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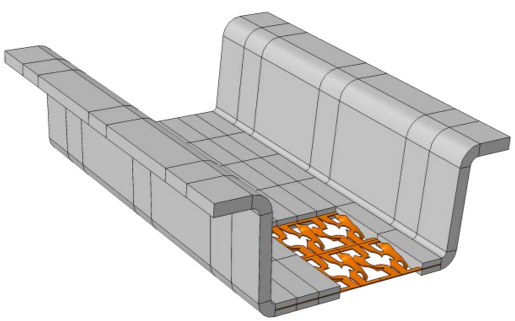


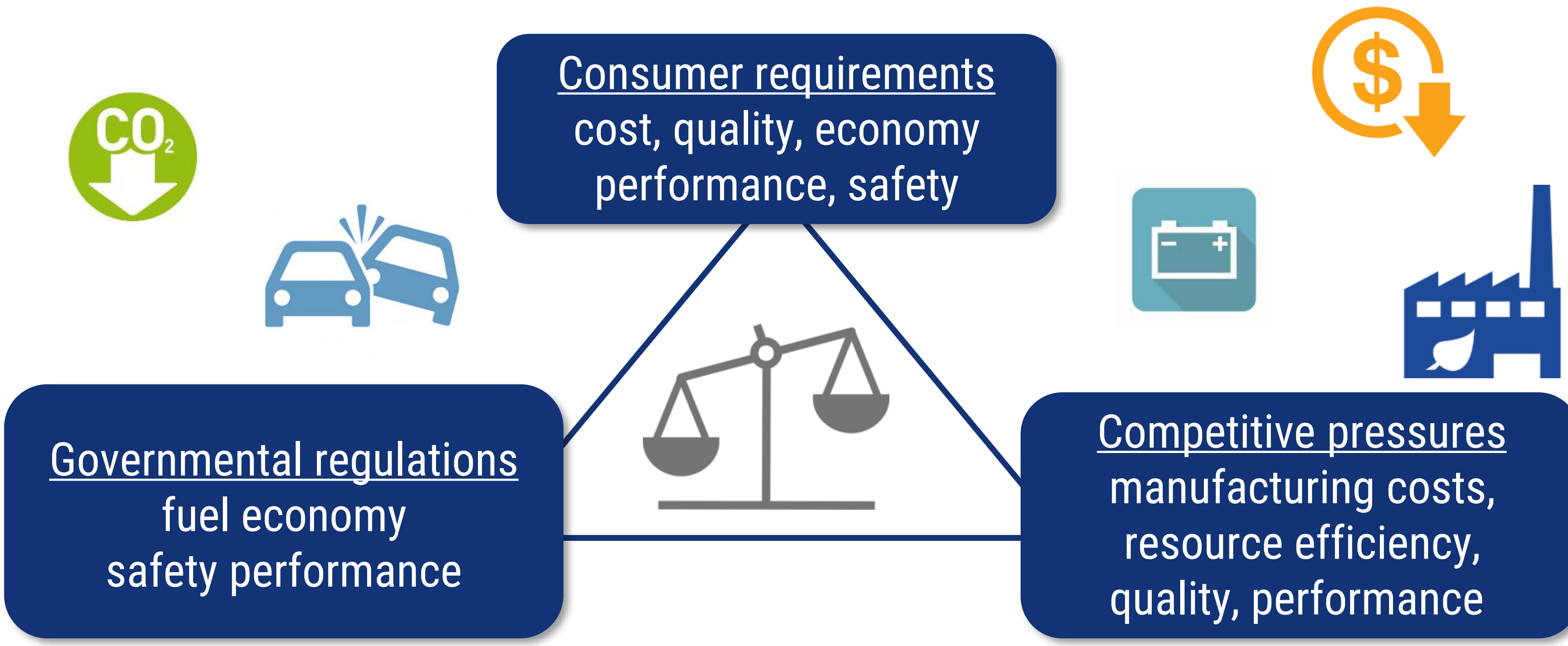
DFG Deutsche Forschungsgemeinschaft

Crash-loaded structural components: Efficient lightweight design through intrinsic hybridization

M. Riemer, R. Kießling, A. Dittes, S-D. Schwöbel, I. Scharf, M. Scholze, M. Böhme, W.-G. Drossel, J. Ihlemann, T. Lampke, M. F.-X. Wagner

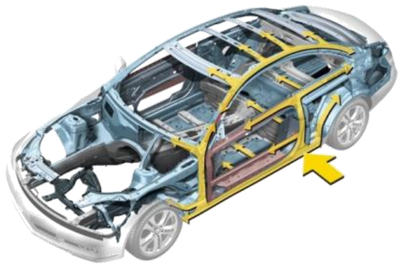
Drivers for the development of new lightweight concepts

- Recent challenges in the field of transportation industries



Modern lightweight concepts are using different materials in one part.
→ Development of hybrid structures

[Source: http://media.daimler.com/marsMediaSite/ko/de/9271675]

