Projekt SmartBlade2 – ein innovatives DLR-Rotorblatt

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Sitzung des AG FVW in der Windenergie
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- Why are we doing that?
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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

DLR

- ProductionTechnology Single Components
- Virtual Composite Product Development

Fraunhofer IFAM

- Assembly Technology
- Joining Technology
- Prototype Assembly

DOPAG Process Technologies

- Technology Development, Customer Service

Olin

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

Profile NTH

Technische Universität Carolo-Wilhelmina zu Braunschweig

TU Clausthal

Leibniz Universität Hannover

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

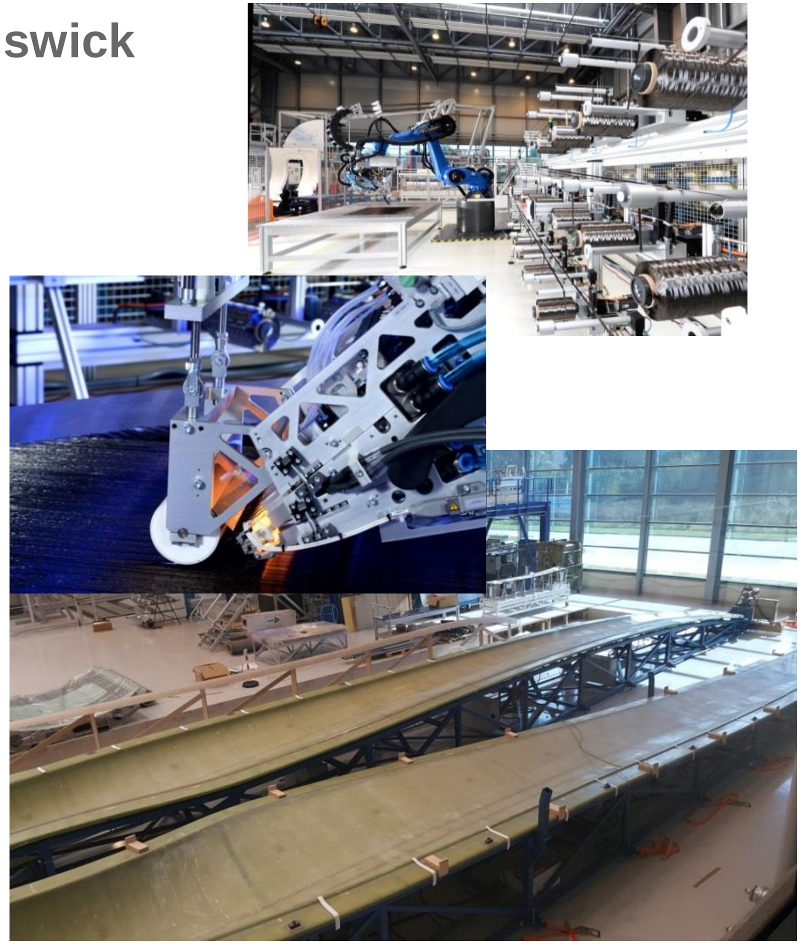
- Robot based Multi-Head Fiber Layup research platform
- Holistic simulation of technology and process
- Online quality assurance and control

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

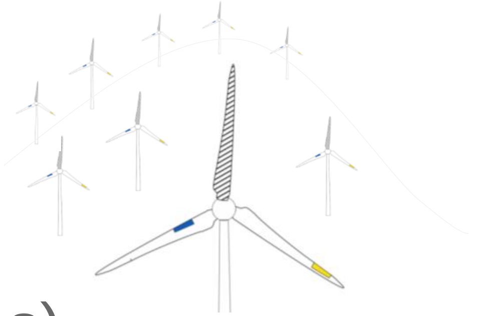
Automated Textile Preforming and RTM Technology

- 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

DLR

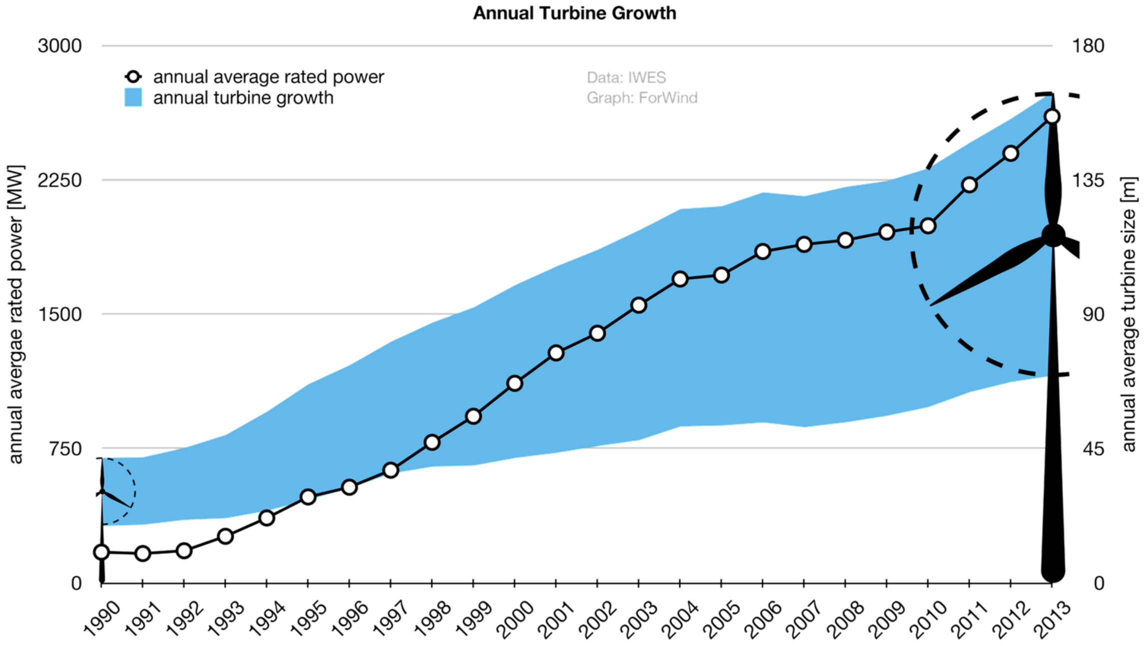


Why are we doing that?

