Efficient and sustainable rotor blade manufacture enabled by online quality assurance systems in combination with low-waste resin flow control

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Wind Turbine Blade Manufacture 2019
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DLR

DLR – German Aerospace Center

Tasks

Publicly funded non-profit organisation

- Research Institution
- Space Agency
- Project Management Agency

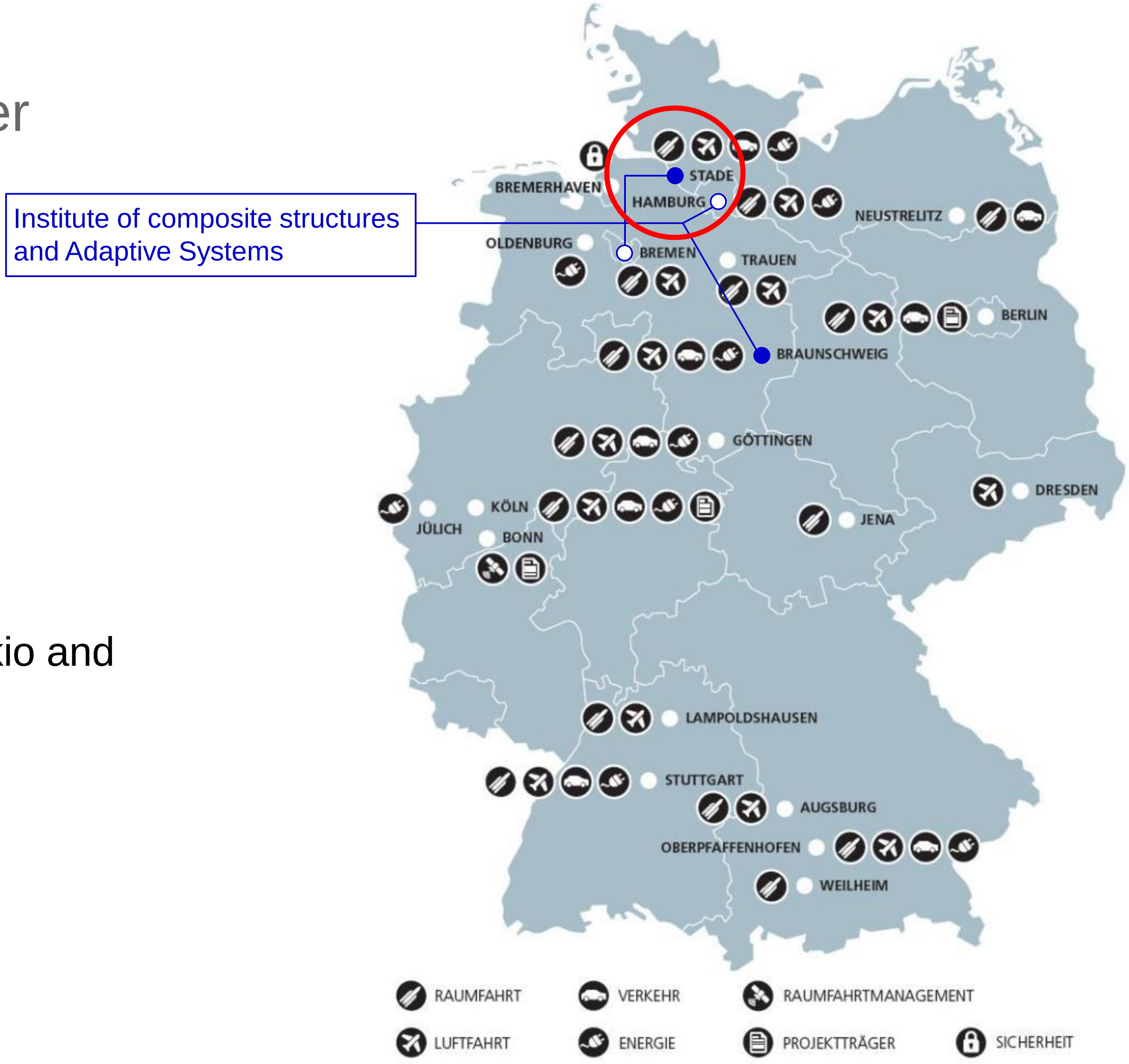
Research Areas and Cross-link-fields

- Aerospace
- Space Research and Technology
- Energy
- Transport
- Security
- Digitization (e.g. „Factory of the Future“, „Condition Monitoring“)

DLR – German Aerospace Center

Sites and Staff

- Approx. 8.500 employees
- 50 Institutes and Institutions
- More than 20 Sites
- Offices in Brüssel, Paris, Tokio and Washington.



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Center for Lightweight-Production-Technology (ZLP®) Stade in “CFK Nord”

DLR
- ProductionTechnology Single Components
- Virtual Composite Product Development

Fraunhofer IFAM
- Assembly Technology
- Joining Technology
- Machining Technology

FFT
- Technology Development, Customer Service

Olin
- Fundamental Materials Research (e.g. novel resins)

HP-CFK: Technische Universität Carolo-Wilhelmina zu Braunschweig · TU Clausthal · Leibniz Universität Hannover

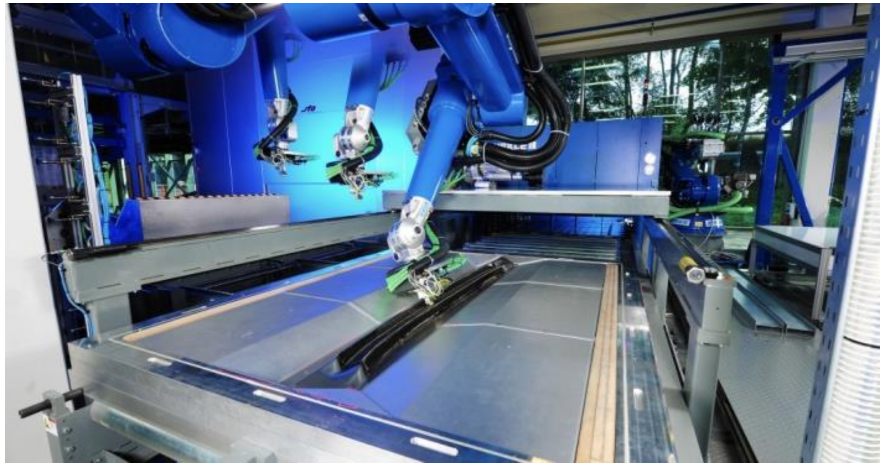
20.000 qm for cooperation and innovation

