



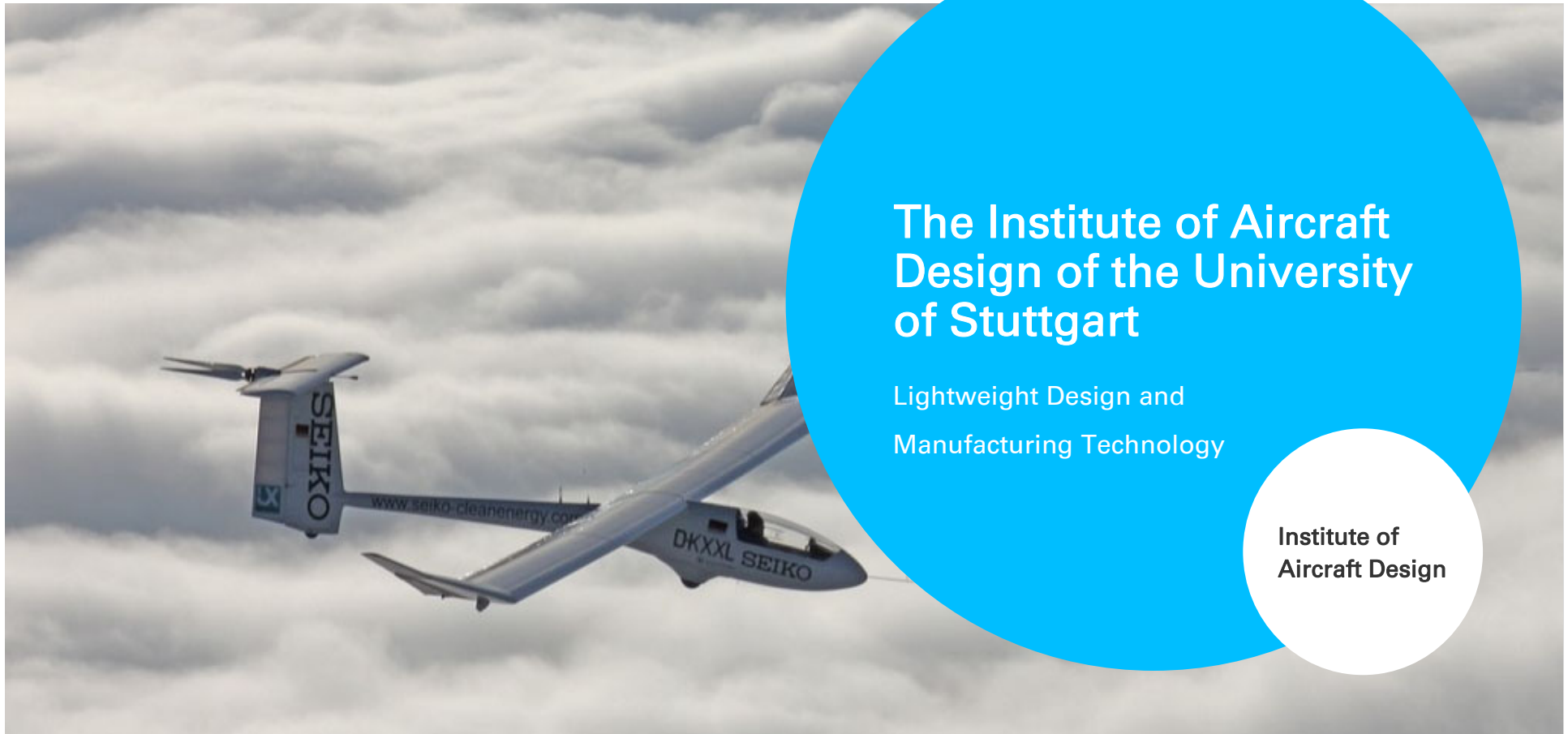
Universität Stuttgart

 **IFB**
Institut für Flugzeugbau
Institute of Aircraft Design

The Institute of Aircraft Design of the University of Stuttgart

Lightweight Design and
Manufacturing Technology

**Institute of
Aircraft Design**



Institut für Flugzeugbau

Research areas





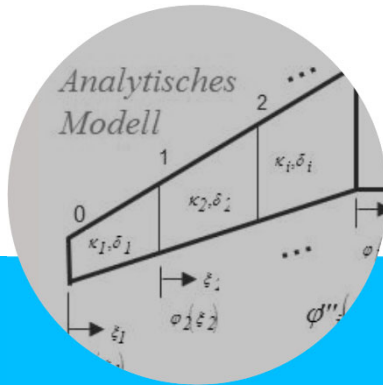
University of Stuttgart
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Institute of Aircraft Design



Lightweight Design
and Simulation

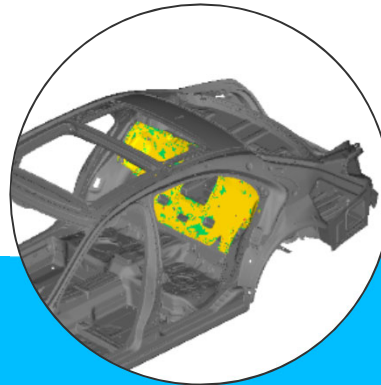
Lightweight Design • Lightweight construction methodology



Analytical models

Detailed and realistic consideration of strength and stability behavior

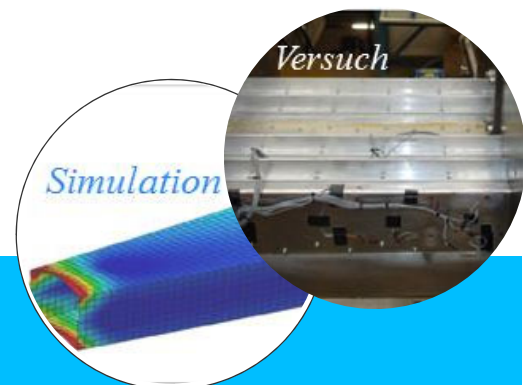
Structural elements in the field of aerospace as well as mechanical and automotive engineering



Construction evaluation

Evaluation of new concepts and material systems

Effects of design changes on structural weight

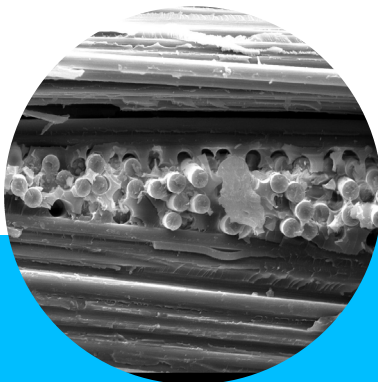


Validation

Use of the computational models in the validation of simulations and tests

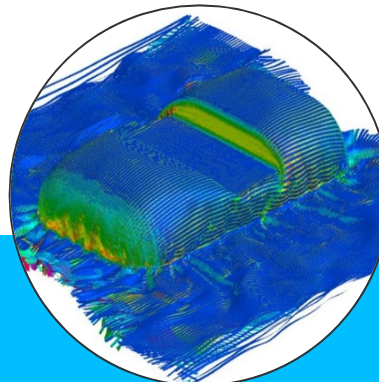
Lightweight Design • Simulation

Overview



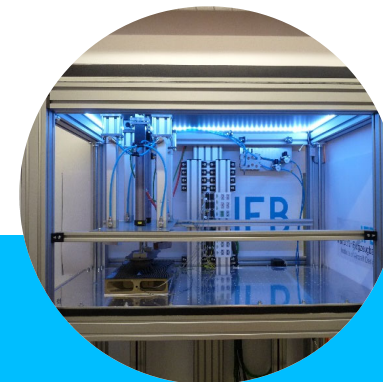
Material characterization

- Textile test methods
- Mechanical test methods
- Structural test methods
- Non-destructive testing



Numeric reproduction

- Various simulation methods (FEM, CFD, analytical)
- Process simulation
- Structural simulation