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

DLR

ForWind

IWES

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

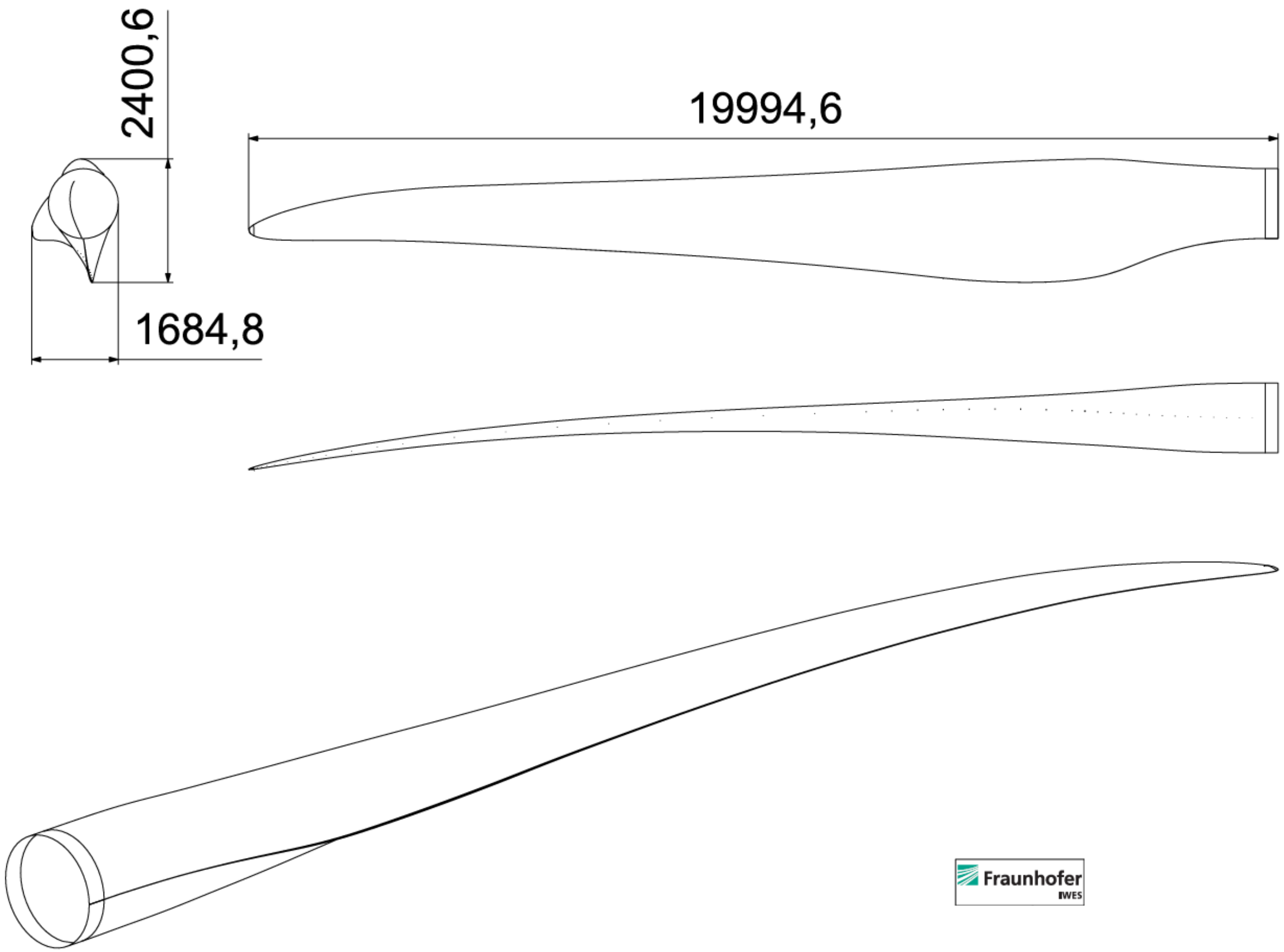
What are we constructing?
Technology 1: blade design and specification

- 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

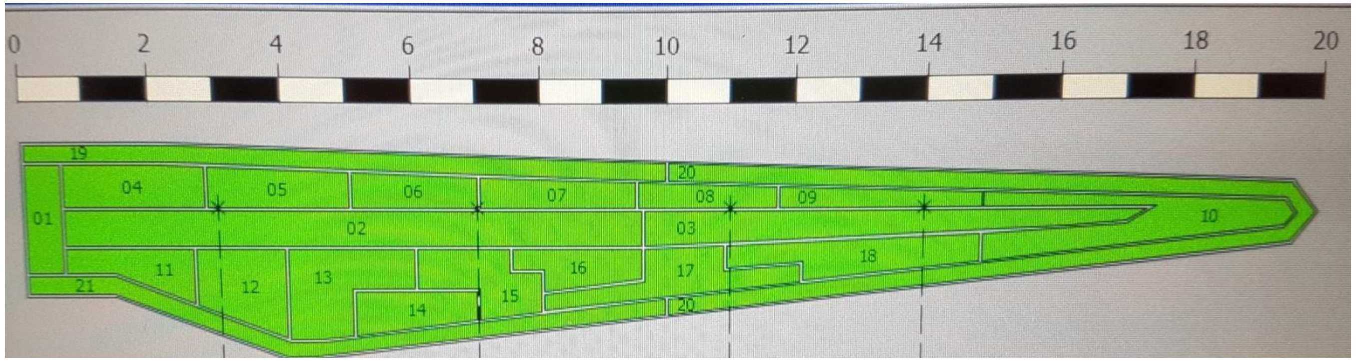
• Fiber mass (dry)	**889,5 kg**
• Infusion Resin	**579,3 kg**
• Bonding Resin	**44 kg**
• Other materials (e.g. Foam)	**80,5 kg**
• Extra masses (e.g. Sensors)	**123,4 kg**
• Total mass of the blade	**1716,8 kg**



Which tools and materials do we use?
The Smart Blades 2 - mold

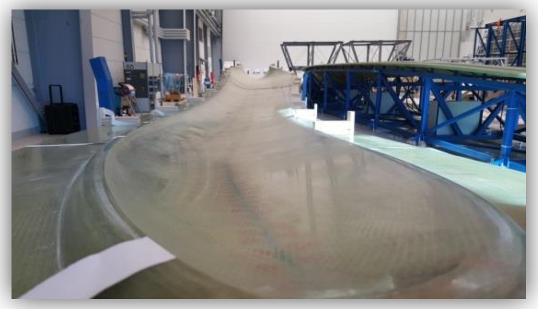
- Electrically heated GFRP mold manufactured by Sinoi GmbH

Parameter	Suction side	Pressure side
Length	c. 21 m	c. 21,3 m
Width	c. 3 m	c. 3 m
Hight	c. 1,8 m	c. 1,6 m
Weight	c. 4,4 t	c. 5,3 t
Electrical heating	21 heating units	21 heating units



Distribution of heating units


Root end


Tip end

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

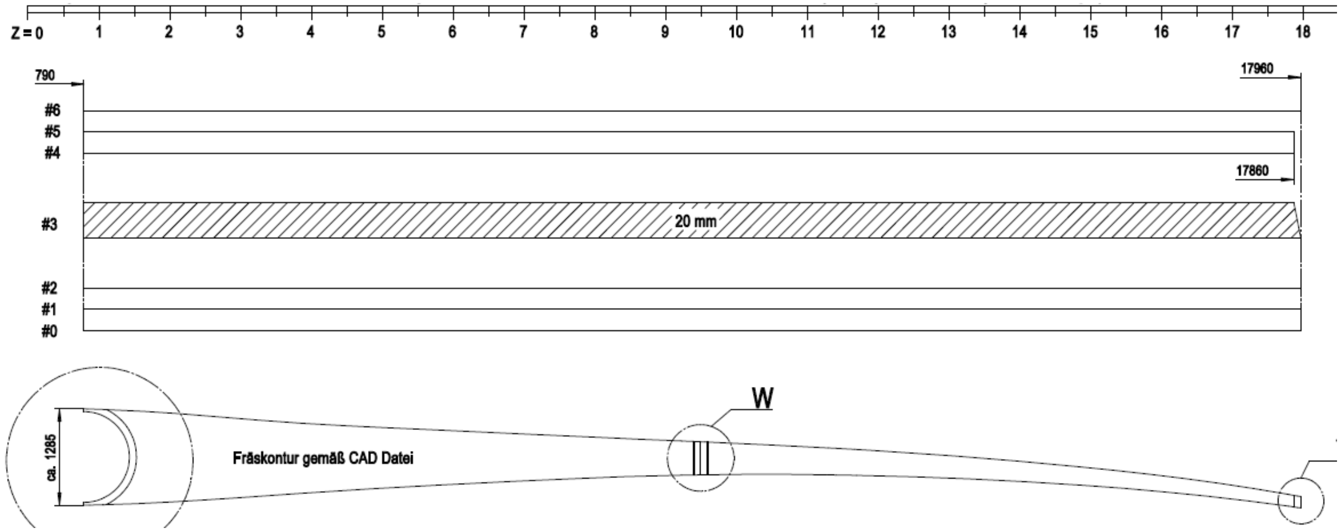
- Materials
  - Resin System: Olin Airstone 880 kindly supported by Olin
  - Bonding Resin: Sika WTG 1280- 1050 kindly supported by Sika
  - Glass fiber material: Saertex (different uniaxial, biaxial and triaxial NCF)
  - Airex C70-55 foam supplied by Gaugler & Lutz

