University of Stuttgart
Institut für Flugzeugbau
Institute of Aircraft Design

Manufacturing of Hybrid Steel-FRP Specimen for the Characterization of Material Properties

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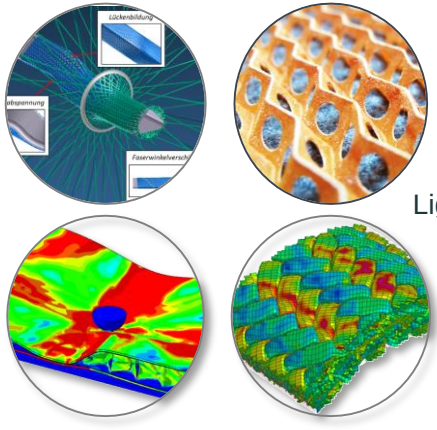
Research Areas

Aircraft Design
Prof. Strohmayer



Lightweight Design
Prof. Middendorf

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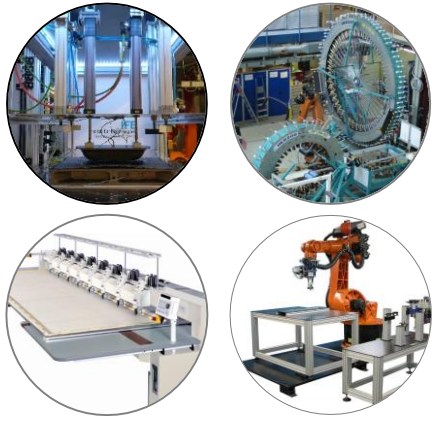
Manufacturing Technologies
Prof. Middendorf