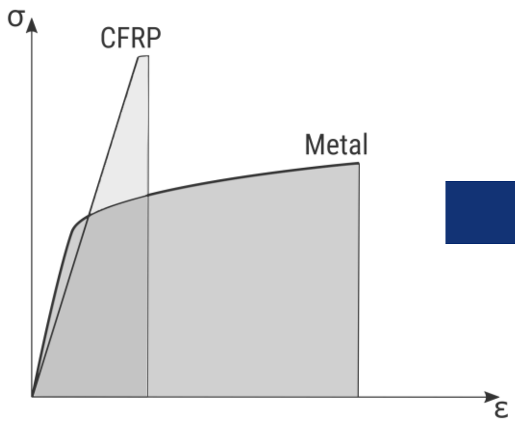


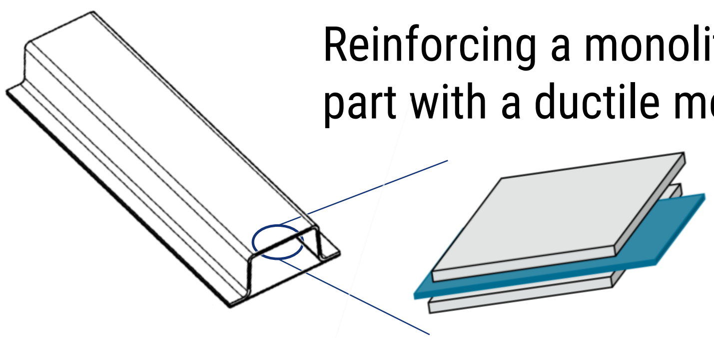
Concept of the developed part

Objective: Development of crash relevant lightweight structure

Major Requirements: high specific load capacity
high energy dissipations in the case of crash

Approach: Combination of high strength with high plasticity



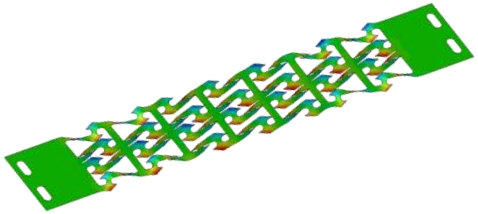


Reinforcing a monolithic CFRP part with a ductile metallic insert

CFRP → working loads
Metal → energy dissipation

- Improved interface performance by combining adhesive bonding and mechanical form fit
- Efficient production due to an intrinsic process approach
- Accurate numerical prediction of the mechanical part behavior by advanced modelling approaches

The project consortium



metallic insert

Production technology
- metallic insert
- process design

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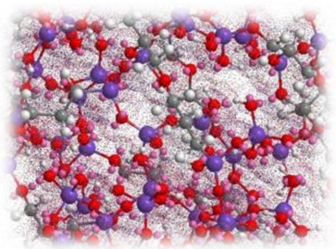
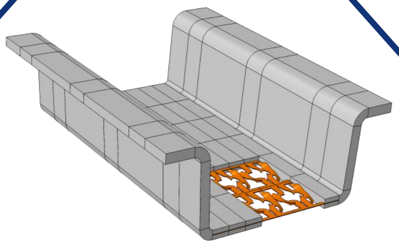
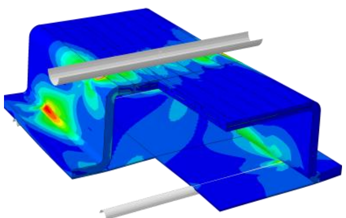