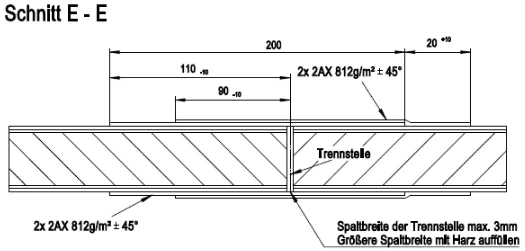
DOPAG Infusion system


DOPAG Adhesive system

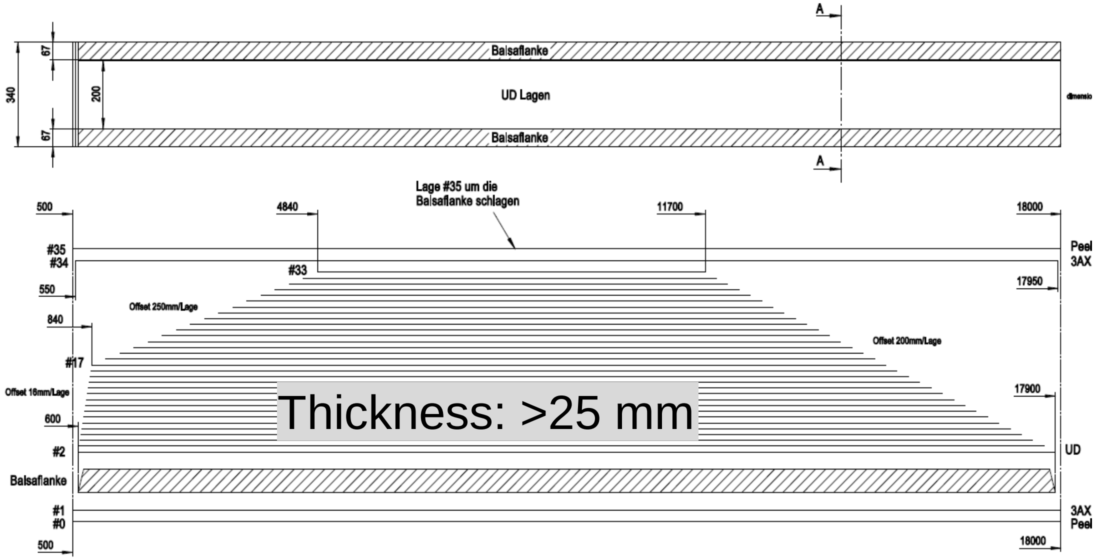
Construction strategy
Prefab components

Spars



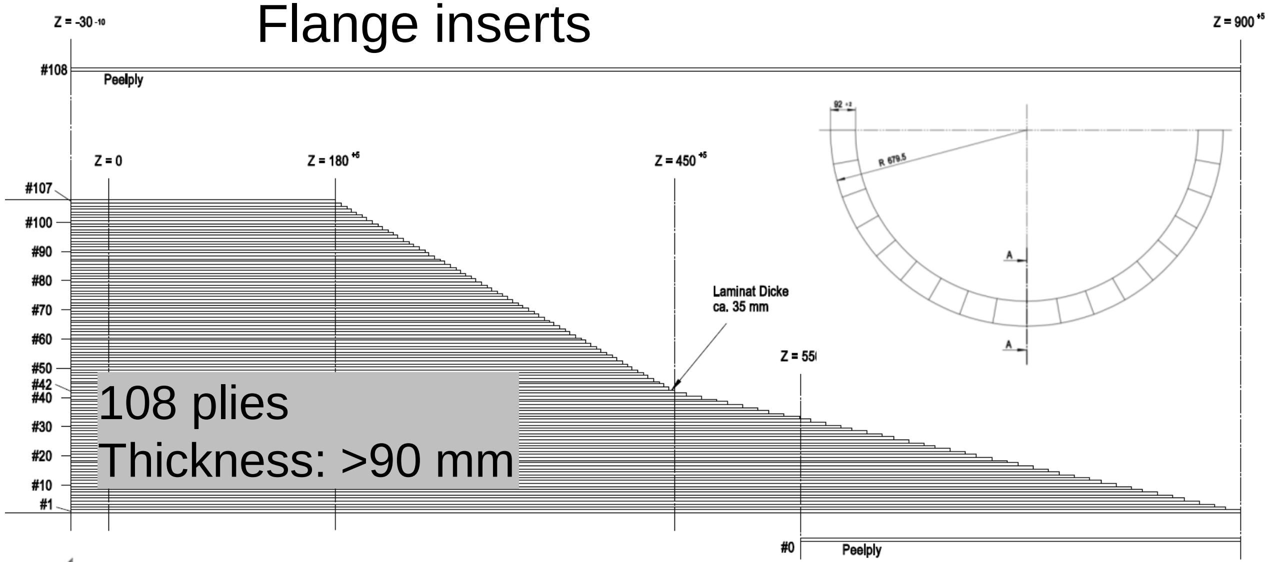


Spar caps



Thickness: >25 mm

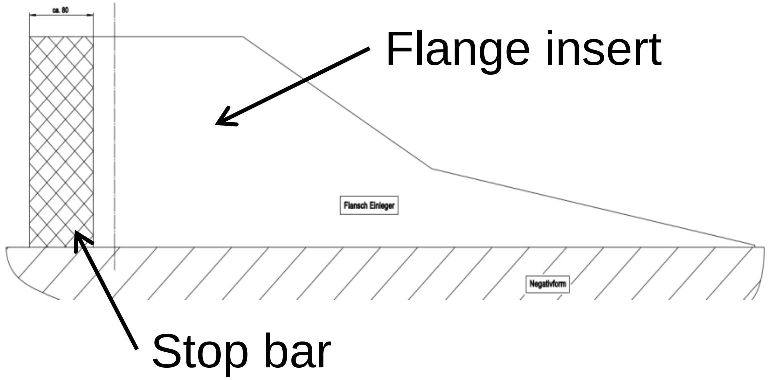
Flange inserts

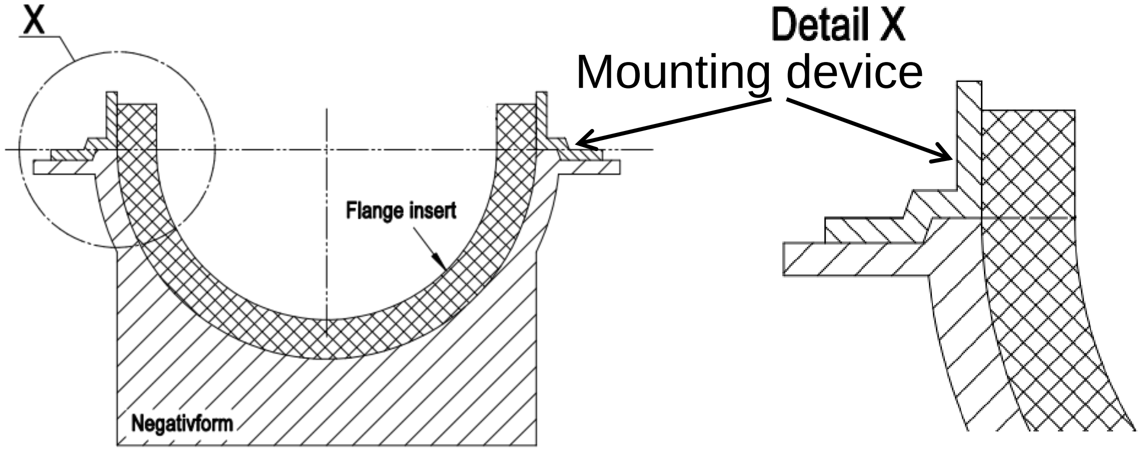


108 plies
Thickness: >90 mm

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)