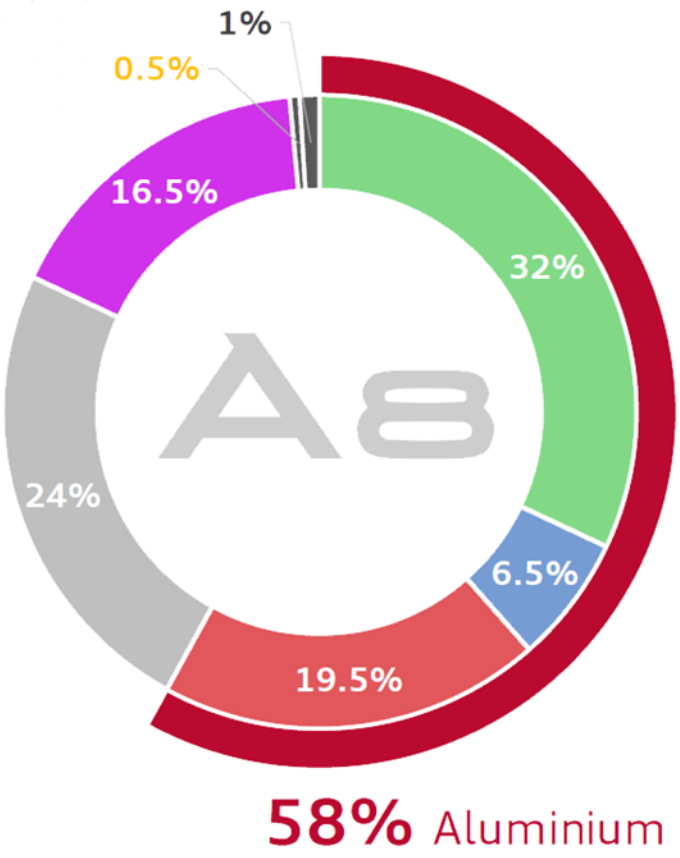


Wind Energy
Prof. Cheng

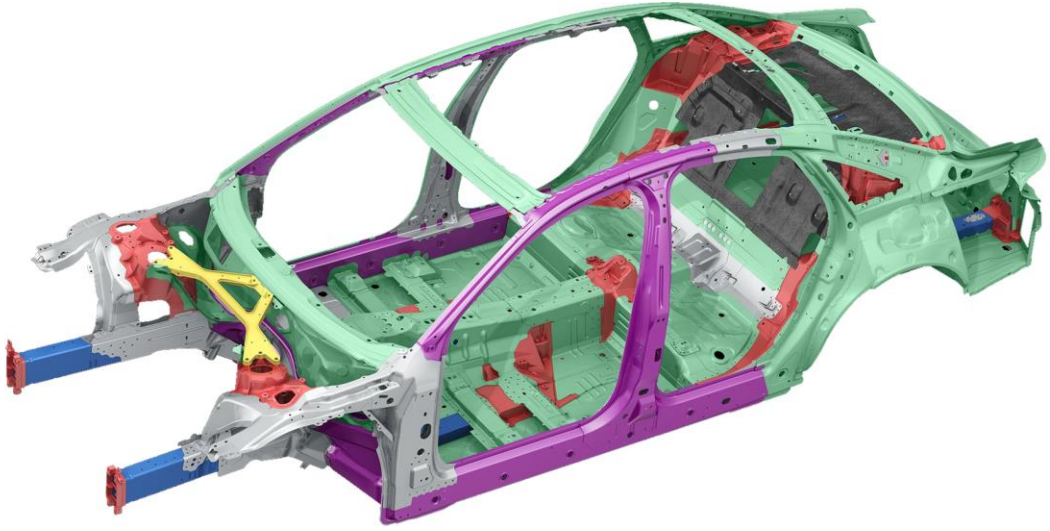
staff: 3 professors - 70 academics - 11 engineers - 5 administative - ~80 students - 4 trainees
funding: 25% public - 75% third-party

facilities: 2 buildings - 1000m^2 office - 250m^2 seminar rooms - 300m^2 laboratories - 1300m^2 workspace - 300m^2 storage

Multimaterial Design at AUDI [1]



- Aluminium sheet
- Steel conventional
- Aluminium extrusion
- Steel hot-formed
- Aluminium casting
- Magnesium casting
- Carbon fibre reinforced plastic



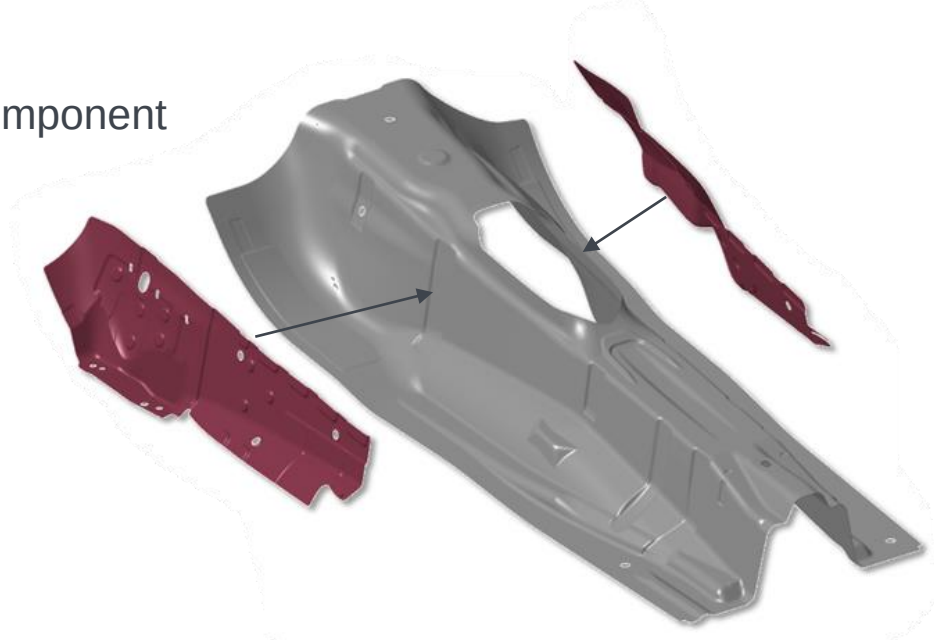
FRP-Patches: Load-path Optimized Reinforcement

EXAMPLE: GENERIC GEARBOX TUNNEL

- Steel part reinforced with steel patches
- Reinforcement adds 30% mass to base-component

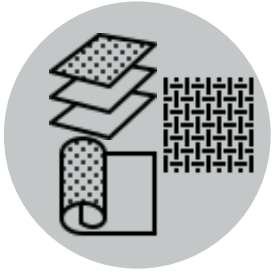
➢ Goal in using FRP patches:

- reduce weight by
  - employing lightweight materials
  - reinforcing according to load-paths
- CFRP-patches (stiffness-/strength-driven)
- GFRP-patches (strength-driven)



Exemplary generic tunnel-structure

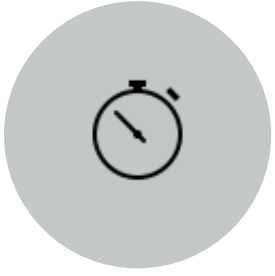
Things to Consider when Patching with FRP



- **Material:** reinforcement/resin?

