Projekt SmartBlade2 – ein innovatives DLR-Rotorblatt

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• Which tools and materials do we use?
• Construction strategy
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• How we monitor quality
• How we make it a blade
• Outlook
What has the German Aerospace Center (DLR) to do with rotor blades?

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“)
What has the German Aerospace Center (DLR) to do with rotor blades?
Center for Lightweight-Production-Technology Stade

- Production Technology
  - Single Components
  - Virtual Composite Product Development

- Fraunhofer IFAM
  - Assembly Technology
  - Joining Technology
  - Prototype Assembly

- DOPAG
  - Technology Development, Customer Service

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

Profile NTH

20,000 qm for cooperation and innovation
What has the German Aerospace Center (DLR) to do with rotor blades?
Center for Lightweight-Production-Technology Stade

• Run by Institute of Composite Structures and Adaptive Systems, Brunswick

**Automated Fiber Layup**
- Robot based Multi-Head Fiber Layup research platform
- Holistic simulation of technology and process
- Online quality assurance and control

**In- and Out-of-Autoclave Infusion Technology**
- Biggest Autoclave Laboratory Unit of the world
- Dynamic autoclave control
- Process simulation using a virtual autoclave
- Sensor development and integration for quality assured production

**Automated Textile Preforming and RTM Technology**
- Fully automated process chain as research platform
- Isothermal processing for productivity increase
- Process assessment using integrated sensors and process simulation

Research on rotor blade production
Why are we doing that?
Project Smart Blades 2
(Construction, Test and further Development of Intelligent Rotor Blades)

• Motivation
  • Reduction of wind energy production costs
  • Trend towards larger rotor blades valid for both, offshore and onshore areas: need to develop new actuation systems

• Problems
  • Inhomogeneous wind fields → Strong aero elastic loads
  • Own weight loads

• Solution approaches
  • Reduction of aerodynamic loads through the use of Smart Blades
  • Development of the necessary know-how & methods for an efficient system design
Why are we doing that?
Project Smart Blades 2

• Goals
  • Validation of the developed tools and models
  • Demonstration, wind tunnel tests and in field tests of the developed blades
  • Enabling of profitable utilization of the blades for the industry

• Contents
  • Investigation of three concepts:
    – Passive (bend-twist-coupling) (Technology 1)
    – Active trailing edge flaps (Technology 2)
    – Active leading edge flaps (Technology 3)
  • Further development of tools, models, methods and concepts
  • Improvement of the smart blades design
  • Manufacturing of the blades
  • Blade tests under real conditions

Further information: www.smartblades.info
Why are we doing that?
Project Smart Blades 2

Successful only with partners

- DLR
- ForWind: Uni OL, Uni H
- Fraunhofer – IWES
- Industry: GE, Henkel, Nordex, Senvion, SSB Wind Systems, WRD Enercon, Suzlon

- Duration: 01.06.16 – 30.09.19
- Overall Budget: 15.4 MEuro

Supported by:

- Federal Ministry for Economic Affairs and Energy
- on the basis of a decision by the German Bundestag
What are we constructing?
Technology 1: blade design and specification

- General data of the blade
  - diameter of the rotor: 41.61 m
  - nominal rotational speed: 37.1 rpm
  - Length of rotor blade: 19.99 m
  - Maximum chord length: 2.38 m
  - Max. pre-bend: 1 m
  - Surface of main shell: 69.8 m²

- Blade mass
  - Fiber mass (dry): 889.5 kg
  - Infusion Resin: 579.3 kg
  - Bonding Resin: 44 kg
  - Other materials (e.g. Foam): 80.5 kg
  - Extra masses (e.g. Sensors): 123.4 kg
  - Total mass of the blade: 1716.8 kg
Which tools and materials do we use?
The Smart Blades 2 - mold

- Electrically heated GFRP mold manufactured by Sinoi GmbH

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Suction side</th>
<th>Pressure side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>c. 21 m</td>
<td>c. 21.3 m</td>
</tr>
<tr>
<td>Width</td>
<td>c. 3 m</td>
<td>c. 3 m</td>
</tr>
<tr>
<td>Height</td>
<td>c. 1.8 m</td>
<td>c. 1.6 m</td>
</tr>
<tr>
<td>Weight</td>
<td>c. 4.4 t</td>
<td>c. 5.3 t</td>
</tr>
<tr>
<td>Electrical heating</td>
<td>21 heating units</td>
<td>21 heating units</td>
</tr>
</tbody>
</table>

Distribution of heating units
Which tools and materials do we use?
Periphery and materials

- Infusion system: DOPAG Compomix
  - → loan from DOPAG

- Adhesive metering system: DOPAG
  - → loan from DOPAG

- Technical Support in operation and production of the blade (infusion and bonding) by DOPAG

- Materials
  - Resin System: Olin Airstone 880 kindly supported by Olin
  - Bonding Resin: Sika WTG 1280-1050 kindly supported by Sika
  - Glass fiber material: Saertex (different uniaxial, biaxial and triaxial NCF)
  - Airex C70-55 foam supplied by Gaugler & Lutz
Construction strategy
Prefab components

Flange inserts

108 plies
Thickness: >90 mm

Spar caps

Thickness: >25 mm
How we do it!
Prefab of flange insert

- Preparation
  - Pre-cut of the plies with a CNC Cutter
  - Coating the surface with a suitable release agent
  - Integration of a stop bar at the root point of the blade to assure an accurate ply placement
  - Integration of mold mounting device to assure an optimal fiber orientation at the connection point (PS/SS)
How we do it!
Prefab of flange insert