Ormosil network





crash simulation

Material science
- surface Engineering
- high dynamic testing

Institut für Werkstoffwissenschaft und Werkstofftechnik

Mechanics
- material modelling
- design optimisation

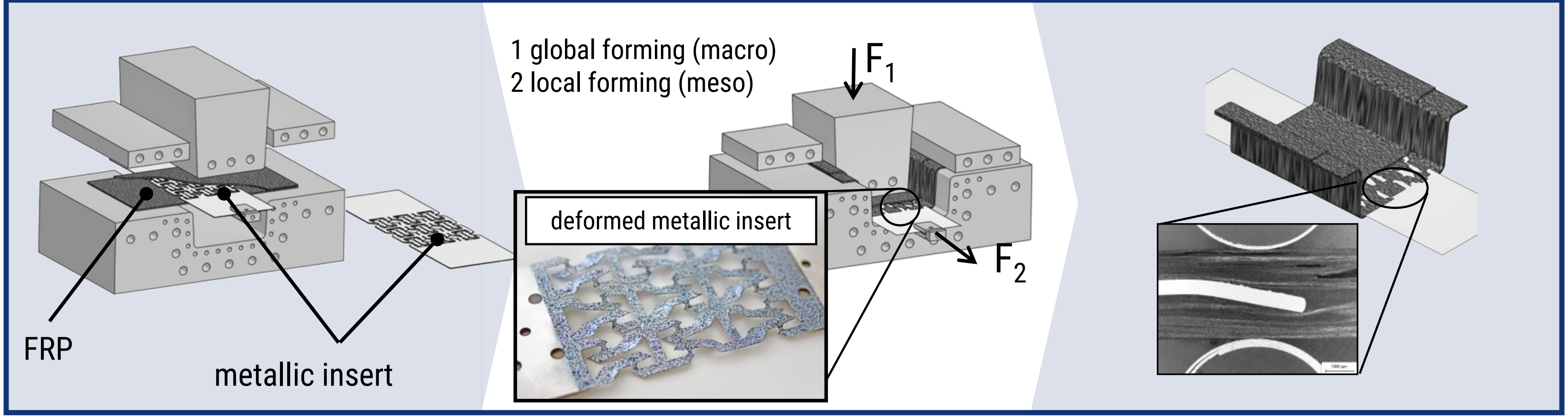
Outline

1. Intrinsic manufacturing process
2. Organosilica coating system
3. High dynamic interface testing
4. FE simulation considering the manufacturing history
5. Mechanical testing of the demonstrator part
6. Summary

1 Intrinsic manufacturing process - process chain approach

- Generation of the part geometry, the form fit elements and the hybridisation in one manufacturing step

Forming process on different geometric scales

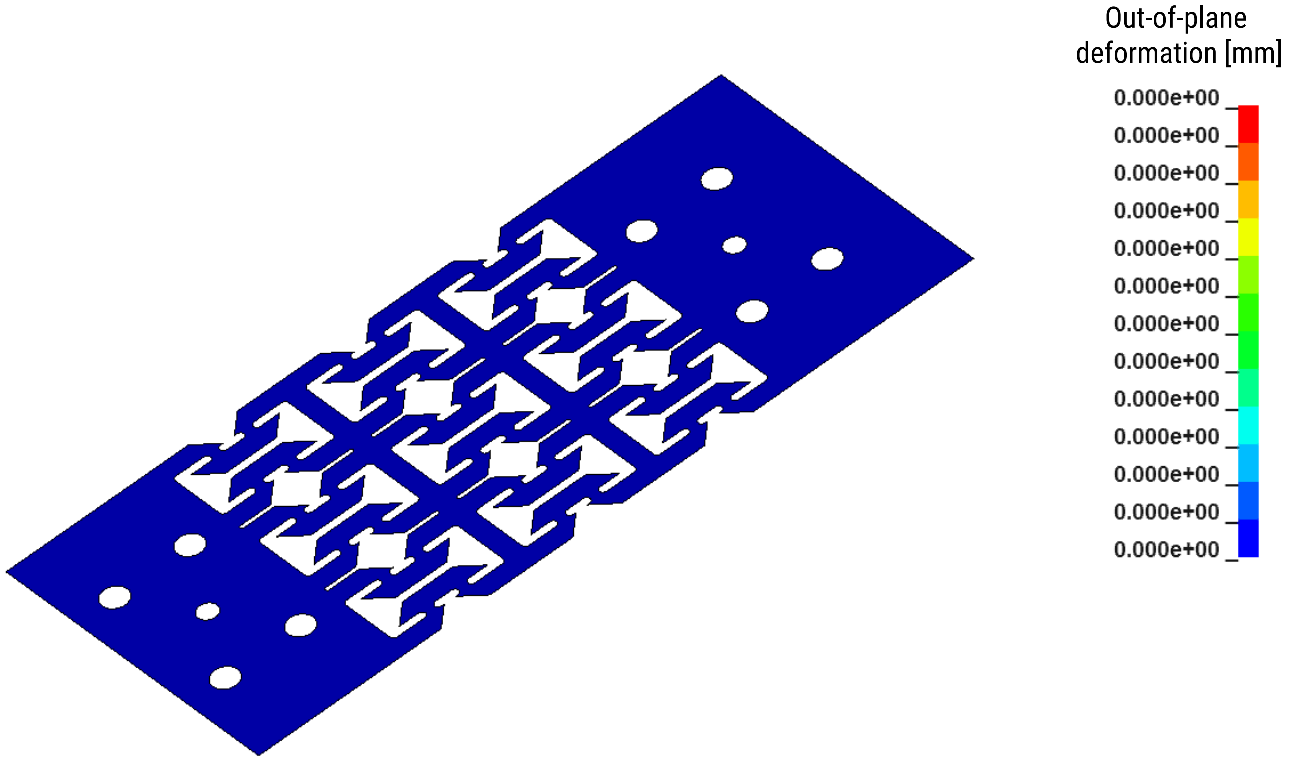


Components of the hybrid composite

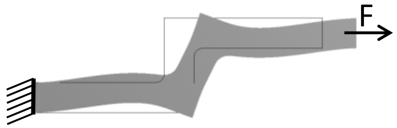
- Unidirectional carbon fibre sheet with thermoplastic PA6 matrix (FRP)
- Innovative, special shaped aluminium layer to improve crash performance