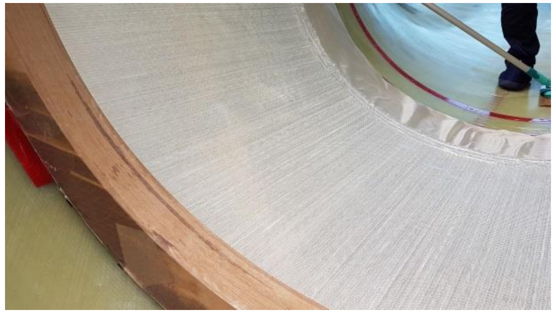


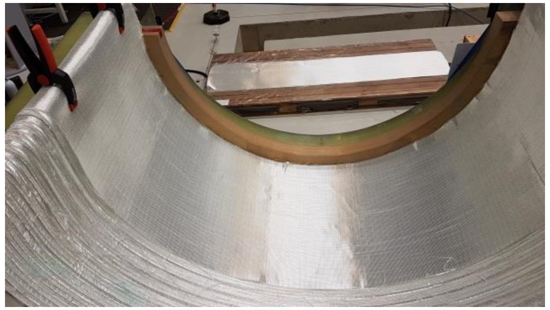


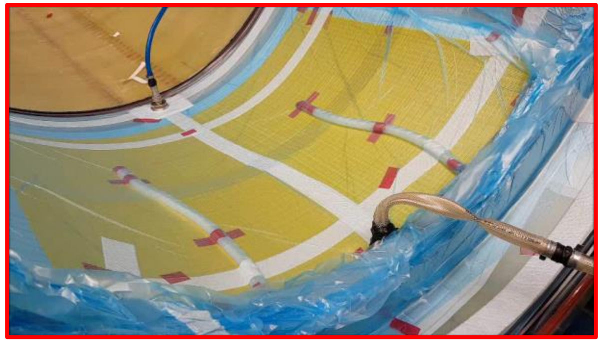
How we do it!
Prefab of flange insert

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

FVC : +/- 55%







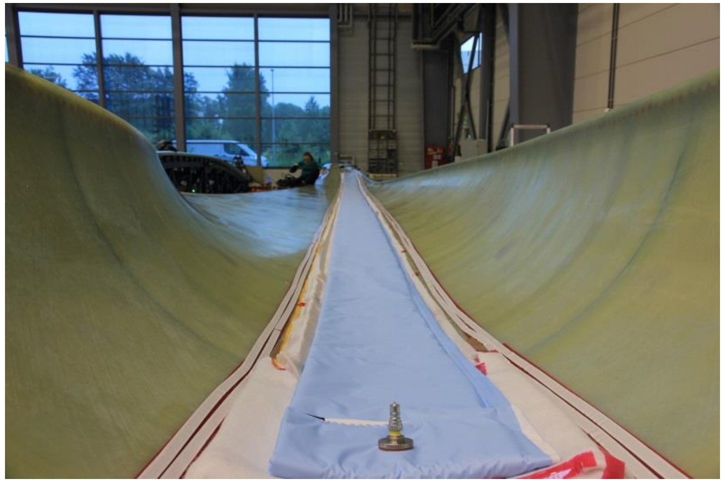
How we do it!
Prefab of spar cap

- 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

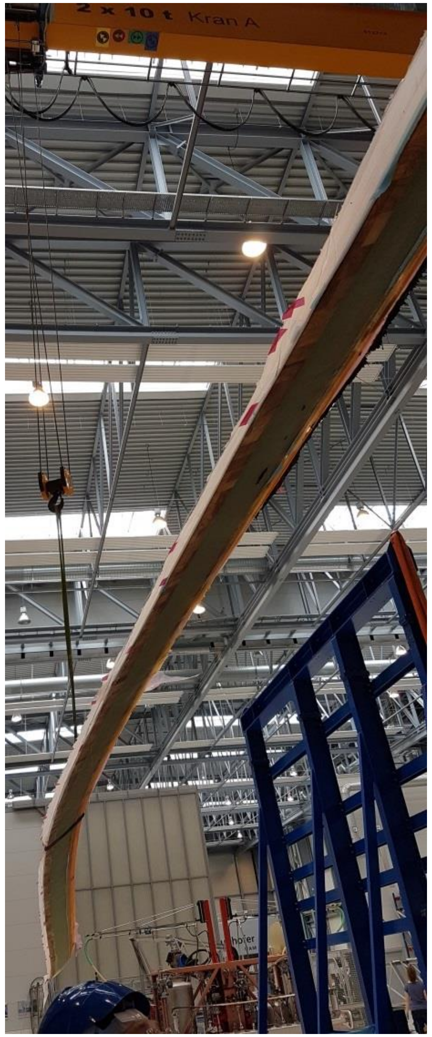
moisture measurement on balsa slope

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

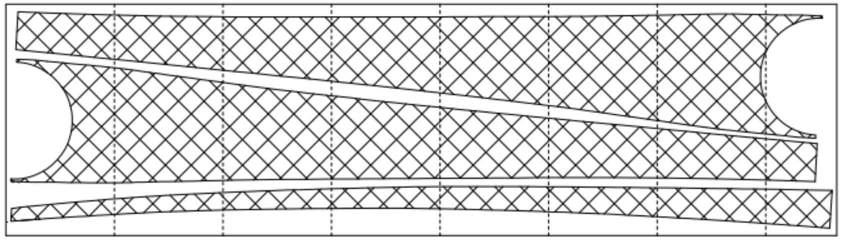


FVC : +/- 55%