Center for Lightweight-Production-Technology (ZLP®) Stade

- Research platforms and main research areas

Large-scale components in Fiber-Placement-Technology (multi-robot-approach)

Research Autoclave for smart autoclave processing



High-rate netshape composite part production using automated textile preforming and RTM

Rotorblade research at ZLP®
SmartBlades I + II (BMWi 2013 – 2018)

Partners: Fraunhofer IWES, ForWind, several Windenergy-OEMs

Results:

- Fiber placement technology for the processing of raw, untreated, dry rovings, see WTBM 2016: J. Stüve, “Proceedings in the development and qualification of the Direct Roving Placement technology (DRP)”
- Manufacture of 4 rotor blades with geometric twist-bend-coupling, see WTBM 2017: J. Stüve, “Construction of rotor blades with twist-bend-coupling using innovative online quality assurance methods”


Source: NREL

Supported by:
Federal Ministry for Economic Affairs and Energy
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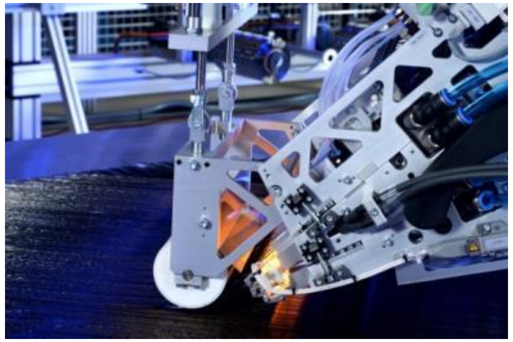

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Classical infusion technology

- Infusion during rotor blade construction

Huge amount of waste

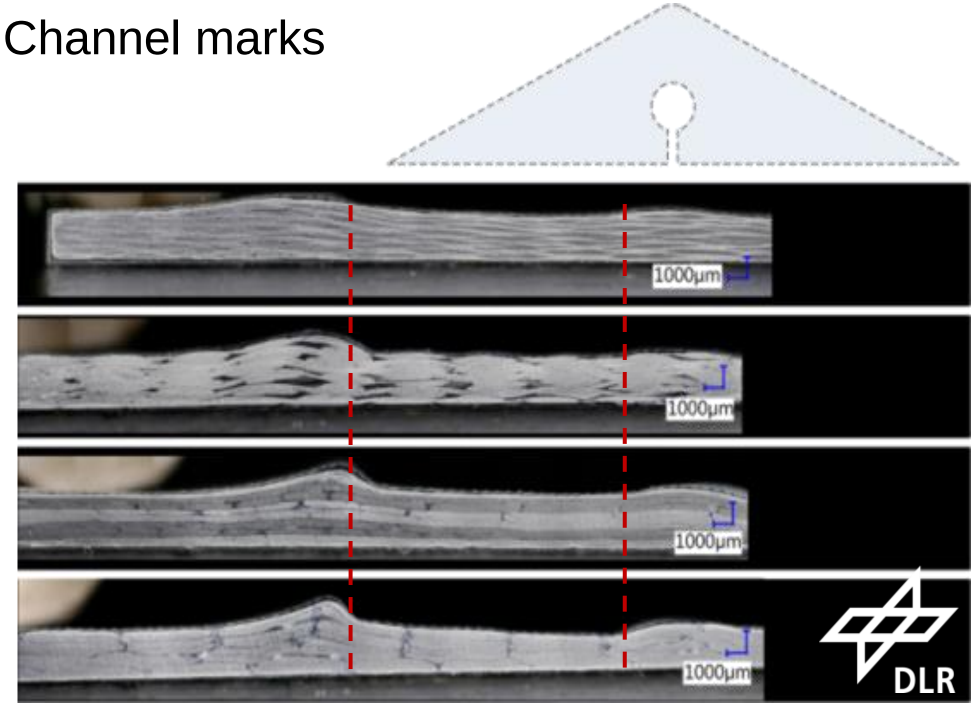
flowmedia
+
additional resin

vacuum bag

Infusion using resin sprues

- Usage of multiple resin sprues on part surface (inside of vacuum bagging)