1 The intrinsic manufacturing process – metallic insert

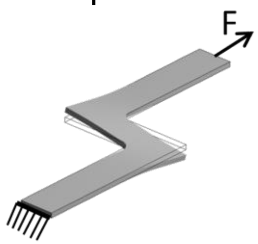
- Generation of local out-of-plane deformations (form fit elements) due to a globally applied in plane load



Fundamental principle



basic element – behaviour without imperfections

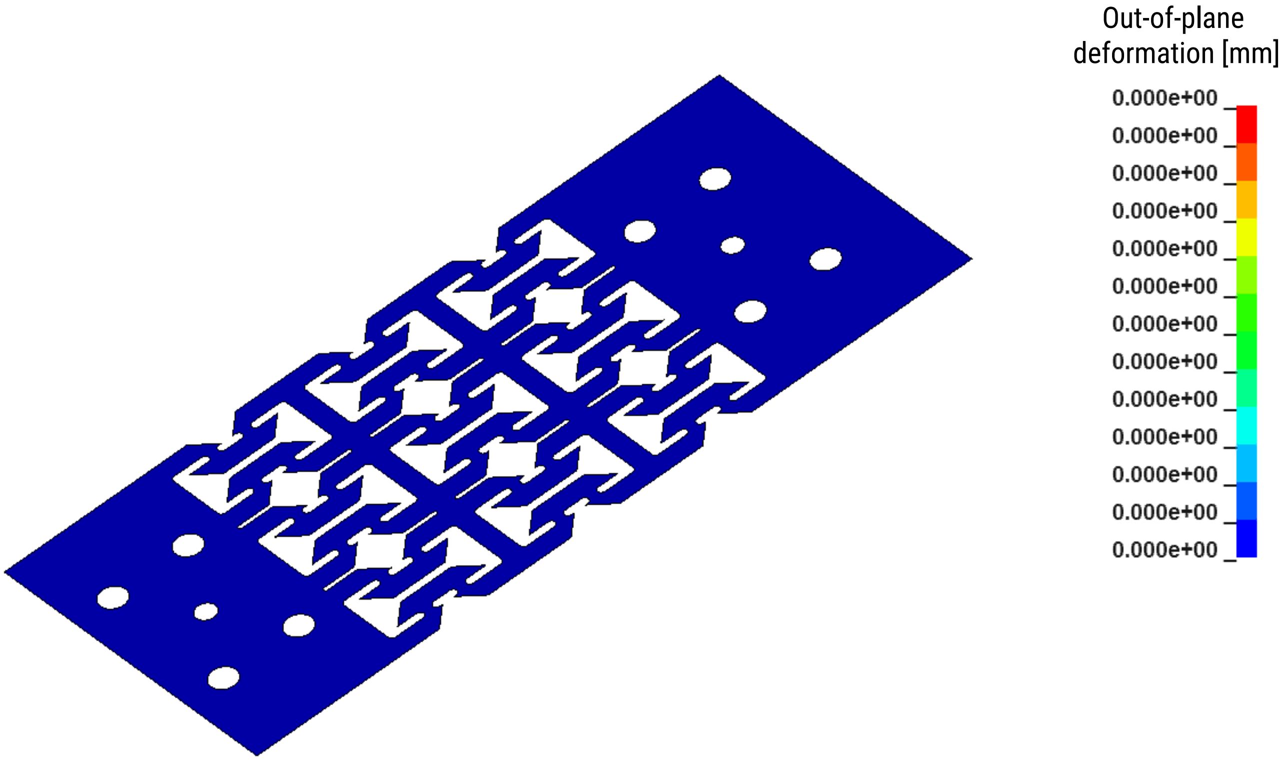


out-of plane deformation induced by buckling

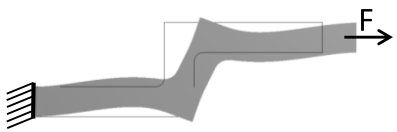
- Out-of-plane deformations were realised under in-plane load

1 The intrinsic manufacturing process – metallic insert

- Generation of local out-of-plane deformations (form fit elements) due to a globally applied in plane load



Fundamental principle



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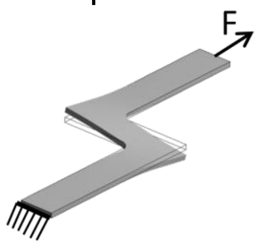
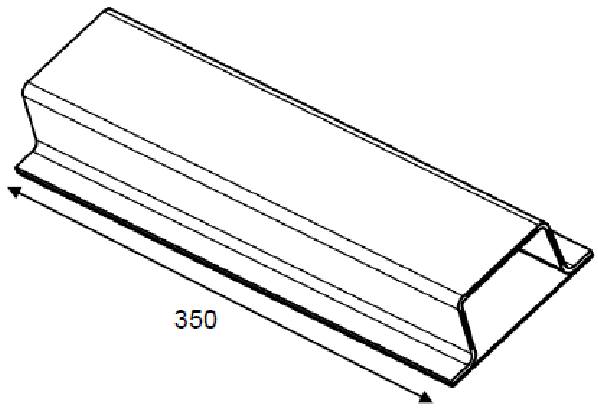