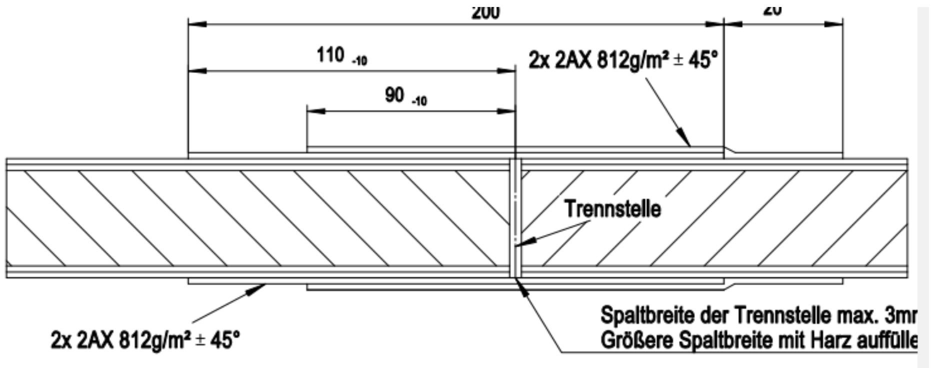


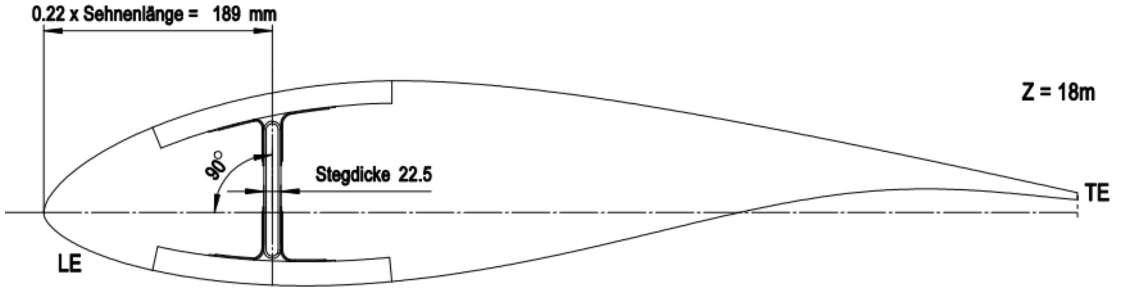
How we do it!
Prefab of blade spar

- 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



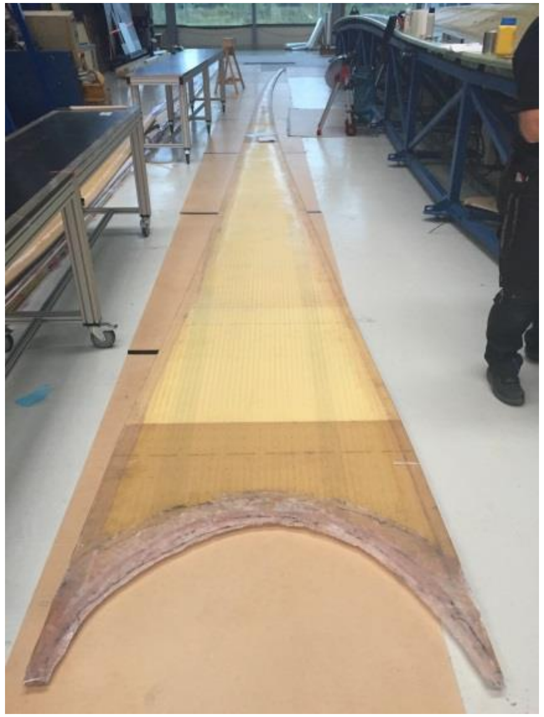
Milling pattern for sandwich panel



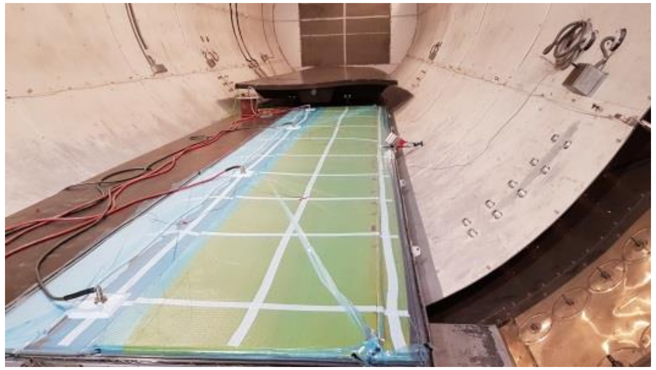


How we do it!
Prefab of blade spar

- 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

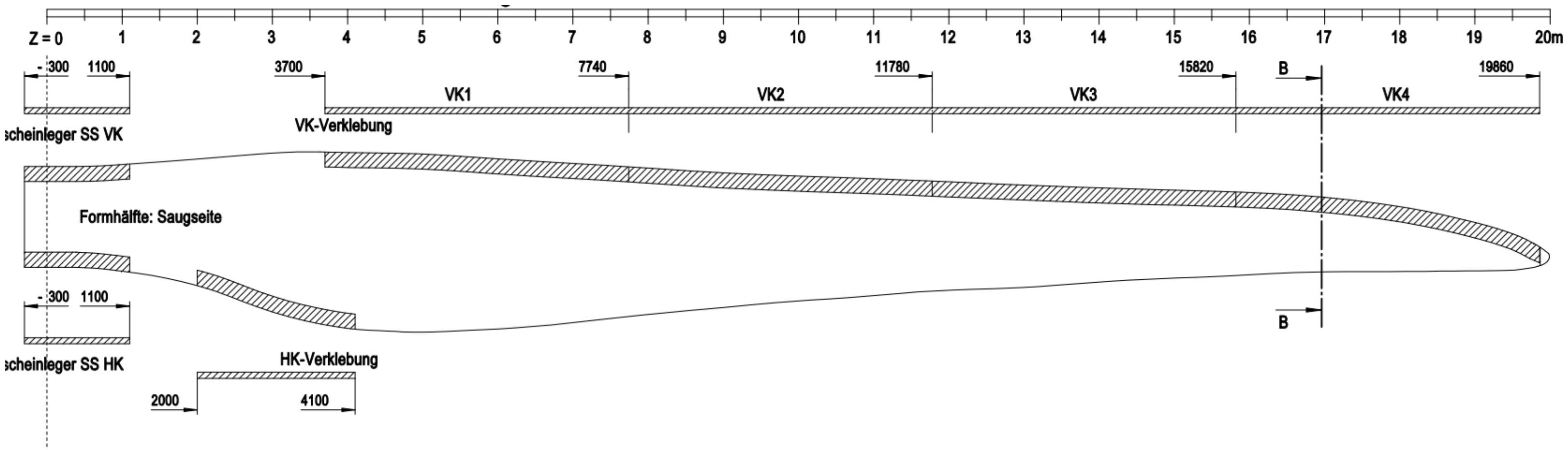

Finalized spar

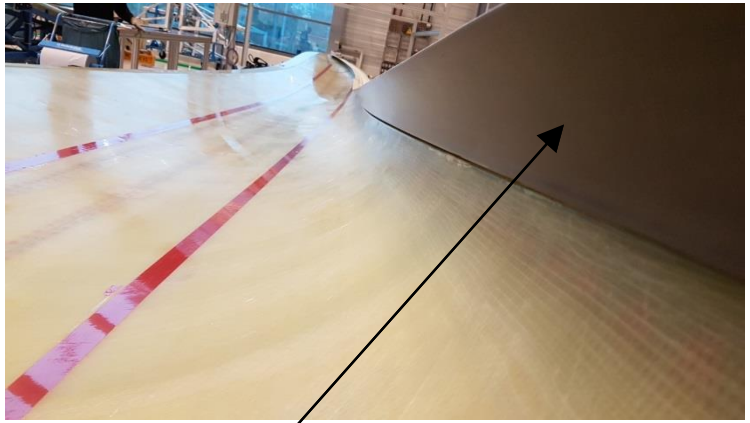

Resin infusion


Curing in oven

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)