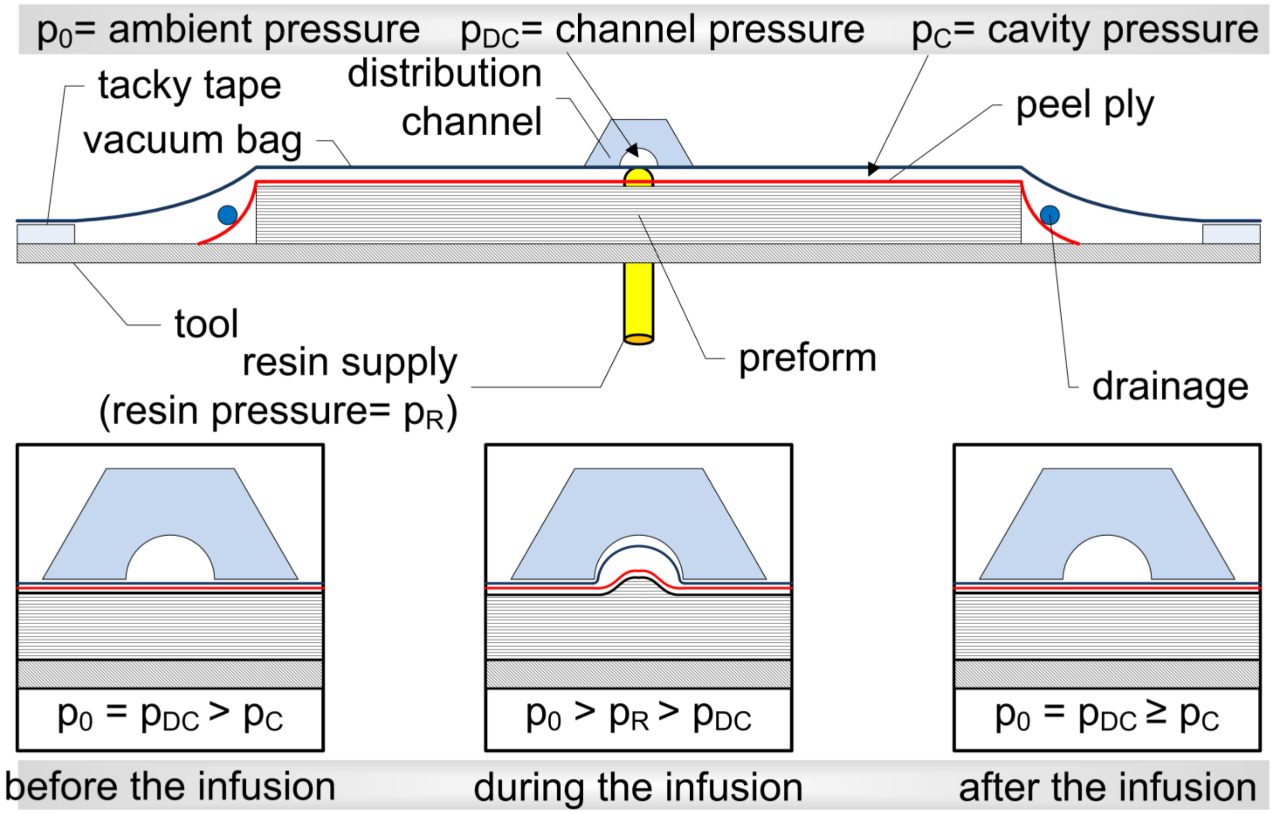
Channel marks



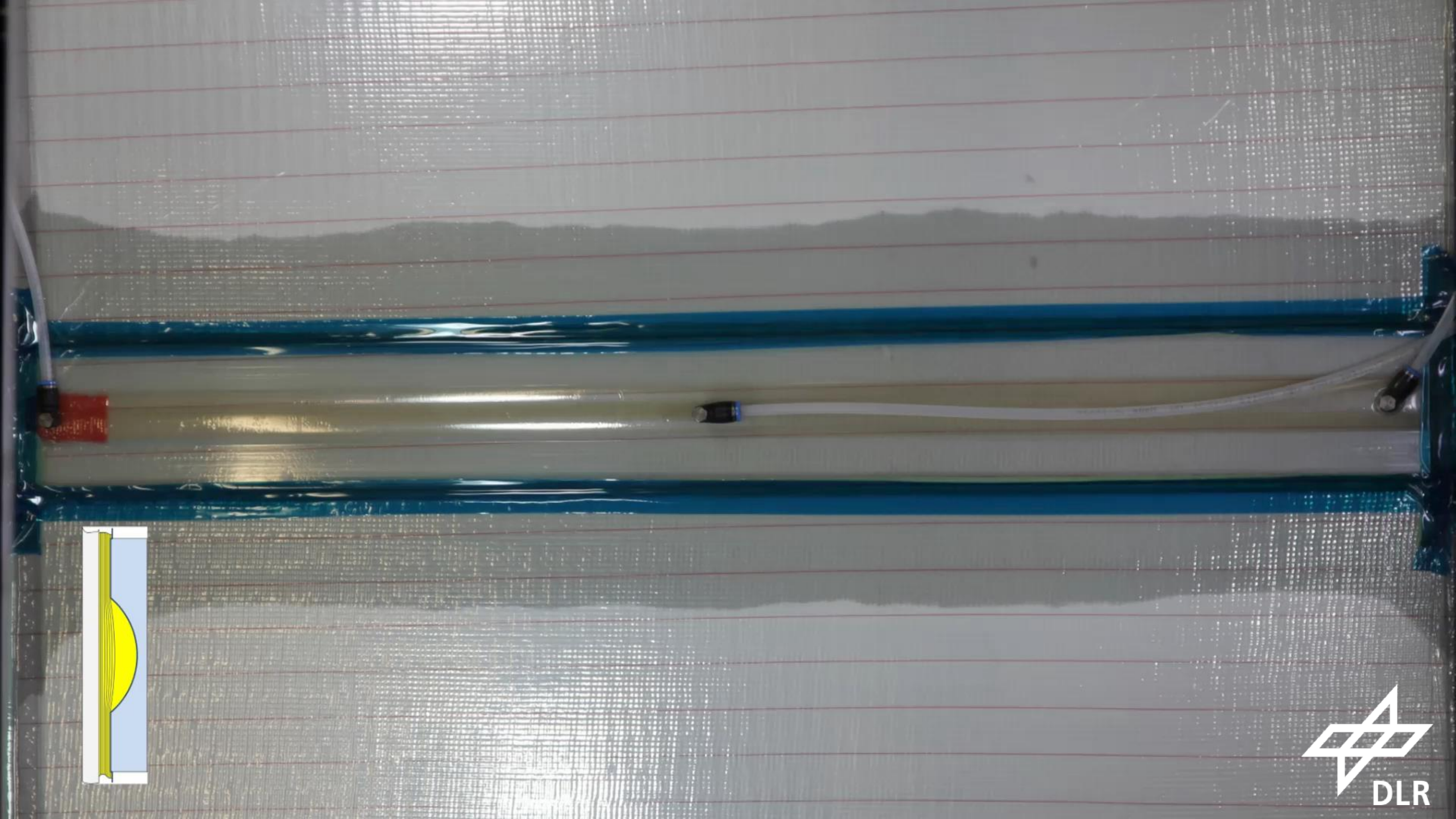
→ Ondulation of fibers in laminates made of different textiles