- **EPD coating:** before or after?

- **Bonding:** Method?



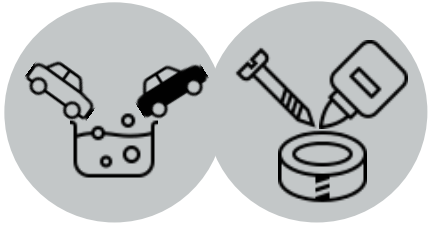
- **Cycle-Time:** Inline/Offline?

- **Weight:** specific properties

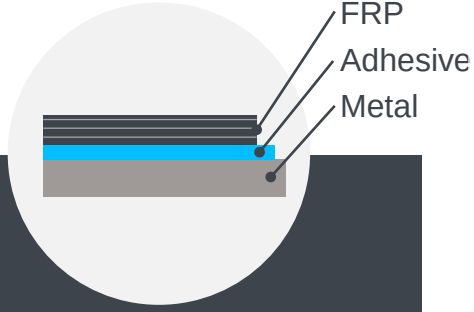
- **Cost**
- **Recycling**
- **Temperature/Moisture**
- **No. of units**

Considerations: EPD and **Bonding**

Three possibilities

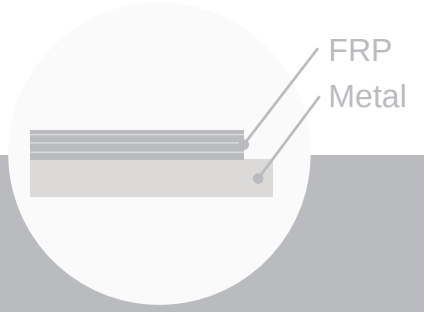


BEFORE EPD COATING



Adhesive joining

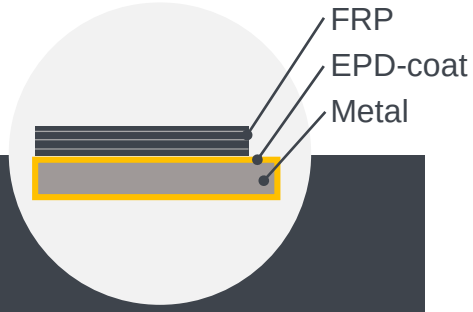
- Film with same curing cycle
- Hybrid properties depend on adhesive properties
- Ideally for strength-driven applications



Direct joining

- Using fibre resin for joining
- Hybrid properties depend on surface treatment and resin
- Ideally for stiffness-driven applications

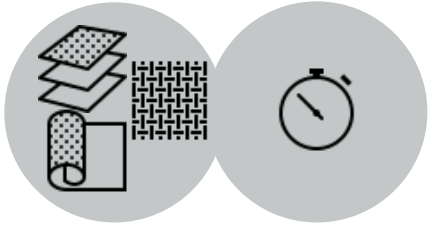
AFTER EPD COATING



On EPD

- Using epoxy-based EPD coat
- Hybrid properties depend on bonding of EPD to metal
- No Δα/ΔT problems

Considerations: **Material** and **Time**



- Typical automotive cycle times between assembly stations < 2 min
- Requirements for the material:
  - Fast cure
  - Low pollution
  - Low demand on new equipment
  - Automatization/Handling

