Project TB-Rumpf:
Manufacturing of a thermoplastic fuselage demonstrator

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German Aerospace Center (DLR) - Institute of Structures and Design
Location and Thermoplast Technologies

Component Manufacturing

- Hotpress / Thermoforming
- Out-of-Autoclave Processing
- In-Situ AFP
- Robotic 3D printing

Joining Technologies

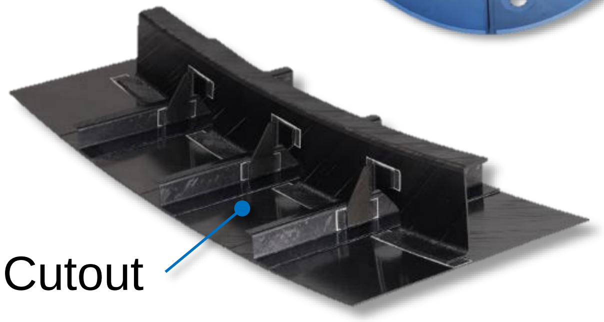
- Co-Consolidation
- Resistance Welding
- Continuous Ultrasonic Welding

German Aerospace Center (DLR) - Institute of Structures and Design

Thermoplastic Demonstrators

Fuselage Applications

RPB

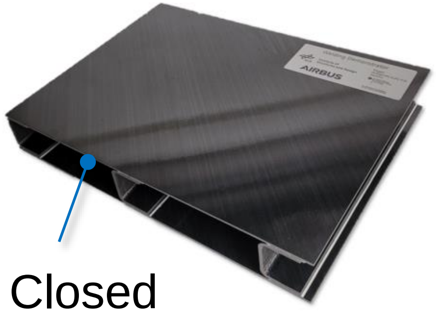


Cutout

Testshell

Wing Structures

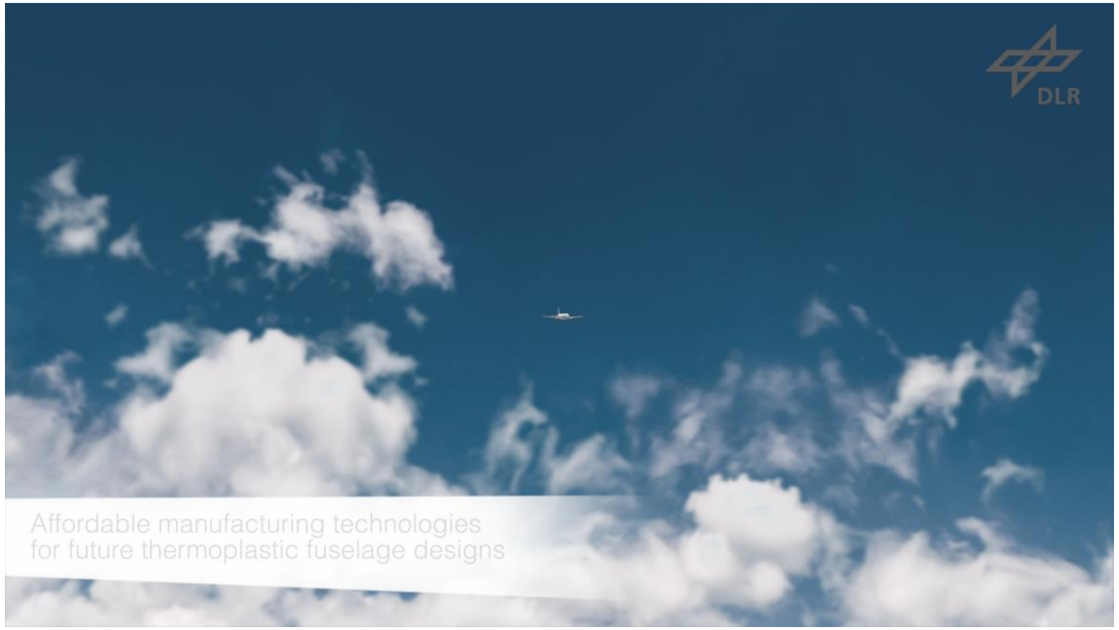
A340 Slat



Closed Box

Why?

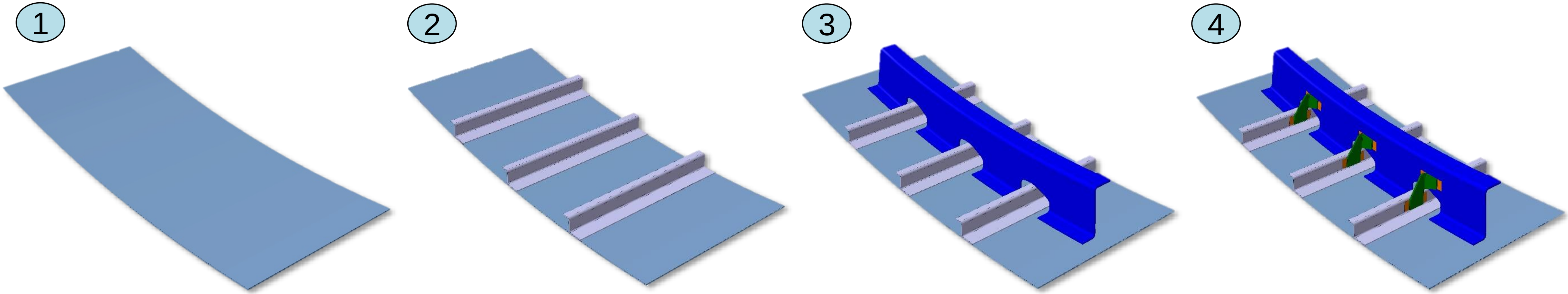
Where and What?

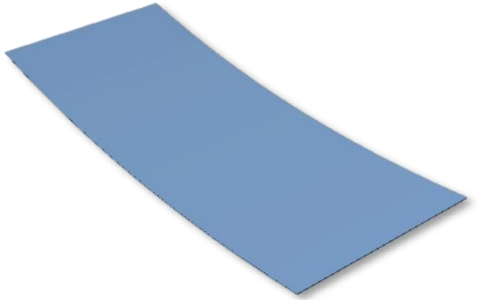


How?
Manufacturing process of stiffened fuselage panels

Material System: TC1225 LM-PAEK CF UD

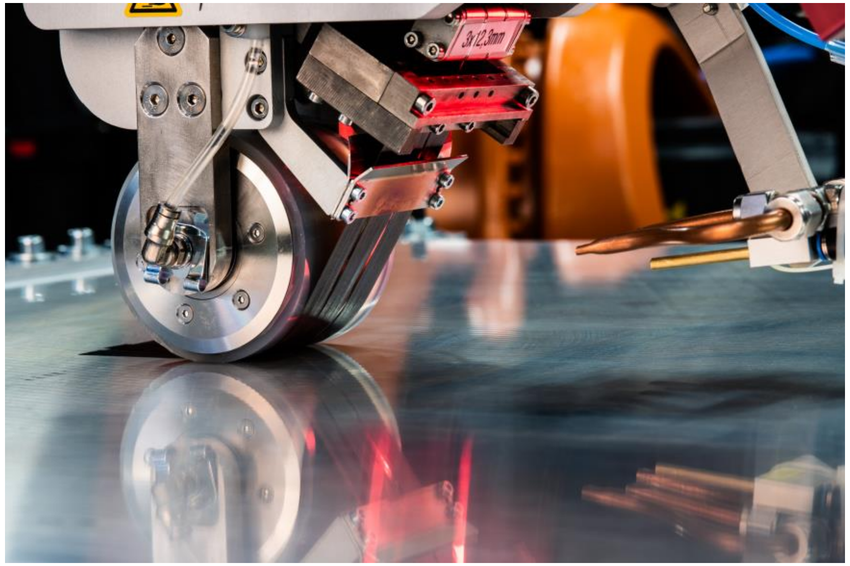
1. Skin manufacturing with in-situ automated fibre placement (AFP)
2. Skin consolidation and stringer integration using a one-step out-of-autoclave technology
3. Frame integration by resistance welding
4. Cleat integration by resistance welding