Innovative infusion by pressure controlled resin distribution channels

- Usage of reusable resin distribution channels



- Resin distribution channels are positioned outside of the cavity
- Channels can be activated temporarily by differential pressure between cavity and channel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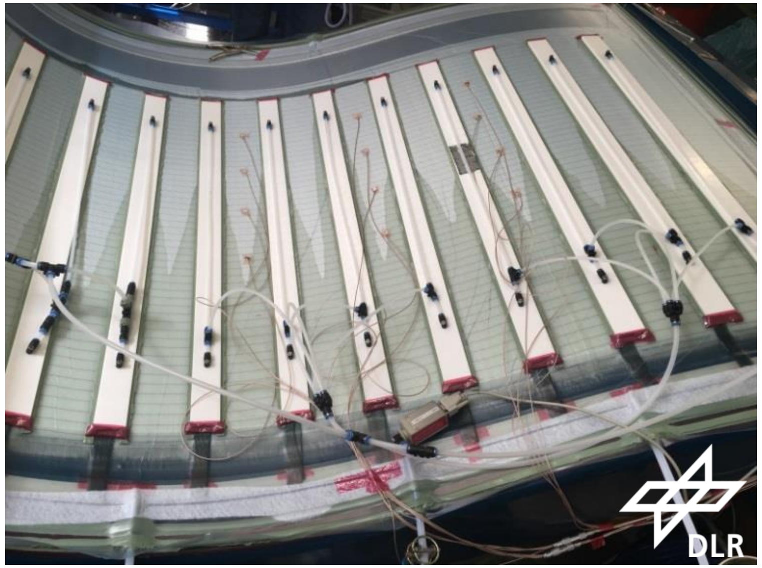
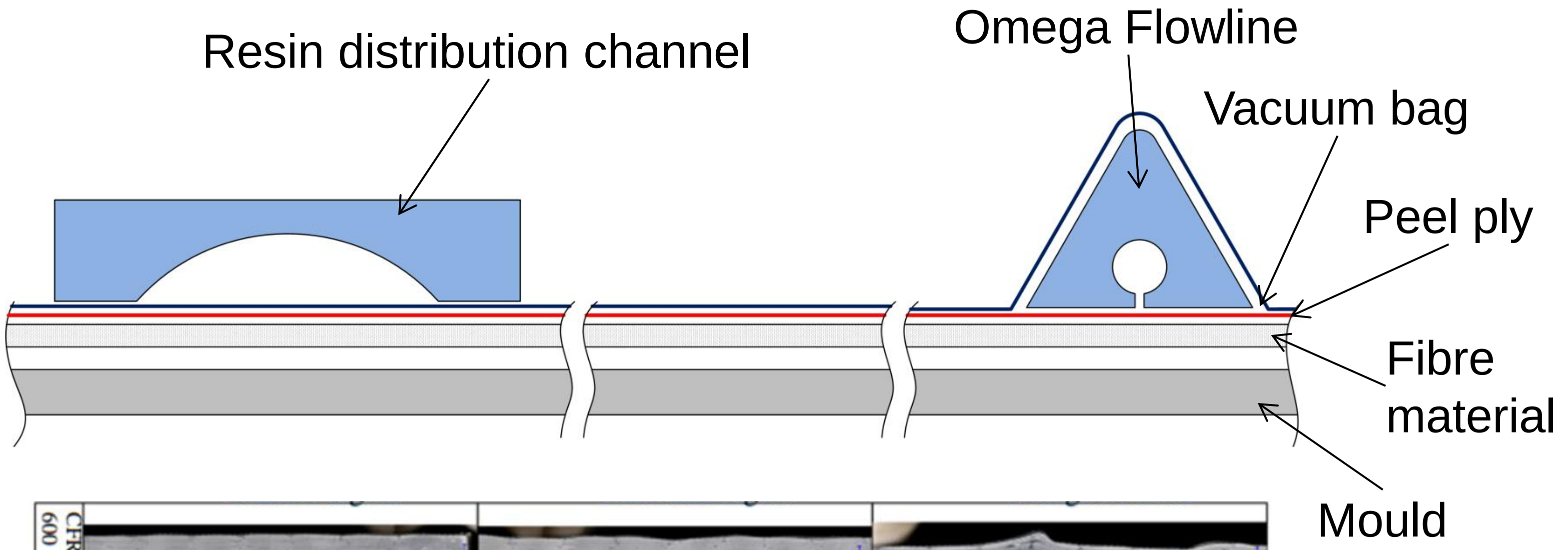
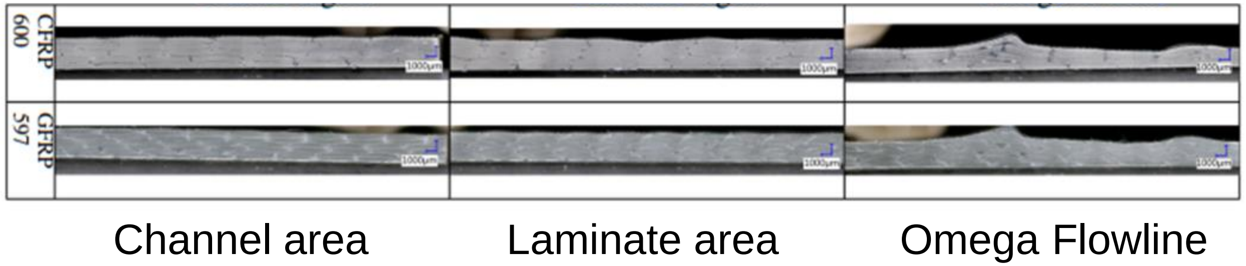
Validation of innovative infusion technology

- Example: Micrographs of UD Material



Demonstrator: Rotor blade sandwich panel





Advantages of innovative infusion technology

Material related

- No channel marks left on the composite parts surface → no undulation of fiber material
- Channel systems can be assembled and are reusable
- Amount of used resin can be minimized
- Production waste is reduced

Process related

- Positioning of distribution channels on stiff preform (under vacuum conditions)
    - Faster preparation, lower quality risk
    - No displacement of fiber material or prefabs
- Flexible positioning of distribution channels during infusion
    - channels can be repositioned or additional channels can be applied (modular concept)
    - risk of dry spots is reduced
- Resin flow and distribution can be actively controlled during production

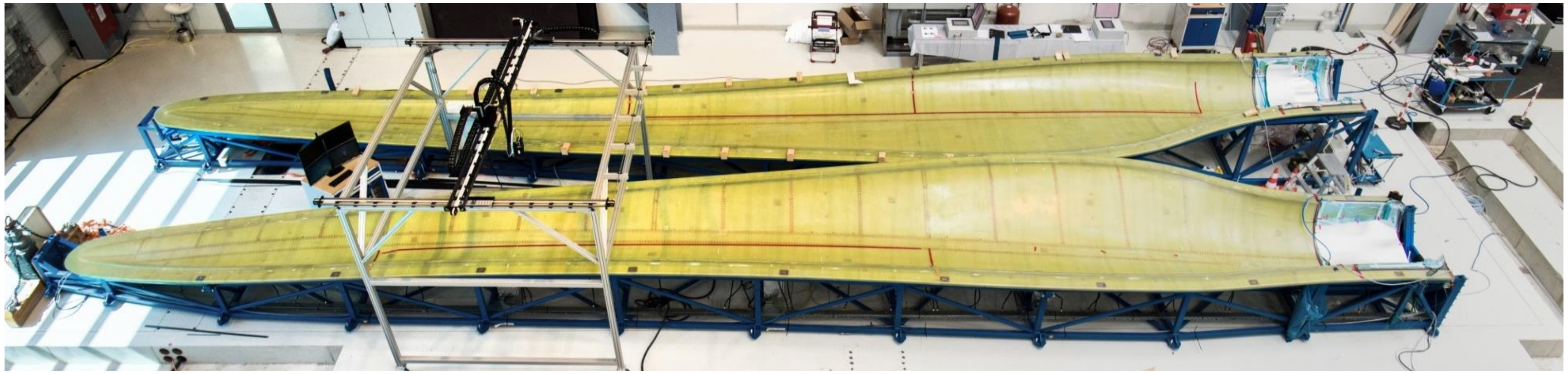
Monitoring of blade manufacturing
Parameters and sensors

Monitoring of:

- Global temperature distribution
- Flow front detection
- Leakage detection
- State of cure
- Components thickness

How to monitor?