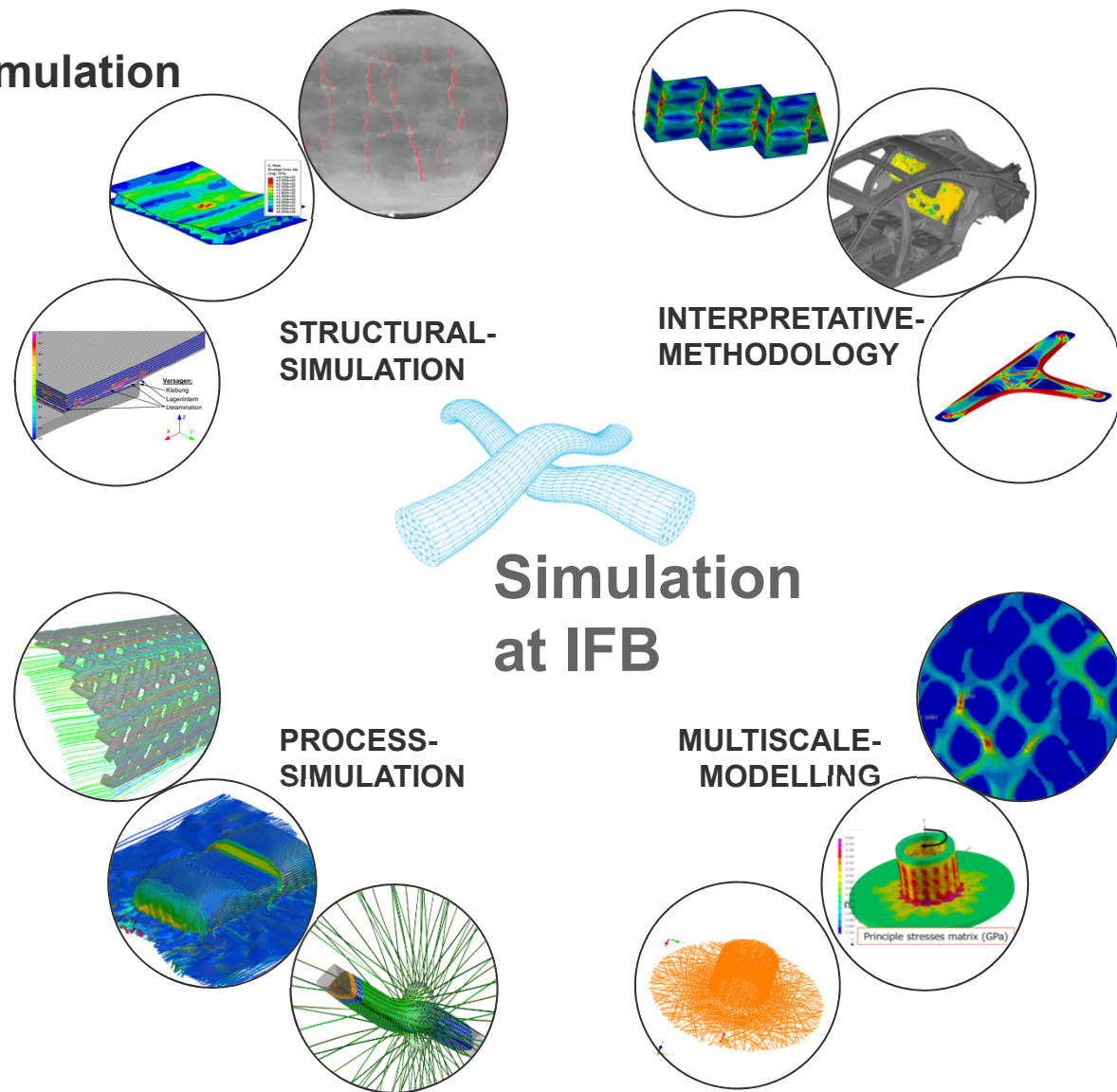


Manufacturing processes & validation

- Textile processes (braiding, draping, TFP)
- Resin injection (VARI, VAP, RTM, wet pressing)
- Prepreg

Lightweight Design • Simulation

Virtual Processchain



15 employees, 2 teams

Manufacturing Process Simulation
Braiding process simulation, forming simulation, resin application simulation, CAM

Structural simulation

SFB, Crash, Fatigue, Load path optimization, joining technology, sandwich structures

Software

ESI, Abaqus, LS Dyna, Hyperworks, Matlab, etc.

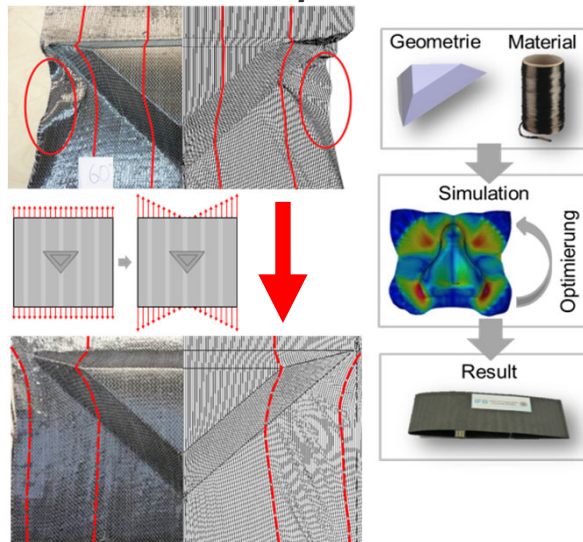
Hardware

HPC Cluster,
Intel XEON, Quad-, Octa-, 12-Core
4,7TFlops

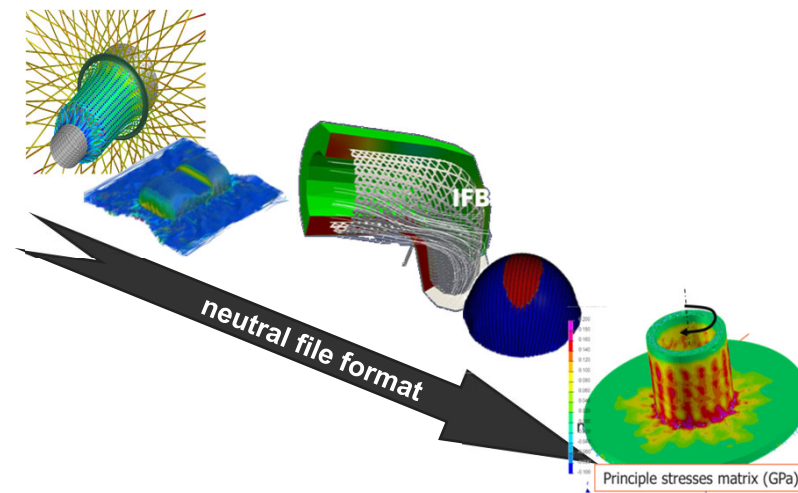
Process simulation

Overview

Virtual Processoptimisation



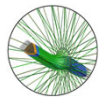
Data transfer



- Modelling the manufacturing processes of FVK structures
- Consideration of physical effects
- Application-oriented detailing
- Neutral exchange data format
- Prediction of real fiber architecture under consideration of manufacturing influences
- CAM interface
- Virtual process optimization



MULTISCALE-
MODELLING



PROCESS-
SIMULATION



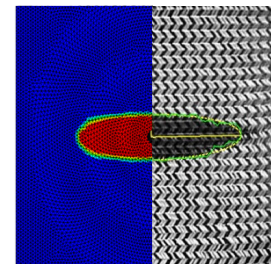
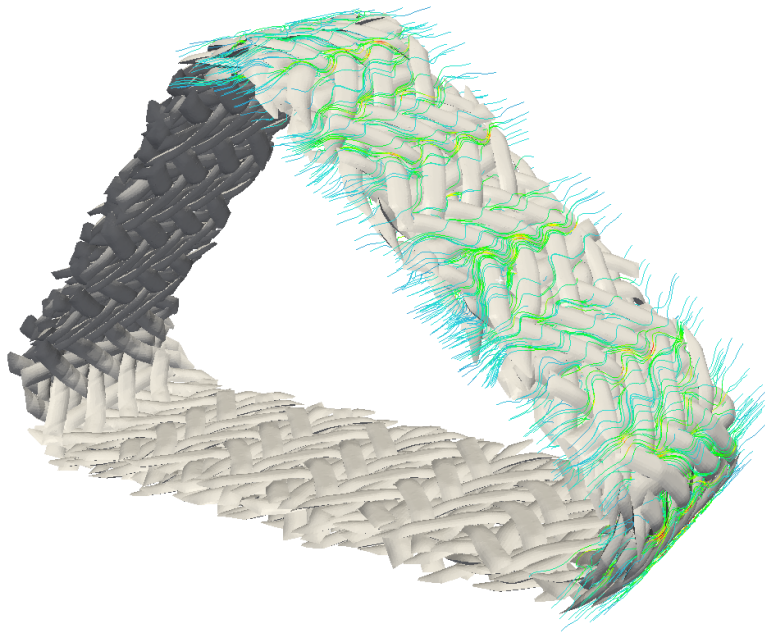
STRUCTURAL-
SIMULATION



INTERPRETATIVE-
METHODOLOGY

Process simulation

Virtual Infiltration & Permeability Prediction



2D permeability determination



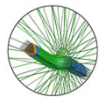
3D permeability determination



- Numerical permeability prediction with CFD
- Exp. permeability determination (K_1 , K_2 , K_3)
- Explicit FEM filling simulation
- Software: ESI, TexGen, WiseTex, RTM-Worx, OpenFOAM, InHouse-Codes
- Advantage: Predesign of molds, near-net-shape permeability determination