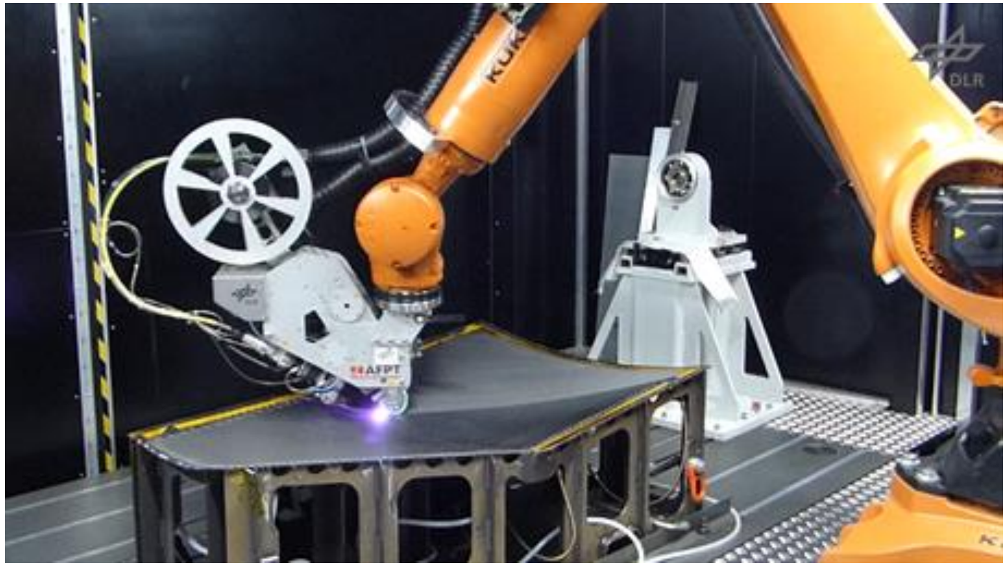


Thermoplastic fibre placement – skin manufacturing

- AFP is an additive process
- Multi tow endeffector with 3 x ½” tapes
- Demonstrator tooling with double-curved surfaces

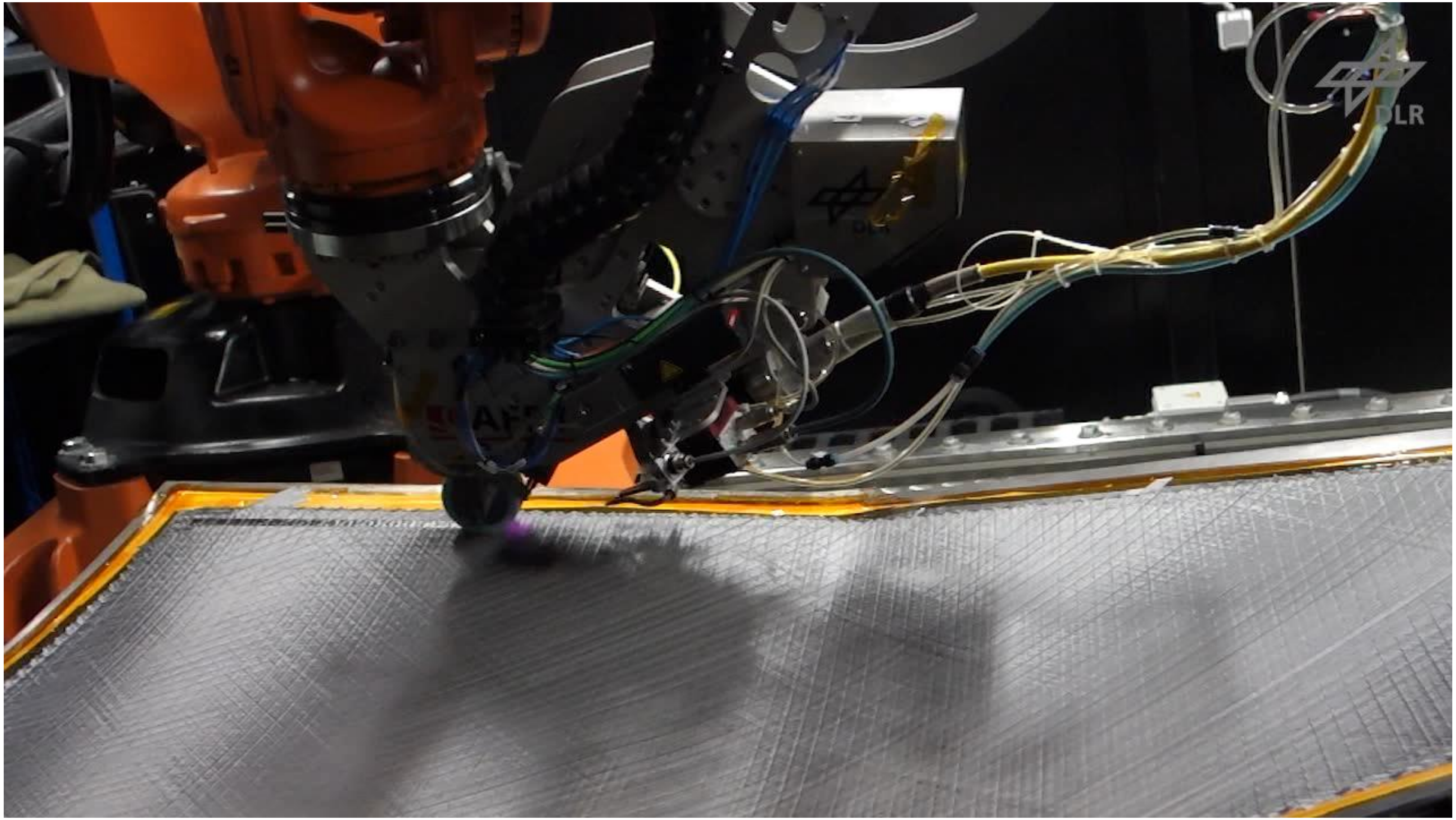


Tape placement head

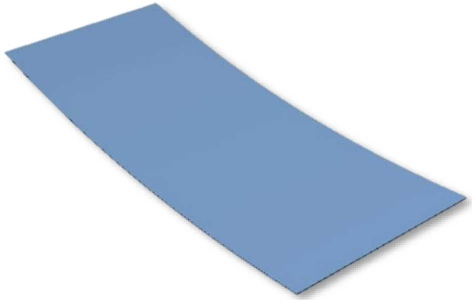


Tape placement on curved part

DLR

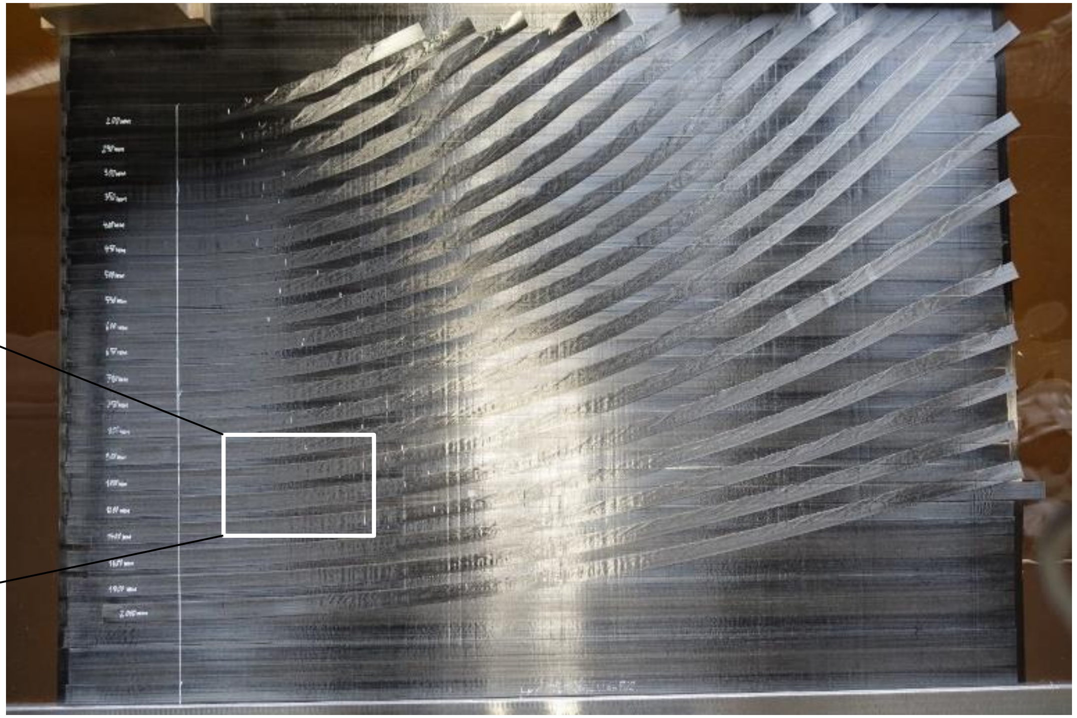


Thermoplastic fibre placement – fibre steering

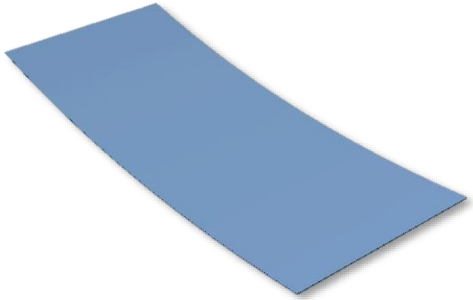


〉 Steering analysis for minimal steering radius

No fibre steering



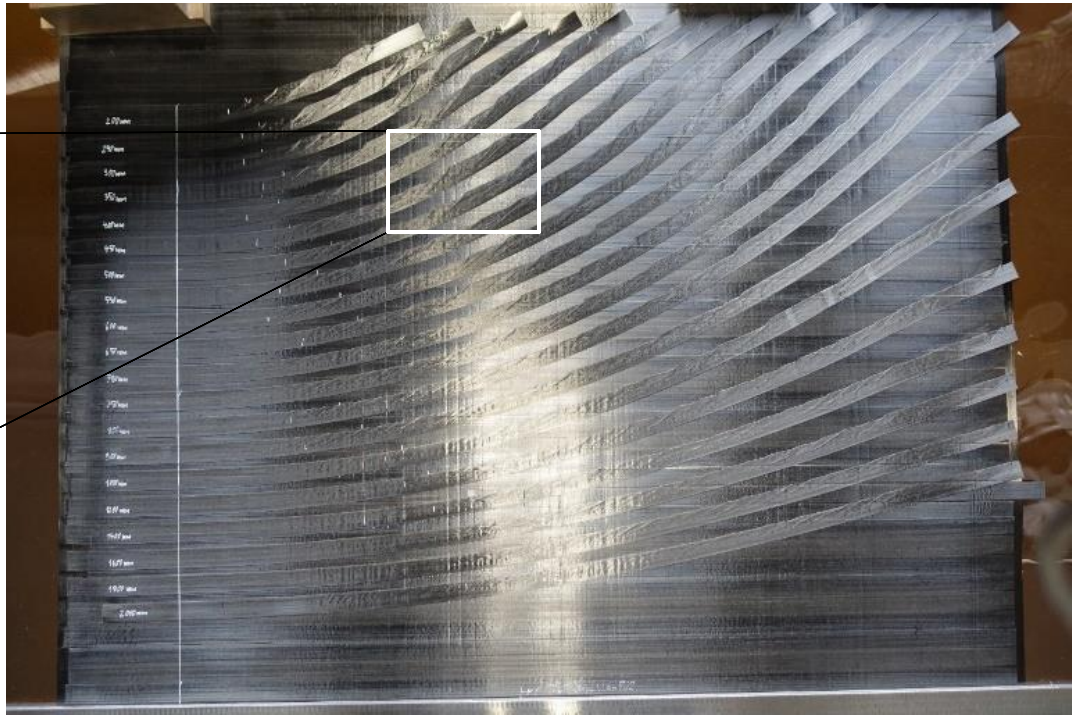
Steering analysis



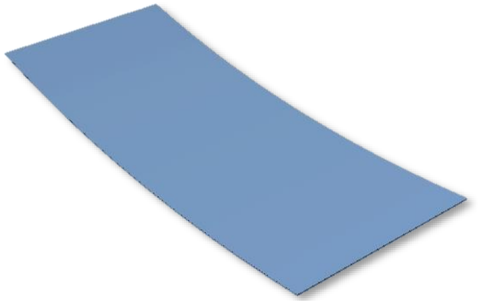
Thermoplastic fibre placement – fibre steering

- AFP layup quality dependent on track length & radii
  - Minimal radius of 4000mm

Fibre steering

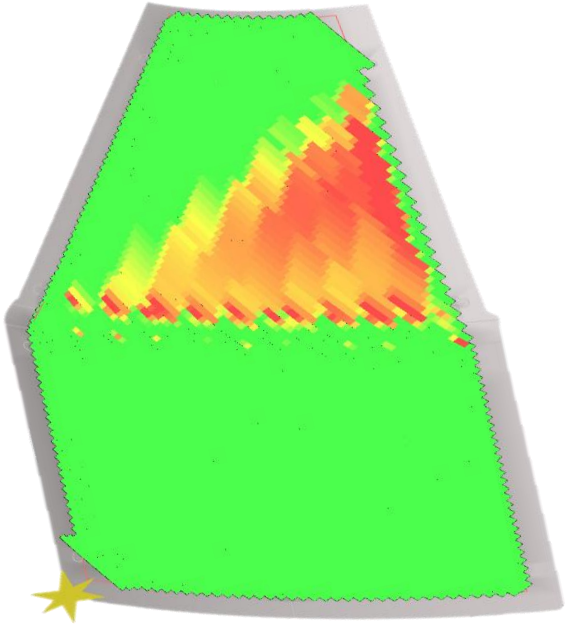


Steering analysis

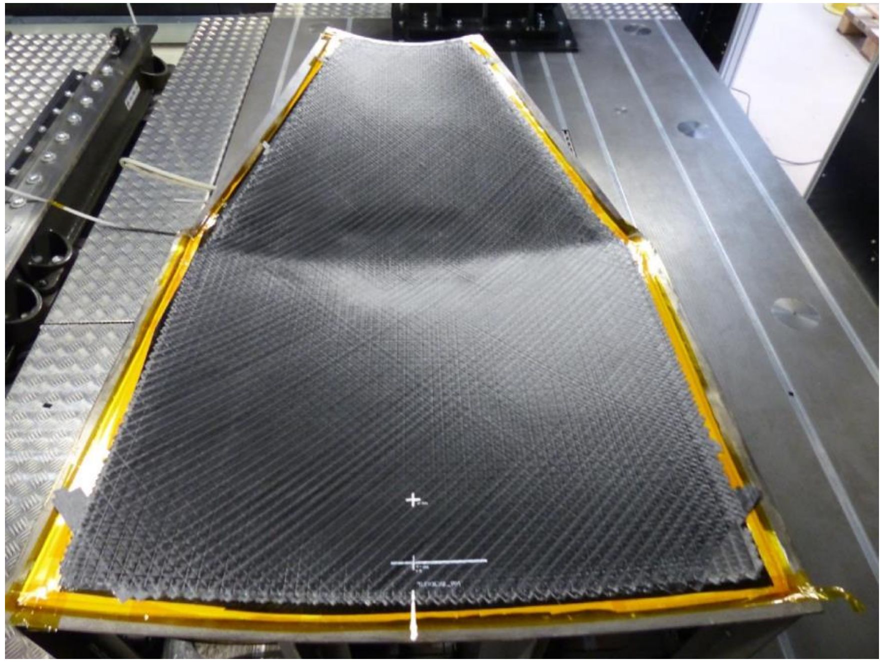


Thermoplastic fibre placement – fibre steering

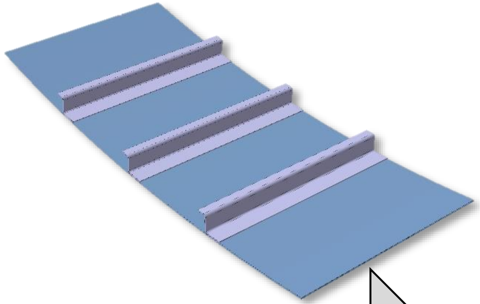
- Demonstrator was digitally analyzed before production
- All radii were uncritical
- Successful manufacture of the demonstrator skin



AFP Path Analysis



Finished Part

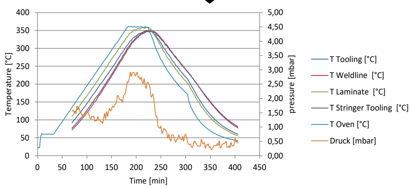


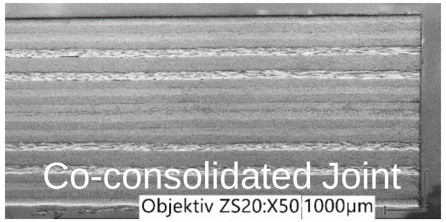
Thermoplastic OoA consolidation & stringer integration

Development of the co-consolidation process

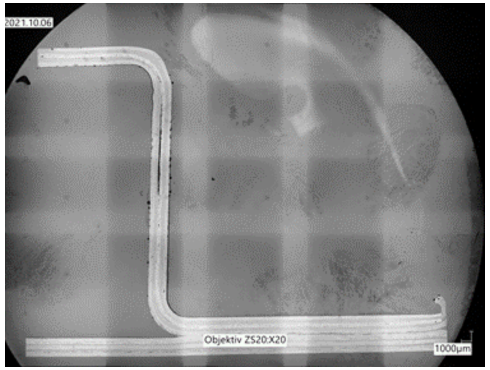
Manufactured Laminate

Unconsolidated plies

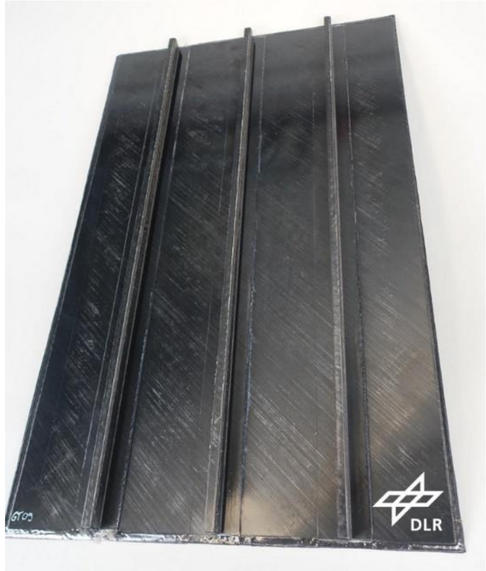




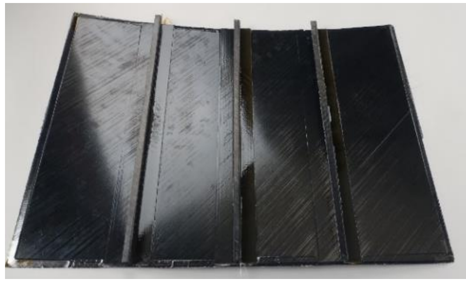
Integration of prefinished stringers during consolidation



Manufacturing of flat stiffened panels for testing

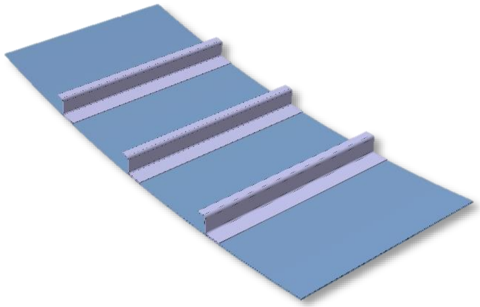


Adaption of technology to curved panels

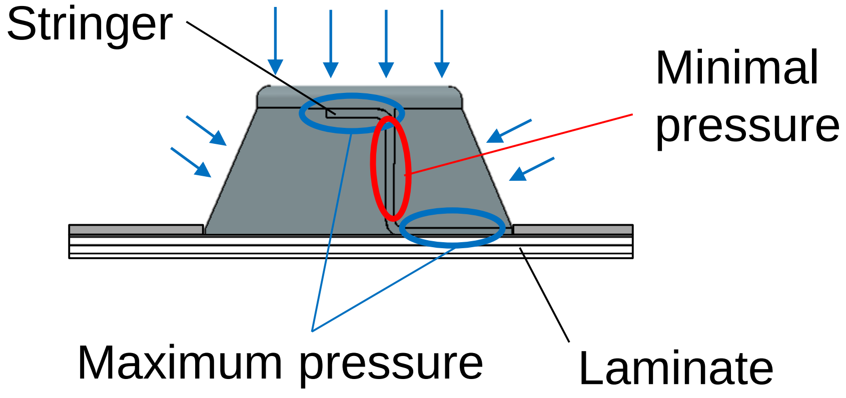


Thermoplastic OoA consolidation & stringer integration

Stringer integration on flat panels

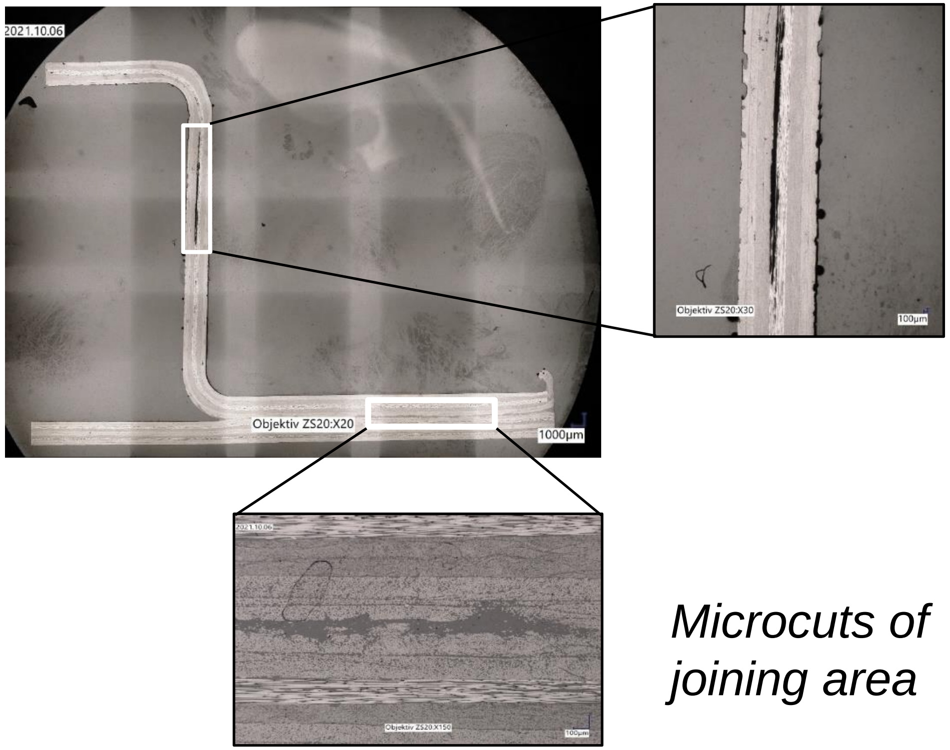


- Differential tooling design for the prefinished stringers
- Excellent joint at laminate area
- Delamination in stringer web

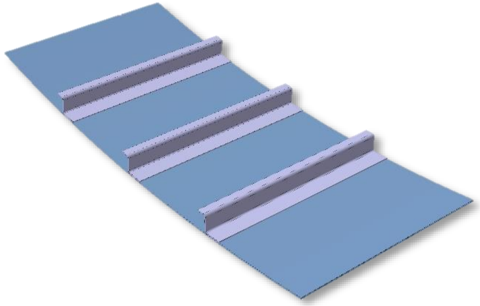


Tooling concept for stringer integration

NDI of stringer foot & skin

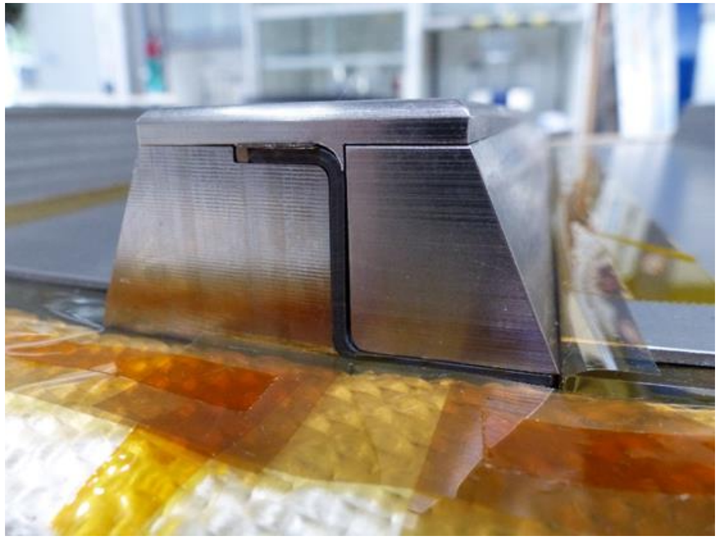


Microcuts of joining area

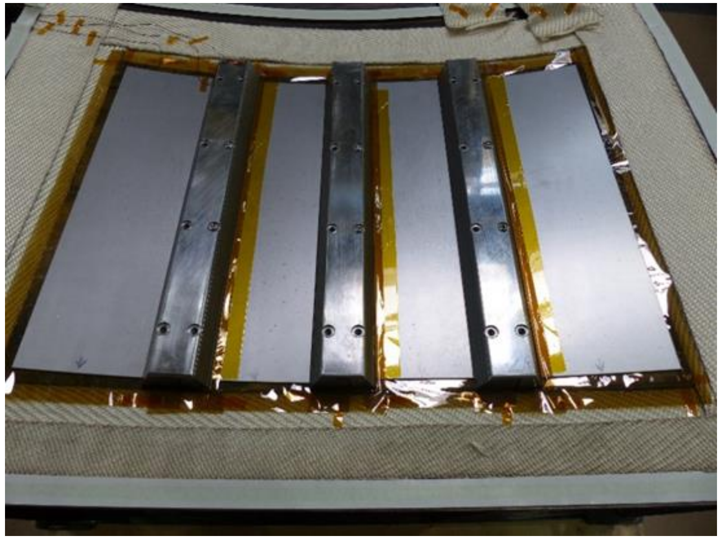


Thermoplastic OoA consolidation & stringer integration
Stringer integration on curved panels

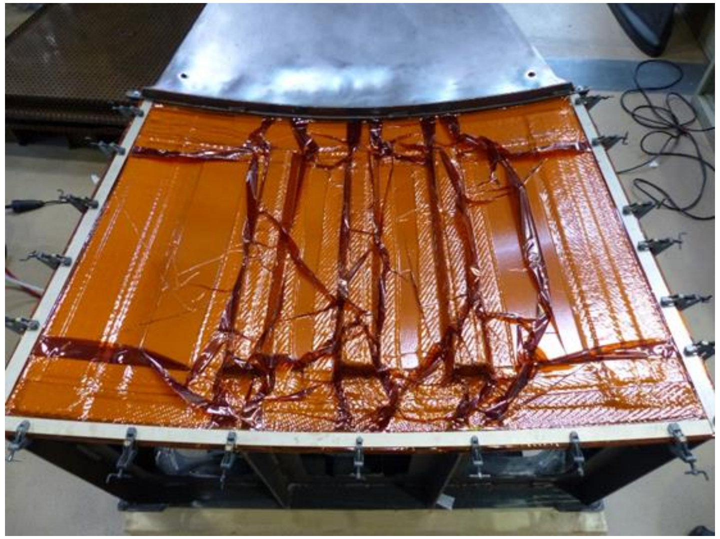
- Positioning of stringers & tooling
- Curved metal sheets as caul plates
- Application of Kapton foil and vacuum



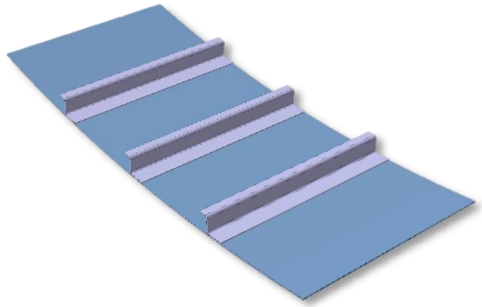
Integration tooling



Setup before vacuum bagging

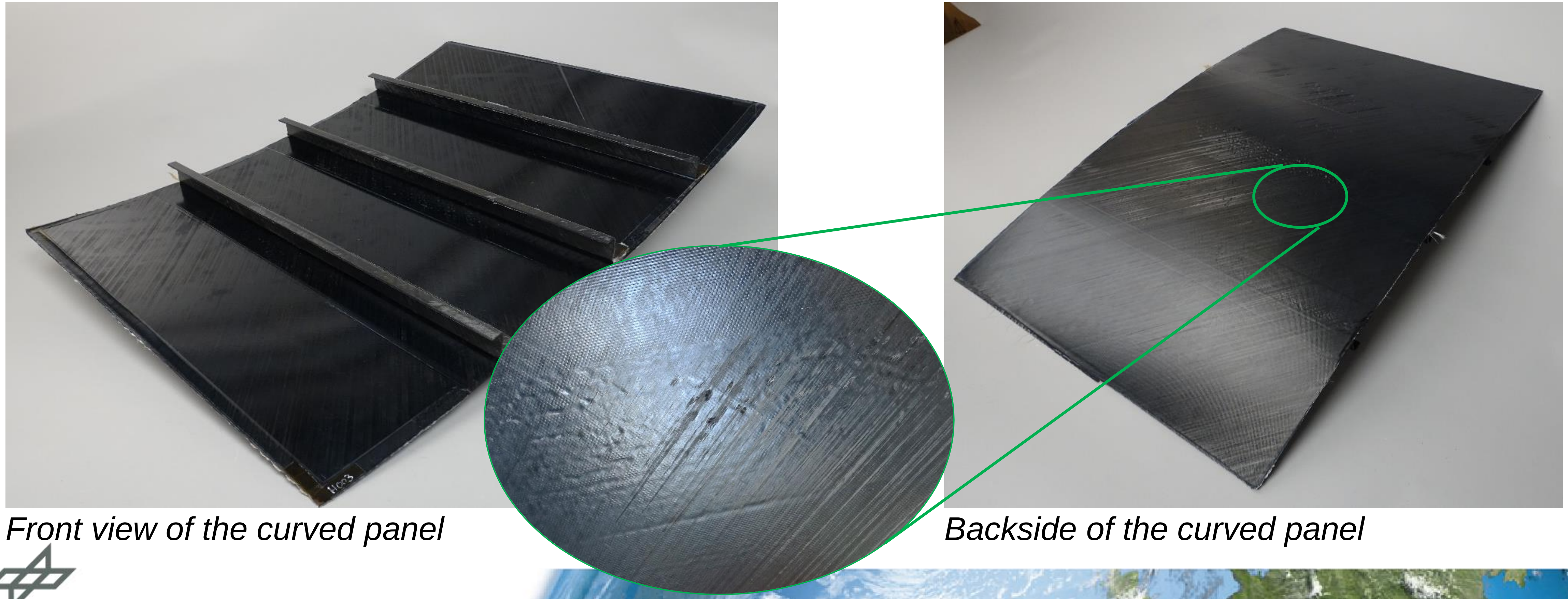


Final setup for oven



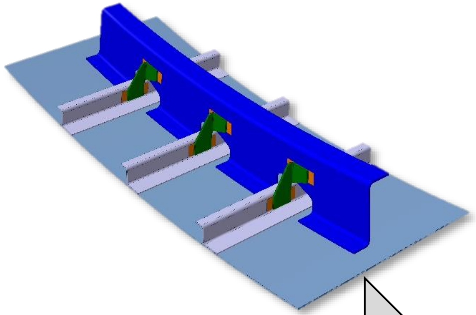
Curved panel

- Good quality and accuracy of shape
- Small wrinkles & „roughness“ indicate porosity due to tolerance issues of the tooling



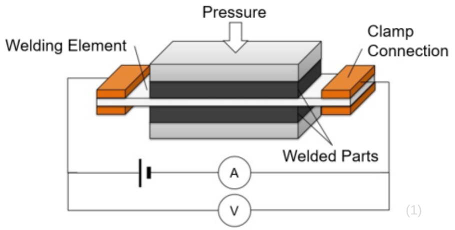
Front view of the curved panel

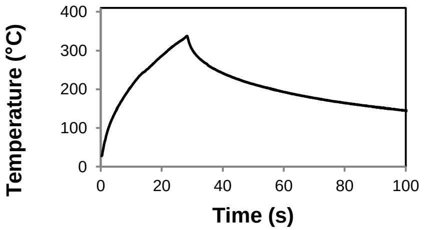
Backside of the curved panel



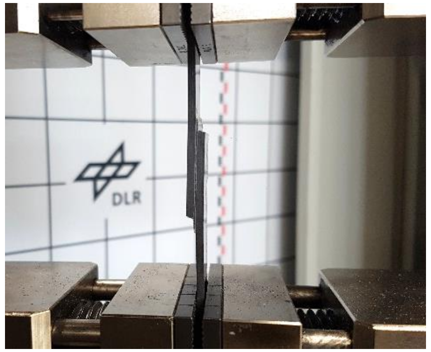
Resistance welding of frame and cleats

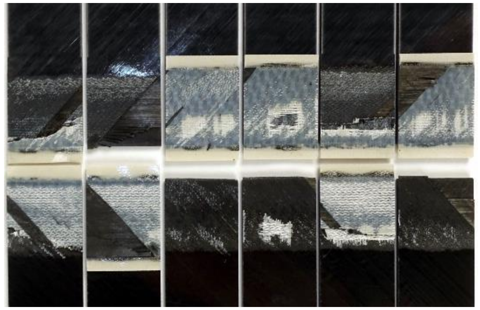
Development of resistance welding process



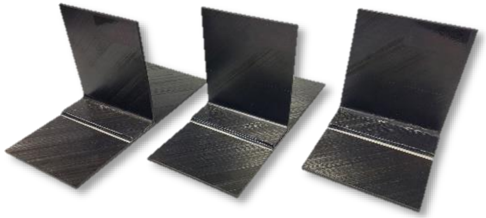


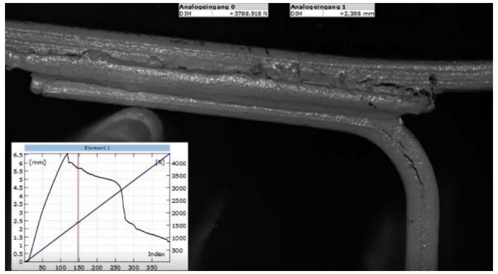
Coupon tests for process evaluation



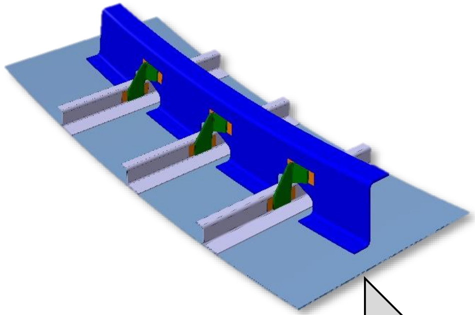


L-Pull tests for validation of frame-skin joint





(1) D. Stavrov and H. E. N. Bersee, “Thermal Aspects in Resistance Welding of Thermoplastic Composites,” 2003.



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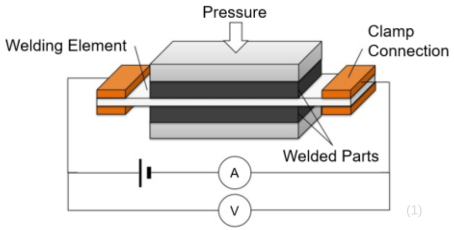

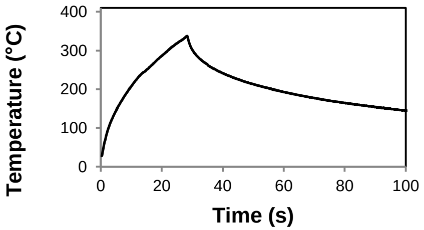

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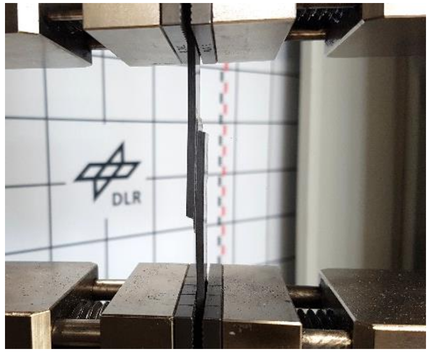

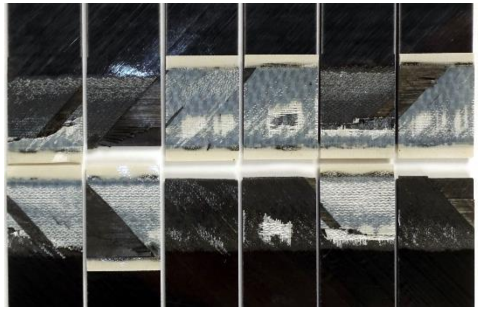

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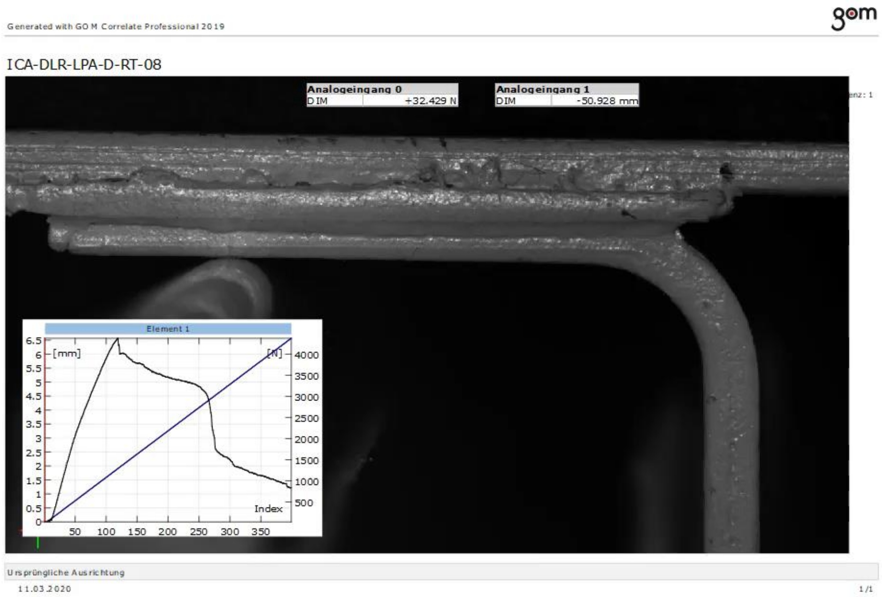

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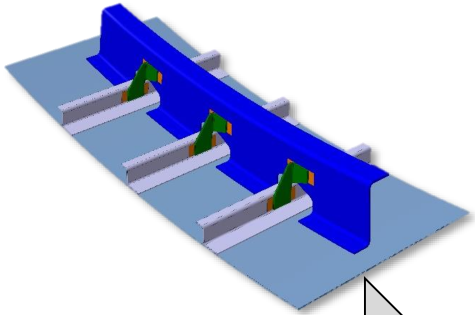

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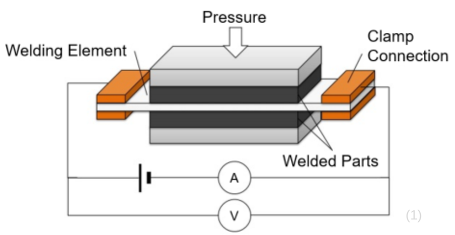

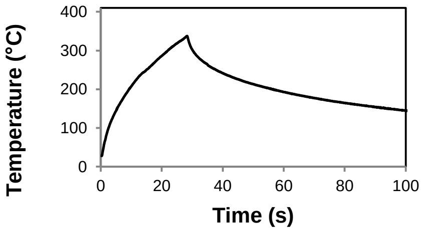

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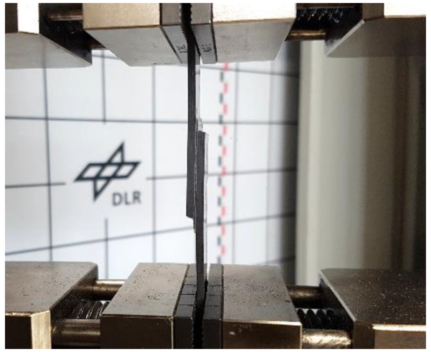

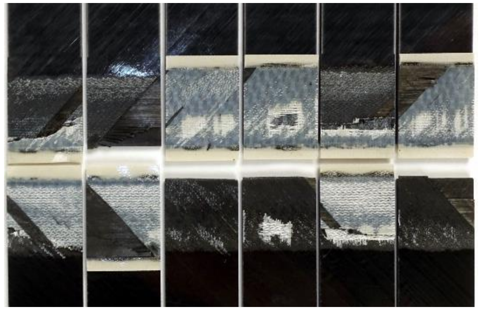

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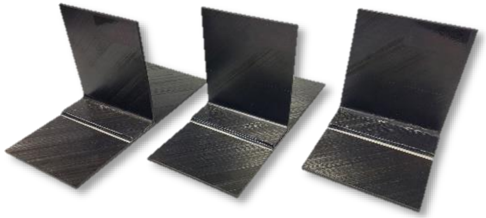
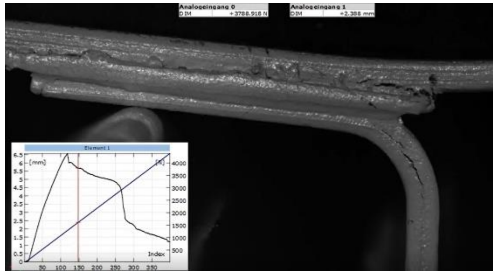
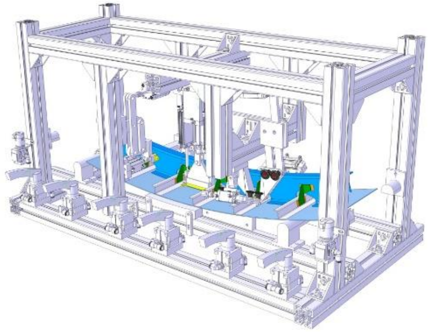




Development of welding rig for cleat and frame integration



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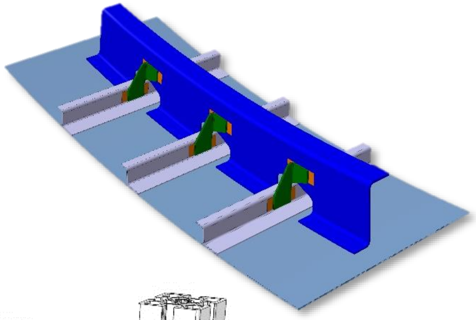
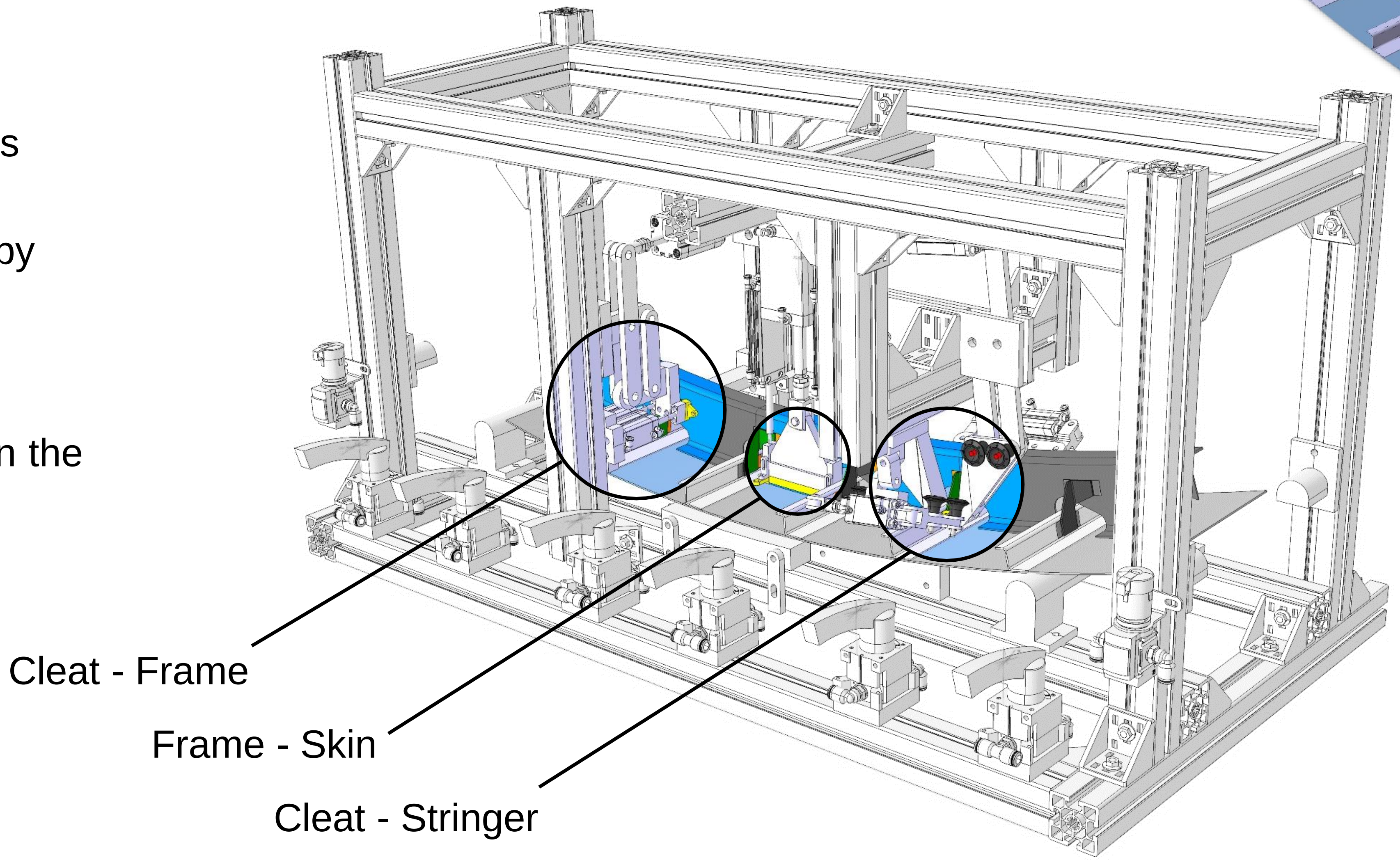
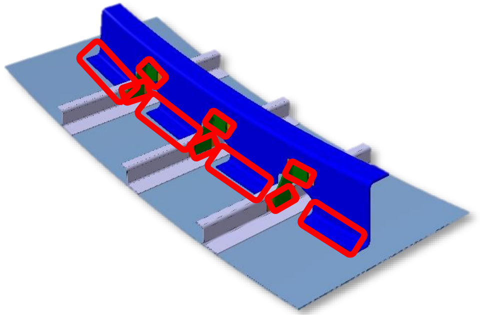


Welding rig

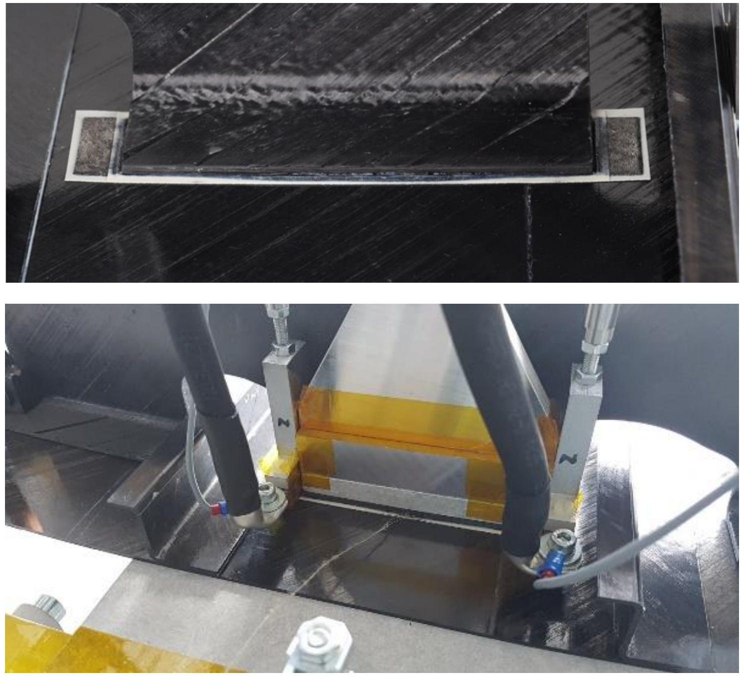
- Three welding stations
- Pressure application by pneumatic cylinders
- Manual shifting of the demonstrator between the stations



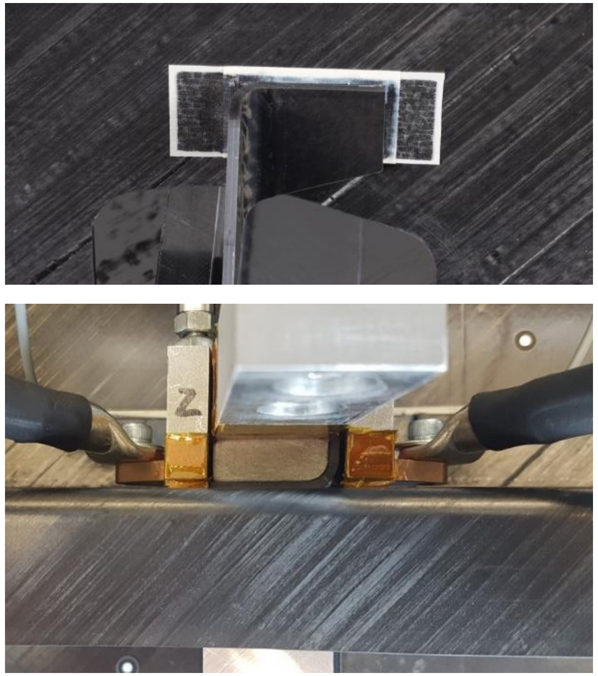


Resistance welding

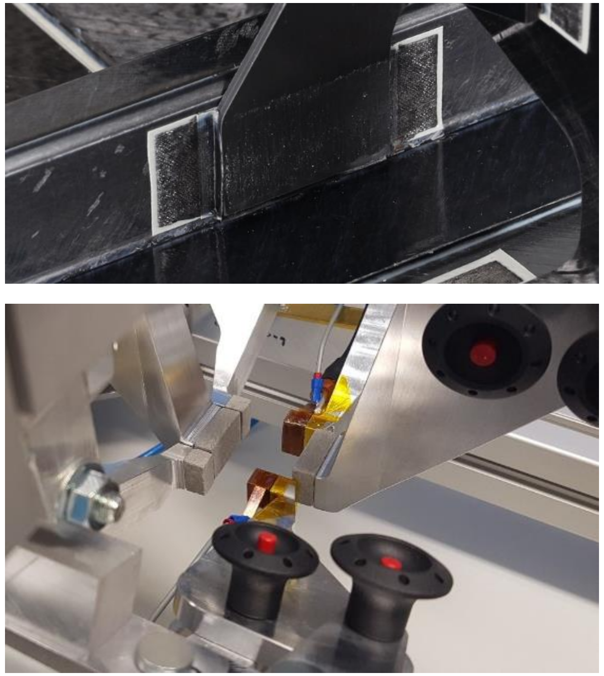
Frame and Cleat integration with Carbon Fibre Welding Element



Frame-skin



Cleat-frame



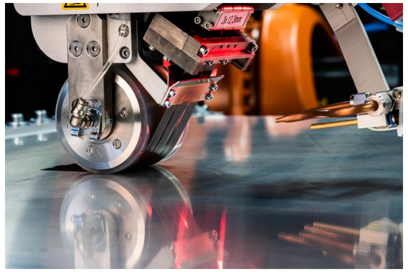
Cleat-stinger


600 mm
300 mm
DLR

Results and lessons learned

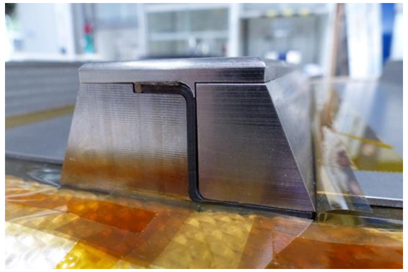
Automated fibre placement

- Double curved structures successfully manufactured
- Fibre steering must be considered but is manageable
- Highly scalable process for larger structures



Vacuum consolidation & stringer integration

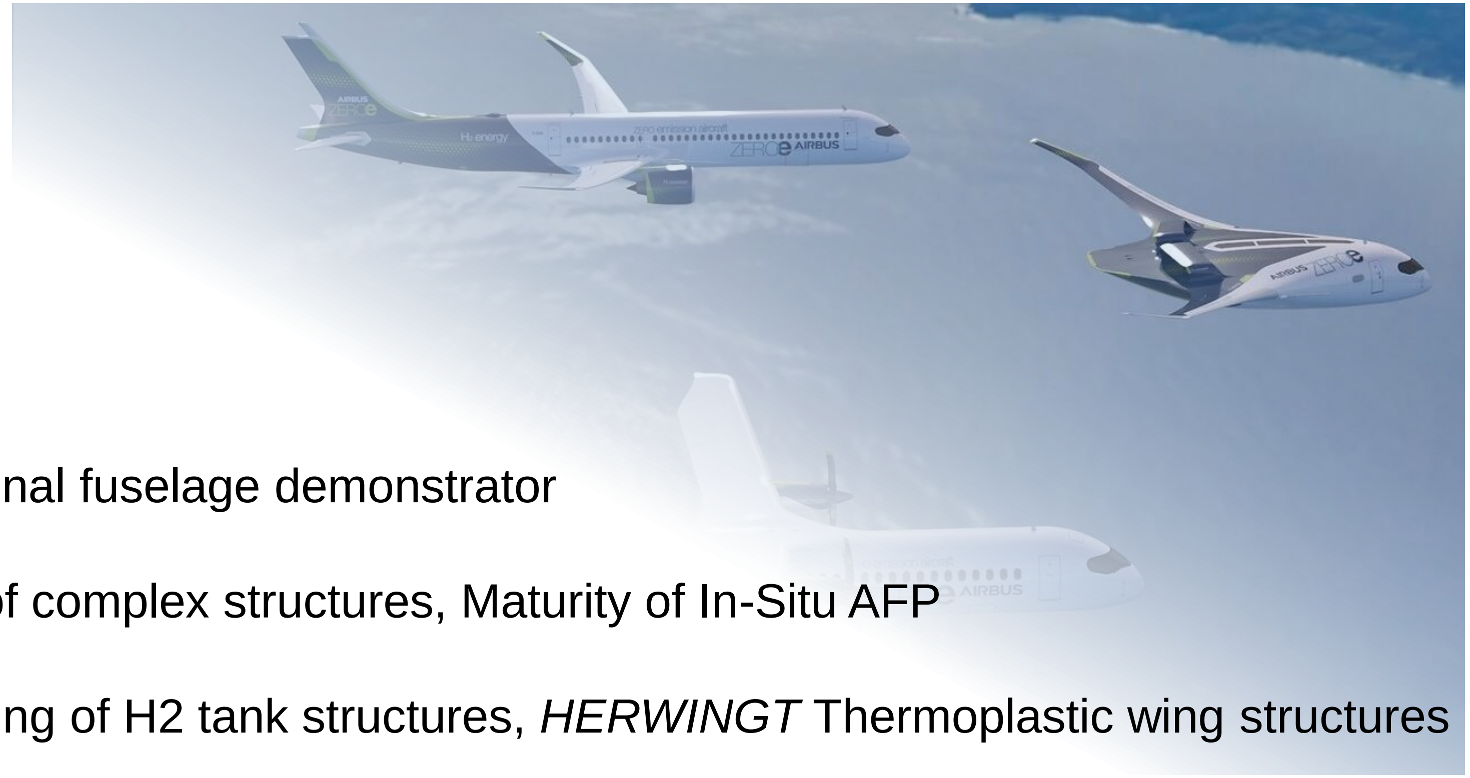
- Process able to manufacture joints in near reference quality
- Integration of prefinished stiffeners shown with flat & curved structures
- Highly sensitive process regarding tolerances of tooling and material



Resistance welding frame & cleats

- Ideal for the integration of short stiffening elements
- Carbon fibre fabrics are suitable as welding conductors
- Welds show excellent performance for out of plane loads

Way forward



Current and future projects:

- EU Clean Sky2: *MFFD* Multifunctional fuselage demonstrator
- LuFo: Hybrid welding, Integration of complex structures, Maturity of In-Situ AFP
- EU Clean Aviation: *FasterH2* Welding of H2 tank structures, *HERWINGT* Thermoplastic wing structures

Thanks to the great team and our partners

Simon Bauer

Georg Doll

Lukas Raps

Samuel Tröger

Matthias Horn

Karsten Reifegerste

AIRBUS

PREMIUM AEROTEC

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Part of: BMWK Project LuFo V-3 TB-Rumpf

DLR