out-of plane deformation induced by buckling

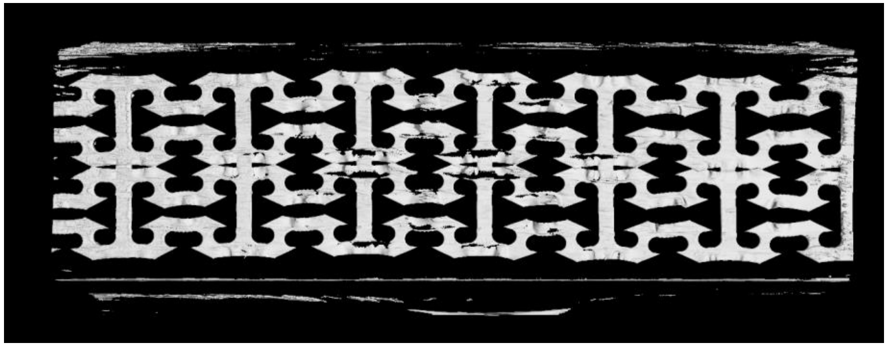
- Out-of-plane deformations were realised under in-plane load

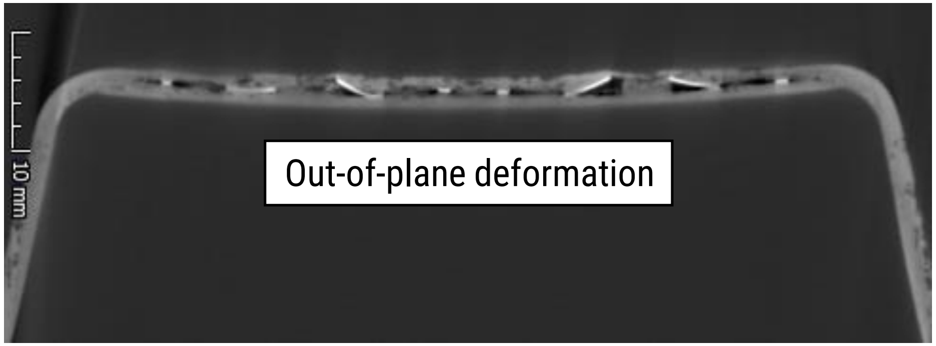
1 The intrinsic manufacturing process - Demonstrator part

- CAD – Model and manufactured part



- CT-scans of the manufactured part

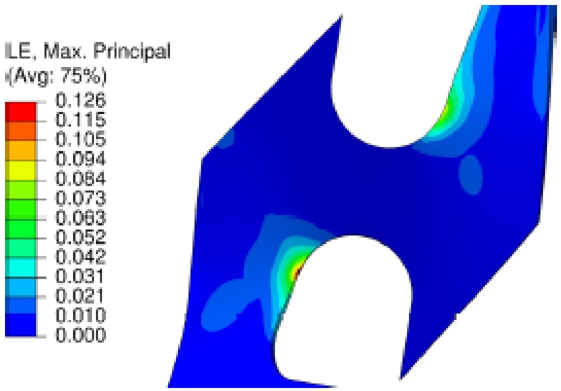


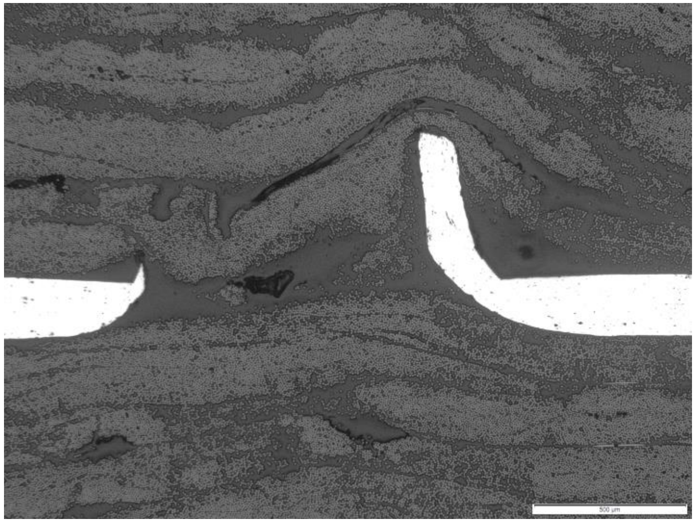


2 Organosilica coating system

Requirements

- decoupling of the corrosion potential between the metallic insert and CFRP
- adhesion promotion between metallic insert and CFRP matrix material
- high ductility
- good processability and scalability

