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

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DLR – German Aerospace Center

Tasks
- 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“)

Publicly funded non-profit organisation
DLR – German Aerospace Center
Sites and Staff

- Approx. 8,500 employees
- 50 Institutes and Institutions
- More than 20 Sites

Institute of composite structures and Adaptive Systems
Center for Lightweight-Production-Technology (ZLP®) Stade in “CFK Nord”

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

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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)”
Classical infusion technology

- Infusion during rotor blade construction

Huge amount of waste

- flowmedia
- additional resin
- vacuum bag

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Infusion using resin sprues

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

→ 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
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
Monitoring of blade manufacturing
Component thickness

Reference
Tool

During infusion process
Fibre material

Final structure
Final component

Sensors
Reference points

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Monitors 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
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

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

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

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

Thermographic monitoring

Control command
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 $\rightarrow$ long process times $\rightarrow$ 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

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

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

- Quality assurance and process control
Thank you for your attention!

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