MULTISCALE-
MODELLING



PROCESS-
SIMULATION



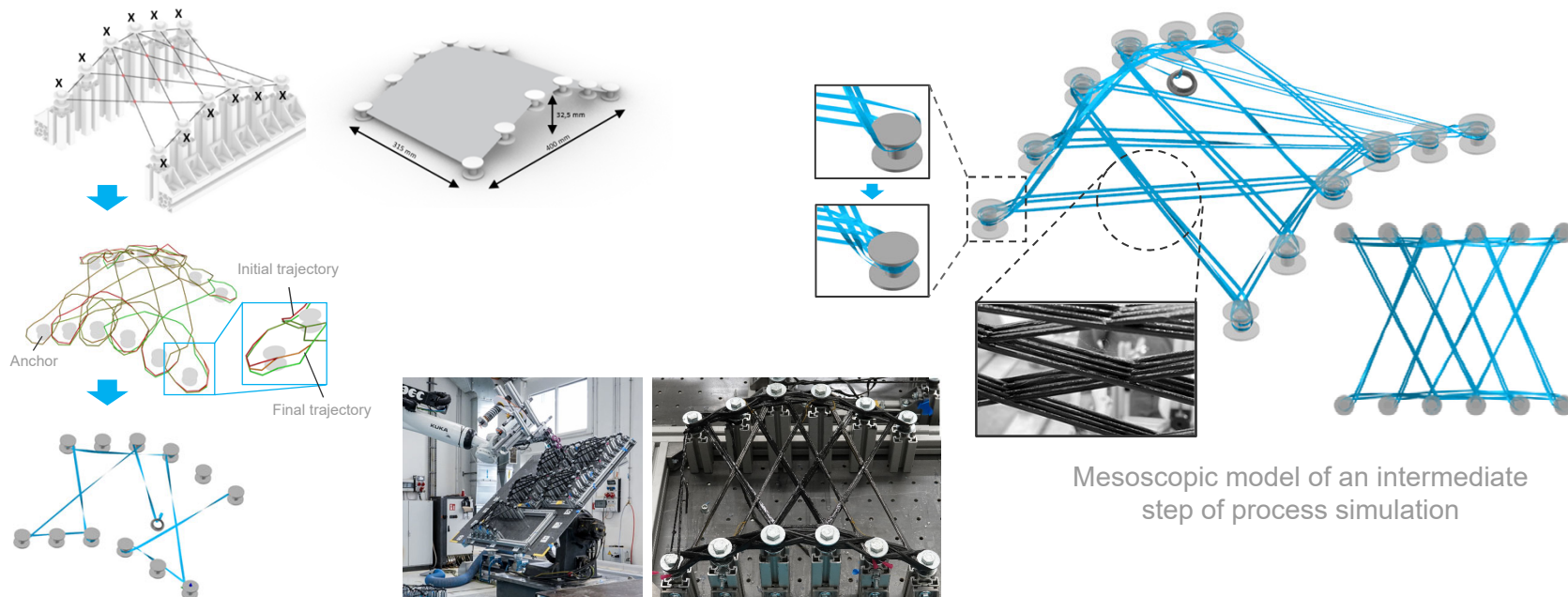
STRUCTURAL-
SIMULATION



INTERPRETATIVE-
METHODOLOGY

Process simulation

Coreless filament winding: Prediction of fiber architecture



- Robot path planning and optimisation
- Numerical prediction of fiber deposition
- Mesoscopic, explicit FEM process simulation
- Software: ESI, InHouse-Codes
- Advantage: Automatic realistic robot path planning, near-net-shape prediction of material properties



MULTISCALE-
MODELLIERUNG



PROZESS-
SIMULATION



STRUKTUR-
SIMULATION



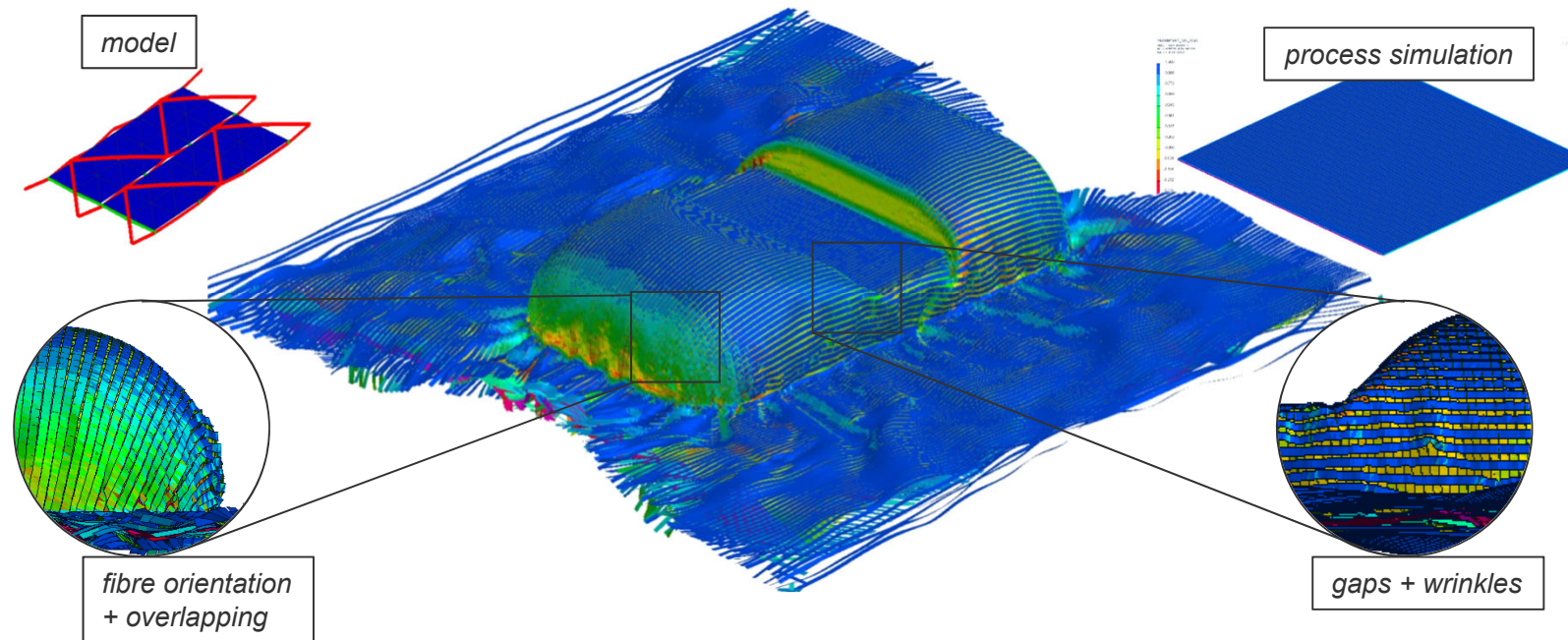
AUSLEGGUNG VON
LEICHTBAUSTRUKTUREN

Process simulation

Draping simulation



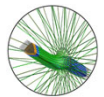
Baden-Württemberg
MINISTERIUM FÜR WISSENSCHAFT, FORSCHUNG UND KUNST



- user oriented models
 - kinematic, macroscopic, mesoscopic
- simulation of dynamic effects and friction
- simulation of physical phenomena
- process oriented part design
- process planning and optimization



MULTISCALE-
MODELLING



PROCESS-
SIMULATION



STRUCTURAL-
SIMULATION



INTERPRETATIVE-
METHODOLOGY

Structural simulation

Low-Velocity Impact Simulation



Bundesministerium
für Wirtschaft
und Energie

Next Move

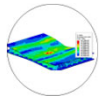
Design & Assembly Concepts of Next Generation of Moveables



MULTISCALE-
MODELLING



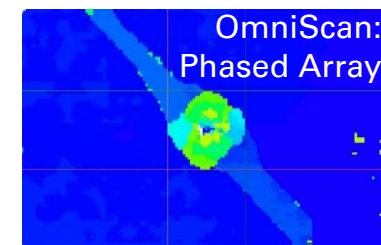
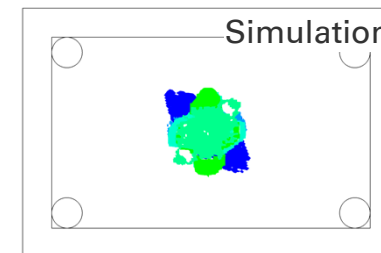
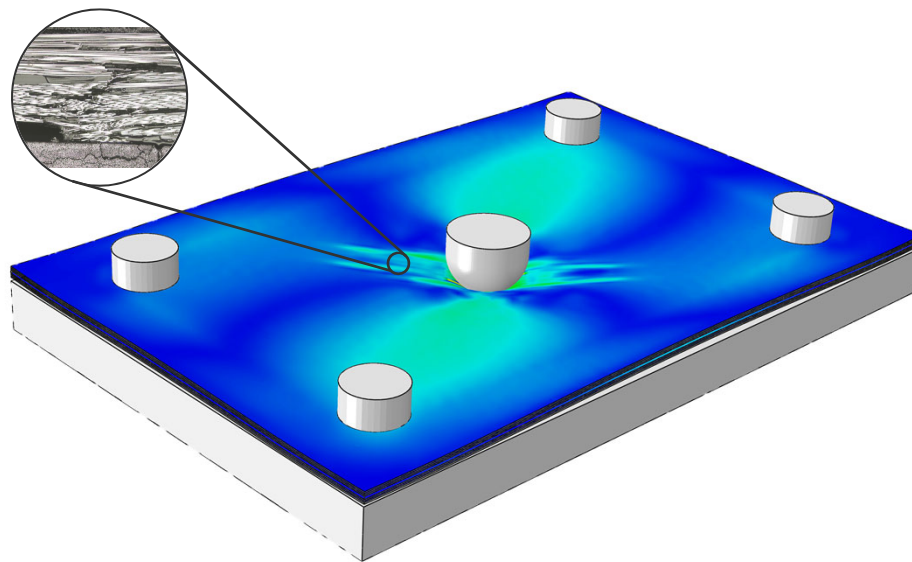
PROCESS-
SIMULATION



STRUCTURAL-
SIMULATION

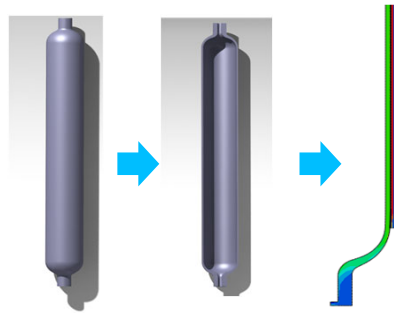


INTERPRETATIVE-
METHODOLOGY

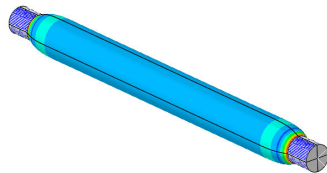


- Material model development
 - Continuum damage mechanics
 - Cohesive zone models
- Ultrasonic measurement(Omniscan MX-2)
- Residual strength simulation:
 - Compression after Impact (CAI)
 - Tension after Impact (TAI)