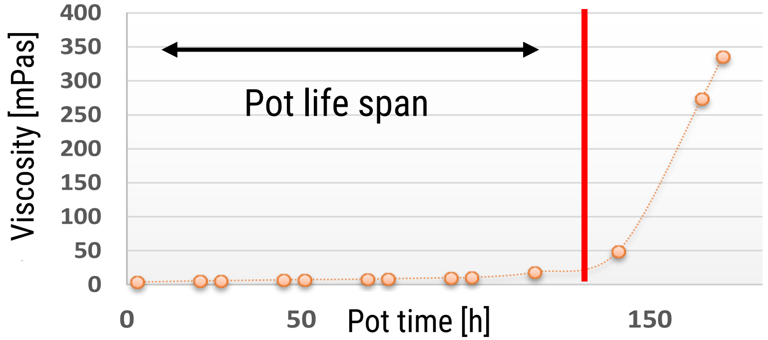




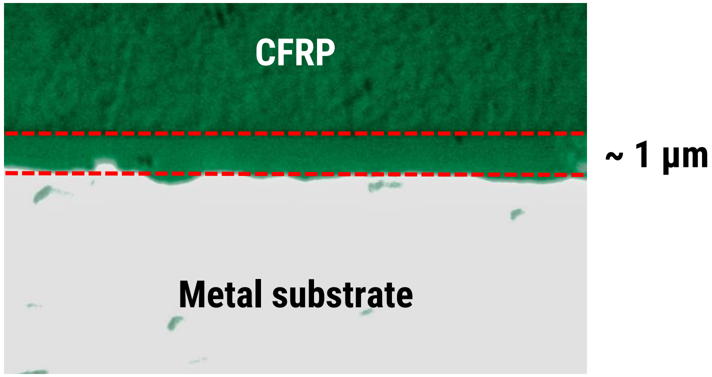
Kießling, Riemer et al.: A process and load adjusted coating system for metallic inserts in hybrid composites. In: Production Engineering 373

2 Organosilica coating system
Contact corrosion issues in metal/CFRP-material compounds

Organosilica coating of the metal component – Sol-gel-process



Decoupling the adherents – Isolation and barrier functionality



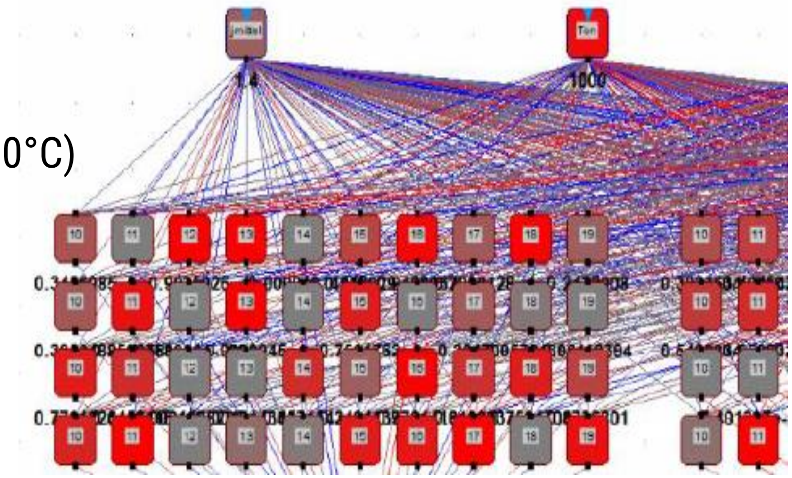
2 Organosilica coating system

High resistance – Corrosion current tends towards zero

Optimization of the coating – Neuronal networks

Layer properties adaptable by:

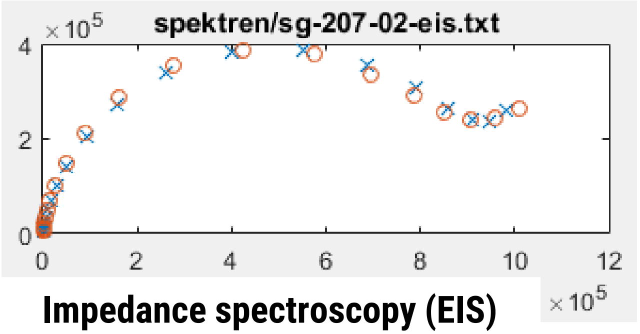
- Concentrations in the sols (c↑↑ R ↑↑)
- Heat treatment temperature (T↑ R↑, constant above 150°C)
- Heat treatment time (t↑ R↑, constant above 100 min)
- Ageing time, 1-4 days yield comparable properties



Specific electrical resistance: $\mathbf{10^{12}\text{-}10^{15}\ \frac{\Omega mm^2}{m}}$