- Optical cameras
- Thermographic cameras
- Temperature sensors
- Cure sensors
- Laser system



First demonstration of a rotor blade manufacturing at the DLR Stade

Monitoring of blade manufacturing
Measuring system

Movable measuring cell:

- Traversable cell
- Additional linear drive for the cameras
  - Leakage detection (thermographic)
  - Resin arrival (optical)
- Able to reach and follow every area during the manufacturing

Tool mounted sensors:

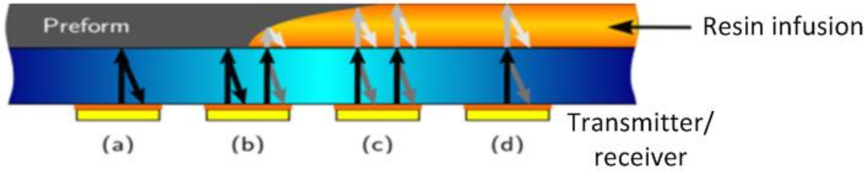
- Integrated adjustable heating
- Curing sensors
- Thermocouples

Measuring cell

Tooling/ Component

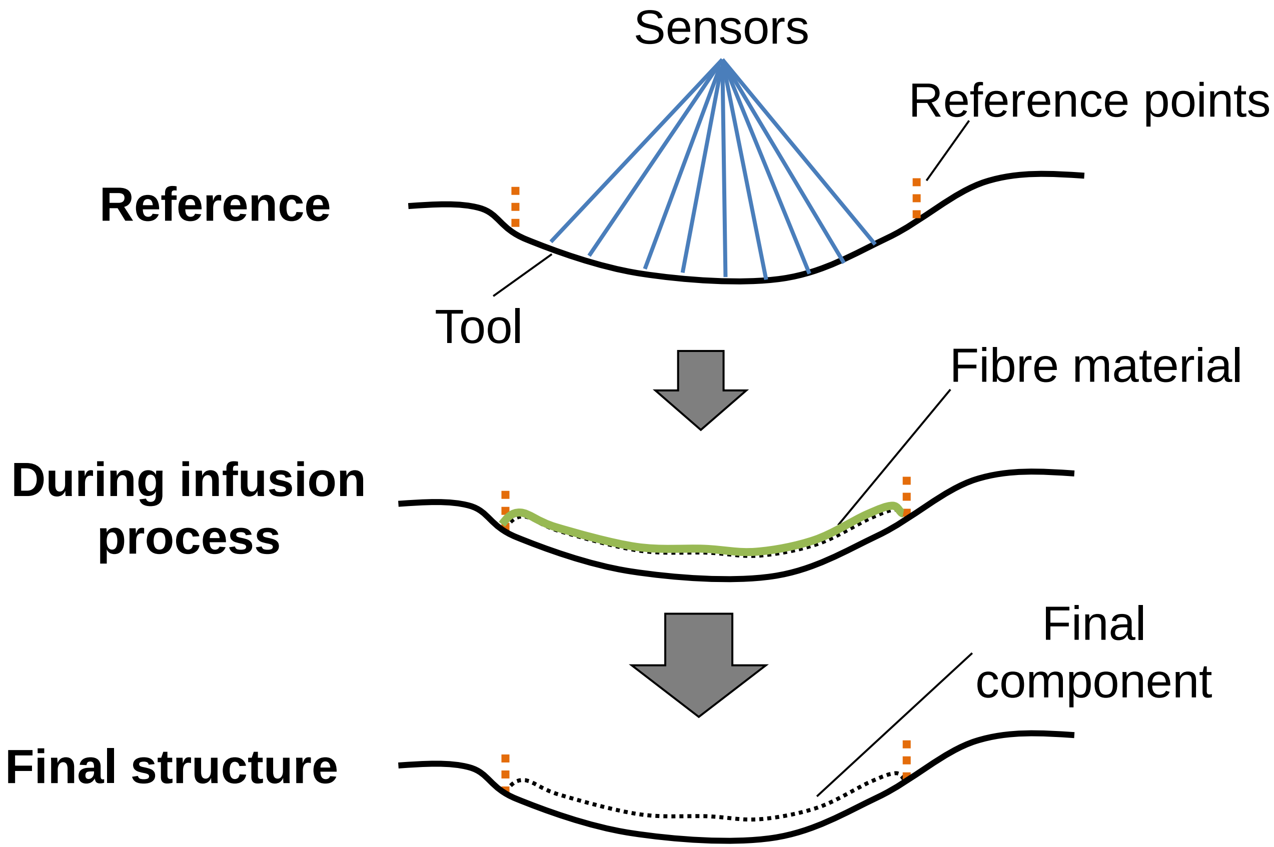