➢ Snap-Cure Prepreg

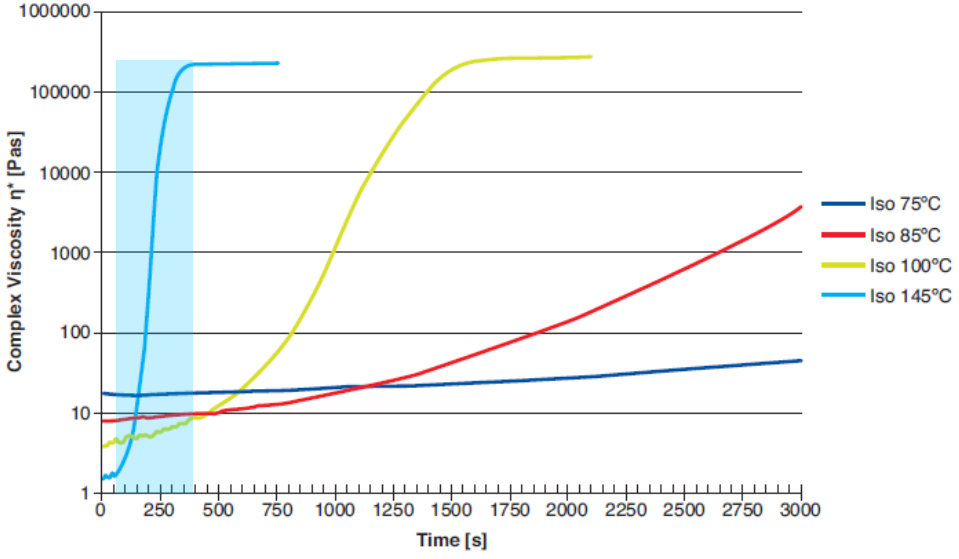
➢ Hexcel HexPly® M77 Epoxy

  ➢ 160°C - 90 sec - 5 bar

  ➢ UD120 Carbon Fibre

  ➢ UD800 Glass Fibre

Viscosity vs. time for the M77 resin system [2]



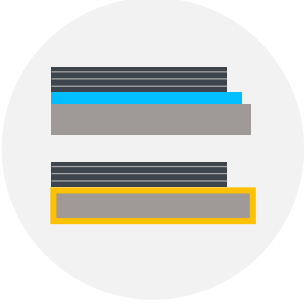
➢ Adhesive film: Hexcel Redux® 677 (cure-cycle adapted to M77)

The Goal: Characterize Materials for the Crash-Simulation

- Crash relevant application → Material simulation in FEA

pure C-/GFRP

- Tensile
- Compression
- Four-Point-Bending
- ±45° Tension
- ±45° Ladeveze



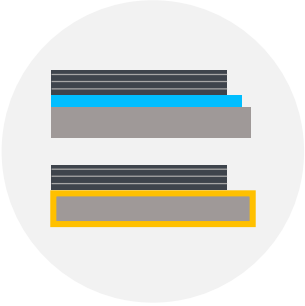
Interface

- Failure criteria
  - Single-Lap-Shear
  - Double-Lap-Shear
  - Tensile Butt-Joint
- Energy release rate
  - Double Cantilever Beam (DCB)
  - End-Notched Flexure (ENF)

- **Goal**: Single-cycle manufacturing - as in production

Production: Hybrid Test Specimen

One-Shot production of hybrid specimen is challenging:



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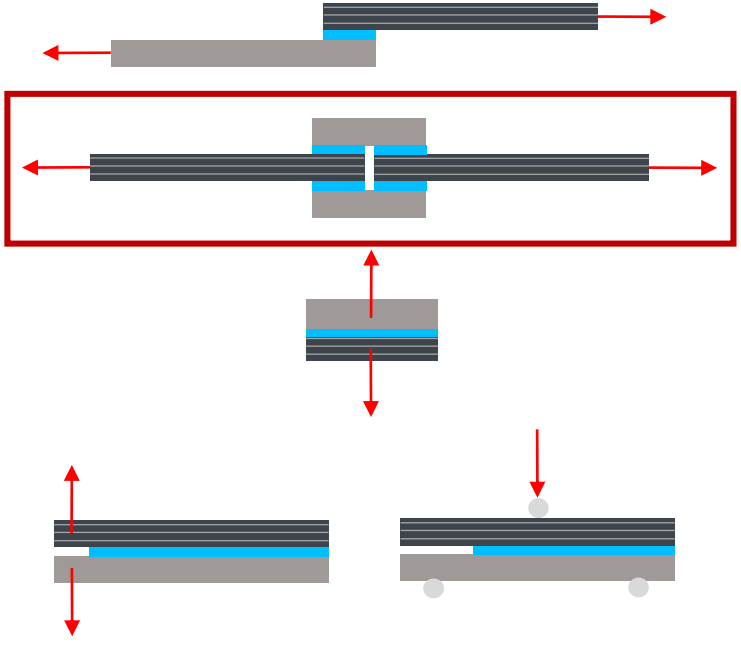
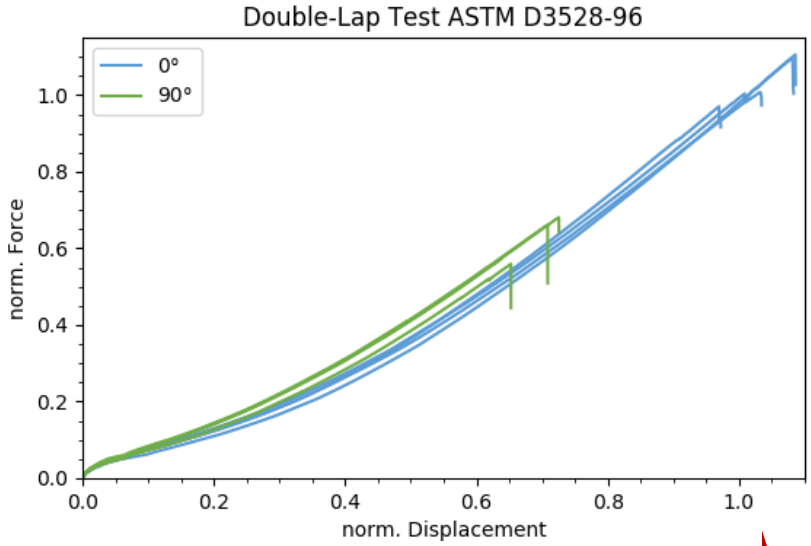
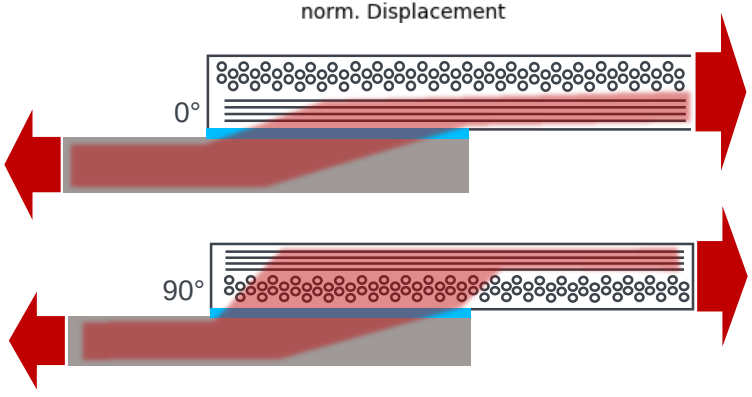