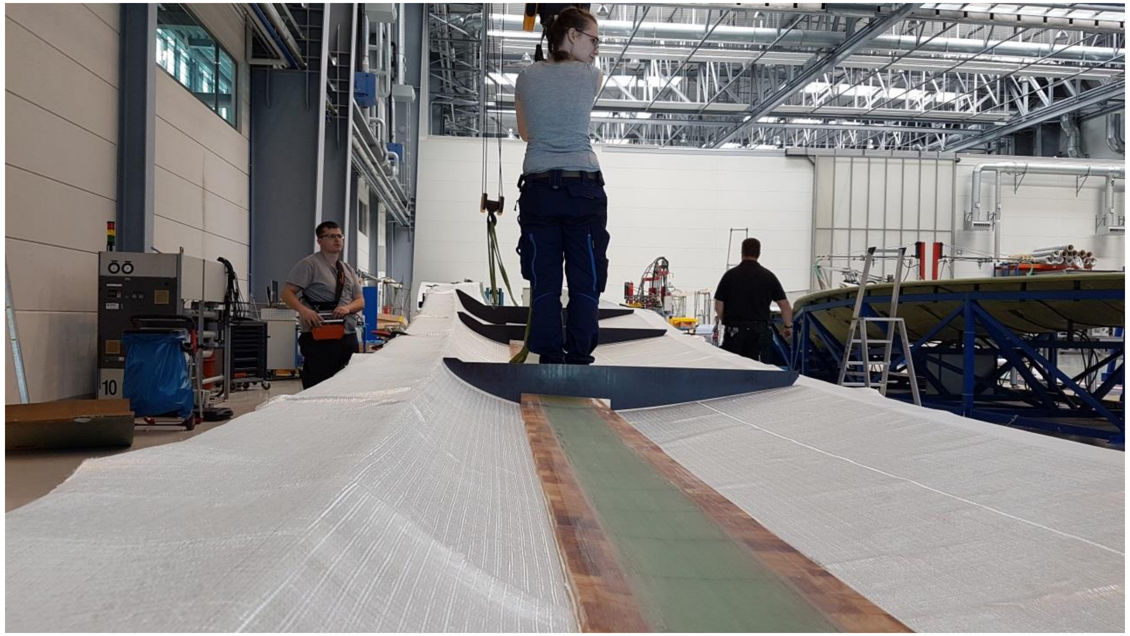
Glue flaps

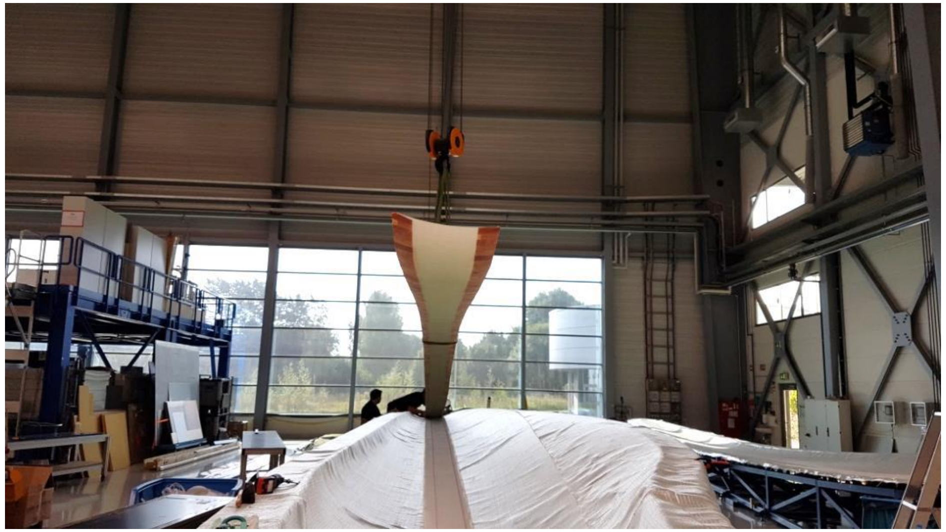
How we do it!
Shell manufacturing

- 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

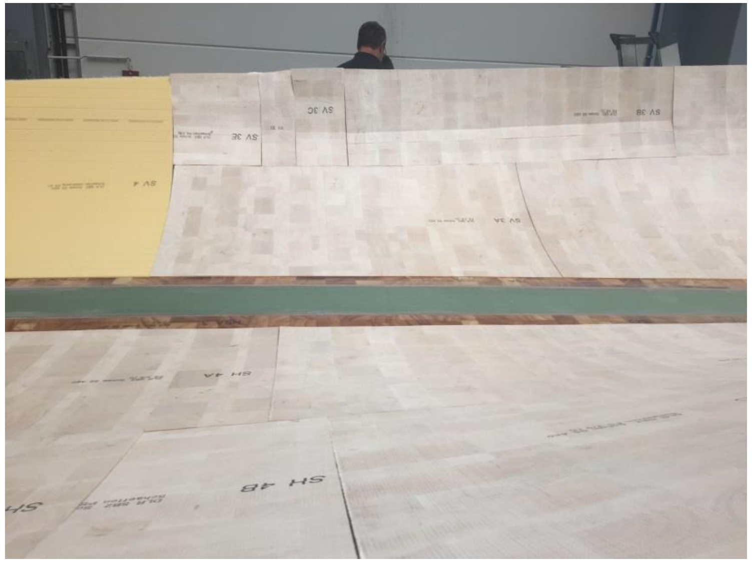
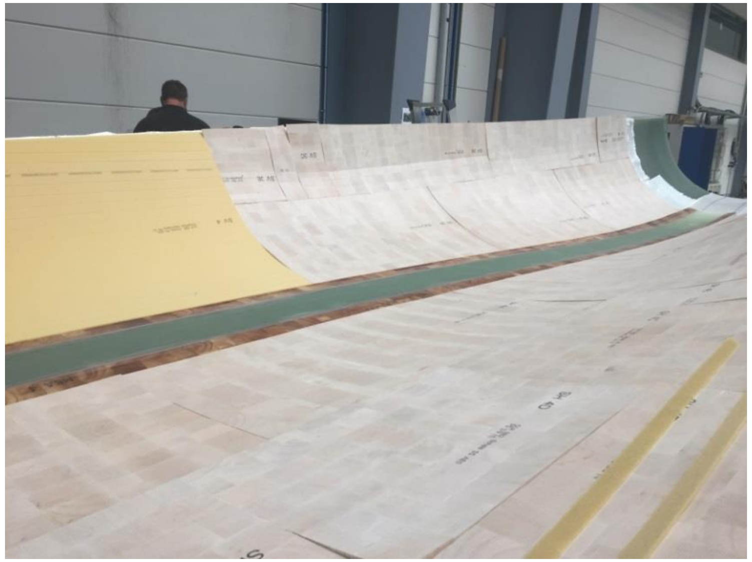
- Manufacturing
  - Positioning of flange insert (Prefab) inside the mold
  - Lay-up of the outer laminate
  - Integration and positioning of the spar cap (Prefab) using shape templates