Sensors

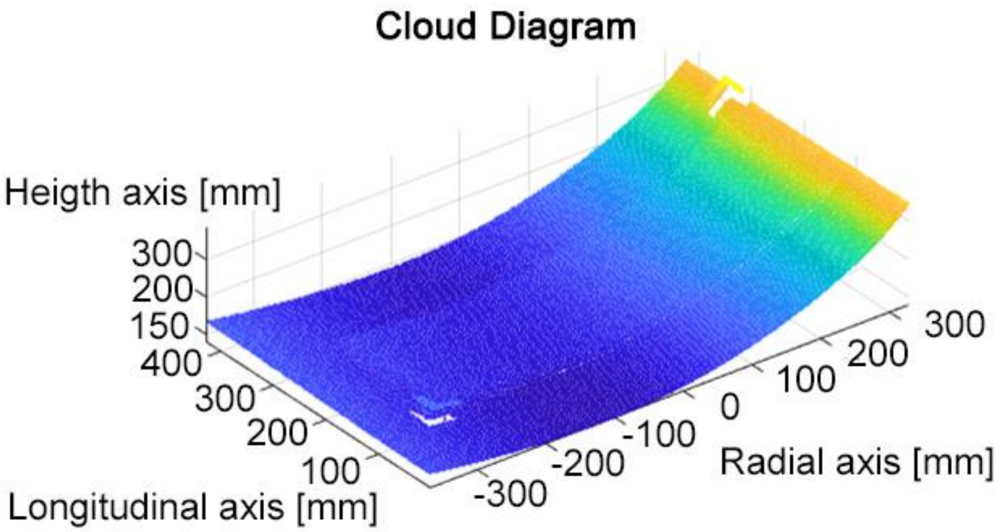
Measuring cell at DLR Stade



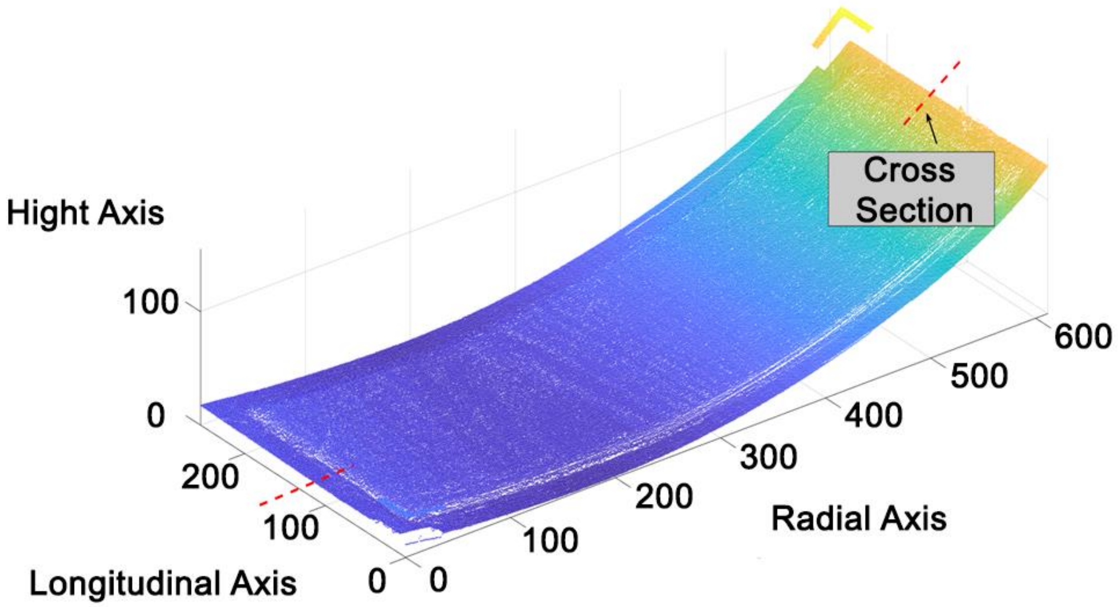
Monitoring with ultrasonic

Monitoring of blade manufacturing
Component thickness





Monitoring of blade manufacturing
Component thickness



3D scan of a section of a rotor blade tooling

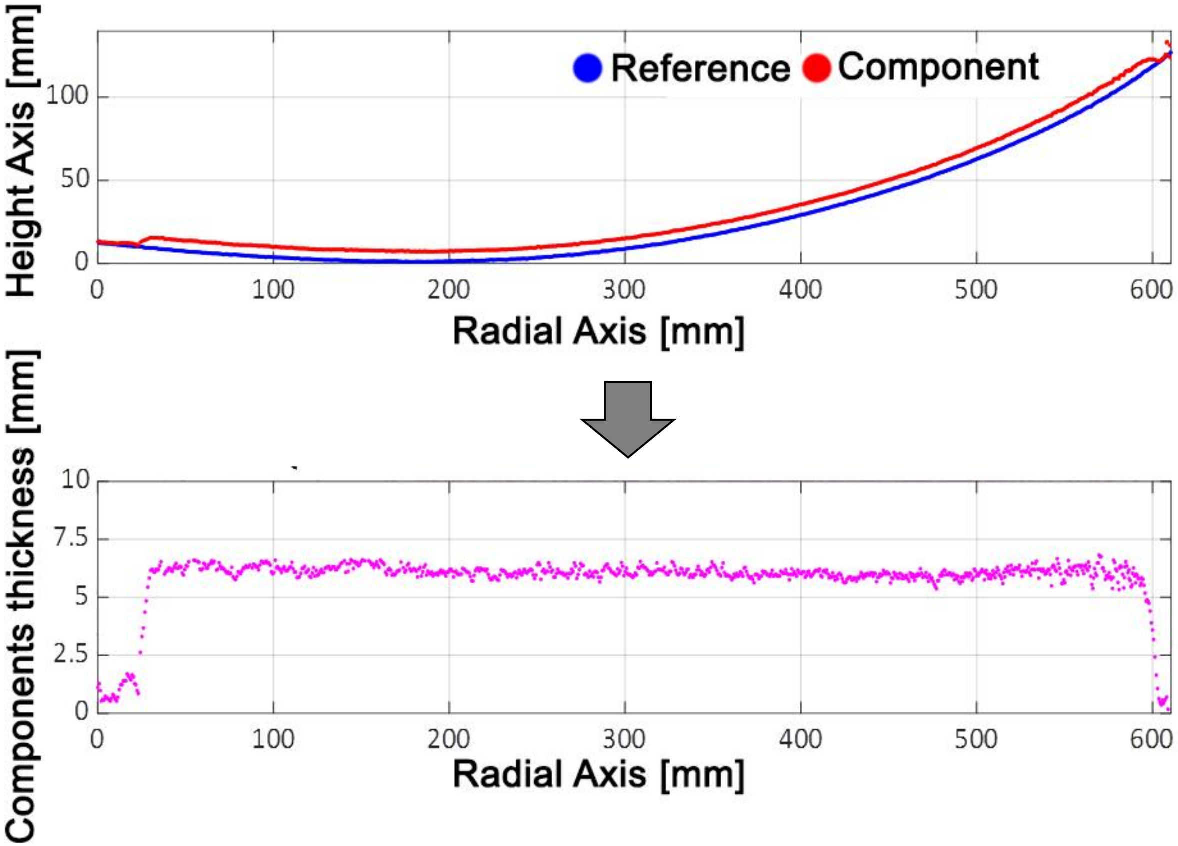


Illustration of cross section and calculation of component thickness

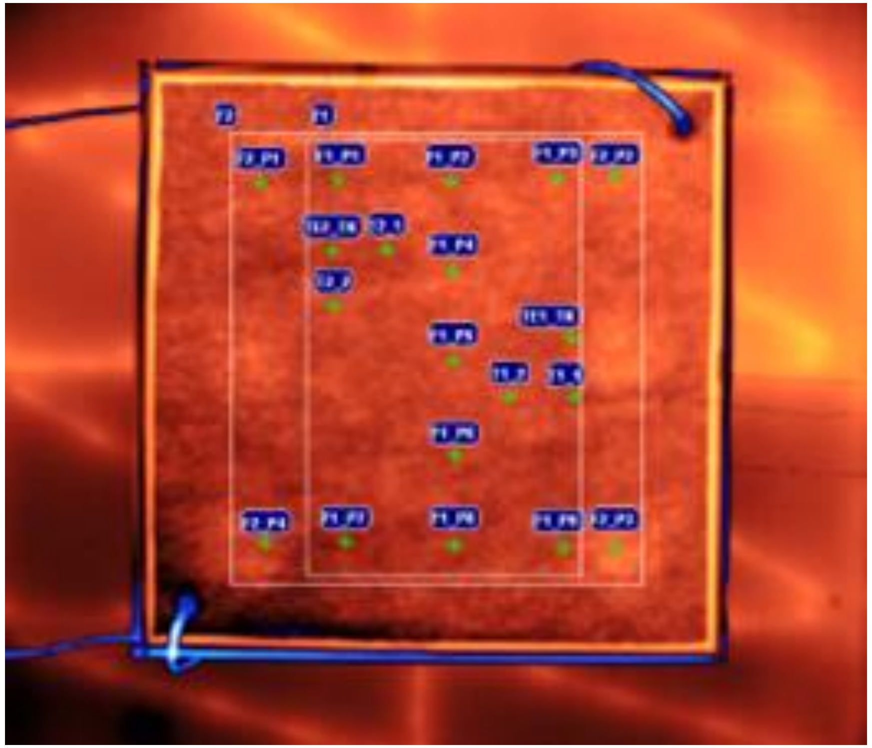
Monitoring of blade manufacturing
Thermographic system/ analysis

Thermographic system during manufacturing for monitoring and quality assurance

- Global temperature distribution