Resulting Specimen: the Zoo

Results: Small Insight into Findings

- Tests carried out show good accordance to literature
- Fibre orientation on the interface is important
  - with 90° fibres at interface reduction by 1/3 in failure strain compared to 0°

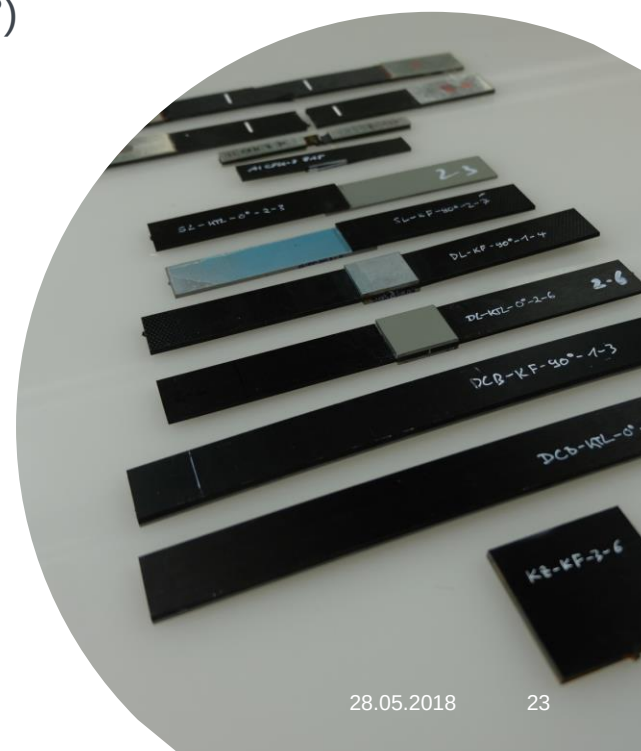




Conclusion

- **Cost-effective tooling** is usable for **parameter identification**
- **Tested Configurations**:
  - HexPly® **M77 CFRP** and **GFRP**
  - with different **orientations** on the **joint** surface (0° and 90°)
  - on…
    - … untreated steel with Hexcel Redux® 677 adhesive film
    - … EPD-coated steel without bonding agent
- **Results** have been transferred to **FEA**

➢ **FRP patch technology** is **ready to use** at **AUDI**



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Vielen Dank!

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Sources:

[1] Benjamin Bender,
Concept Study of a Hybrid Aluminum Rear Wall with Local CFRP Reinforcement,
Materialien des Karroseriebaus, 2017, Bad Nauheim

[2] Hexcel Corporation,
HexPly® M77: 80°C – 160°C curing epoxy matrix,
Publication FTU 291 JY17, 2016

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