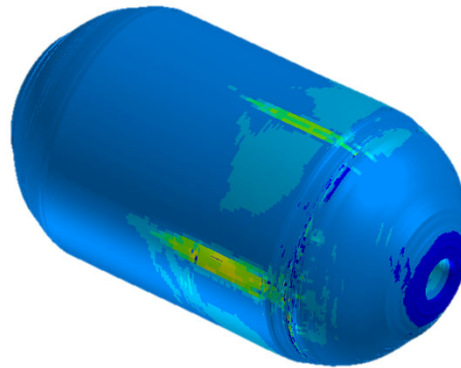
Simulation of H₂-pressure storage tanks



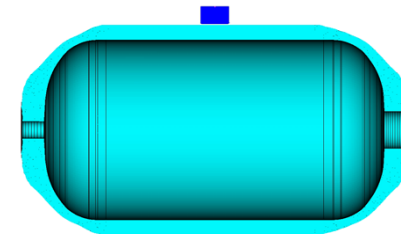
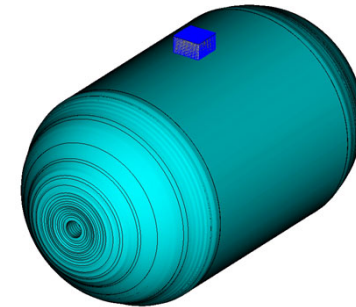
Steel + CFRP reinforcement (+ adhesive)



Design of wound CFRP pressure storage tanks



Burst simulation conventional H₂-pressure tank



Impact on H₂-pressure tank with subsequent residual burst pressure simulation

- Design of simple wound CFRP pressure tube accumulators
- Design CFRP pressure tank

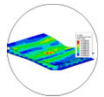
- Burst simulation
- Impact simulation with subsequent residual burst pressure



MULTISCALE-
MODELLING



PROCESS-
SIMULATION



STRUCTURAL-
SIMULATION



INTERPRETATIVE-
METHODOLOGY

Design / Optimization of FRP-Structures

Variable Stiffness Design using Tailored-Fiber-Placement



MULTISCALE-
MODELLING



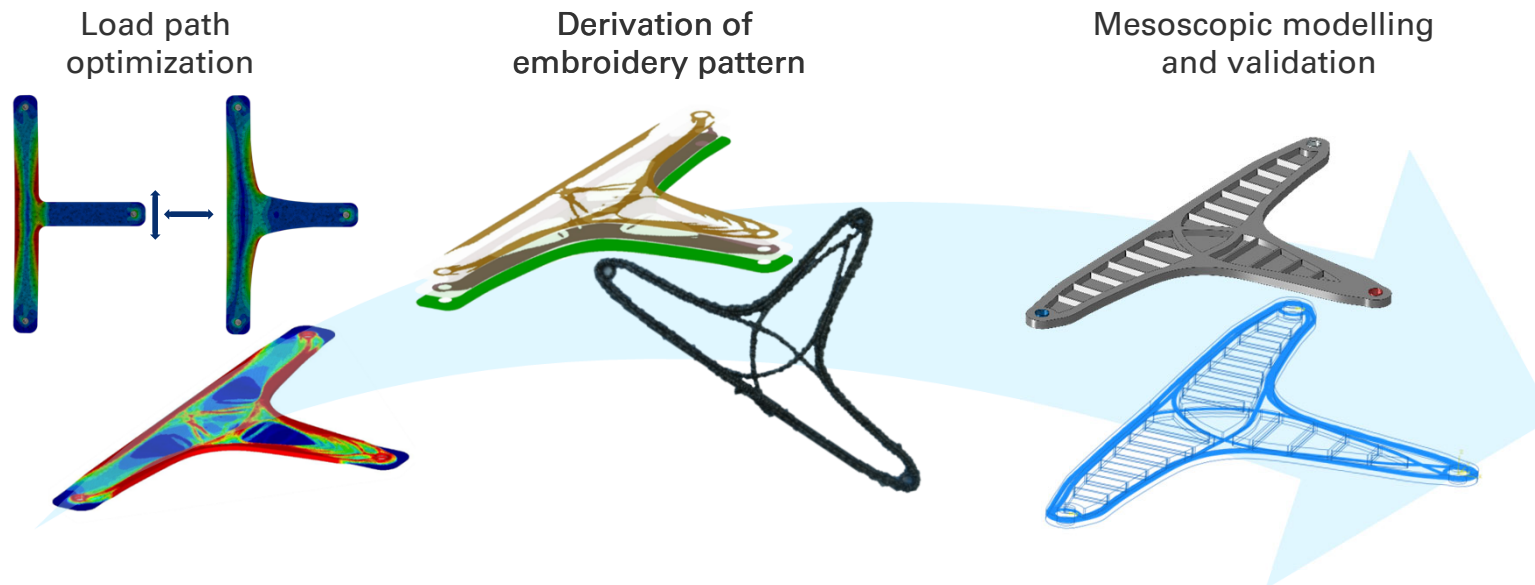
PROCESS-
SIMULATION



STRUCTURAL-
SIMULATION



INTERPRETATIVE-
METHODOLOGY

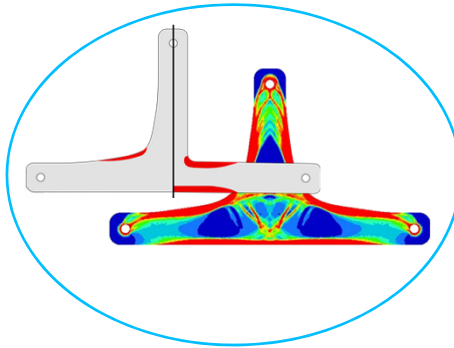


- Notch shape optimization according to C. Mattheck
- Fiber angle / thickness optimization based on stress analysis
- Layer view of the thickness profile and embroidery pattern derivation
- Mesoscopic modeling using beam elements

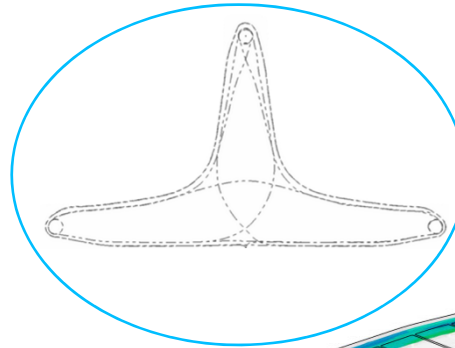
Tailored Fiber Placement

Process Chain

1. FRP-Optimization



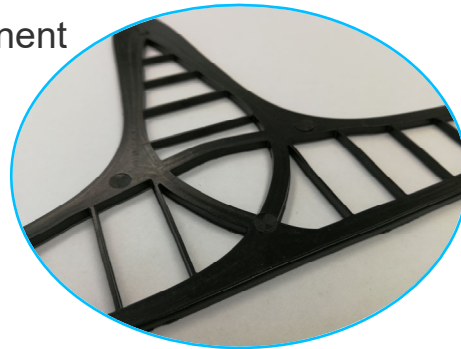
2. Embroidery pattern



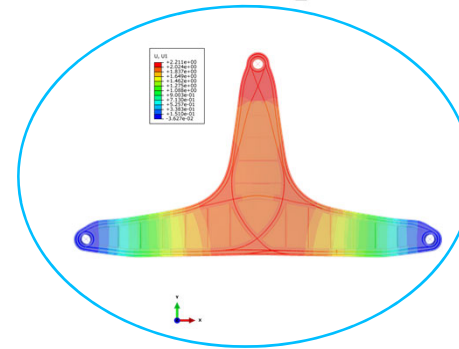
3. Preform manufacturing



5. Final component



4. Mesoscopic simulation





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Institute of Aircraft Design



**Manufacturing
Technologies**

Manufacturing Technologies

Overview



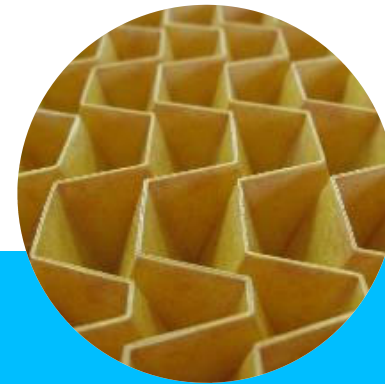
Fiber composites

- Automated manufacturing processes
- FRP functionalization
- Digital FRP structures



Additive manufacturing

- Processes
- Construction and design
- Design and Optimization
- Fiber reinforced 3D printing



Sandwich structures

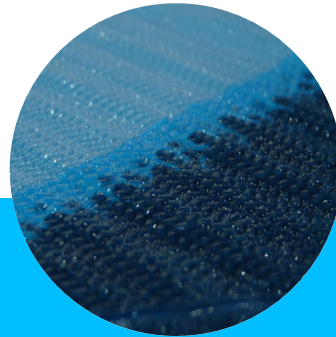
- Construction methods
- Design and optimization
- Innovative core materials