- Cold spot and Hot Spot
- Flow front progress

Leakage detection

- Detection of “cold spots”
- Necessary / possible intervention during process
- Avoid rejects

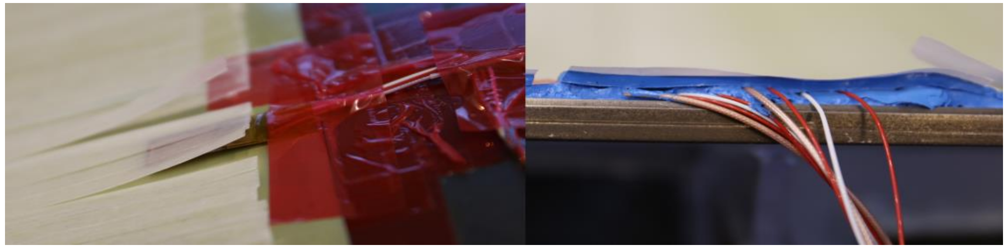


Thermographic leakage detection

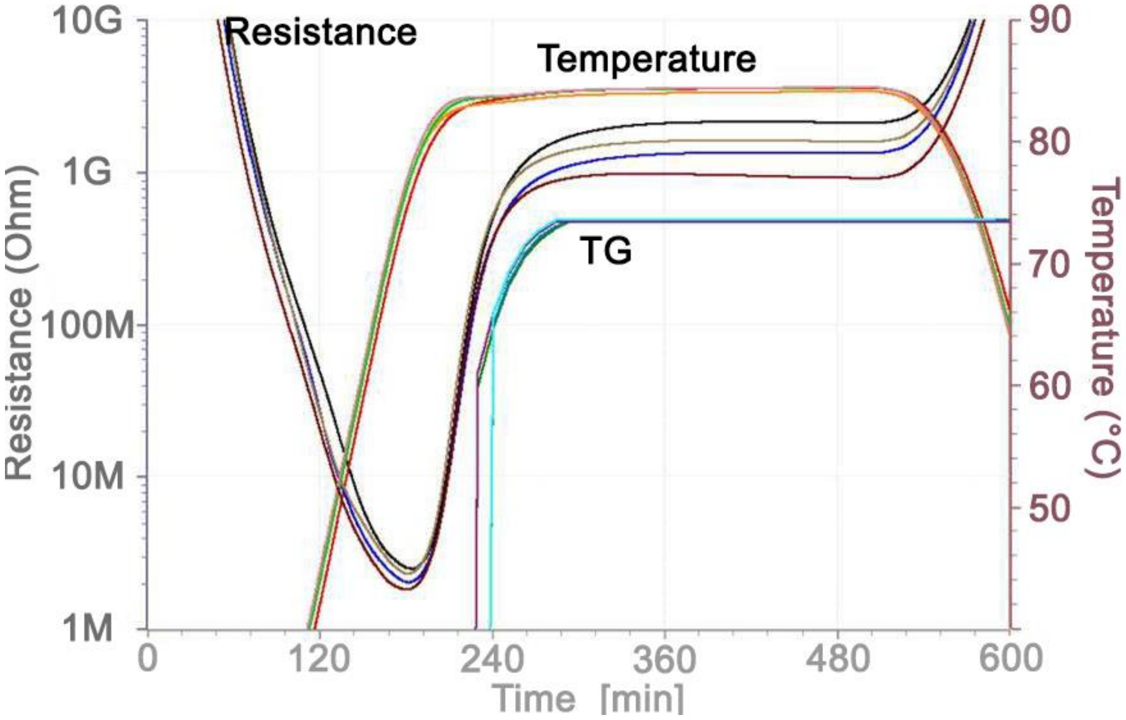
Monitoring of blade manufacturing
State of cure

Online quality control

- Detect degree of cure and temperature
- Quality assurance
- decrease curing time



Sensor integration during production



Evaluation of the sensors after testing

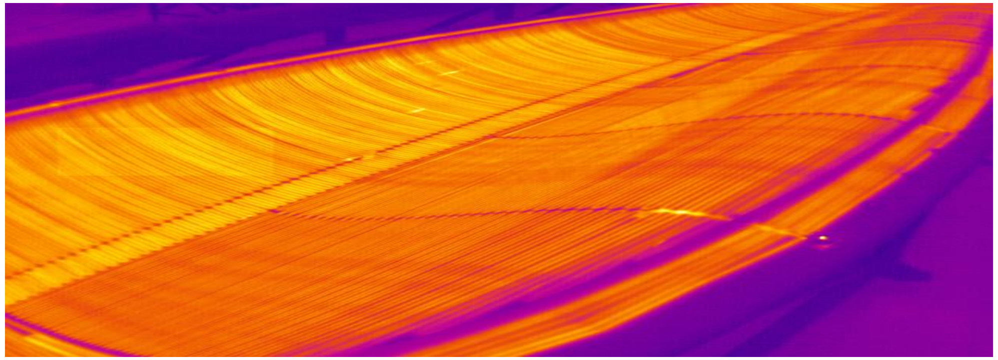
Monitoring of blade manufacturing
E.V.A.R. – capture and process

