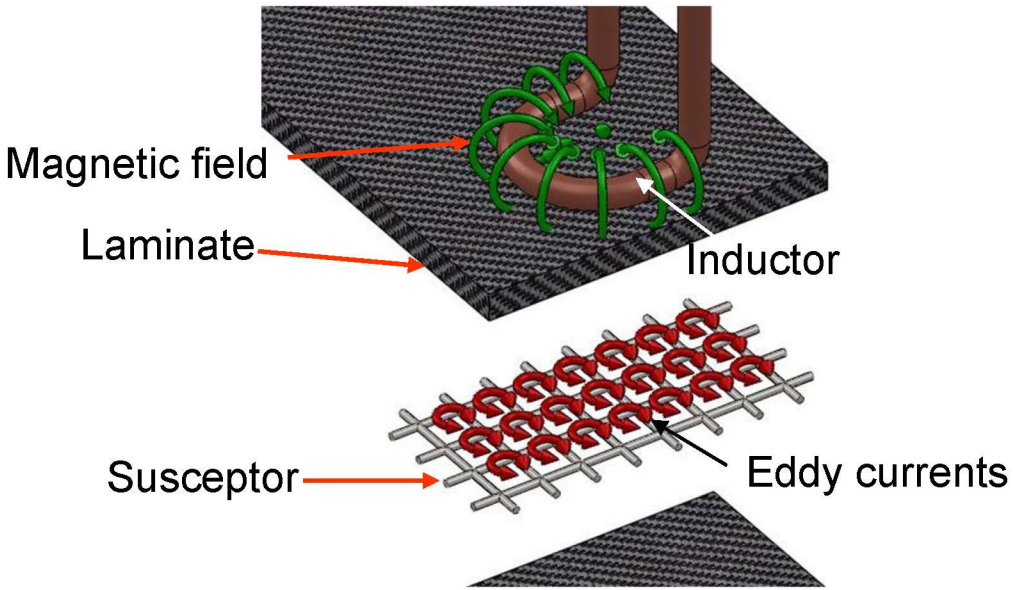
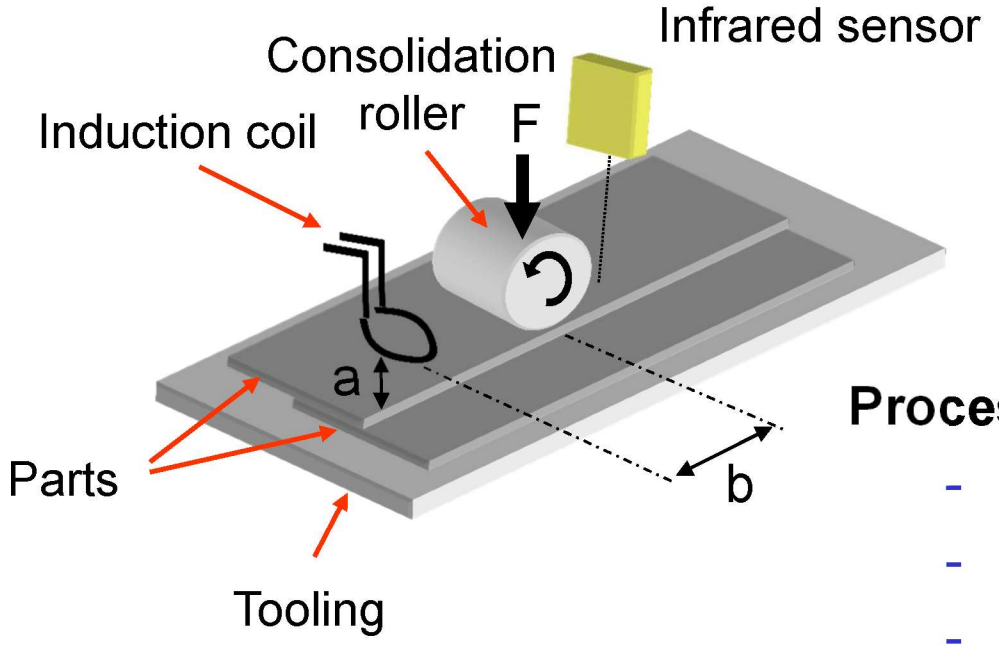
- Alternating magnetic field
- Dominant heating mechanism: Eddy currents induced in electrically conductive materials
- Additional heating mechanisms: Hysteresis, dielectric, and contact resistance heating
- Intrinsic heating ability of carbon fiber reinforced composites and metals
- Welding susceptor for glass fiber reinforced laminates





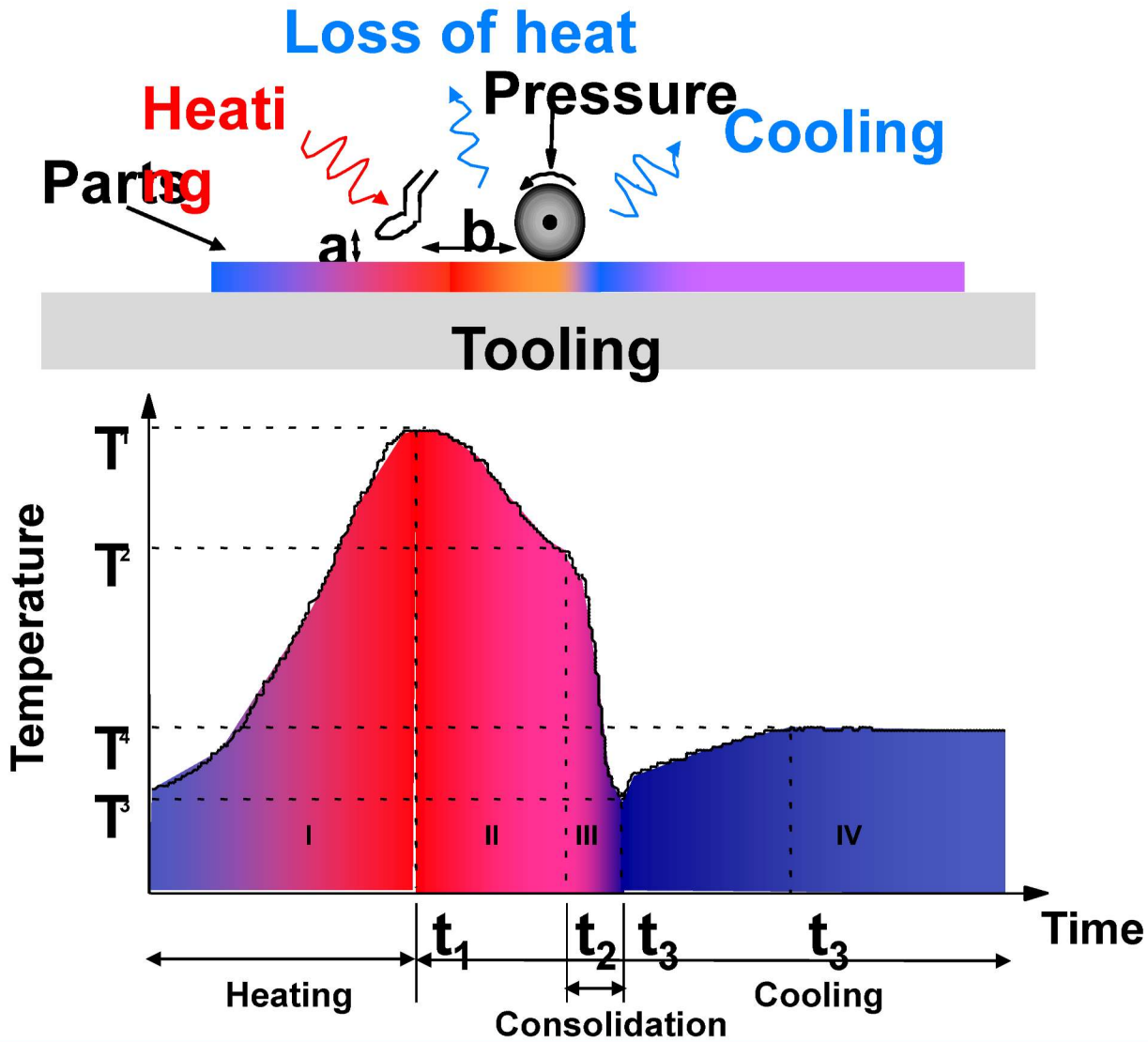
Typical Parameters for Induction Welding



Processing parameters:

- Consolidation force (50 to 600 N)
- Inductor shape
- Power (max. output 6 kW)
- Coupling distance (a) (1-3 mm)
- Distance to compaction roller (b) (50-60 mm)
- Feed rate (0 bis 6 m/min)

Temperature Profile in Continuous Induction Welding



Influence of Inductor Shape on the Temperature Field

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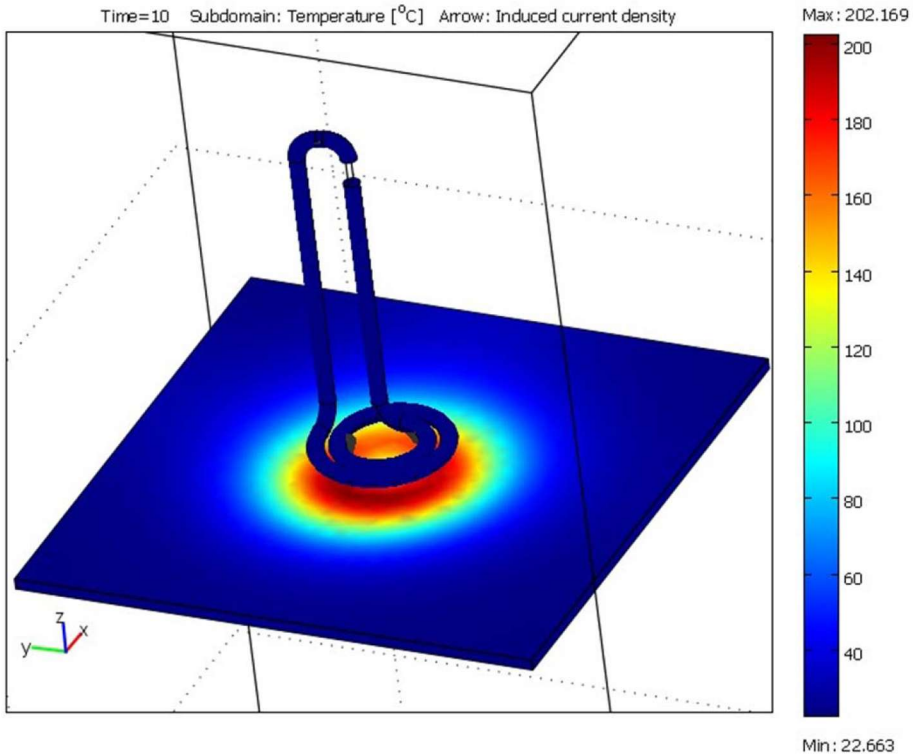
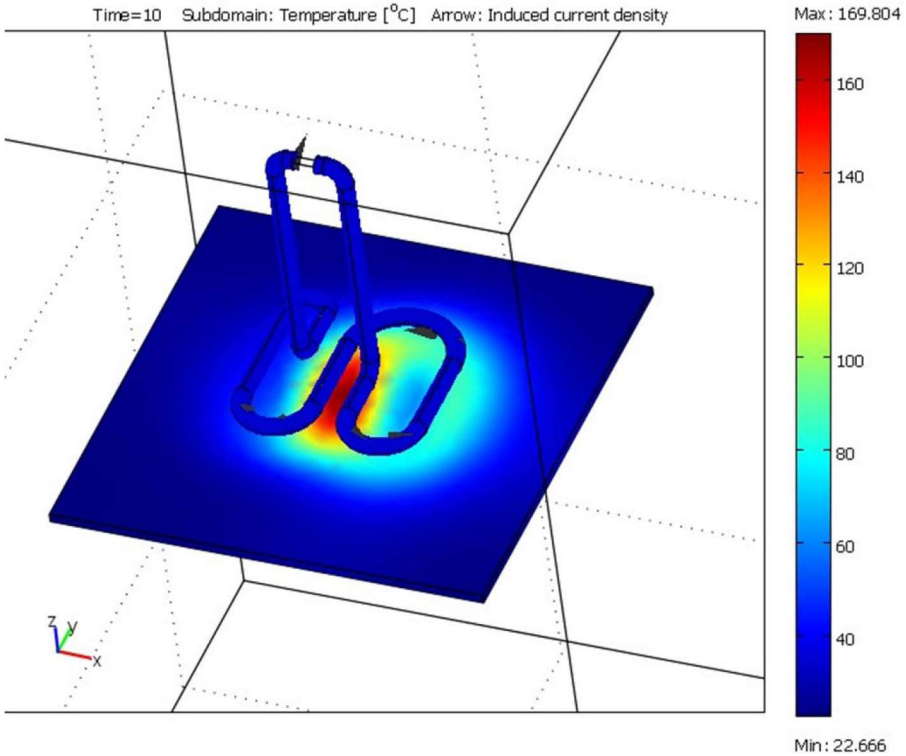
Pancake coil



Double-D coil



- Heating of CF/PPS (electrical conductivity 2000 S/m)
- Coupled thermal/electromagnetic transient models

Technology Demonstrator

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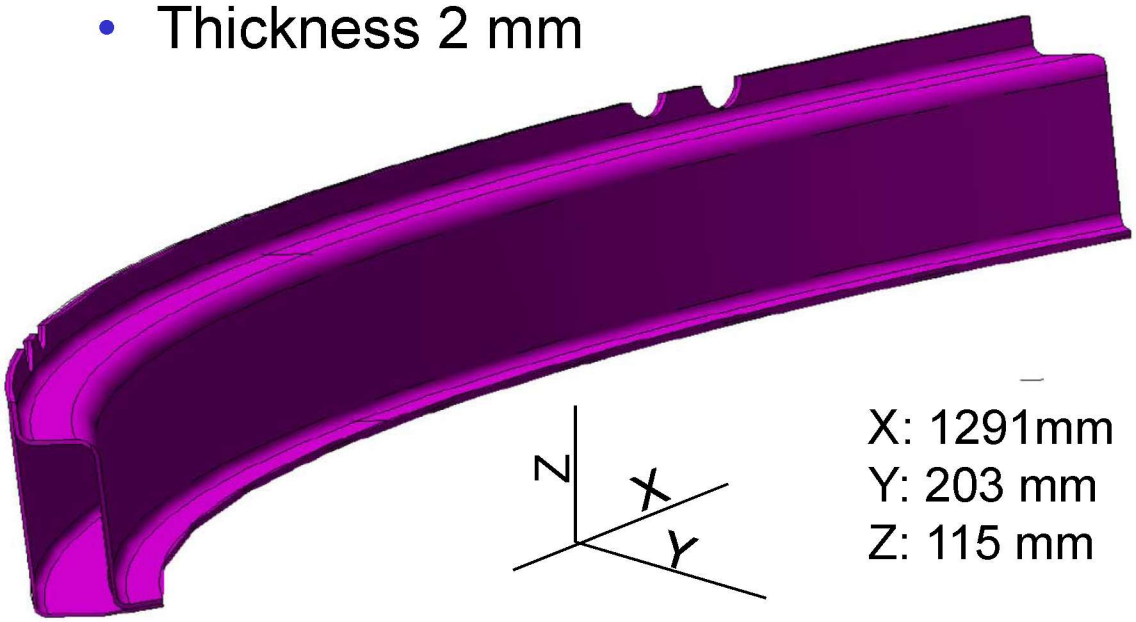
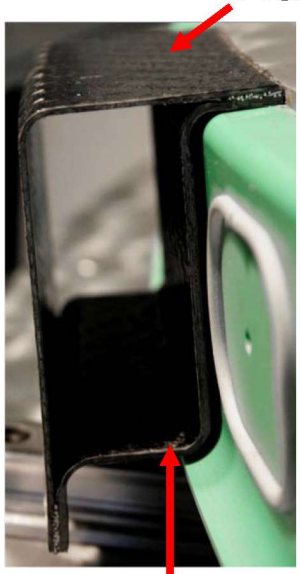
- Welding of two thermoformed half shells
- Assessment of thermally induced distortion
- Material: Glass fiber reinforced polyamide 6
  - Tepex RG(4)600, provided by Bond-Laminates GmbH, Brilon, Germany
  - Thickness 2 mm



X: 1291mm
Y: 203 mm
Z: 115 mm



Consolidation Modes of Welding Unit

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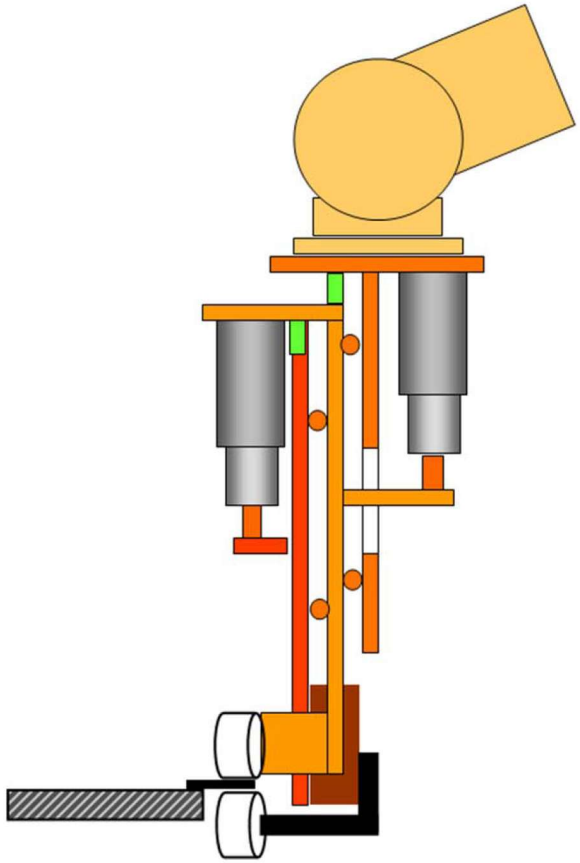
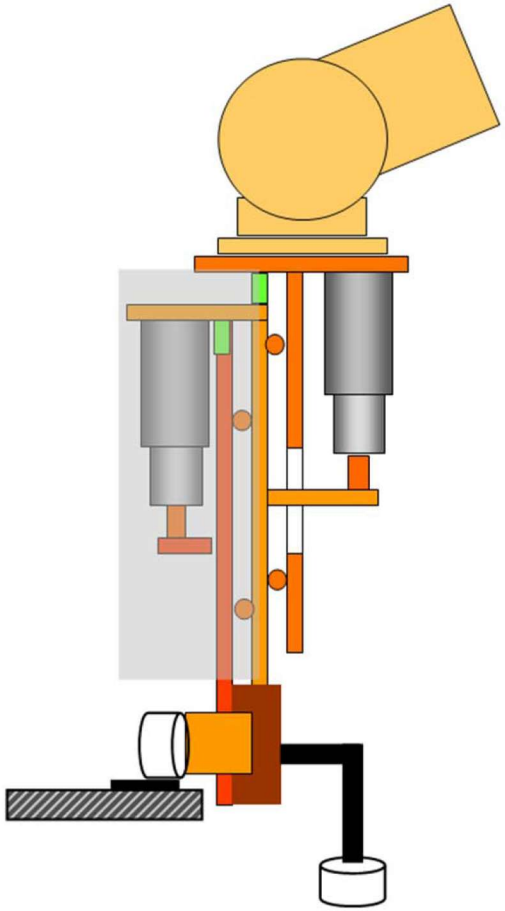