Manufacturing Technologies • Fiber composites



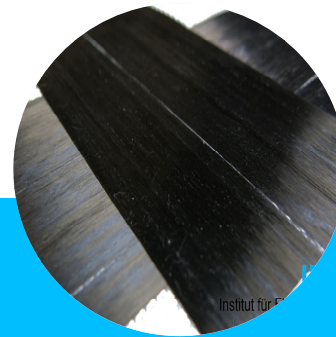
Preforming

- Tailored Fiber Placement
- Braiding
- Draping
- 3D sewing



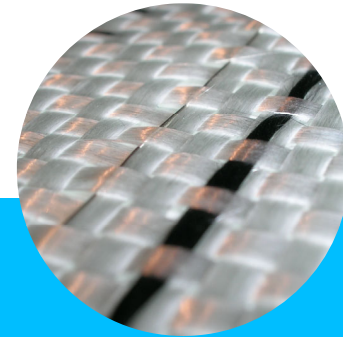
Impregnation

- VARI /VAP
- RTM
- Wet molding
- Tooling concepts



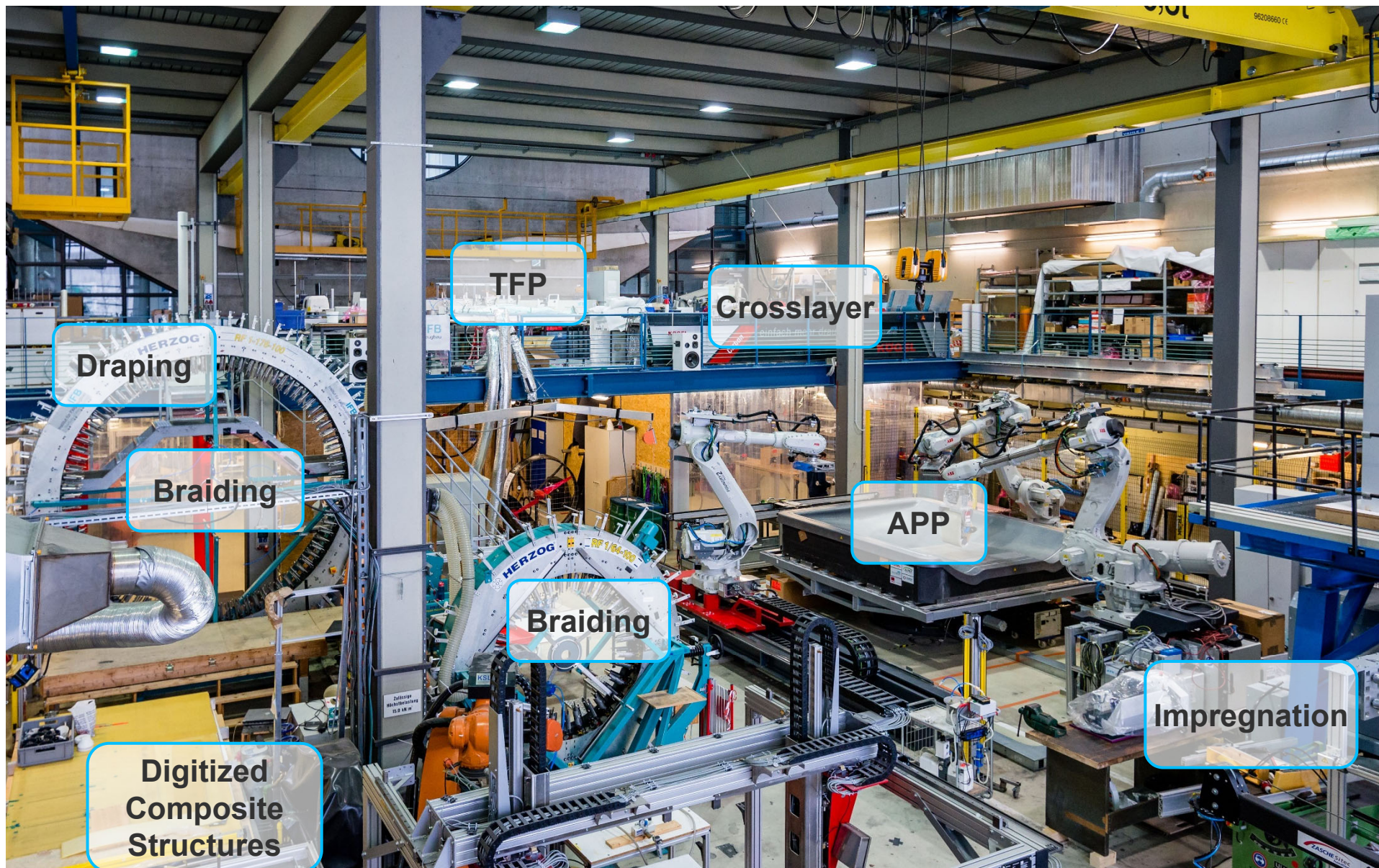
Placement technologies

- Advanced Ply Placement
- Single yarn placement



Functionalization

- Integration of sensor for structure health monitoring
- Extension of material properties



Draping

Braiding

TFP

Crosslayer

APP

Braiding

**Digitized
Composite
Structures**

Impregnation

Manufacturing Technologies • Braiding

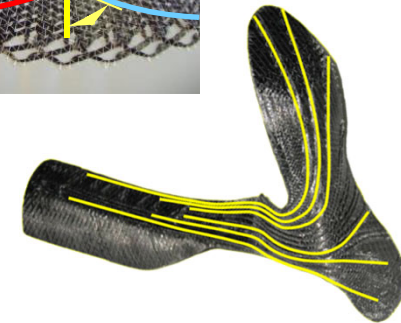
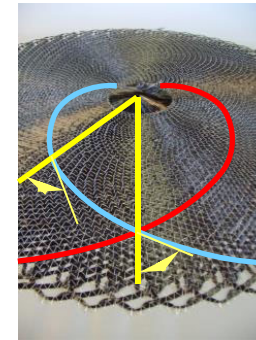
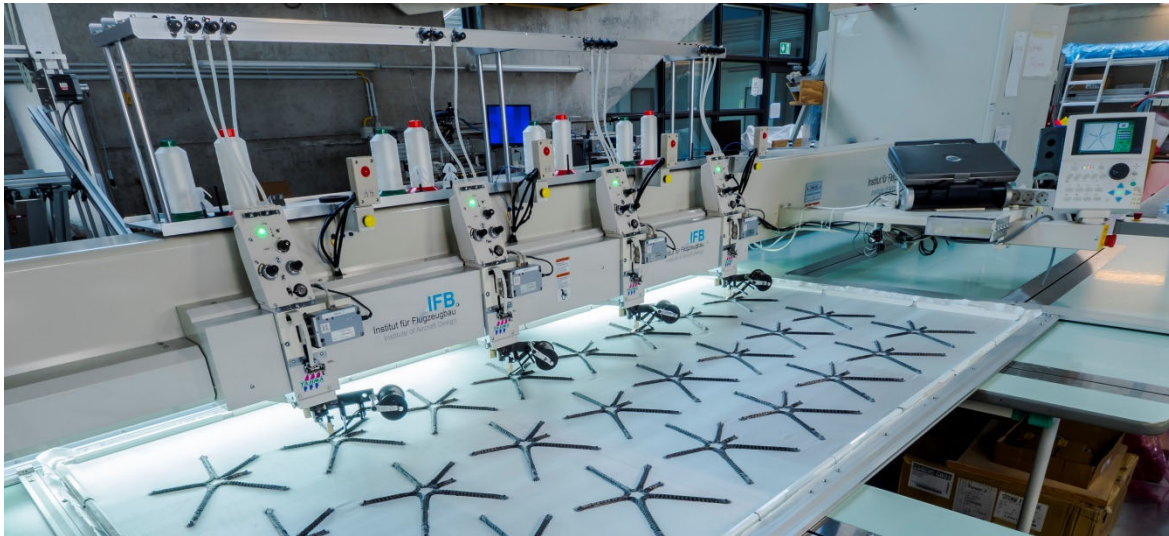
Robot-assisted braiding with radial braiding technology



- Development of complex hollow parts with diameters up to 200 mm
- Optimization of material properties by the process or by combination of various fiber materials

Manufacturing Technologies • Tailored Fibre Placement (TFP)

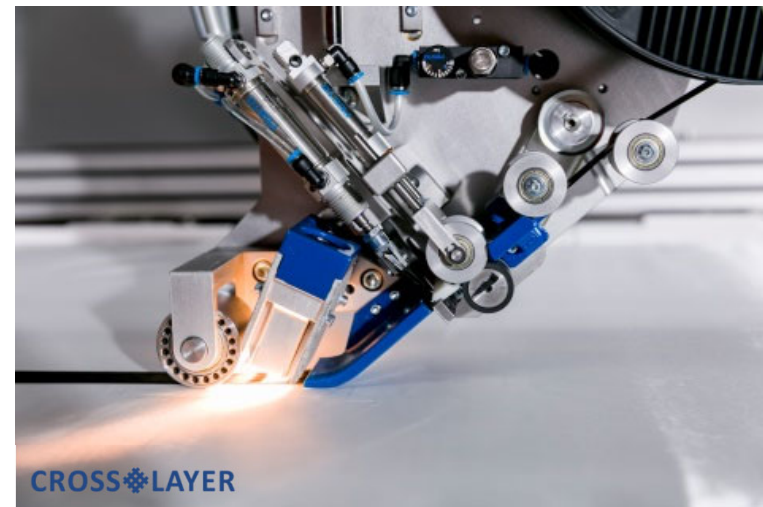
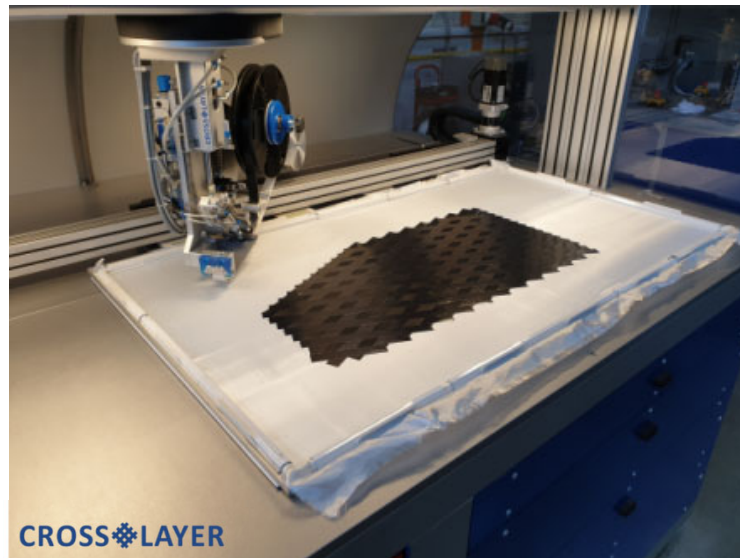
Load path-compatible fiber placement