Data (Capture Handle Analyze React):
- Capture
- Archive / documentation
- Process

Sensor data

Measuring system:
- Recording process data based on different sensors
- Above/underneath
- Throughout the whole process

Control command



Thermographic monitoring

Information Manufacturing

Heating control:
- based on sensor data
- Based on EVAR evaluation

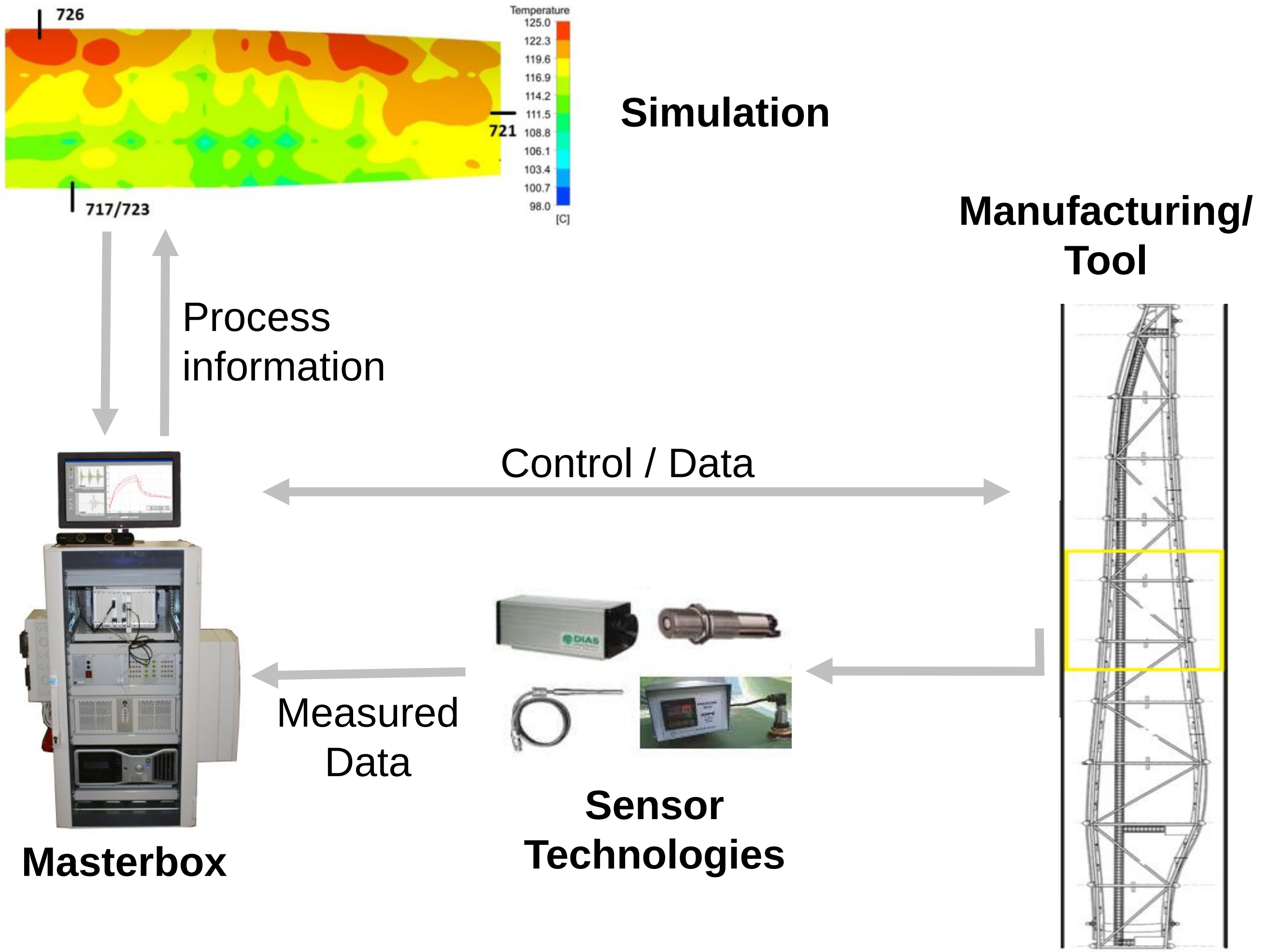
Change process parameter

Blade manufacturing
- Improve the process
- Avoid errors
- Rating the component

Motivation
Why we need industry 4.0?

Fiber reinforced plastics

- Essential material, uses in production
- Material advantages
- Complex production insufficient quality assurance
- Strong impact of degree of cure
- Large tolerances → long process times → cost intensive



Opportunities by using „Industry 4.0“

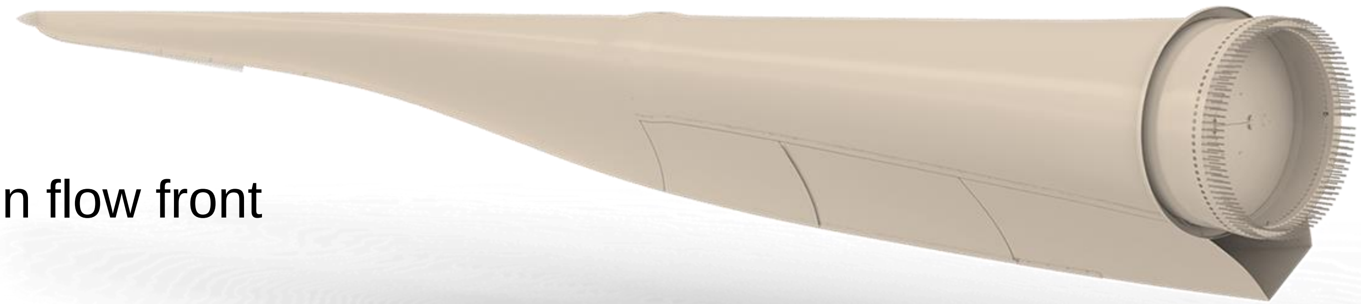
- Quality Assurance
- Cost reduction
- Low waste

Conclusion
Advantages of presented manufacturing methods

Reduction of production costs

- Less production waste
- Less curing time
- Less material use
- Lower wastage rate

- suitable sensors for specific measuring tasks
  - Data analyses
    - Sustainable infusion



- Active control of resin flow front and distribution
  - Create a basis with relevant data for new design generation

- Quality assurance and process control

Thank you for your attention!

We gratefully thank the Federal Ministry for Economic Affairs and Energy of Germany for funding the research activities in the project "DFWind"

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