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

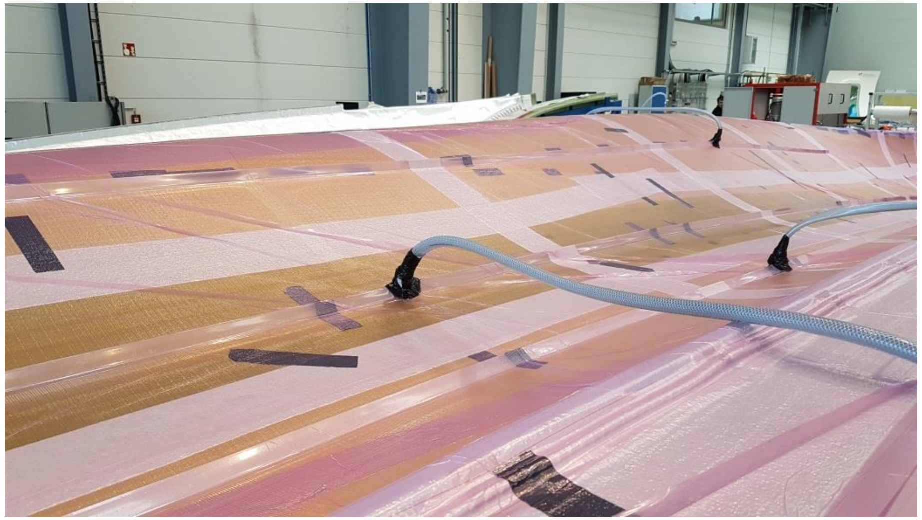



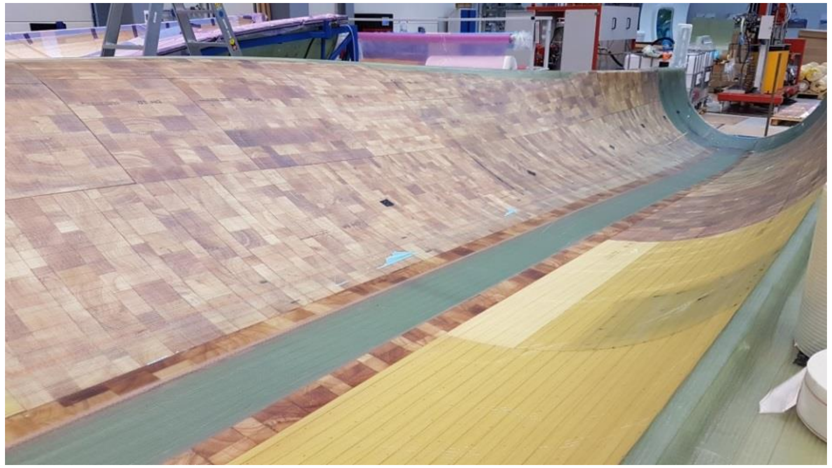

How we do it!
Shell manufacturing

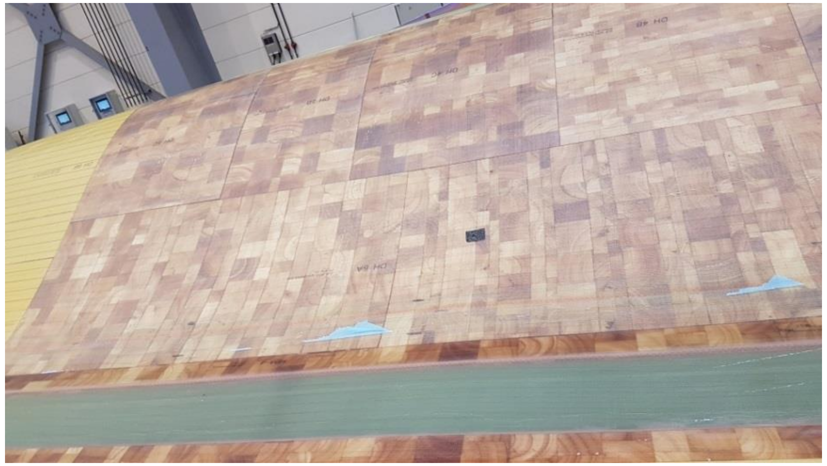
- Manufacturing
  - Positioning of flange insert (Prefab) inside the mold
  - Lay-up of outer laminate
  - Integration and positioning of the spar cap (Prefab) using shape templates
  - Integration of foam and balsa core material
  - Lay-up of inner laminate

