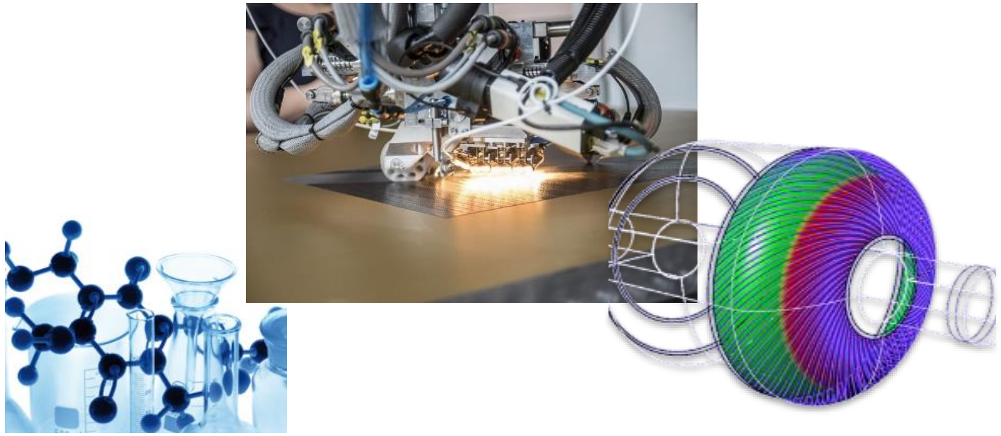
Fraunhofer Institute for Applied Polymer Research IAP
Research Division Polymeric Materials and Composites PYCO

18. Schwarzheider Kunststoffkolloquium 2021

Funktionsintegrierter 3D-Druck mit gedruckter Elektronik

Marcello Ambrosio, M.Sc.

Fraunhofer Institute for Applied Polymer Research IAP, RD6 Polymeric Materials and Composites PYCO



Wildau, 29.09.2021

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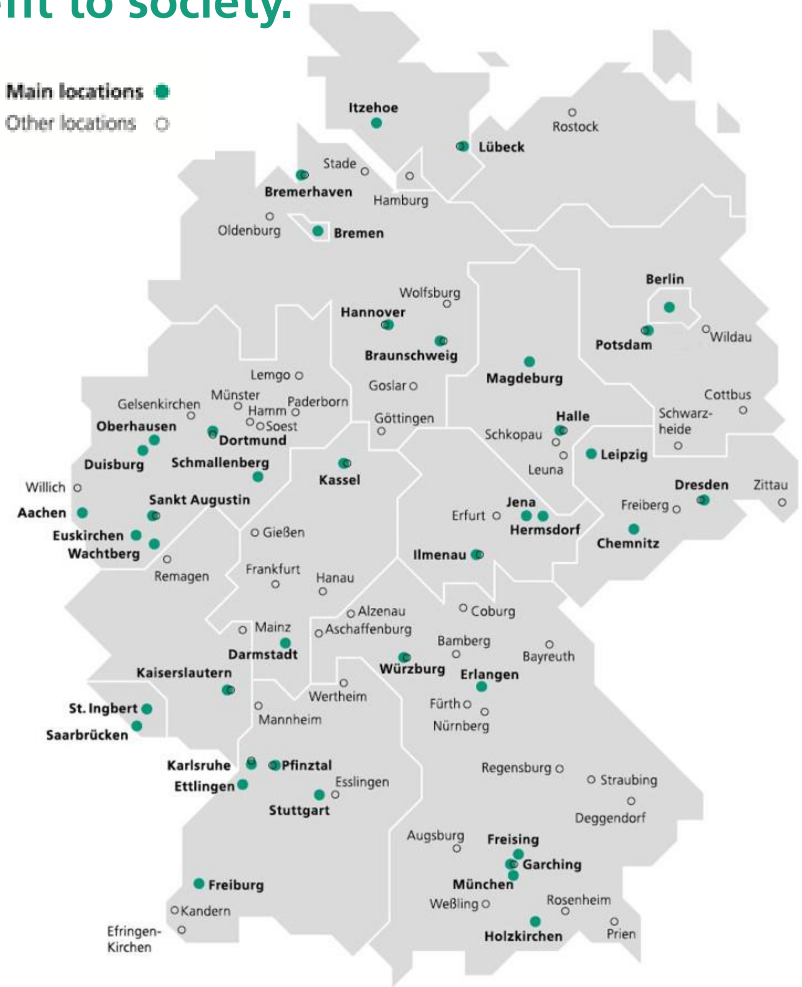
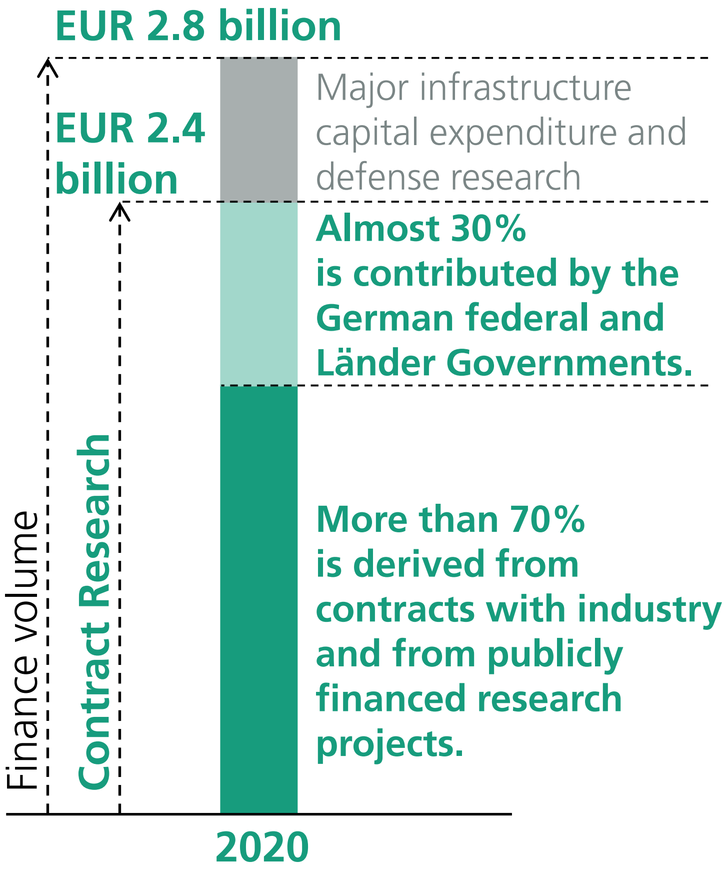
Fraunhofer-Gesellschaft at a Glance

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society.

29,000 staff

75 institutes and research units





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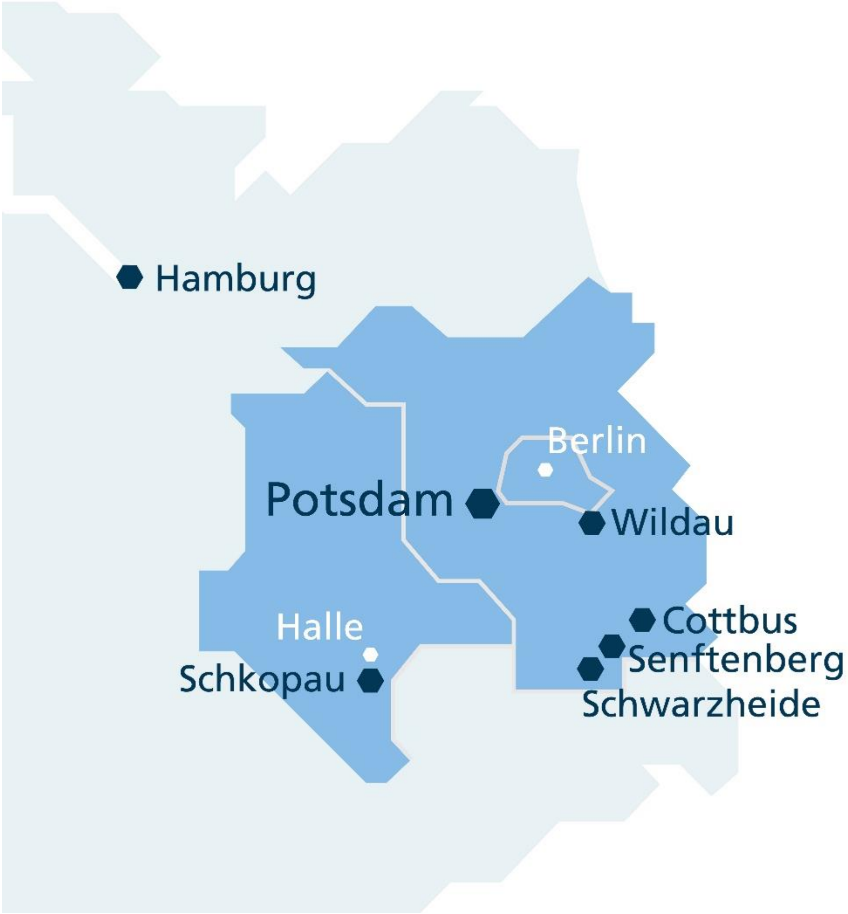
Fraunhofer IAP

- 254 employees (Status 12 | 2020)
- 2020: EUR 25.0 million institute's budget
  EUR 15.1 million external revenues
- Locations: **Potsdam-Golm**
  Cottbus } Lightweight Design
  Wildau }

b-tu Brandenburgische Technische Universität Cottbus - Senftenberg

INSTITUT FÜR LEICHTBAU UND WERTSCHÖPFUNGS-MANAGEMENT



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Research Division Polymeric Materials & Composites PYCO

Univ.-Prof. Dr.-Ing. Holger Seidlitz
Director Research Division Polymeric Materials and Composites PYCO at Fraunhofer IAP
BTU Cottbus – Senftenberg, Department Polymer-based Lightweight Design

Tailored Materials
Prof. Dr. Christian Dreyer, Deputy Director Division PYCO
TH Wildau, Department Fiber Reinforcement – Material Technologies

Design & Processing Technologies
Univ.-Prof. Dr.-Ing. Holger Seidlitz

Polymer Development
Prof. Dr. Christian Dreyer

- High performance polymers
- Recycling and repair
- Microelectronics, photonics
- Functional integration
- Nanocomposites
- Alternative curing methods (UV, microwave, IR)

Semi-finished Components
Dr. Sebastian Steffen

- SMC, BMC
- Bio-based thermosets
- Natural fiber-reinforced plastics
- Bio-functional surfaces (functional integration)
- Prepregs
- Fire retardant systems

Simulation & Design
Marcello Ambrosio, M.Sc.

- Design (CAD)
- Structural- and process-simulation (FEM)
- Processing design
- AFP, additive manufacturing
- Injection molding, extrusion
- Tools and demonstrators

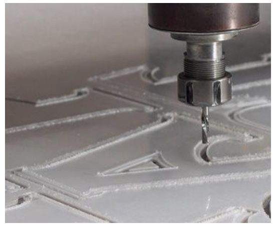
Structural Testing & Analytics **Dr. Mathias Köhler**

- Analytics
- Thermomechanical characterization
- Mechanical testing
- Optical characterization
- Reliability
- Non-destructive testing
- Fire testing

Large Scale Additive Manufacturing (LSAM)

Direct granulate extrusion

- Filament not needed → low material costs
- High material output (10…300 kg/h)
- Second step: subtractive finishing process
  - → surface quality
  - → manufacturing tolerances
  - → warpage



"In a project spanning two weeks worth of working days, and 30 hours 3D printer time, Indiana's Thermwood Corporation has completed a 3,000 lb (1,363 kg) pattern for the hull of a fiberglass motorboat."

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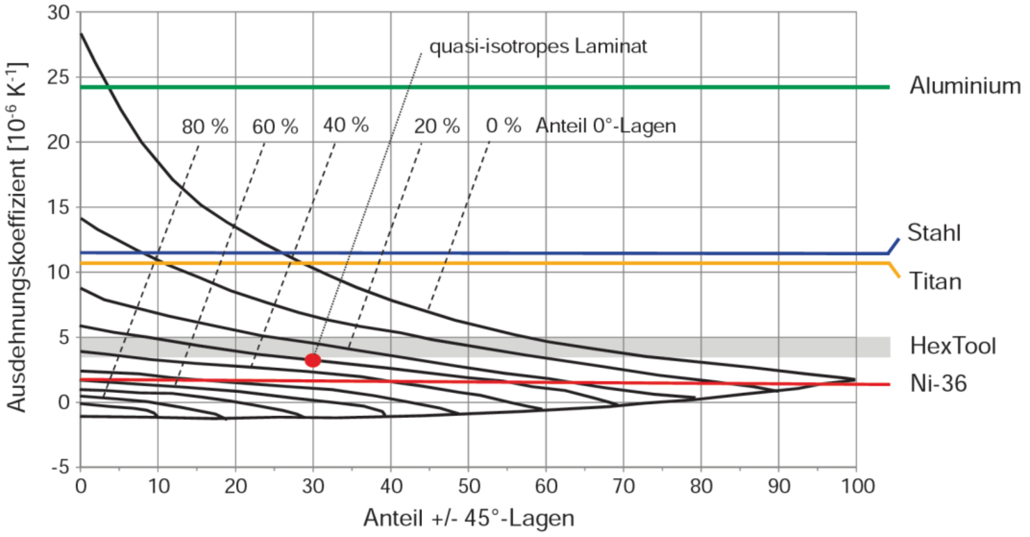
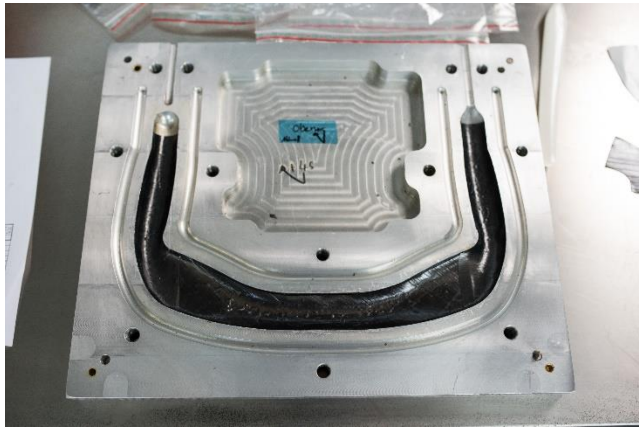
Tooling

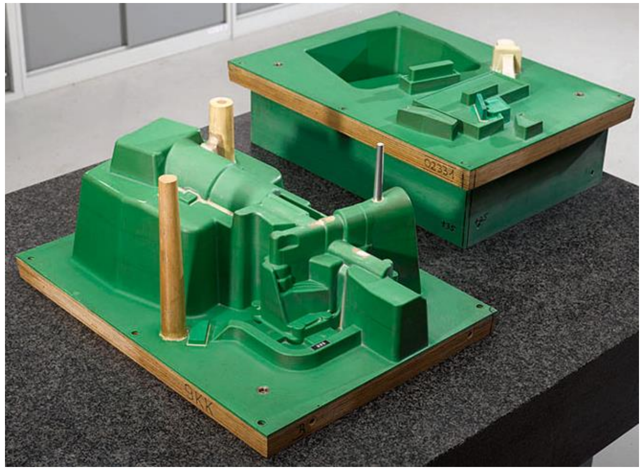
Costs: Effort and sustainability?

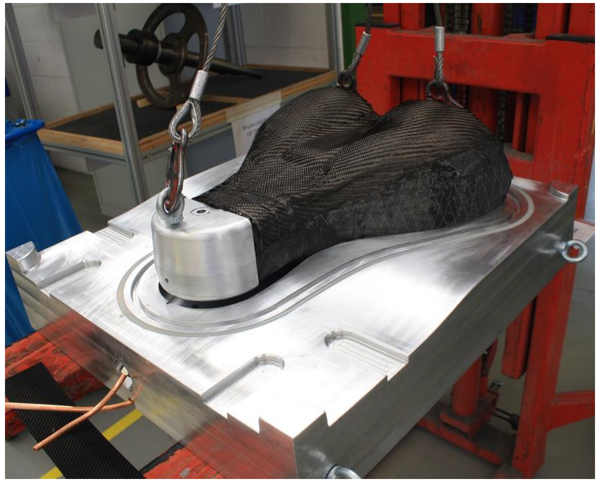
- Material prices
- Degrees of design freedom
- Wear and sustainability

Coefficient of thermal expansion (α) of metallic moulded materials in comparison with CFRP as a function of the laminate structure









- Steel (1.7131, 16 MnCr 5)
- Nickel-iron alloys (Ni36)
- Aluminium (EN AW 5083)
- Plastics (PUR)

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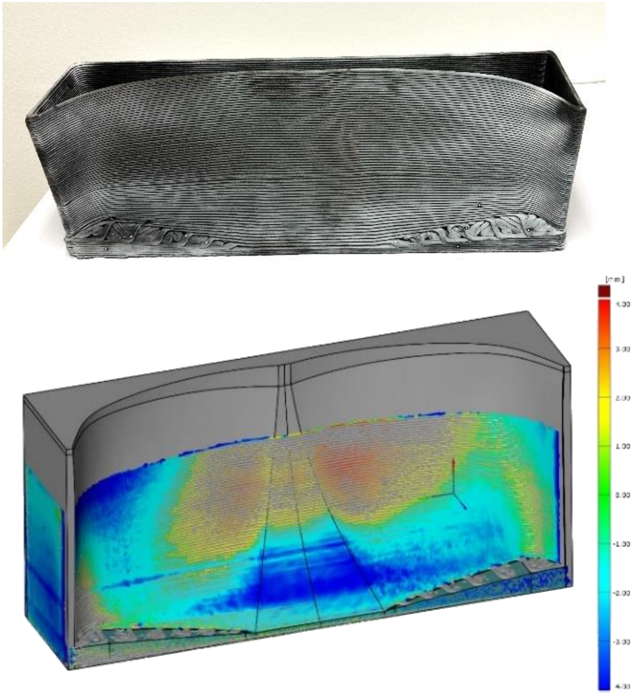
Procedure for process calibration: AM

Analysis of thermal distortion for process calibration

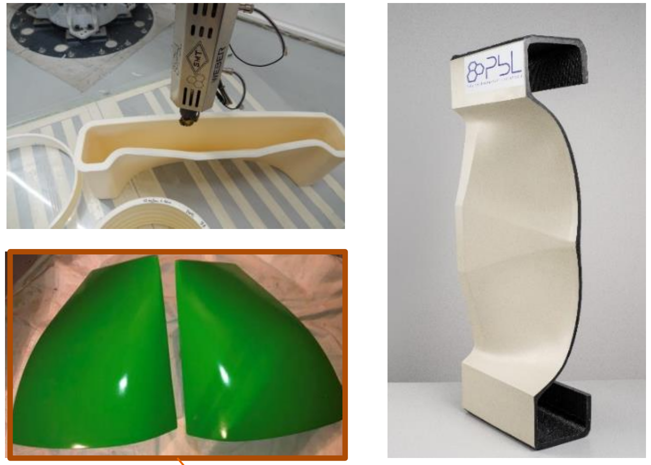
- Glass transition temperature
- Melting temperature (ISO 11357) and melt flow index (MVR)
- Heat distortion temperature (A/B)
- Anisotropic linear expansion (ISO11359)

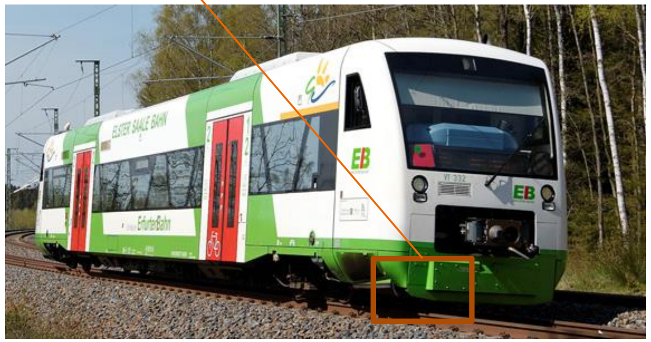
Materials used

- ABS-PC Blend Maurer Plastics Technology
- PC ABS 35% Glass fibre Luvotec Eco
- PA HT with CF 20% 9743 Luvocom
- PET CF 20% 9780 Luvocom



Thermal distortion analysis





Stadler Regio –Shuttle RS 1, Erfurter Bahn

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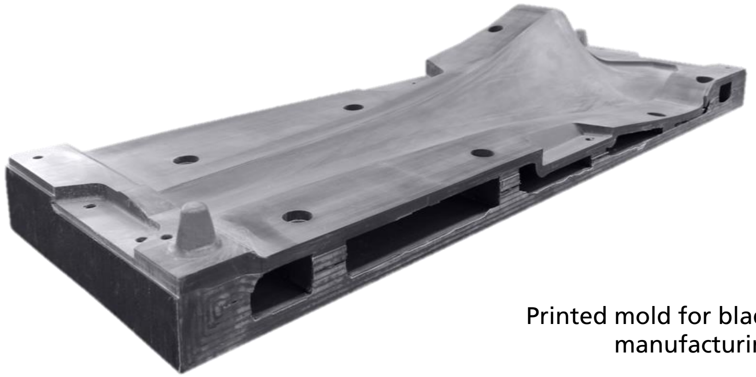
Function-integrative fibre composite designs using additive manufacturing technologies

Large Scale Additive Manufacturing (LSAM)

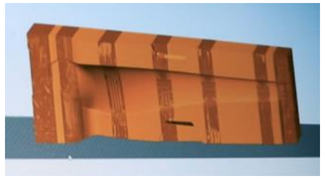
- Manufacturing of FRP-Molds and components
- Thermoplastic material extrusion, milling of surfaces (+/- 0,05 mm)
- Build volume: 1300 x 2500 x 1000 mm
- Cost reduction: direct pellet extrusion
- Printrate: 10…40 kg/h
- Nozzle diameter: 6…20 mm
- Min. Layer-Thickness: 0,5 mm
- T_{max} Nozzle: 450°C, Tmax Printbed: 175°C

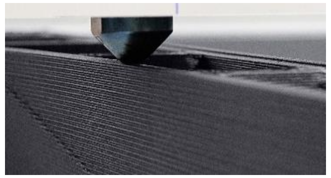


Printed mold for blade manufacturing

CNC bárcenas Discovery 3D printer

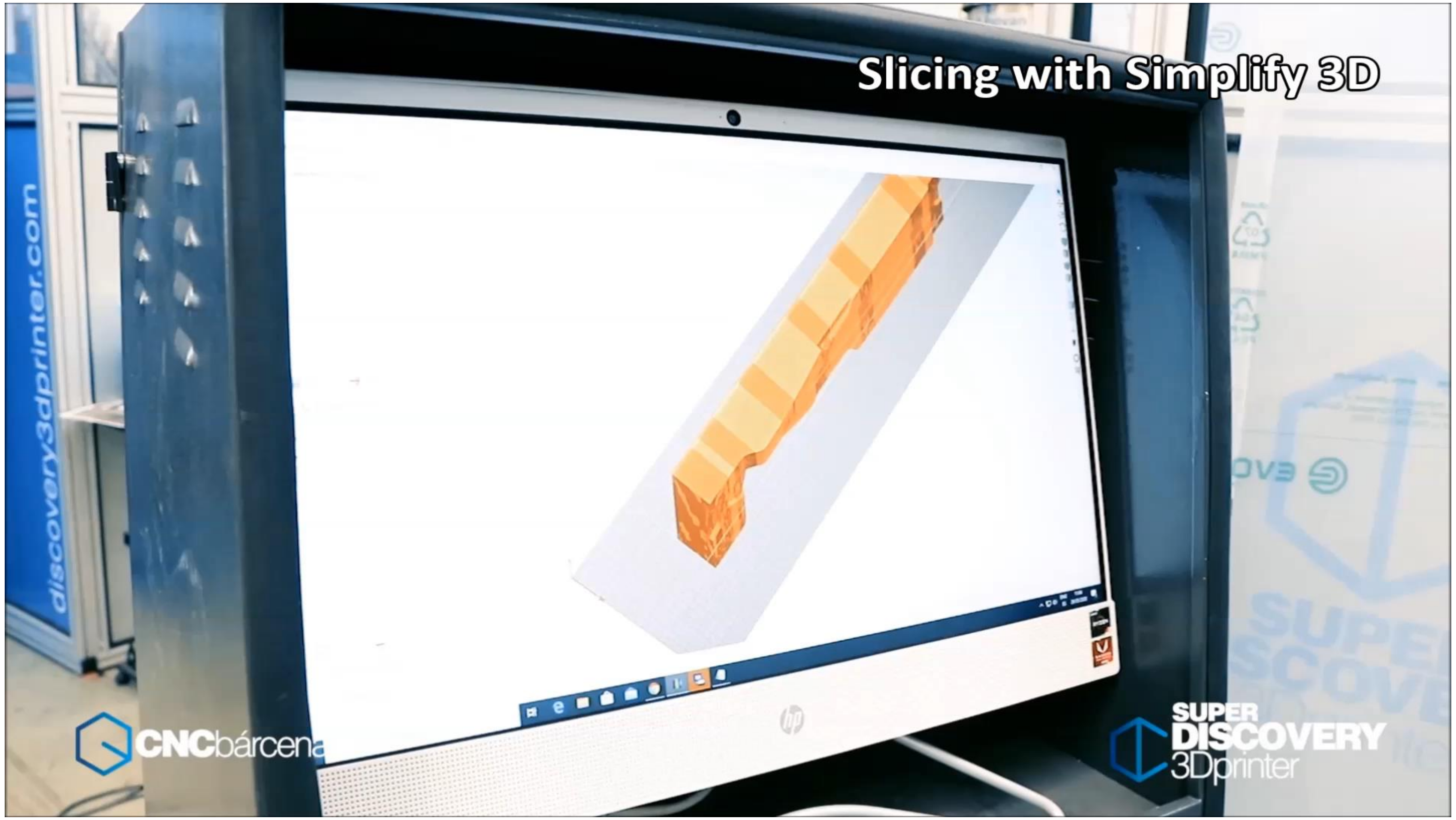
CAD Files Offset/Final → Slicing Simplify 3D → Direct extrusion 10 kg/h → Milling of surfaces → FRP manufacturing Infusion/Autoclave

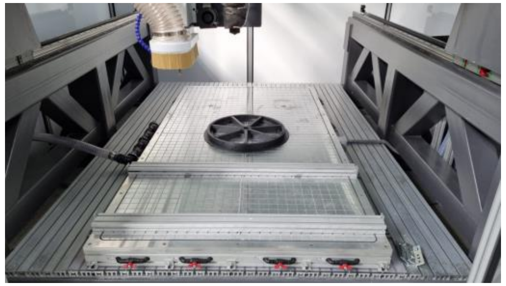




Function-integrative fibre composite designs using additive manufacturing technologies

Large Scale Additive Manufacturing (LSAM)

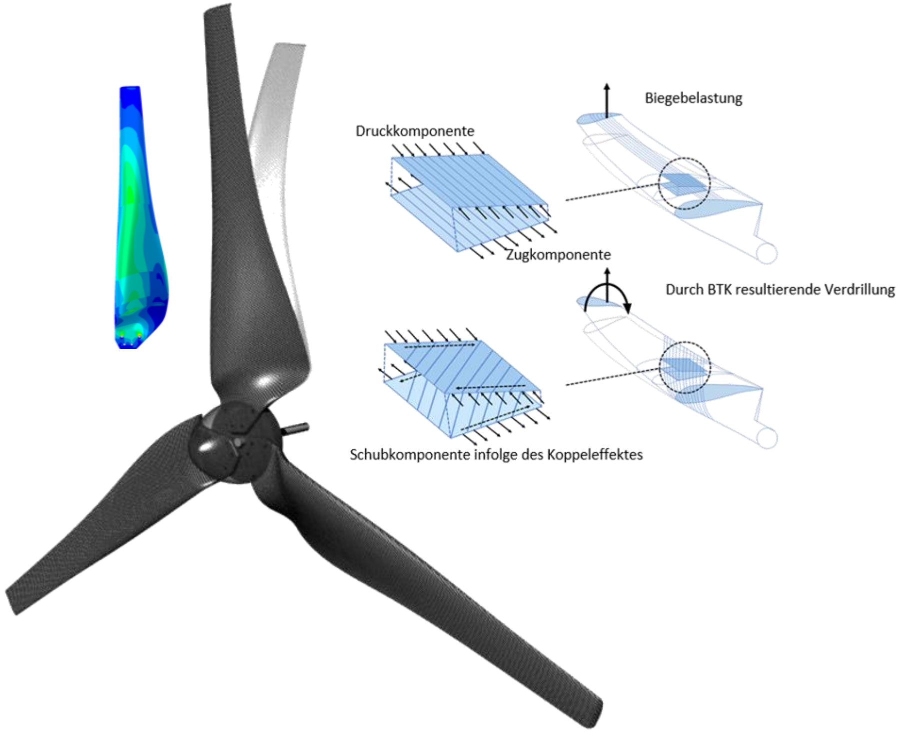




Extrusion process

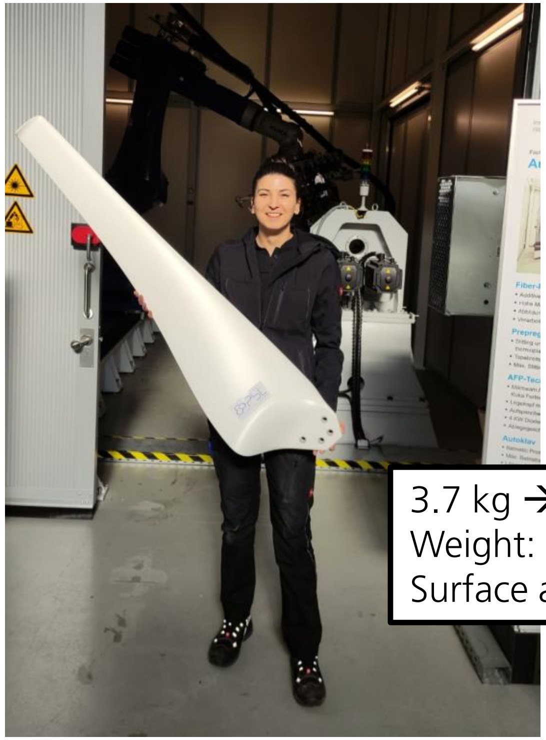
Final results

Adaptive lightweight rotor blade by means of bending-torsion coupling



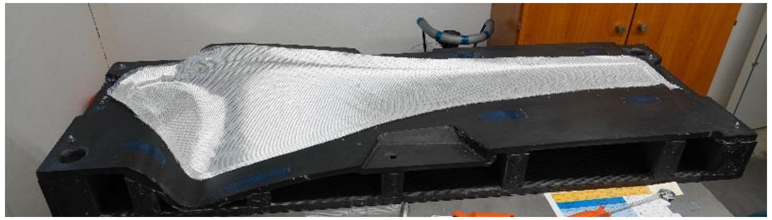
EAB Gebäudetechnik Luckau GmbH

Installation of demonstrator blade on test plant



3.7 kg → 2.4 kg
Weight: -35 %
Surface area: +45 %

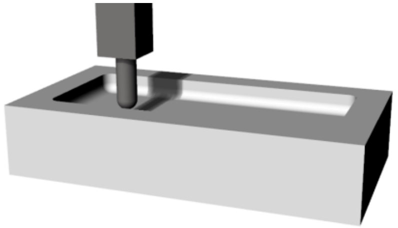
Smart blade demonstrator



Manufacturing of the blade demonstrator

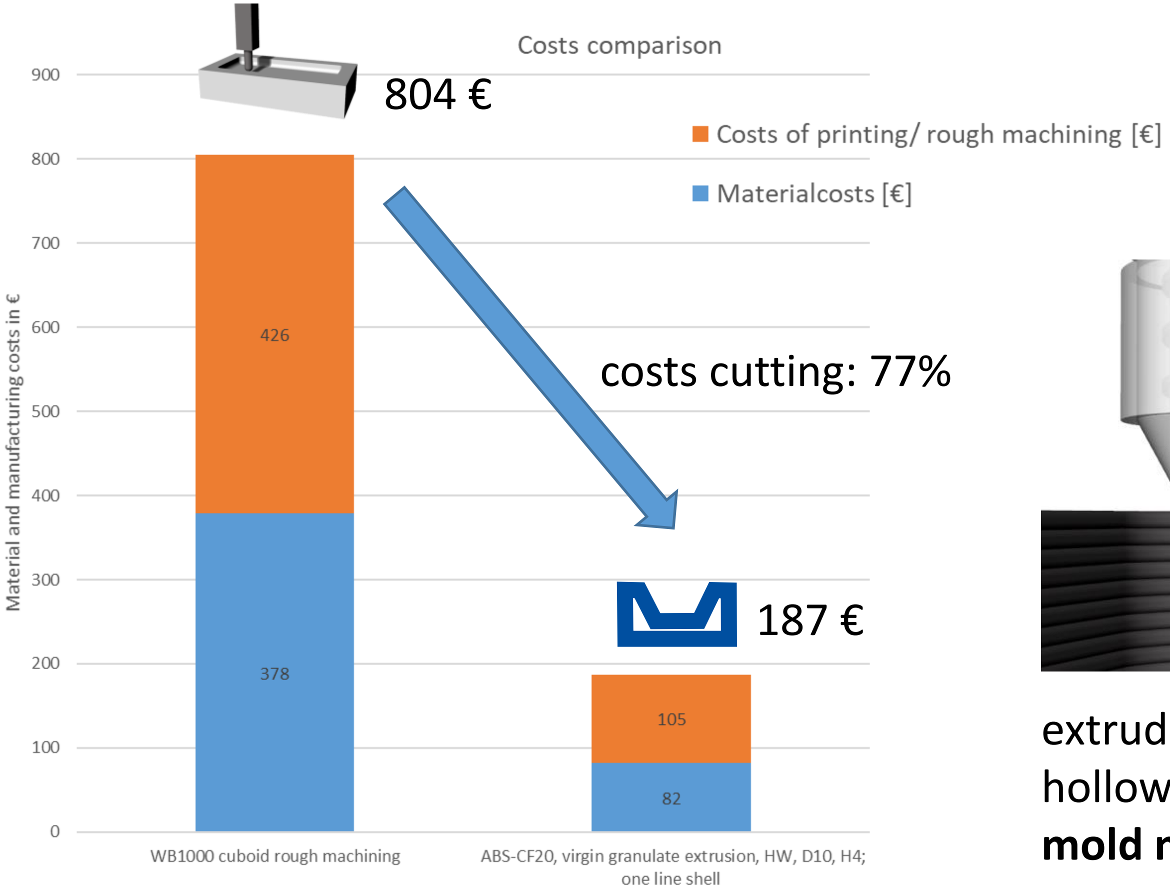
Comparison of subtractive and hybrid manufacturing of FRP molds

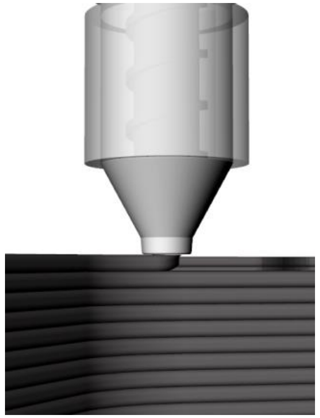
- Print strategy
- Nozzle diameter
- Extruder output
- Re-use of granulate



Standard milled PUR
Cuboid WB 1000

machined <u>full</u> cuboid material
mold mass = <u>37,2 Kg</u>





extruded <u>shell</u>
hollow geometry
mold mass = <u>15,01 Kg</u>

Comparison of subtractive and hybrid manufacturing of FRP molds

- Stone guard on the mountain bike
- Hybrid manufacturing for prototyping
  - Additive near-net-shape process (1h)
  - Fine finishing process (4h)
  - Coating (0,5h)
  - frp manufacturing (1h)
- Post-processing (0,5h)
- Polymer: PA HT CF
  (3F PAHT CF 9743 BK, Lehmann und Voss)
- Granulate costs: 55 €
- Block material EN AW 5083 costs: 140 €

Lehmann&Voss&Co. LEHVOSS Group

LAST

PbL Polymerbasierter Leichtbau

Fakuma

27th Fakuma 2021
12.-16. OCTOBER
FRIEDRICHSHAFEN

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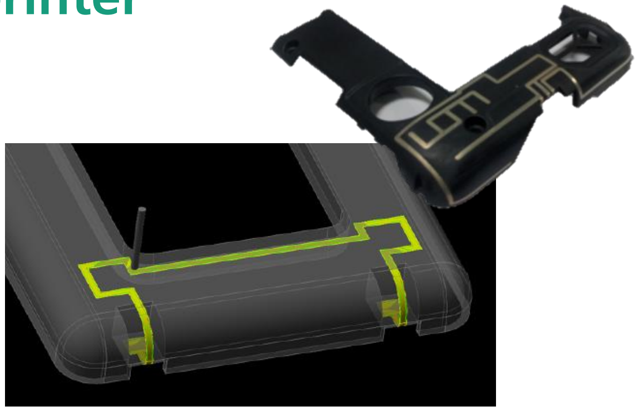
Function-integrative fibre composite designs using additive manufacturing technologies

Printed Electronics – Neotech AMT GmbH PJ15X printer

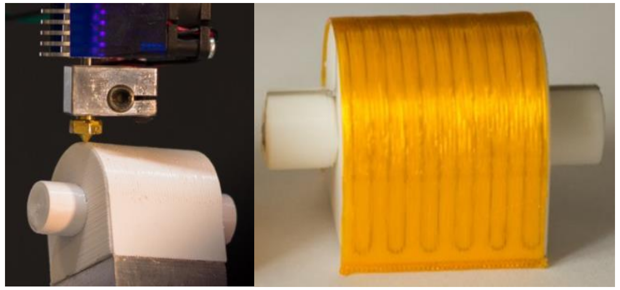
- Rapid Prototyping system for 3D Printed Electronics
- Combines multiple printing technology with 5-axis motion control enabling complex 3D printing

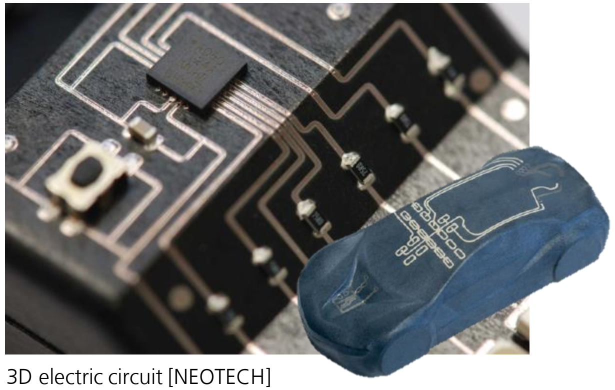
- Piezo-Jet print head
- Excentric screw dispenser
- FFF 3D-print-head
- SMD Pick & Place module
- Milling
- Infrared and UV curing
- Fiducial-camera and confocal sensor

- Build volume: 400 mm / 300 mm / 140 mm (X/Y/Z)
- Max. printing speed: 100 mm/s
- Repeat accuracy linear axis: ± 10 µm
- Rotational axis repeatability: ± 0.017


Internal electric circuit [NEOTECH]

PJ15 X printer [NEOTECH]


FDM incremental method head; heating element [NEOTECH]


3D electric circuit [NEOTECH]

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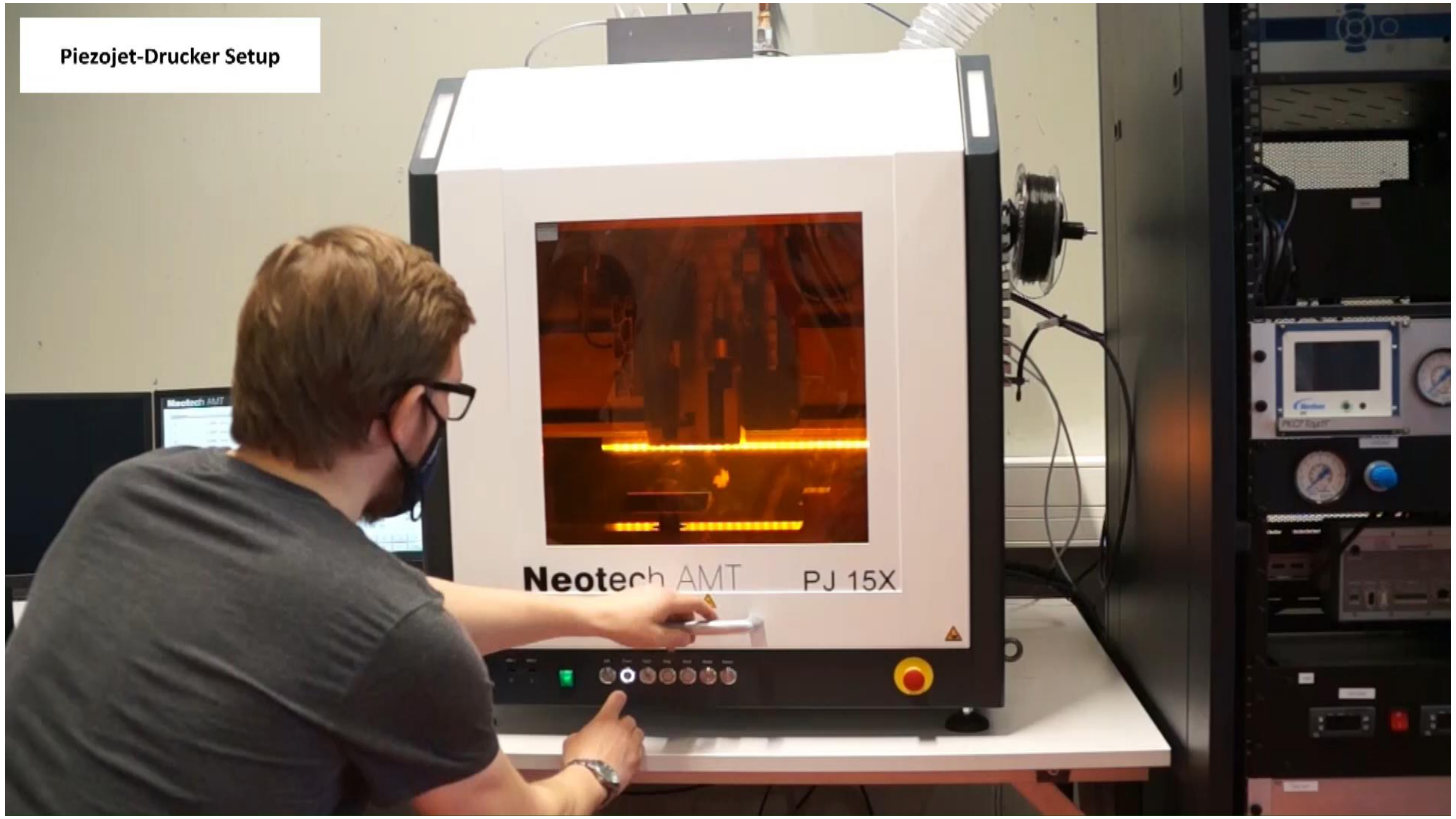
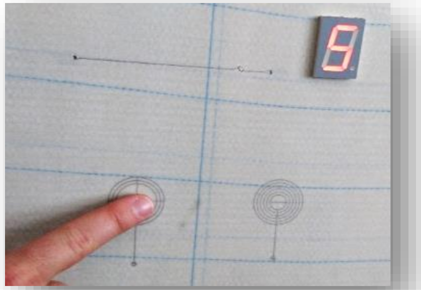
Function-integrative fibre composite designs using additive manufacturing technologies

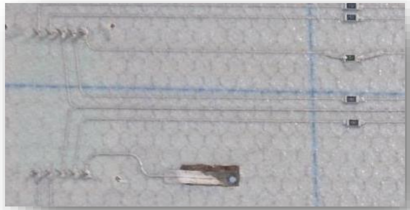
Printed Electronics



interactive elements, sensors, strain gauges, etc.

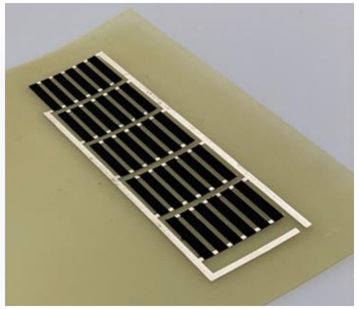


printed interconnections



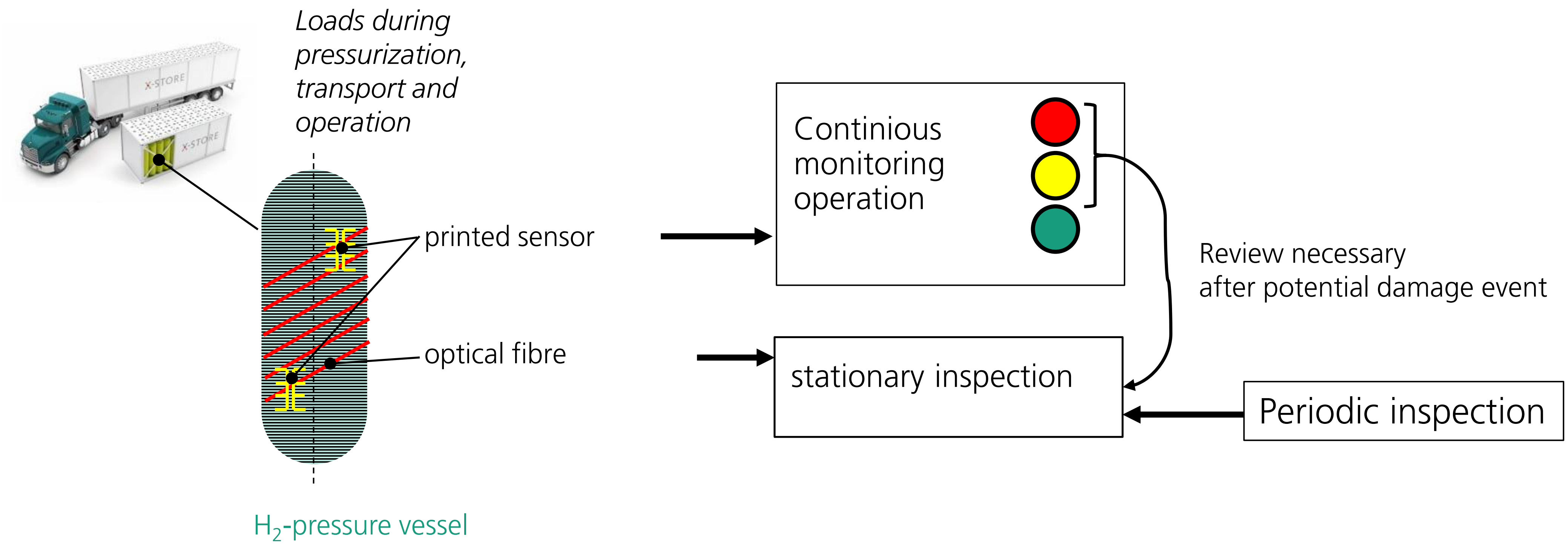
printed illumination

heating systems



Function-integrative fibre composite designs using additive manufacturing technologies

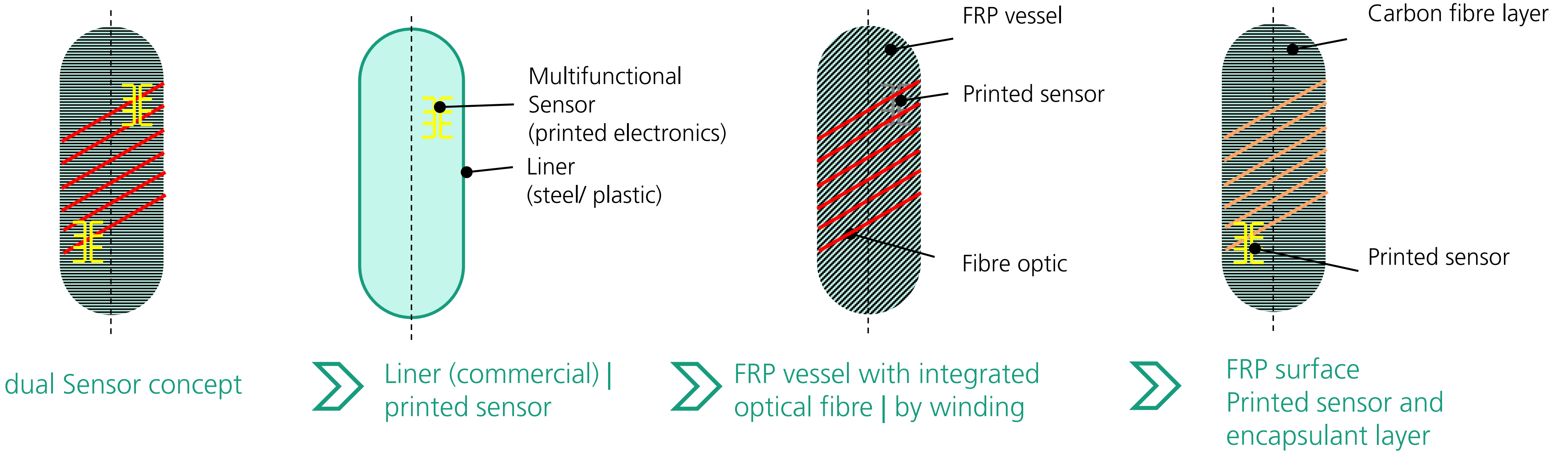
Printed Electronics - Structural Health Monitoring (SHM) for FRP hydrogen pressure vessels



Function-integrative fibre composite designs using additive manufacturing technologies

Printed Electronics - Structural Health Monitoring (SHM) for FRP hydrogen pressure vessels

- Printed sensor: Detection and record of accelerations, impacts, temperature and pressures
- Optical fibre sensor: Analysis and detection of deformations and material failure



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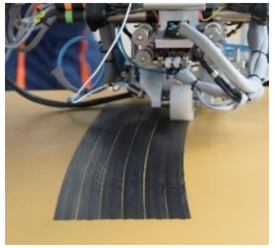
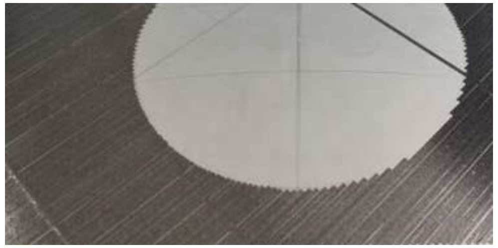
Function-integrative fibre composite designs using additive manufacturing technologies

Automated Fiber Placement Center by Mikrosam DOO

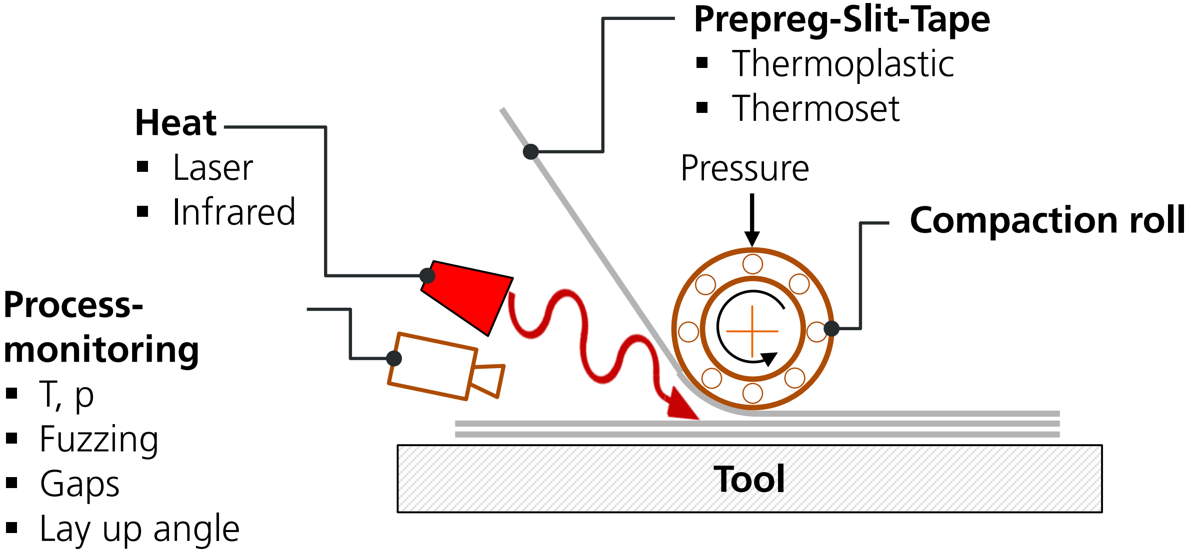
- Processing of slitted prepreg tapes (thermoset, thermoplastic, bindered rovings)
- Flexibility in manufacturing: fiber selection, complex geometries
- High process speed: up to 0,5m/s with diode laser
- High fiber volume fraction (> 60%)



Load path adapted fiber design



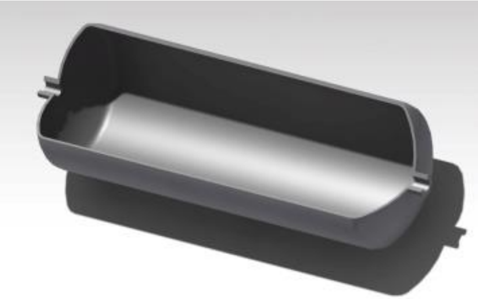
Reduction of waste



→ **Load path adapted/near net shape solutions**

Function-integrative fibre composite designs using additive manufacturing technologies

Automated Fiber Placement Center by Mikrosam DOO



Monolithic metal vessel

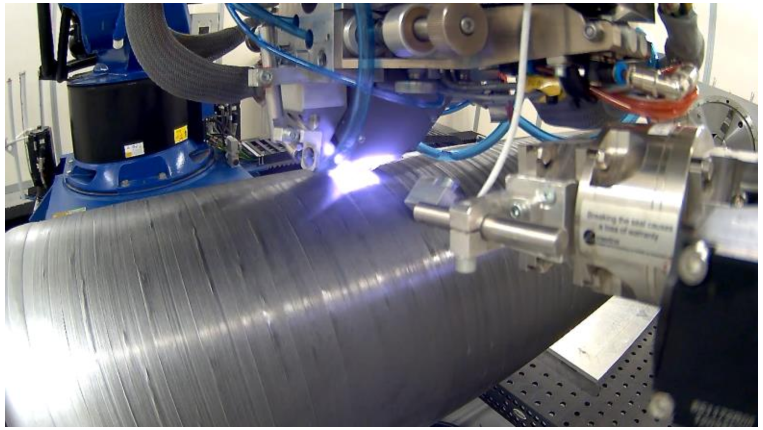
Type I: Monolithic metal vessel

- Inner diameter: 270 mm
- Steel liner thickness: 2.75 mm
- Operating pressure: **11 bar**

Circumferential reinforced metal vessel

Type II: Circumferential reinforced metal vessel

- Steel liner thickness: 2.75 mm
- Inner diameter: 270 mm
- Composite: CETEX TC1200 PEEK AS-4
- Ply thickness: **0.25 mm**
- Angle ply composite lay-up: $[+\theta/-\theta]_{ns}$
- Investigated pressure load: **33 bar**



Manufacturing of Type II vessel using AFP

upcoming soon!

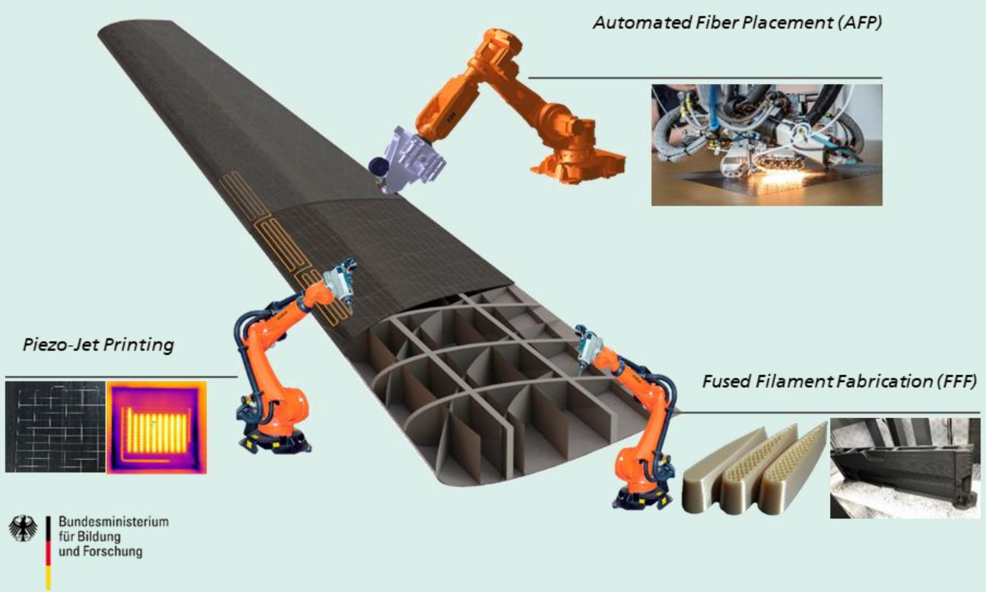
Mikrosam winding machine

Function-integrative fibre composite designs using additive manufacturing technologies

Integration of Printed Electronics and SHM-Systems

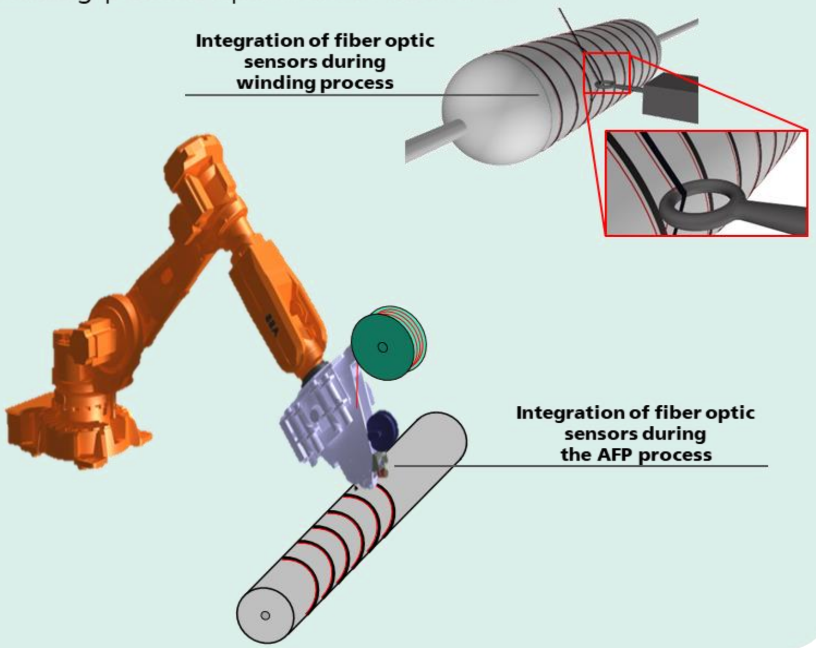
Fusion of additive technologies

- Printing core and sensors / heating cables with additive technologies and applying composite with AFP in one process
- An automatic process that enables the production of a finished hybrid element with a high level of additional functionalization



Automated integration of lightweight sensors during AFP process and SHM winding

- Modification of the head for applying optical fibers parallel to the reinforcing fibers
- Enabling process optimization and SHM



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Thank you for your attention!

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