• Manufacturing
  • Ply lay-up (108 layers)
  • Infusion build-up
  • Vacuum build-up
  • Infusion
  • Curing process
  • Demolding an trimming

FVC : +/- 55%
How we do it!
Prefab of spar cap

- Preparation
  - Coating of surface with a suitable release agent
  - Integration of a dummy flange insert to ensure the correct shape of the spar cap
  - Lay-up and fixing of flow aid, perforated release film and peel ply for the infusion
  - Integration and fixation of balsa slopes
  - Pre-cutting of individual layers

moisture measurement on balsa slope
How we do it!
Prefab of spar cap

• Manufacturing
  • Ply Lay-up (35 layers) between balsa slopes
  • Infusion build-up with semi-permeable membrane (VAP)
  • Vacuum bagging
  • Infusion and Curing
  • Demolding

FVC : +/- 55%
How we do it!
Prefab of blade spar

- Manufacturing concept
  - Two-piece manufacturing of blade spar using sandwich panels
  - Manufacturing of milling templates for a precise blade spar contour
  - Milling the individual parts with an overhead template router using the mill templates
  - Joining of the two spar parts with additional laminate
  - Manufacturing of bonding flanges (T-spar) in the blade mold during the bonding process by hand lamination
How we do it!
Prefab of blade spar

• Manufacturing of sandwich panels for the blade spar
  • Coating of tool surface with a suitable release agent and a separating foil
  • Lay-up and fixation of flow aid, perforated release film and peel ply for the infusion
• Lay-up of the laminate
  1. Two plies Biax +/-45°
  2. Airex C70-55 foam
  3. Two plies Biax +/-45°
• Lay-up and fixation of peel ply, perforated release film and flow aid for the infusion
• Vacuum bagging
• Infusion
• Curing in Autoclave (Oven)
• Demolding and contour milling
How we do it!

Shell manufacturing

• Preparation
  • Coating of mold surface with a suitable release agent
  • Integration and fixation of mold mounting devices to manufacture the glue flaps (building with the shell laminate)
How we do it!
Shell manufacturing

- Manufacturing
  - Integration of the flange insert (Prefab) in the mold
  - Lay-up of the outer laminate with a depositing device
How we do it!
Shell manufacturing

- Manufacturing
  - Positioning of flange insert (Prefab) inside the mold
  - Lay-up of the outer laminate
  - Integration and positioning of the spar cap (Prefab) using shape templates
How we do it!
Shell manufacturing

- Manufacturing
  - Positioning of flange insert (Prefab) inside the mold
  - Lay-up of the outer laminate
  - Integration and positioning of the spar cap (Prefab) using shape templates
  - Integration of foam and balsa core material
How we do it!
Shell manufacturing

- Manufacturing
  - Positioning of flange insert (Prefab) inside the mold
  - Lay-up of outer laminate
  - Integration and positioning of the spar cap (Prefab) using shape templates
  - Integration of foam and balsa core material
  - Lay-up of inner laminate
How we do it!
Shell manufacturing

- Manufacturing
  - Positioning of flange insert (Prefab) inside the mold
  - Lay-up of outer laminate
  - Integration and positioning of the spar cap (Prefab) using shape templates
  - Integration of foam and balsa core material
  - Lay-up of inner laminate
  - Resin infusion and curing
How we do it!
Shell manufacturing

- Manufacturing
  - Positioning of flange insert (Prefab) inside the mold
  - Lay-up of outer laminate
  - Integration and positioning of the spar cap (Prefab) using shape templates
  - Integration of foam and balsa core material
  - Lay-up of inner laminate
  - Resin infusion and curing
  - Integration of blade spar
How we monitor quality

Sensors

Monitoring of:
- Global temperature distribution
- Flow front detection
- Leakage detection
- State of cure
- Component thickness

How to monitor?
- Optical cameras
- Thermographic cameras
- Temperature sensors
- Ultrasonic sensors

Prototype of movable measuring cell for rotor blade construction
How we monitor quality
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 controllable heating
  - Ultrasonic piezo ceramics
    - Detection of resin arrival
    - Degree of cure
  - Thermographic elements
How we monitor quality
E.V.A.R. – capture and process

- Data (EVAR):
  - 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

Sensor data

Monitoring of heat distribution during curing

Change process parameter

Control command

Manufacturing Information
How we make it a blade
Sensor integration

- Integration of sensors to measure the deformation of the blade
- Resistance strain gauge by IWES
- Torsion sensor by DLR
- Blade Vision System by SSB
How we make it a blade
Bonding of shells

- Preparation and manufacturing
  - execution of a „dry-fit“ to measure the thickness of the glue gap using dough instead of bonding resin
How we make it a blade
Bonding of shells

- Preparation and manufacturing
  - execution of a „dry-fit“ to measure the thickness of the glue gap using dough instead of bonding resin
  - Removing of peel ply, application of glue, check and adjustment of glue gap
How we make it a blade
Bonding of shells

- Preparation and manufacturing
  - execution of a "dry-fit" to measure the thickness of the glue gap using dough instead of bonding resin
  - Removing of peel ply, application of glue, check and adjustment of glue gap
  - closing of molds and integration of doubling laminate
  - Curing at 70°C for 12 h (tool heating supported by a fan heater)
How we make it a blade
Demolding
Testing

• The load-bearing capacity of the rotor blade was tested under extreme loads and under normal operating conditions on a test rig at the Fraunhofer IWES in Bremerhaven

• Innovative vibration test on the blades
  • deformations can be recorded with millimetre accuracy and material stresses analysed
  • Five hundred sensors measure the structural dynamics directly on the rotor blade
Installation and putting into service

Source: NREL
Special thanks to:

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Thank you for your attention!