Counterforce by pivot-mounted roller



Counterforce by fixture

Automated Induction Welding Process

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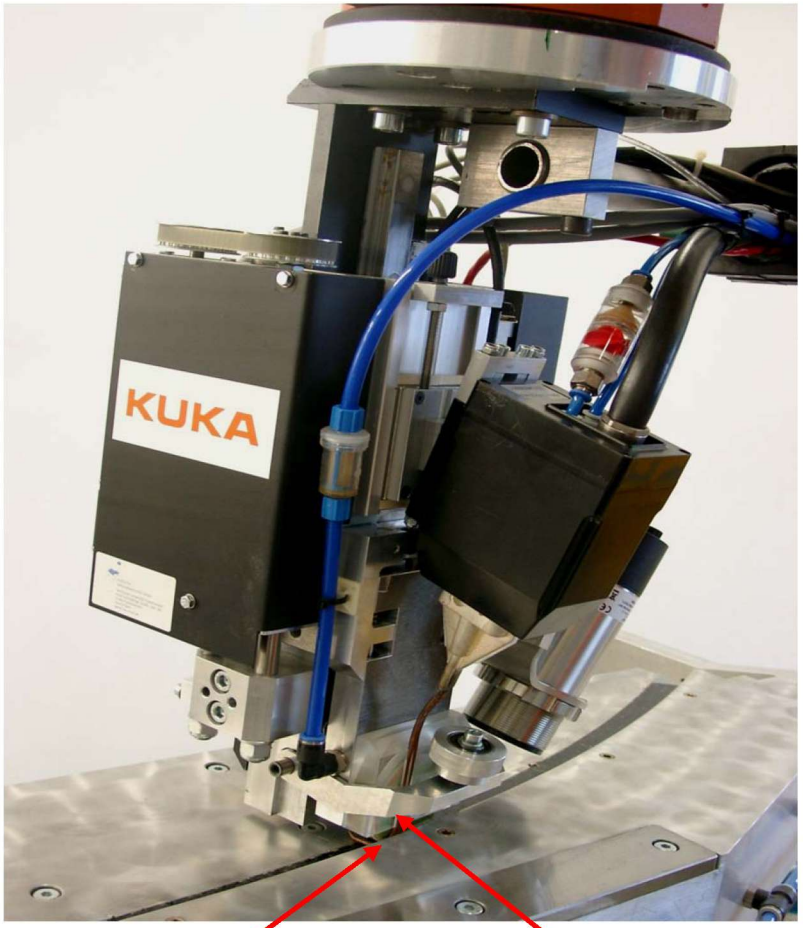
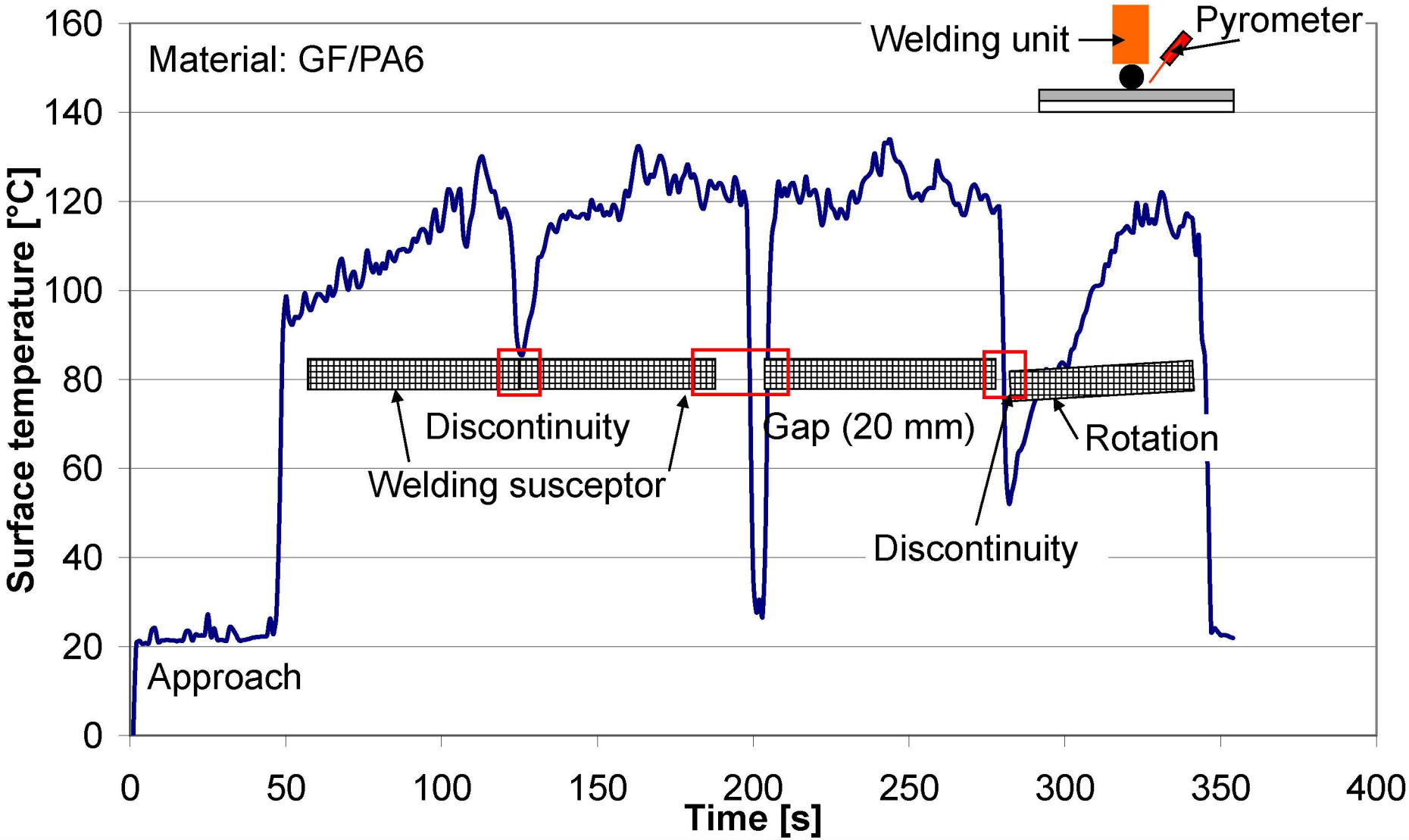


Consolidation tool Induction coil

Online Quality Control by Surface Temperature Monitoring



Robotized Spot Welding of Composites

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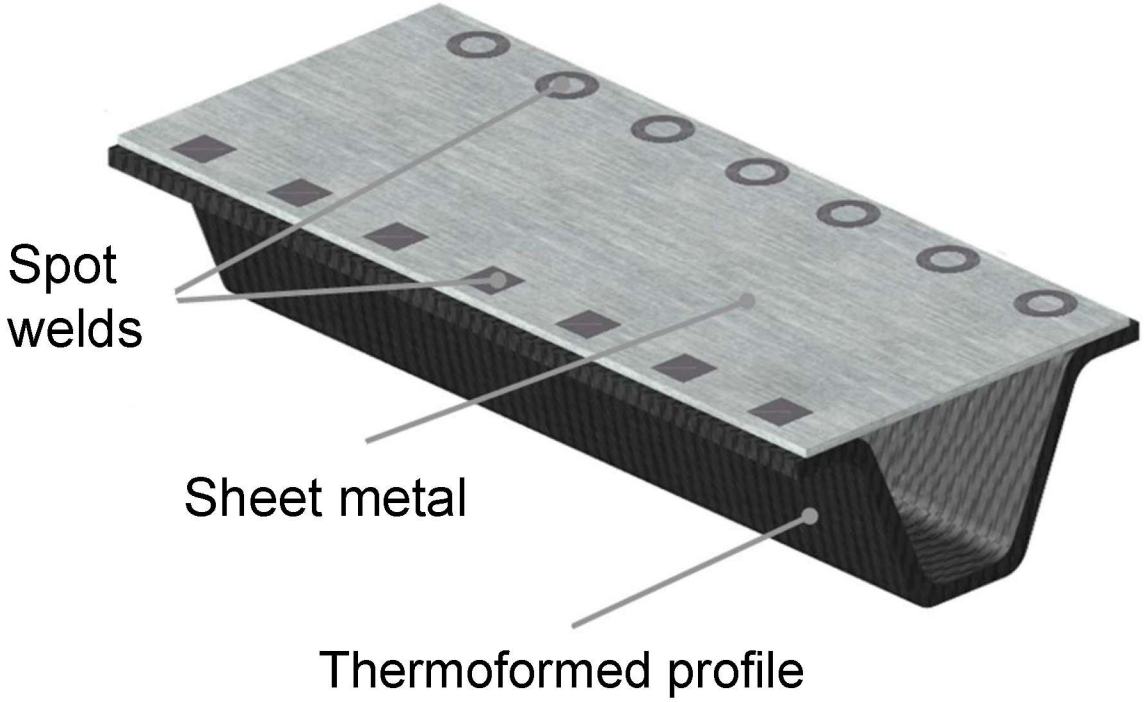
DFG Research Group 524
Demonstrator part



- Multi-material joints
- Processing of thermally sensitive material
- Manufacturing of large and complicated parts
- High degree of automation
- Improved performance due to longer diffusion times compared to continuous welding

Development of a Spot Welding Device

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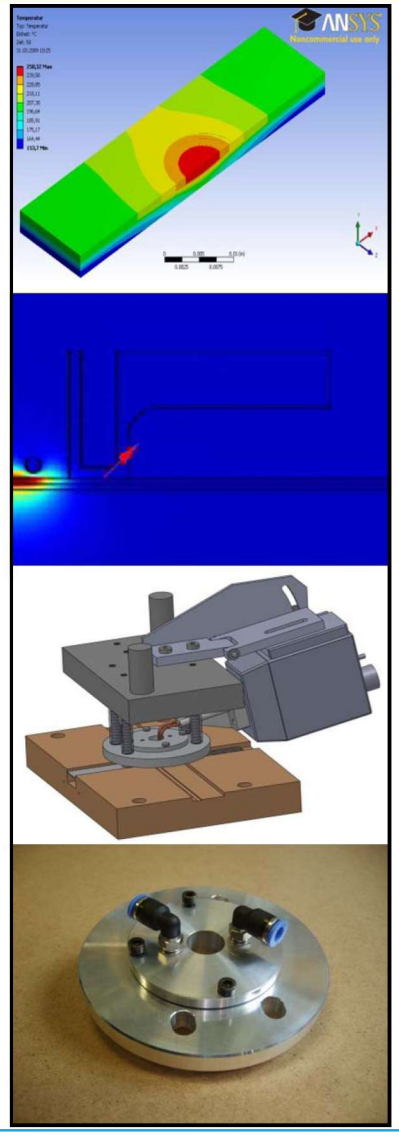
- Thermal Simulation
  - Optimization of temperature profile
- Electromagnetic simulation
  - Sufficient heating of workpiece
  - Heating of welding tool
- Design engineering
  - Implementation of simulation results into a machineable design
  - Integration into existing welding setup
- Manufacturing



Adaption of Spot Welding Device to Welding Robot

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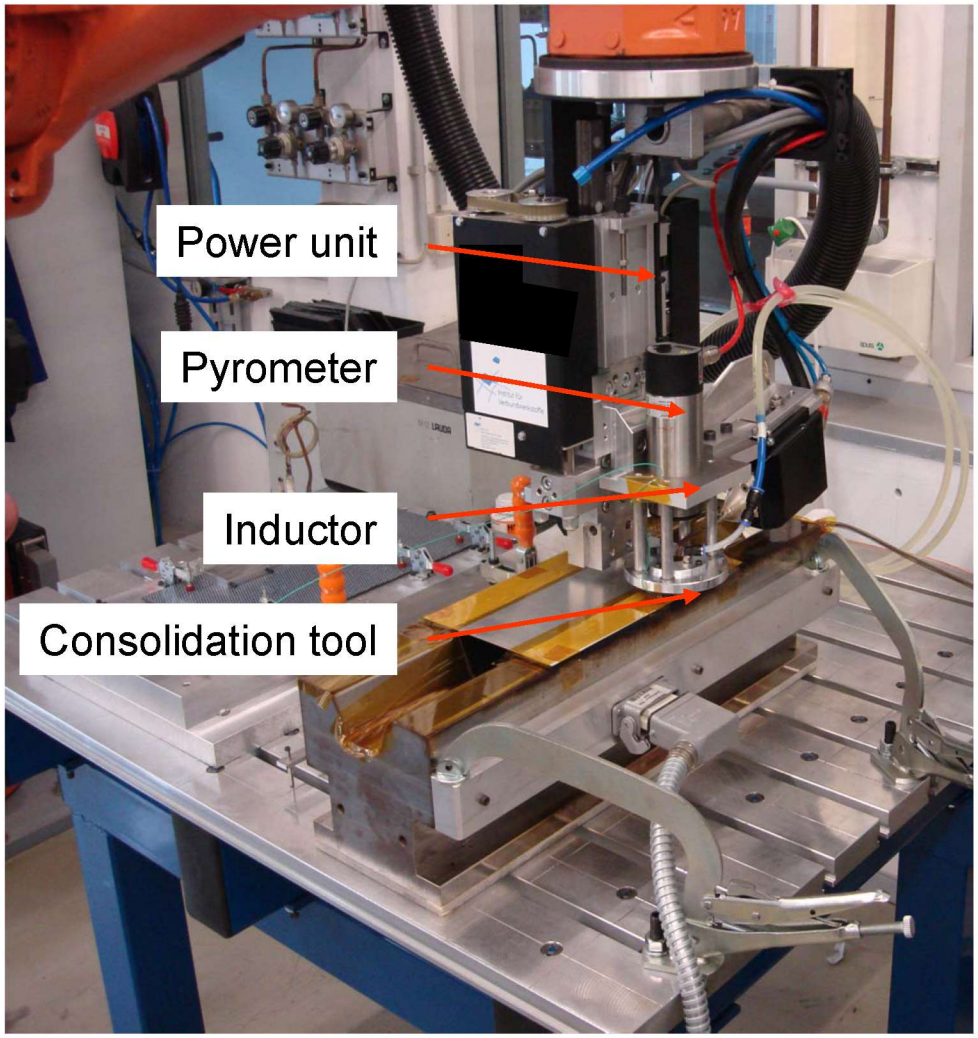
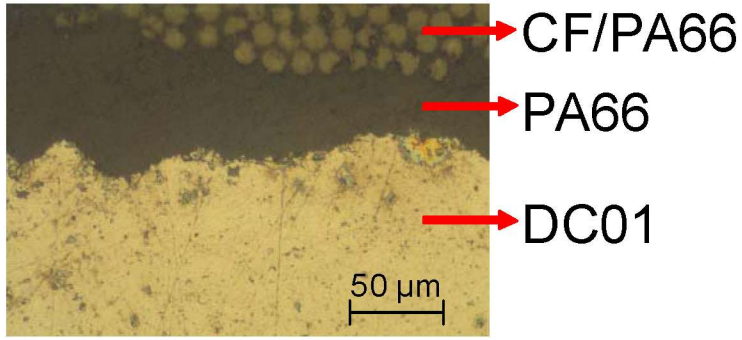
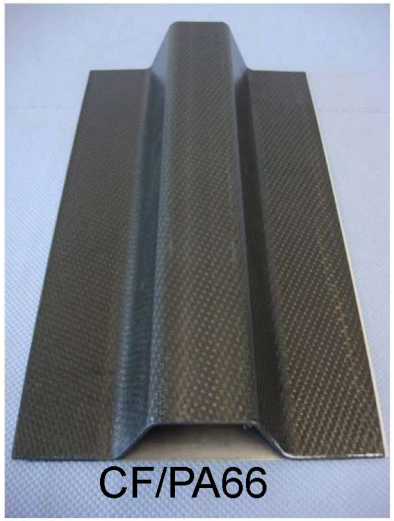
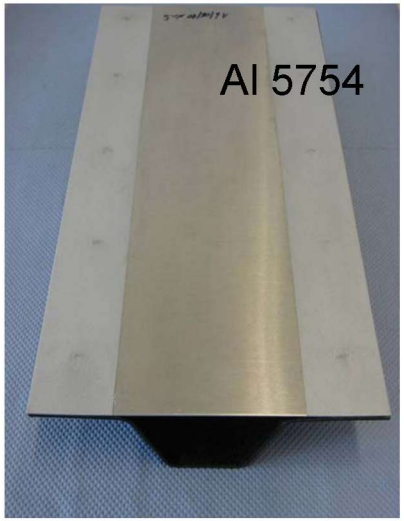
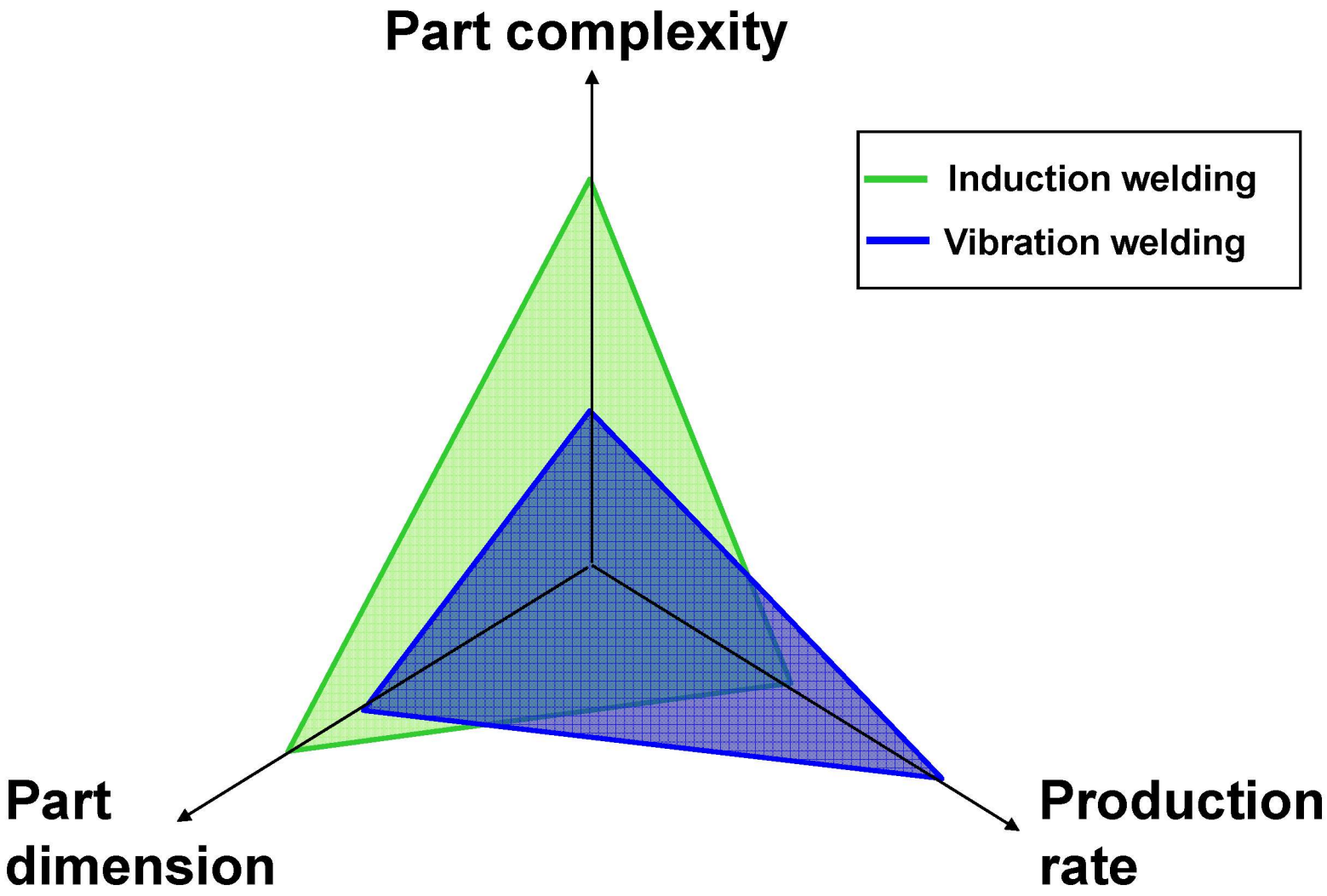








Comparison by Fields of Application



Conclusion and Outlook

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- Fully impregnated semi-finished materials (flat plates and profiles) are the base for high production rates
- Automation is one of the key issues for higher volume productions of fiber reinforced thermoplastics
- Vibration welding is suitable for easy geometries and high production rates
- Three-dimensional induction welding is capable of joining curved, complex structures
- Future work will include further thermal modeling for process optimization and quality control

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Thank you for your attention