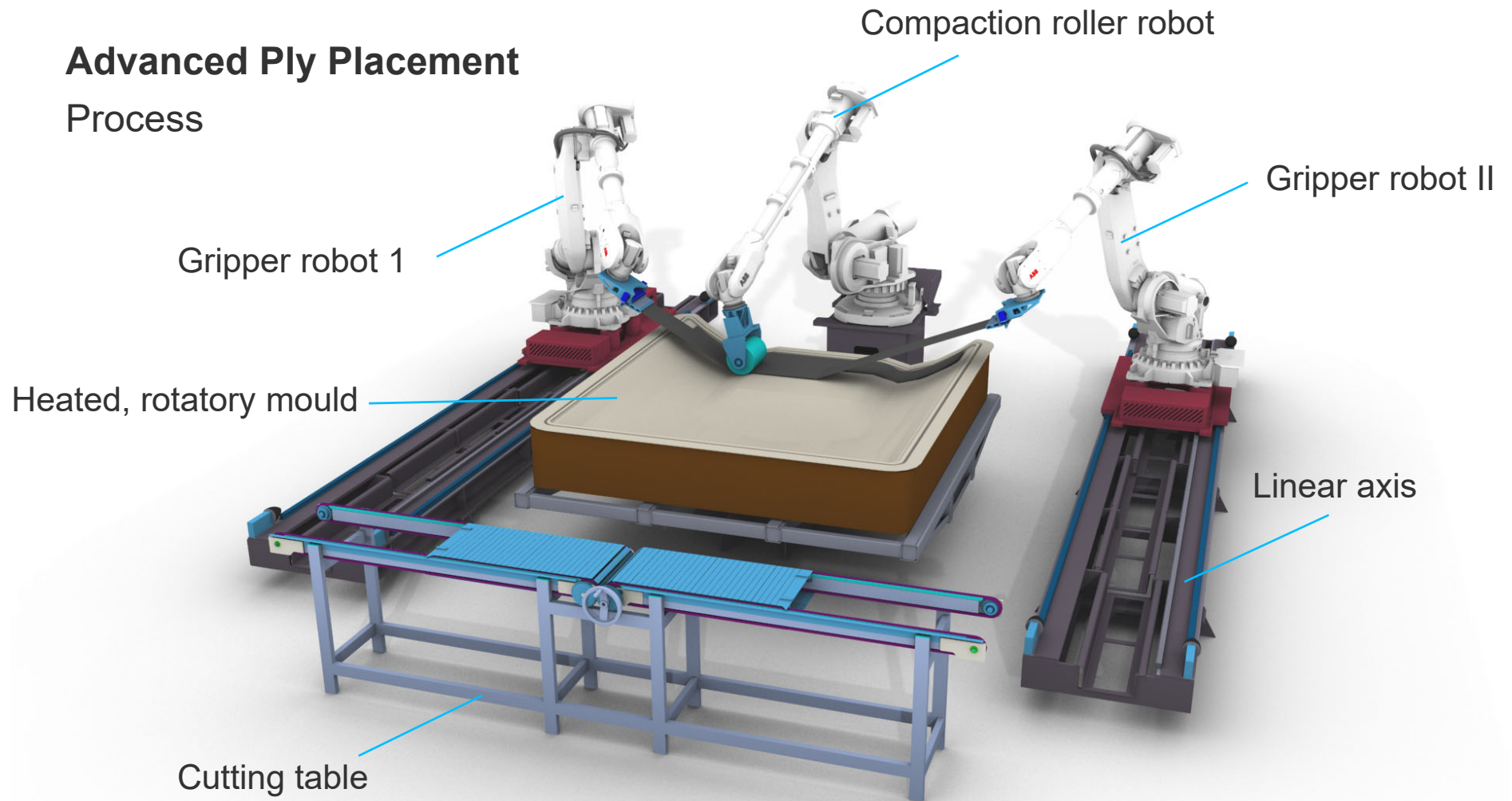
- Lightweight design by load-path optimized fiber lay-up with minimum waste material
- Functionalization by processing fibers or wires made of different materials
- Research at fully automated TFP-process digitalization

Dry fiber and prepreg deposit of single fibers/tapes

Technology development - Crosslayer

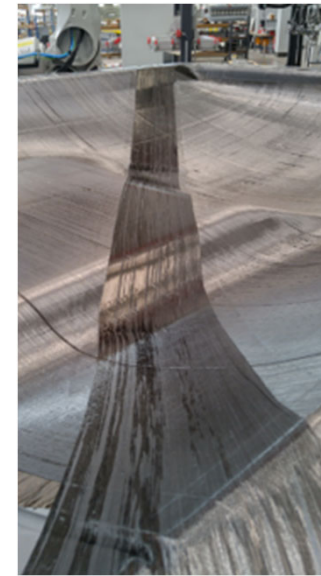
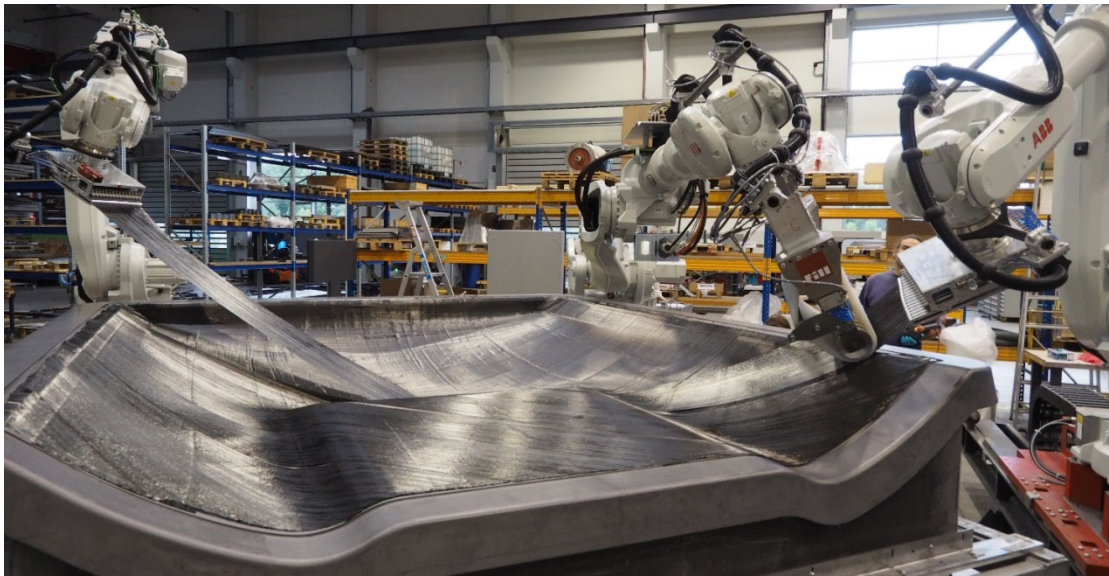


Advanced Ply Placement Process



Manufacturing Technologies • Advanced Ply Placement (APP)

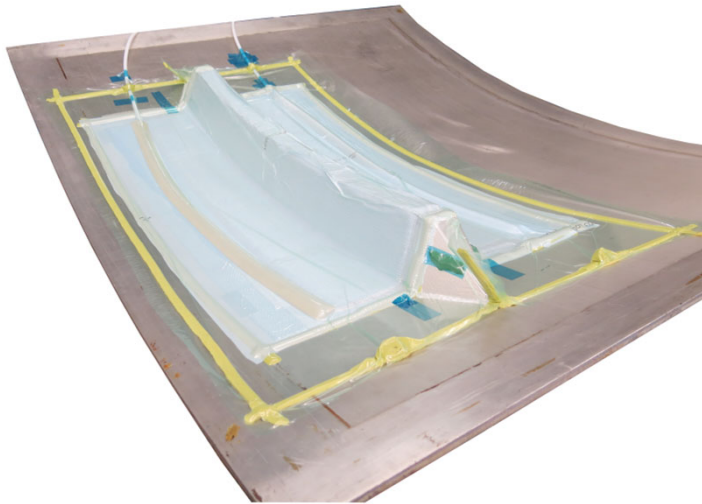
Automated 3D deposition of wide fiber semi-finished products



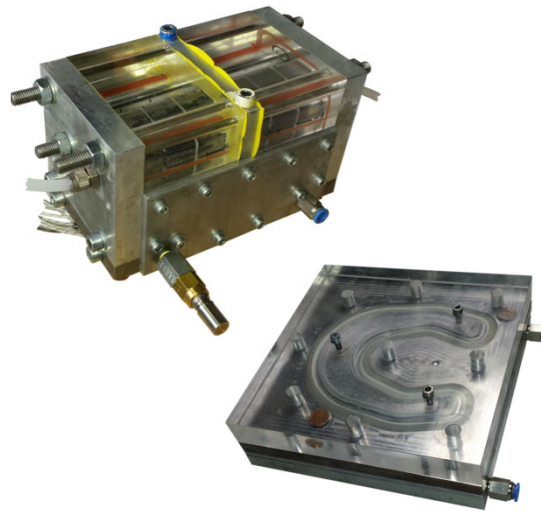
Manufacturing Technologies • Impregnation

Impregnation of the fiber semi-finished products using different processes

VAP-Process



RTM-Process



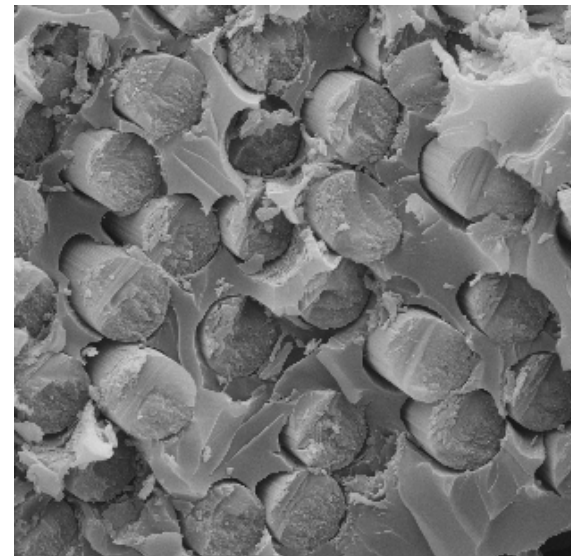
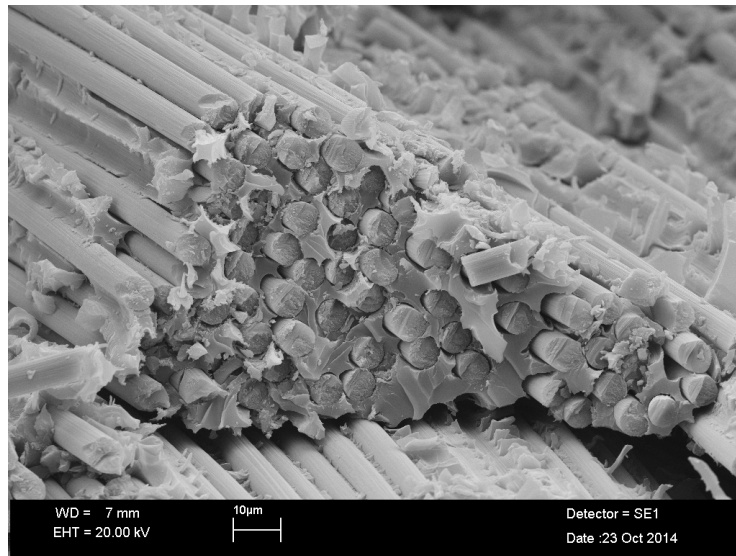
Wet moulding



- Experience in VARI, VAP, RTM and wet moulding
- Development of new impregnation concepts
- Development of new tooling concepts for cost, time and energy efficient heating and cooling
- Part realization from prototype to small batches

Manufacturing Technologies • Extension of the material properties

Modification of the properties by adding new materials



- By admixing or coating with new materials, such as graphene, the base material changes its mechanical, thermal and electrical properties, allowing it to be used as a sensor for certain influencing variables.

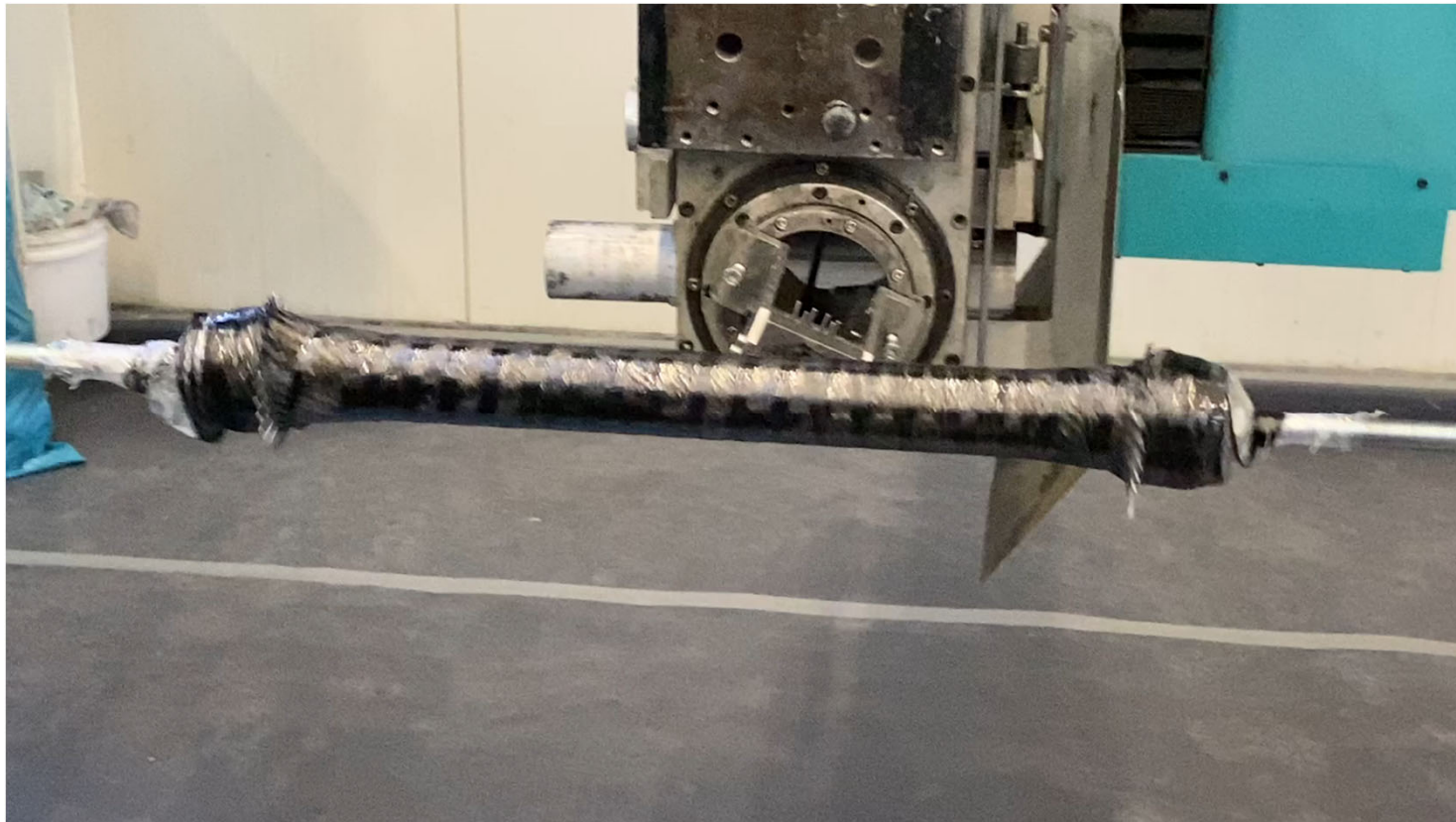
Manufacturing Technologies • Winding techniques

Manufacturing of wound structures



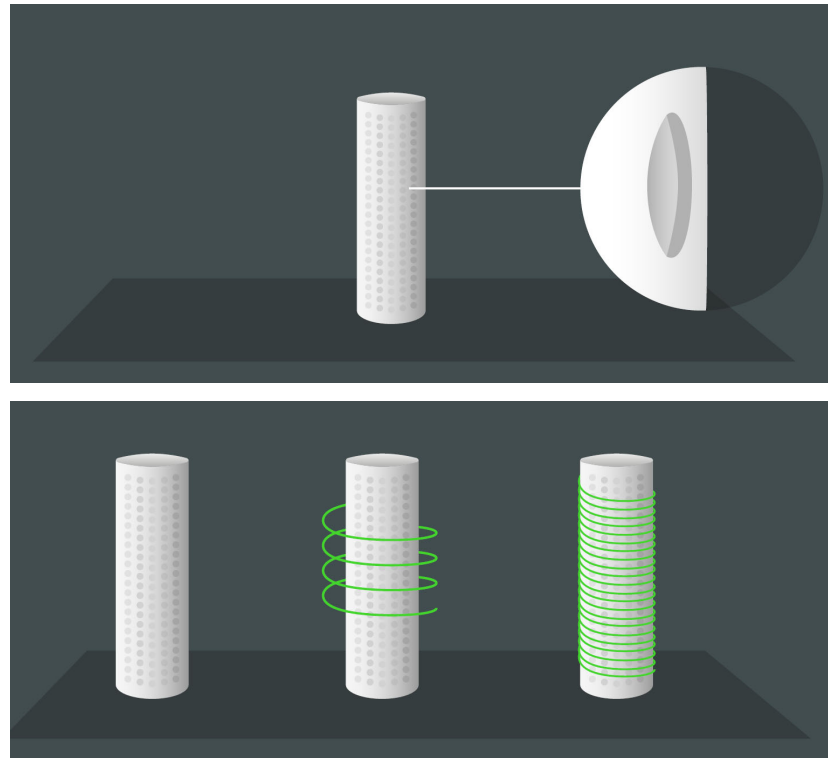
Manufacturing Technologies • Winding techniques

Manufacturing of wound structures



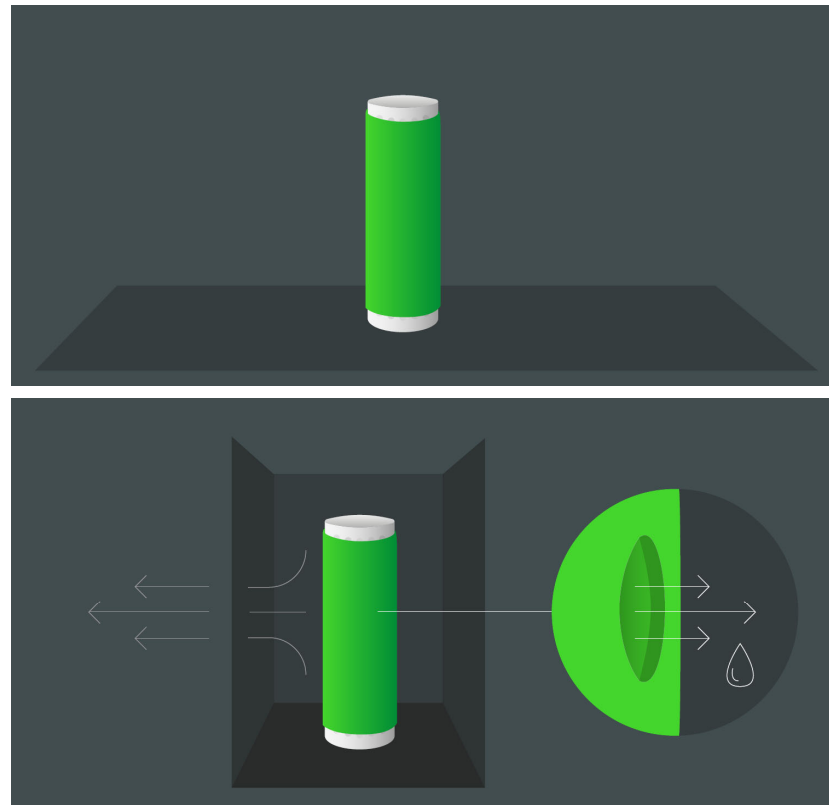
Manufacturing Technologies

TowPreg development



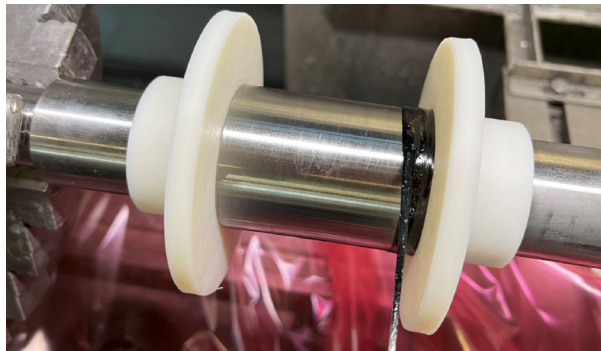
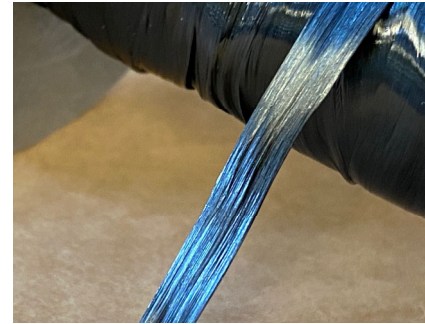
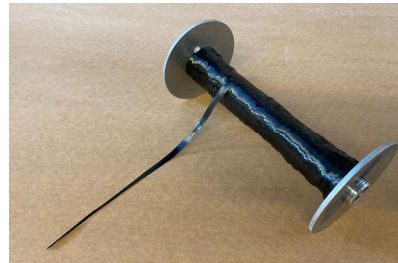
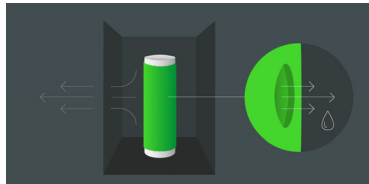
Manufacturing Technologies

TowPreg development



Manufacturing Technologies

TowPreg development and Test at the IFU



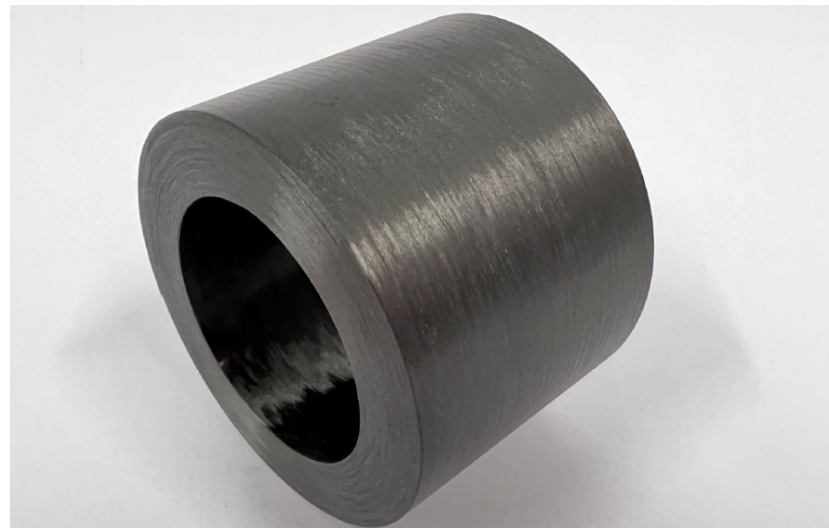
Manufacturing Technologies

TowPreg development and Test at the IFU



Eckdaten:

- Gewicht: 278g
- Breite: 60,1mm
- Außendurchmesser: 80,05mm

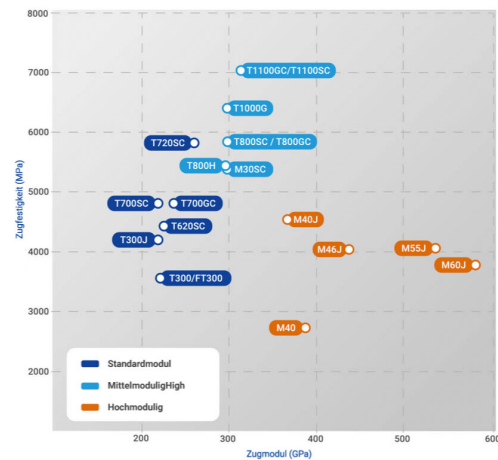


Manufacturing Technologies

TowPreg development and Test at the IFU

Potential Carbon:

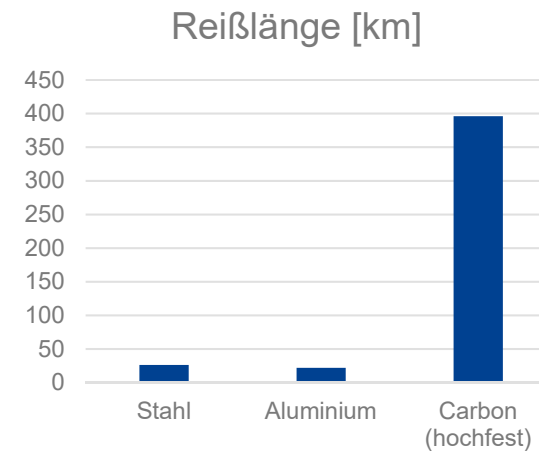
- Festigkeit bis zu 7000MPa aktuell
- E-Modul (Zug) bis zu 900GPa
- Dichte: ca. 1,8 bis 2,2 g/cm³



Quelle: Toray

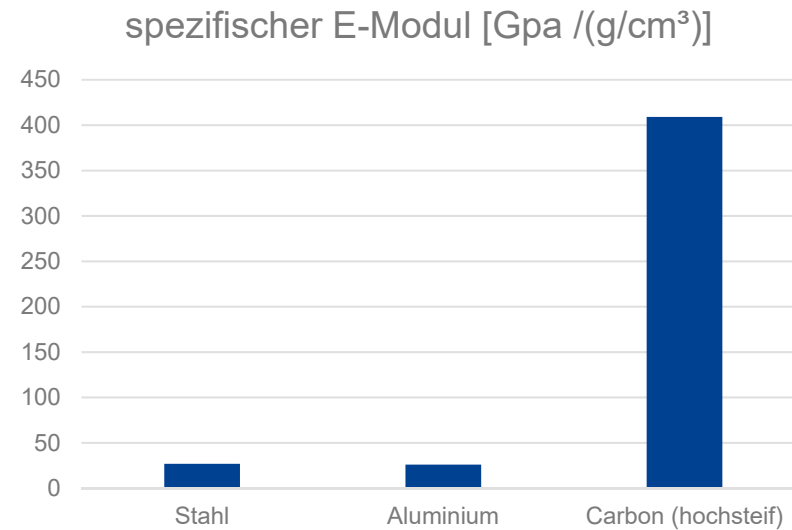
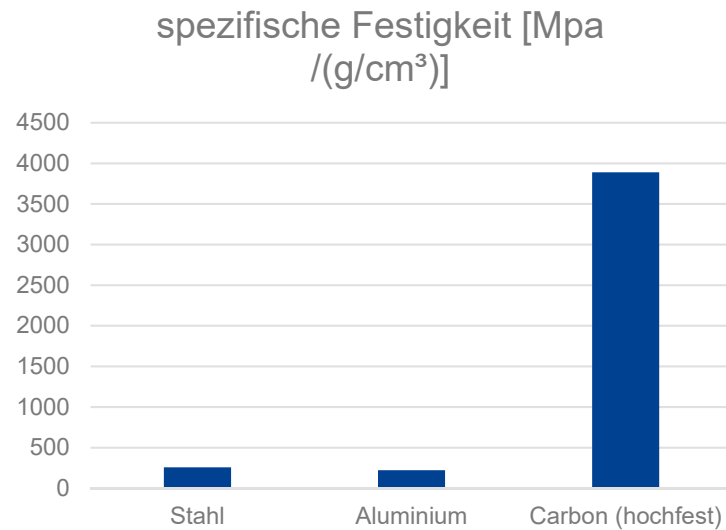
Potential Stahl:

- Festigkeit bis zu 2000MPa aktuell
- E-Modul: 210GPa
- Dichte: ca. 7,8 g/cm³



Manufacturing Technologies

TowPreg development and Test at the IFU





Universität Stuttgart
Institut für Flugzeugbau

Thank you!



Institute of Aircraft Design

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