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

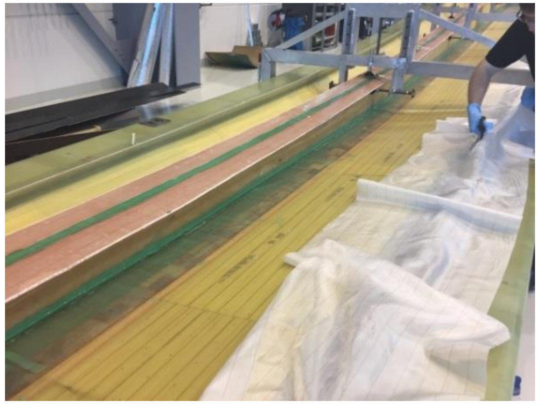


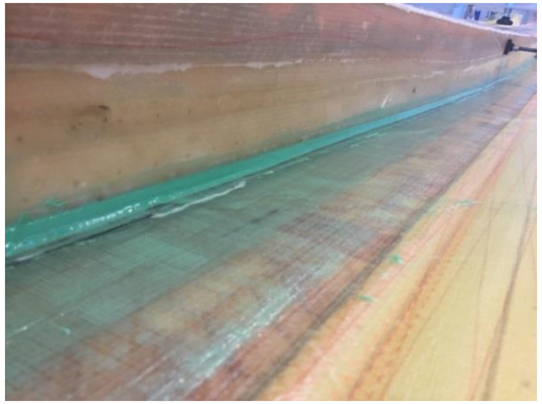




How we do it!
Shell manufacturing

- 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

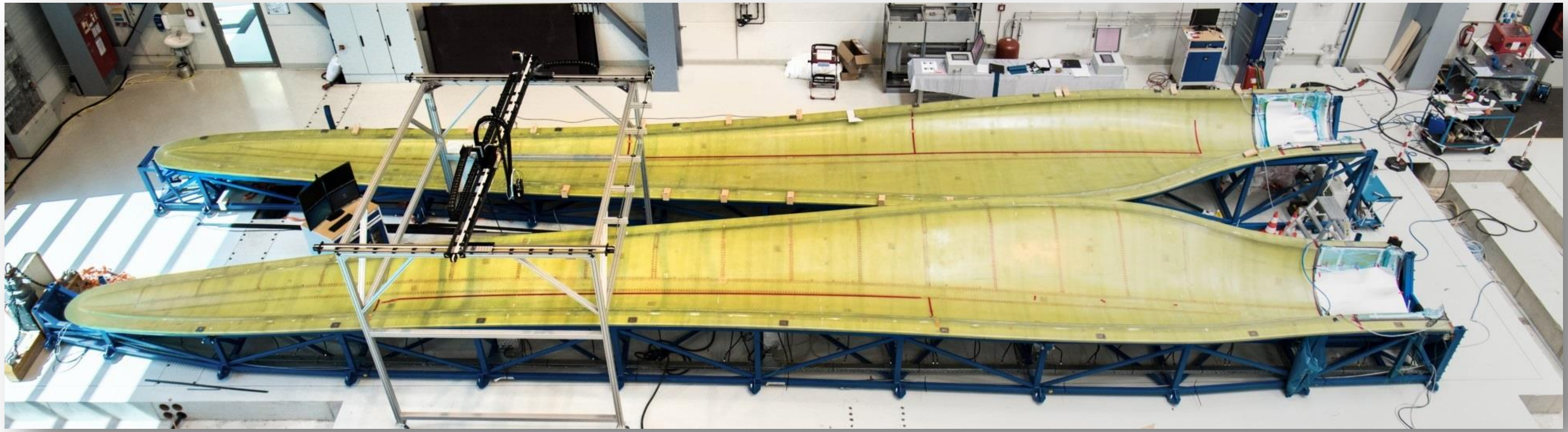




How we monitor quality
Sensors

- **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

Measuring cell

Manufacturing Tooling

Sensors

Fig. 2: Measuring cell at DLR Stade

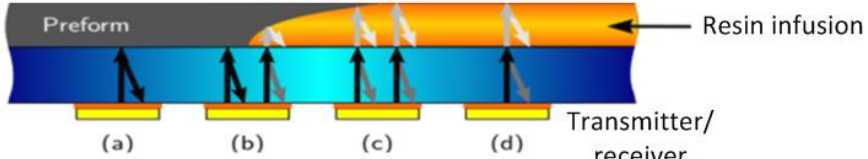


Fig. 3: Monitoring with ultrasonic

How we monitor quality
E.V.A.R. – capture and process

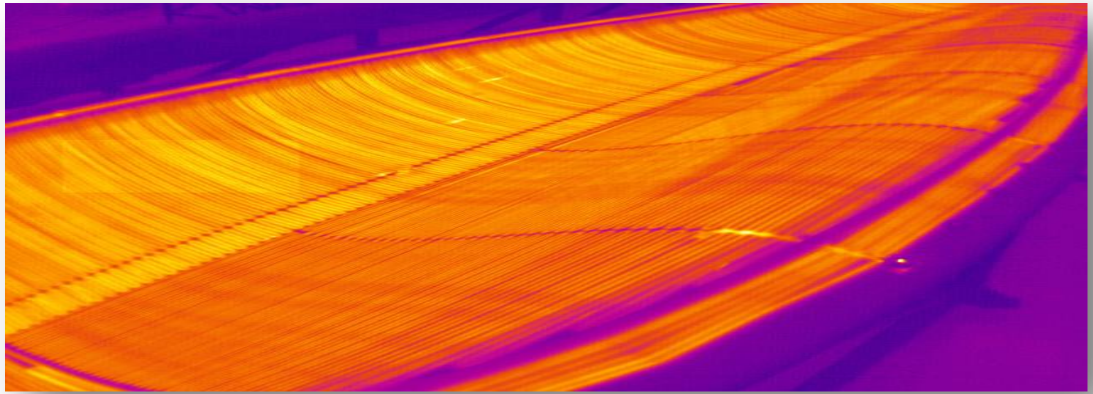
- Data (EVAR):
  - Capture
  - Archive/ documentation
  - Process

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

Sensor data

Control command

Manufacturing Information



Monitoring of heat distribution during curing

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

Change process parameter

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

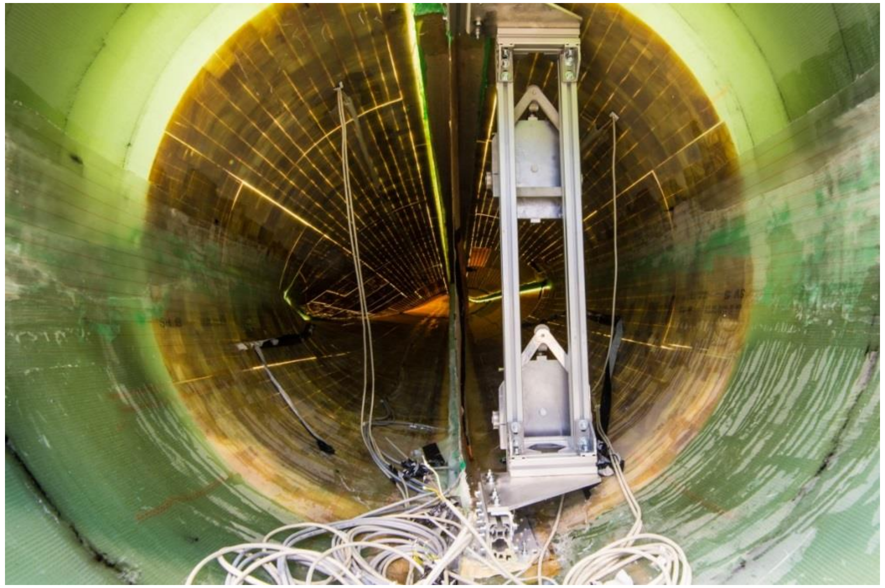
How we make it a blade

Sensor integration

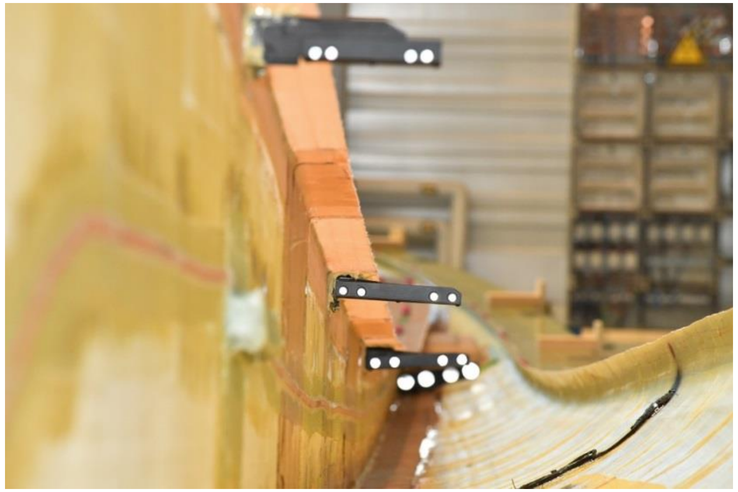
- Integration of sensors to measure the deformation of the blade
- Resistance strain gauge by IWES
- Torsion sensor by DLR
- Blade Vision System by SSB

Resistance strain gauge

Torsion sensor



Blade Vision System



Blade Vision System

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

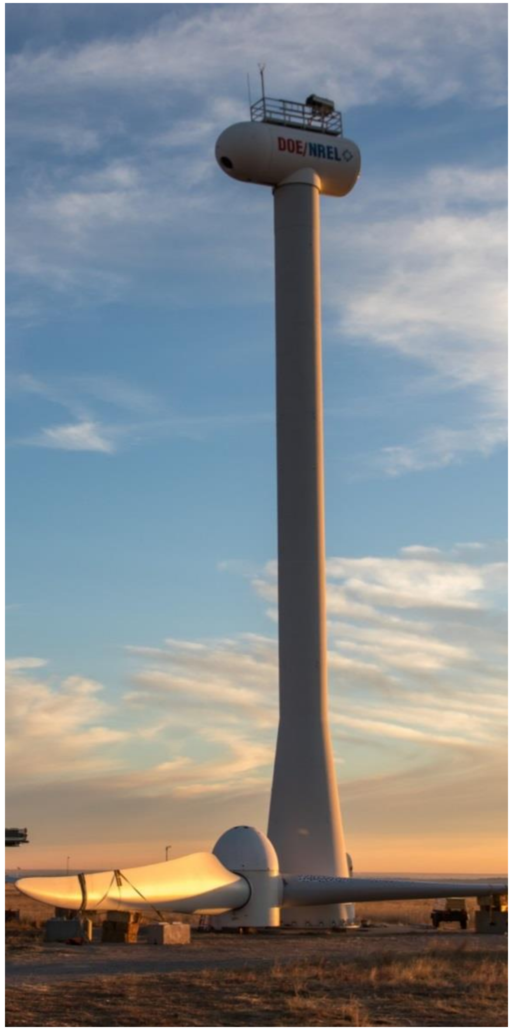
Testing

- 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


Source: IWES

Source: IWES

Installation and putting into service



Source: NREL

Special thanks to:

SSB Wind Systems, ADC, DOPAG, Olin, Sika, Schütz Composites,
all Smart Blades 2 partners & the blade construction team !

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag