Leight weight potential by Multi-Material-Assemblies in Carbodies

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ALSTOM
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Agenda

1. “State of the art” – carbody materials / technologies
2. General weight saving methods
3. Multi Material Headstock TD1.3 (Shift2Rail)
4. Additive manufacturing of big assemblies (AGENT-3D)
5. Specific composite approaches
6. Conclusions

01

“State of the art” carbody materials / technologies

“State of the art” carbodies

- “SoA” Materials / Technologies

  - **Carbon steel** (e.g. S355 / S460)
    Fully welded carbodies by differential construction method
    Alternative welded subassemblies, finally bolted to built the carbody structure

  - **Stainless steel** (e.g. 1.4301 / 1.4307)
    Spot welded carbodies by differential construction method
    Alternative spot welded subassemblies, finally bolted to built the carbody structure

  - **Aluminium** (e.g. ENAW 6005A.T6)
    Fully welded carbodies by integral construction method
    Alternative welded subassemblies, finally bolted to built the carbody structure

- “SoA” Carbodies - sample pictures



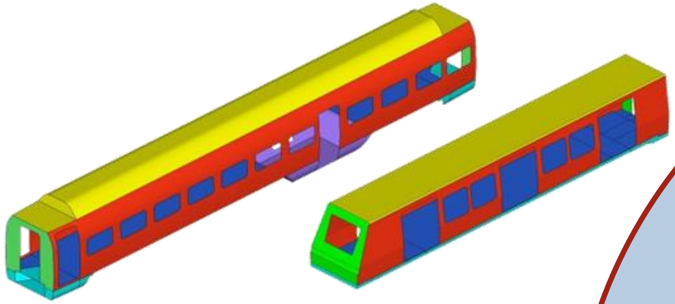


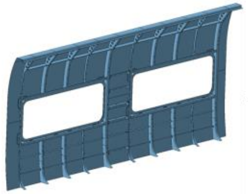


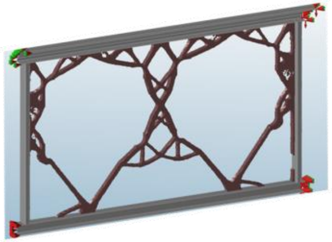

02

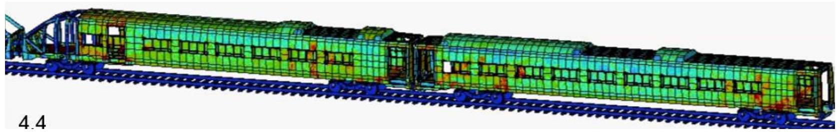
General weight saving methods

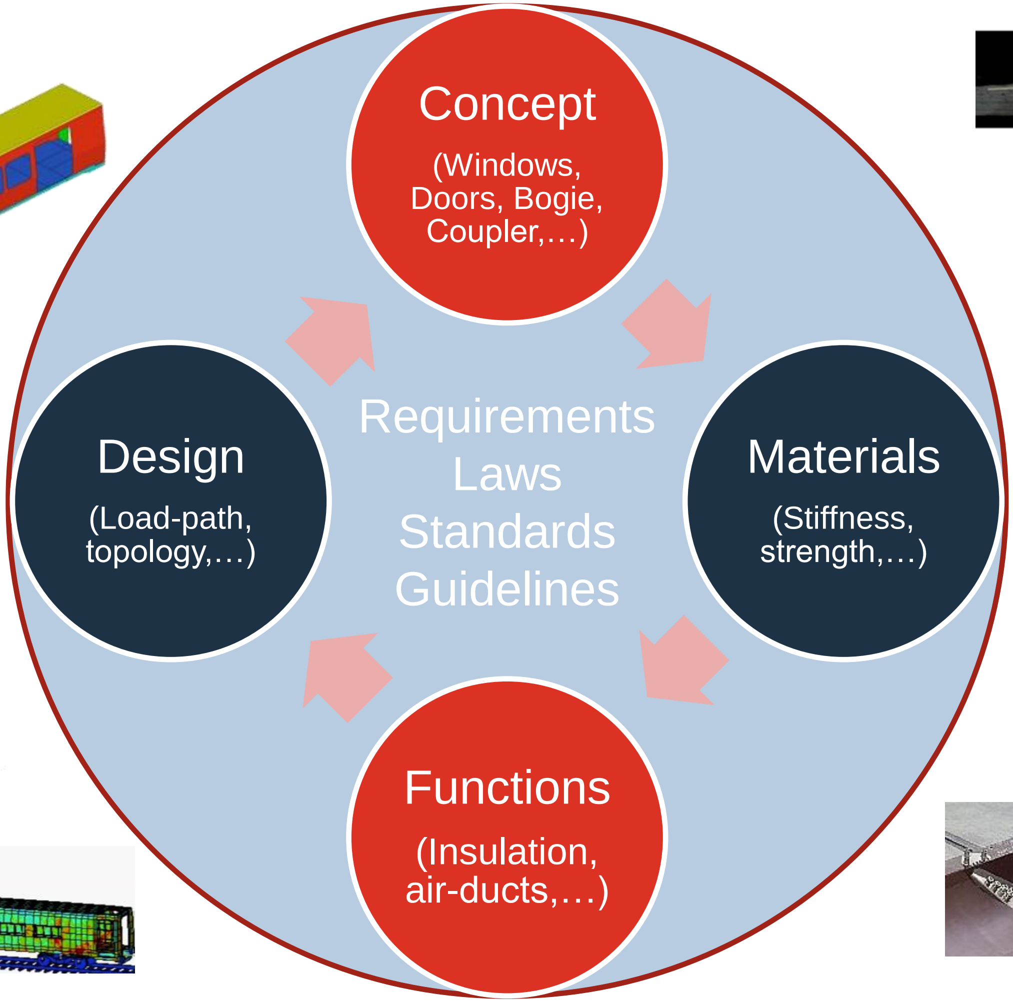
General weight saving methods

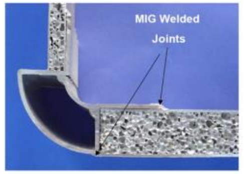


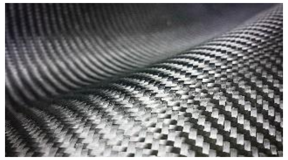


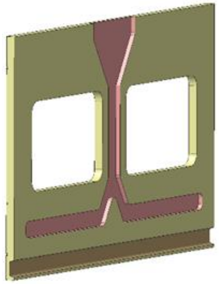












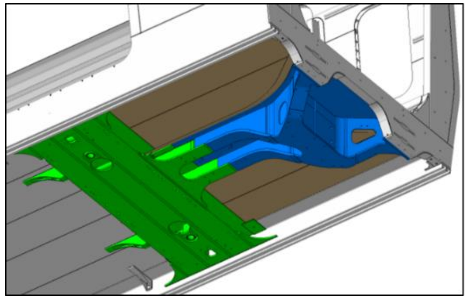
03

Multimaterial Headstock TD1.3 (Shift2Rail_PIVOT + PIVOT2)

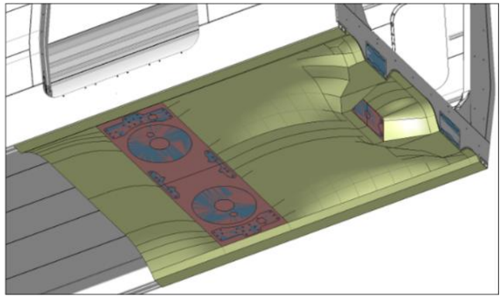
Multimaterial Headstock TD1.3 (Shift2Rail_PIVOT + PIVOT2)

Overview

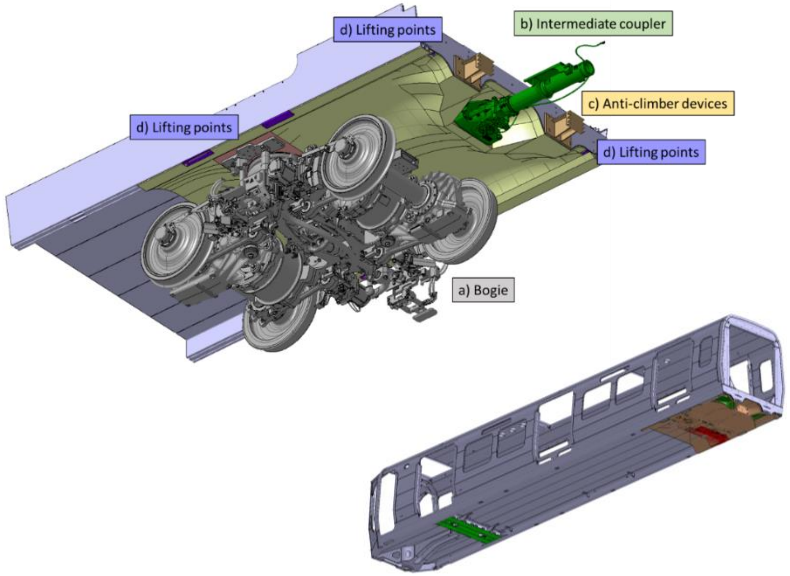
- Design, manufacturing and testing of Technology Demonstrator TD1.3 within the EU funded project Shift2Rail and its carbody related sub-projects PIVOT and PIVOT2 with main target to decrease weight in carbody structures and gain knowledge / skills related to composite materials and alternative technologies
- Chosen BT / ALSTOM demonstrator is a structural load-bearing underframe assembly "Headstock" with its main interfaces to the bogie and coupler. It is based on Alu-Metro carbody "C30" for Stockholm as sample for comparison



Basis: Alu-Design



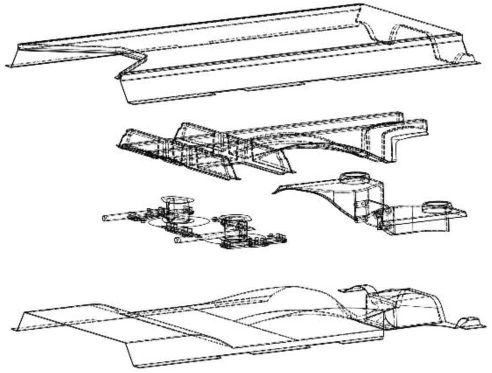
Target: FRP-Design



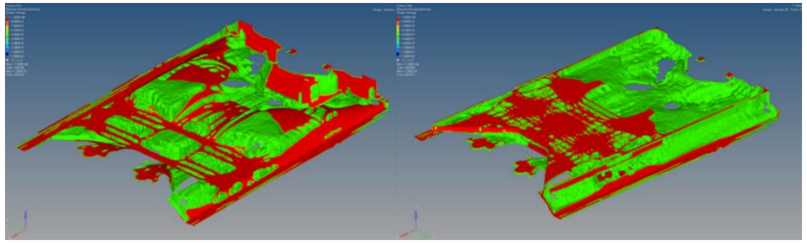
Multimaterial Headstock TD1.3 (Shift2Rail_PIVOT + PIVOT2)

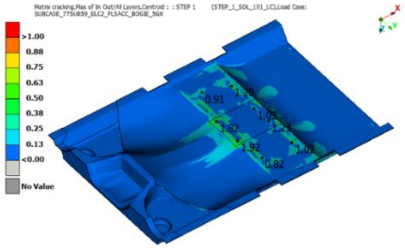
Design

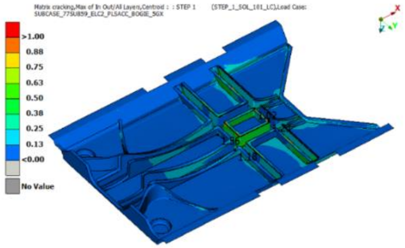
- Topology optimization
- 3D-Design incl. integration of functions:
  - Thermal / acoustic insulation + FST protection
  - Space for air-ducts and electrical installation
  - Earthing / EMV
- FEA

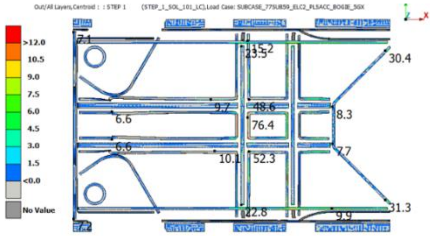


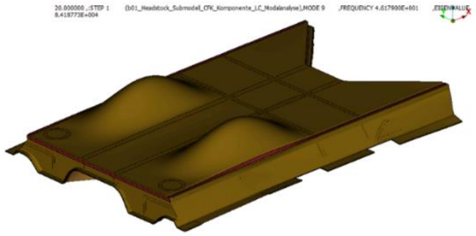
support by Voith Composites VOITH











Multimaterial Headstock TD1.3 (Shift2Rail_PIVOT + PIVOT2)

Manufacturing support by Voith Composites VOITH

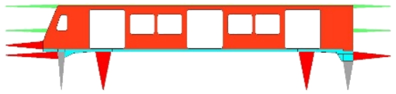
- Tooling
- Sub components
  - adjacent Alu-structure based on original extrusions + CFRP components made by VARI process)
- Final assembly incl. metallic inserts for all relevant mechanical interfaces

Multi-Material-Headstock made of CFRP + Alu

Multimaterial Headstock TD1.3 (Shift2Rail_PIVOT + PIVOT2)

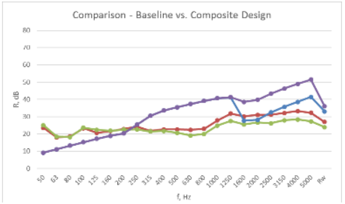
Testing support by IABG, RST, TU Berlin

- Mechanical testing (ongoing)
  - Static: 800kN coupler compression / 600kN coupler tension in combination with max. passenger load
  - Fatigue: 10^7 Load cycles on bogie interface (center pin, damper plate)

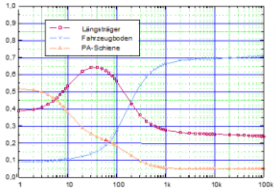


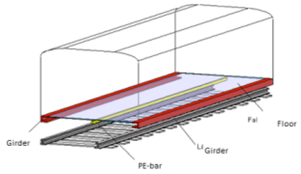
- FST testing
  - Fire protection by outer intumescent layer on CFRP components

- Acoustic testing
  - Opportunity for thin rubber layer, located in neutral fibre area of laminate for further improvement of acoustic damping



- EMV testing planned
  - Opportunity to include thin copper mesh as one of outer laminate layers

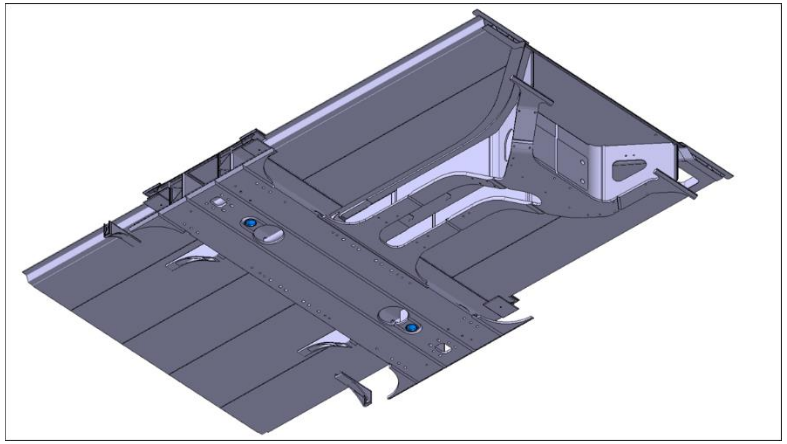




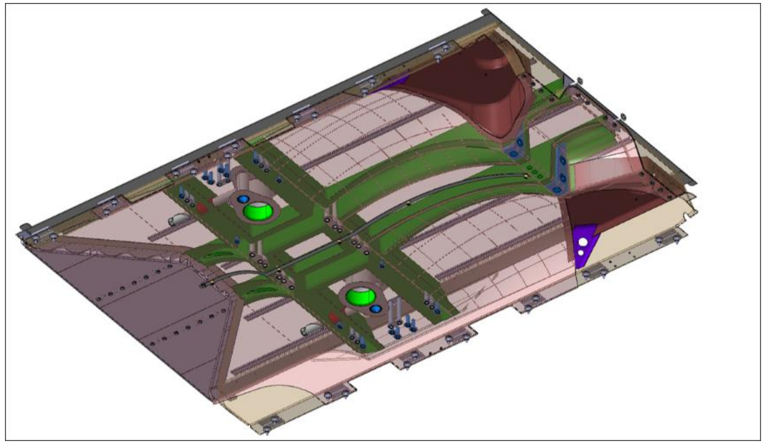
Multimaterial Headstock TD1.3 (Shift2Rail_PIVOT + PIVOT2)

Weight comparison

- Weight saving up to 25% compared to original Alu-structure (size: ~ 4,1 x 2,8 m) possible
- ~ 135 kg less weight per headstock assembly (270 kg per intermediate car)



Basis: Alu-Design (~ 550 kg)



CFRP-Design (~ 415 kg)

04

Additive manufacturing of big assemblies

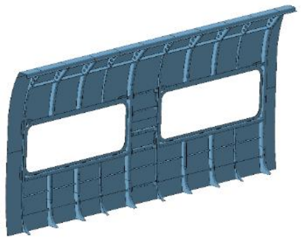
(AGENT-3D_TopoGross + InnoAdd)

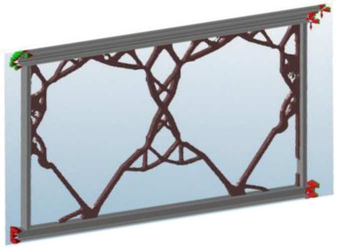
Frame structure of sidewall segment made by additive manufacturing (AGENT-3D_TopoGross + InnoAdd)

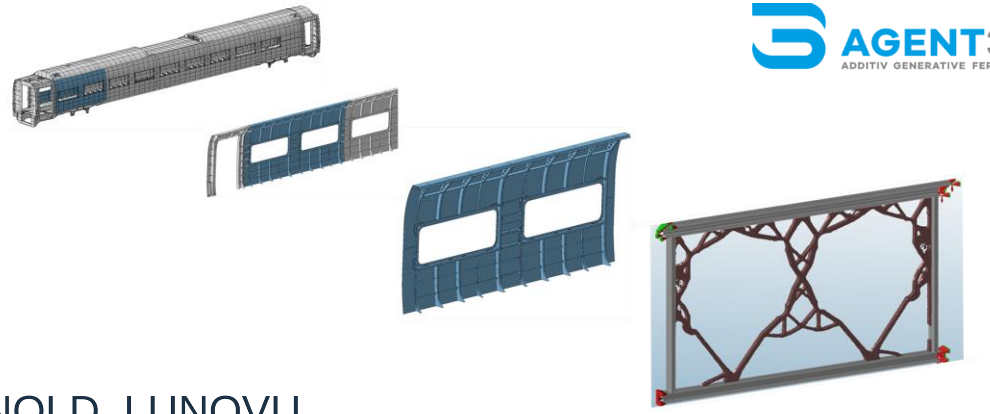
Overview

- Design, manufacturing and testing of Technology Demonstrator within the BMBF funded project AGENT-3D and its carbody related sub-projects TopoGross and InnoAdd with main target to decrease weight in carbody structures, develop additive manufacturing of big-sized metallic structures and gain knowledge / skills of additive manufacturing
- Chosen BT / ALSTOM demonstrator is a load-bearing frame structure of a sidewall segment. It is based on the steel carbody of “ICE4” hight speed train as sample for comparison
- TopoGross: Laser-powder-process
- InnoAdd: Laser-wire-process

GEFÖRDERT VOM
zwanzig20 PARTNERSCHAFT FÜR INNOVATION
Bundesministerium für Bildung und Forschung
AGENT3D ADDITIV GENERATIVE FERTIGUNG


Basis: Frame structure (as built)


Target: 3D-printed structure



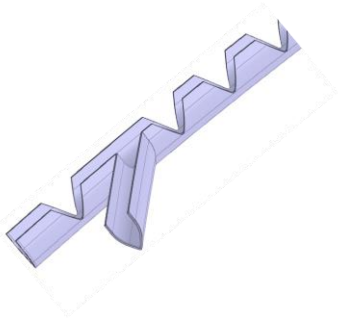
- Consortium partner: Photon AG, FH IWS, OSCAR PLT, ARNOLD, LUNOVU

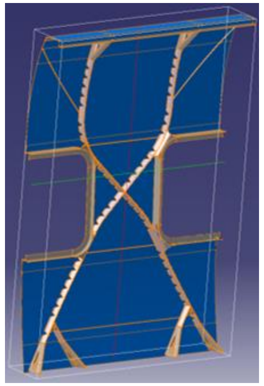
Photon | Fraunhofer IWS | oscar | arnold | LUNOVU

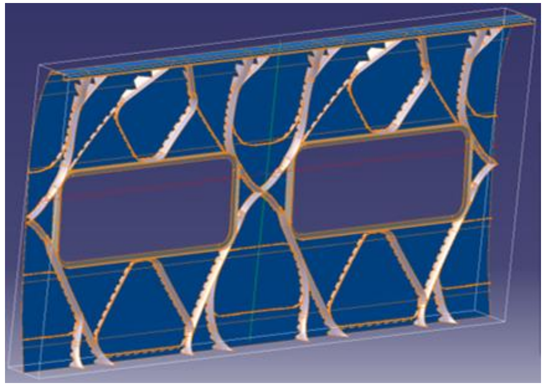
Frame structure of sidewall segment made by additive manufacturing (AGENT-3D_TopoGross + InnoAdd)

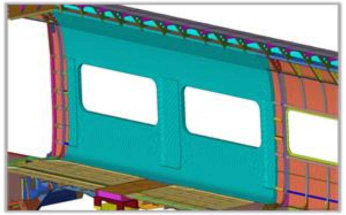
Design

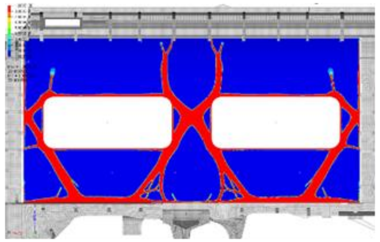
- Definition of design space
- Topology optimization
- 3D-Design of load paths
- FEA and further thickness optimization

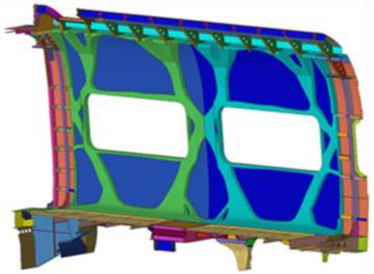


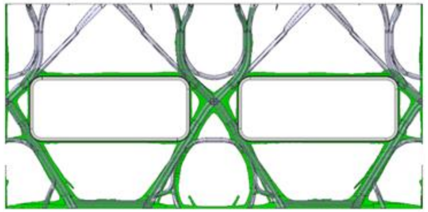


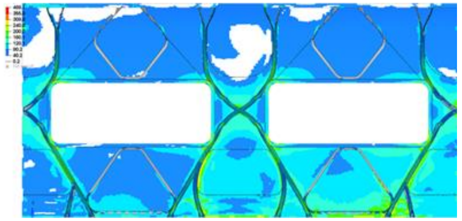












Topo-Struktur-Detail

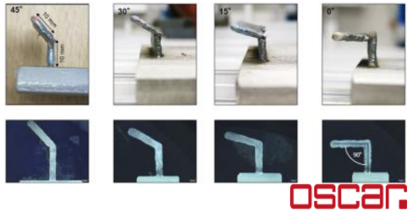
Sub-Demonstrator

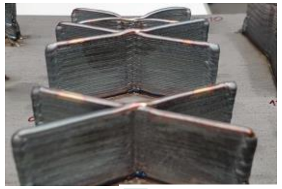
Seitenwand-Segment

Frame structure of sidewall segment made by additive manufacturing (AGENT-3D_TopoGross + InnoAdd)

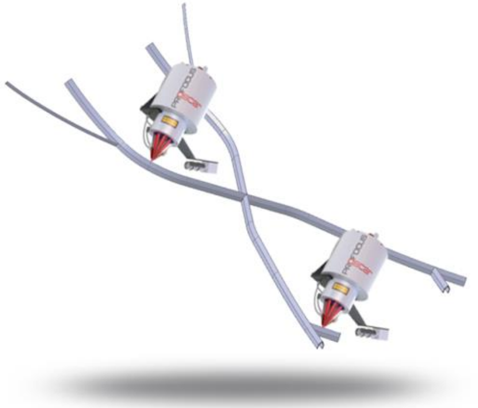
Manufacturing by Photon, OSCAR PLT and FH IWS with support Arnold and Lunovu

- Samples

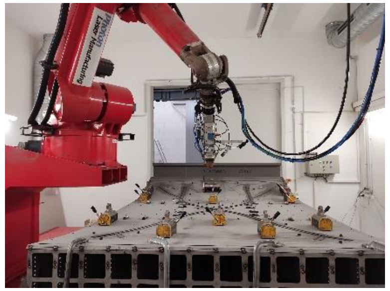




- Sub-Demonstrator
  - Crossing structure on substrate



- Demonstrator in area between two windows
  - Right picture, left hand side: 3D-printed
  - Right picture: right hand side: Laser welded (as built)



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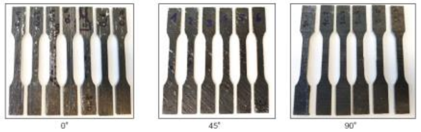
Frame structure of sidewall segment made by additive manufacturing (AGENT-3D_TopoGross + InnoAdd)

Testing by FH IWS

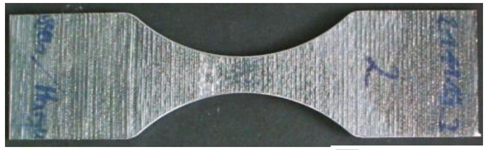
- Mechanical testing (InnoAdd)

  - Static: Tensile testing in three different directions of 3d-printed application (longitudinal + diagonal + transversal)



Results are very similar and comparable to raw material of welding wire.

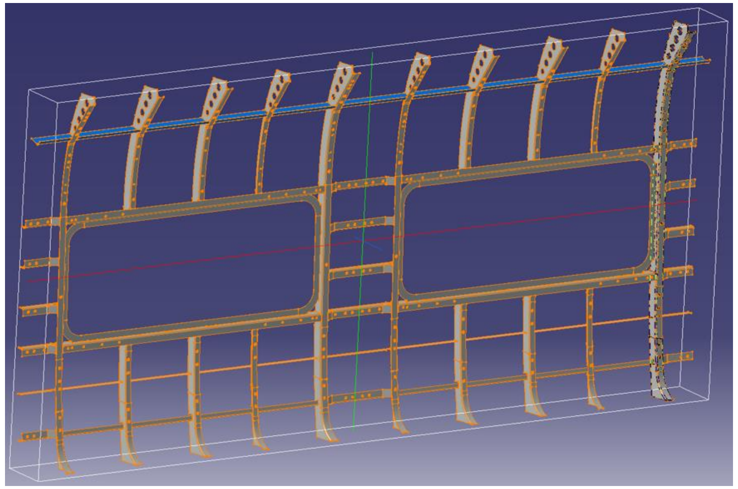
  - Fatigue: $2x10^6$ Load cycles of two different variants
    - Pure 3D printed structures transverse to application direction (picture on left hand side)
    - Hybrid samples: 3D printed structure on steel-plate with same thickness of 2mm (picture on right hand side)



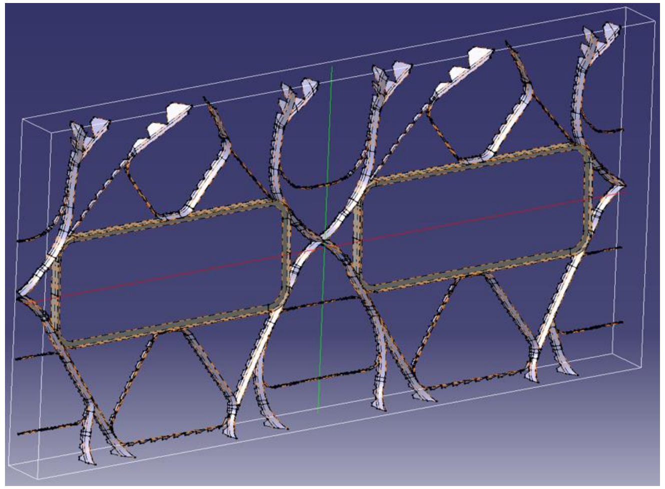
Frame structure of sidewall segment made by additive manufacturing (AGENT-3D_TopoGross + InnoAdd)

Weight comparison

- Weight saving up to 30% compared to original steel-part-structure of sidewall segment possible
- ~ 33 kg less weight per sidewall segment structure (~ 330 kg per intermediate car)



Basis: Steel profile design (~ 110 kg)



3D-printed hybrid design (~ 77 kg)

05

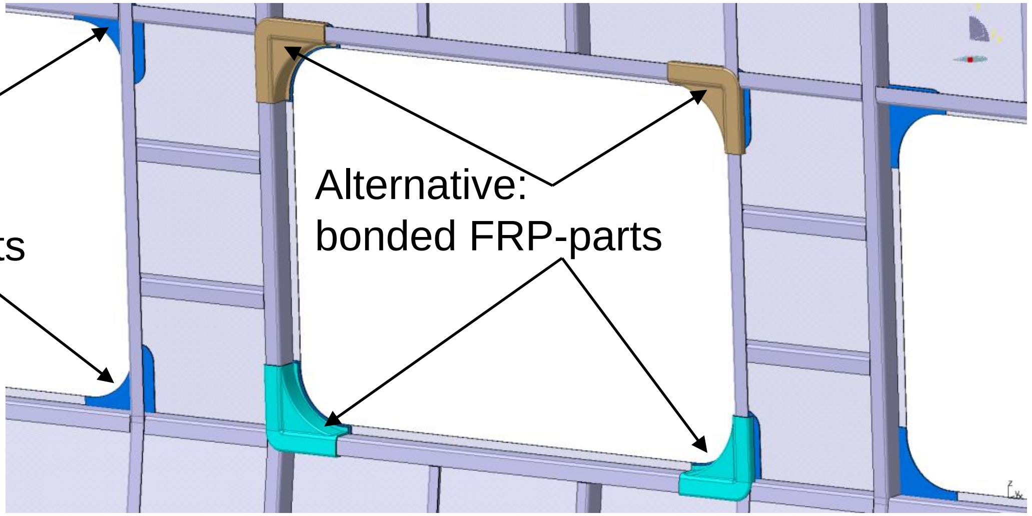
Specific composite approaches

FRP window corner reinforcements

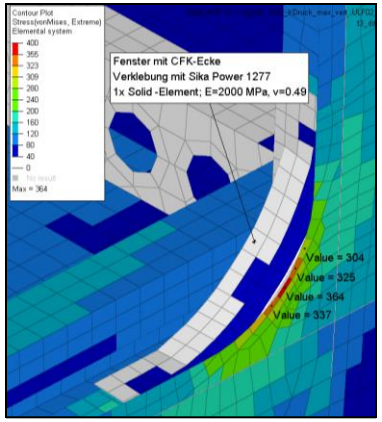
Overview

- Design, manufacturing and testing of CFRP window corner reinforcement with main target to decrease weight in carbody structures and simplify production effort during carbody manufacturing
- Chosen BT / ALSTOM demonstrator is a window corner reinforcement. It is based on regional train “Talent” carbody structure as sample for comparison

Conventional approach: welded steel parts



Example:
Window corner patch for steel structures

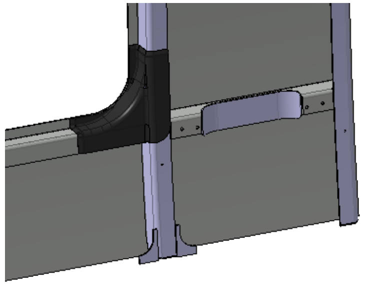


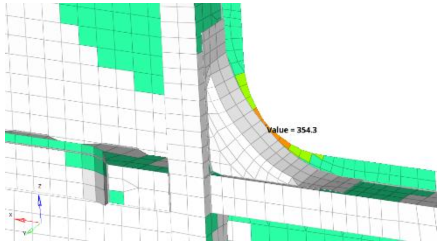
FRP window corner reinforcements

Design, manufacturing and testing of CFRP window corner reinforcement

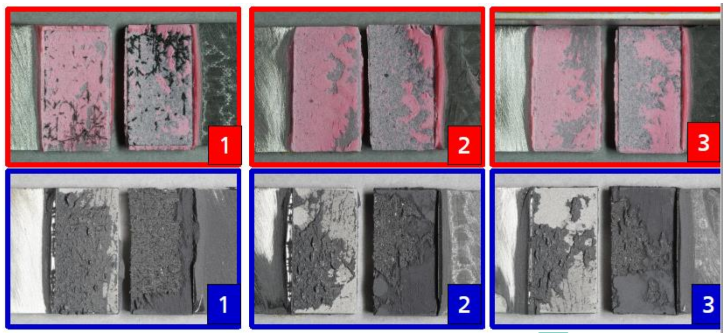
- Design, manufacturing and testing with support by BIONTEC and FH IFAM

BIONTEC Fraunhofer IFAM





BIONTEC



Fraunhofer IFAM

FRP window corner reinforcements

Advantages

- Less deformation and shrinkage in heat affected zone caused by welding of metallic reinforcements
- No straightening in this reinforced areas necessary
- Same yield strength in high stressed areas as in heat unaffected areas of base material
- Less weight compared to metallic reinforcements

06 Conclusions

Conclusions related to alternative materials and technologies

Advantages ←→ Disadvantages

- Proven potential of weight saving in carbody structures up to 30% in certain assemblies
- Less energy consumption of trains during live cycle of around 30…35 years
- Less CO_2 emission
- Experience needs to grow in rail industry
- Skilled personnel necessary
- Further long term test-activities for adhesive joints and composite materials helps to convince customers
- Relative hight costs could be compensated by e.g. integration of functions
- Keeping competitiveness of German and European OEM's

↳ **State of science is a basis to develop a complete multimaterial carbody demonstrator** www.alstom.com

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