Polypropylen: $10^{11}\ \frac{\Omega mm^2}{m}$

Bulk glasses: $10^{16}\text{-}10^{21}\ \frac{\Omega mm^2}{m}$

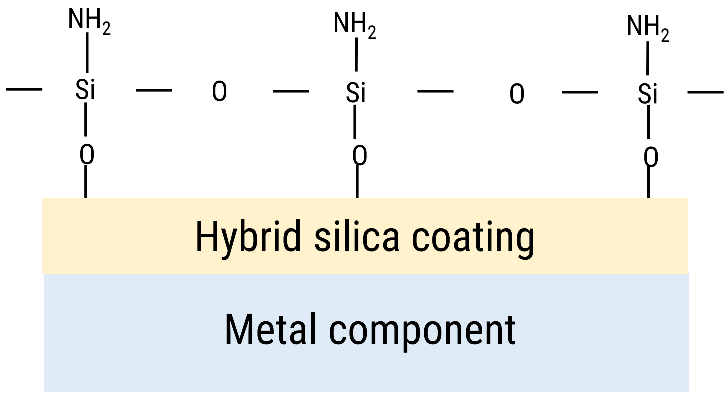


Impedance spectroscopy (EIS)

2 Organosilica coating system

Surface functionalization – Organofunctional silanes

High strength joining – Adaption to different polymer adherents



2 Organosilica coating system

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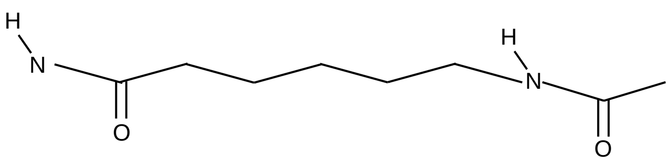
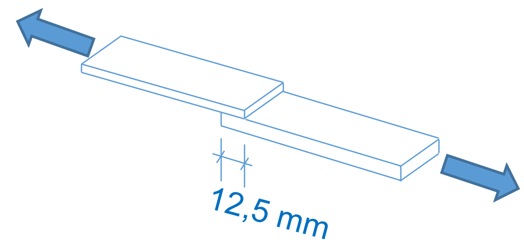
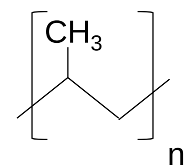
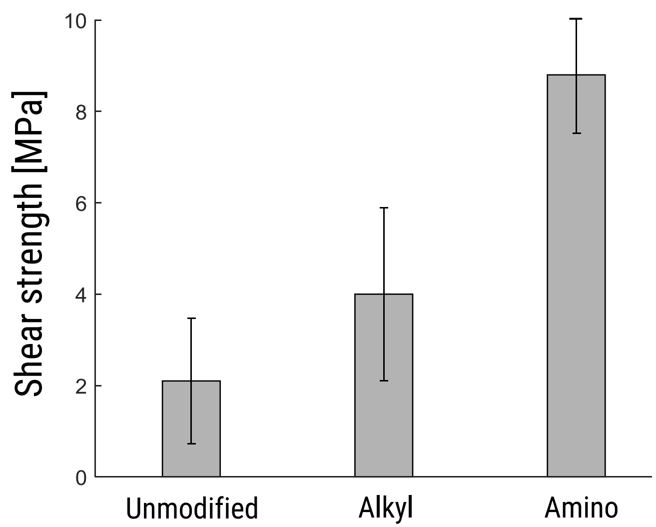


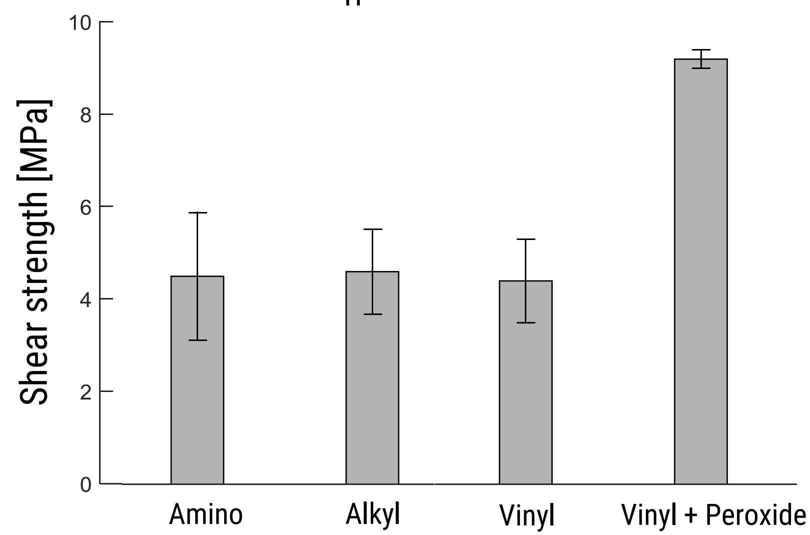
Polyamid





Polypropylen

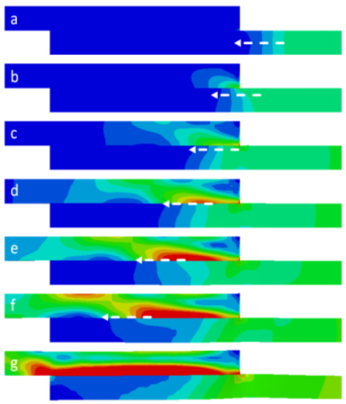




3 High dynamic interface testing

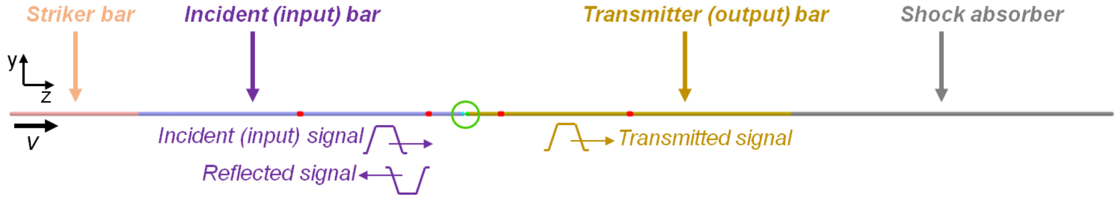
Characterisation of the interface – high dynamic shear test

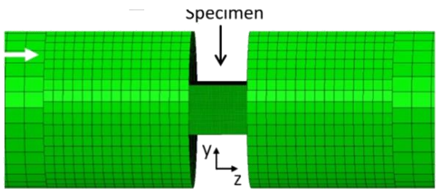
- complex stress distribution at the interface at high strain rates due to
  - strong change of material properties
  - geometric discontinuities



von Mises stress state

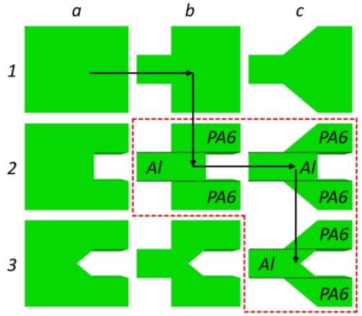
- experiments will be performed with the Split-Hopkinson Pressure Bar (SHPB)





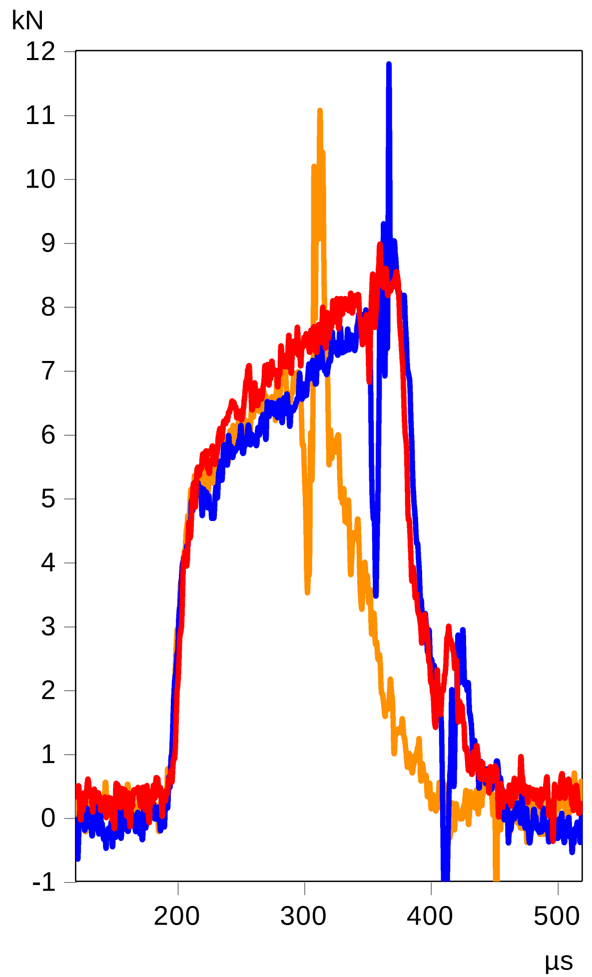
FE-Model SHPB

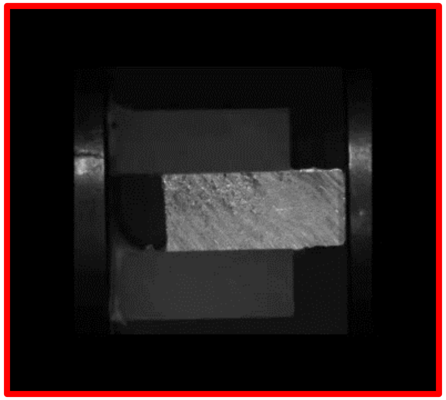
- FE-model of the testing setup was developed and verified
- further work focuses on the FE driven analysis of different specimen geometries

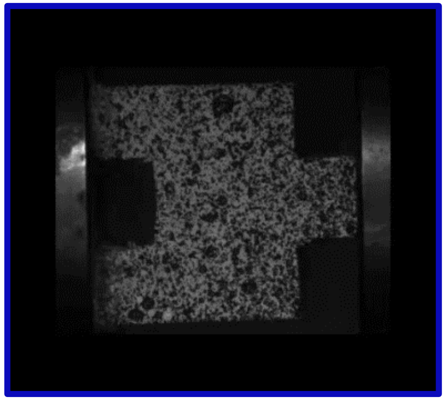


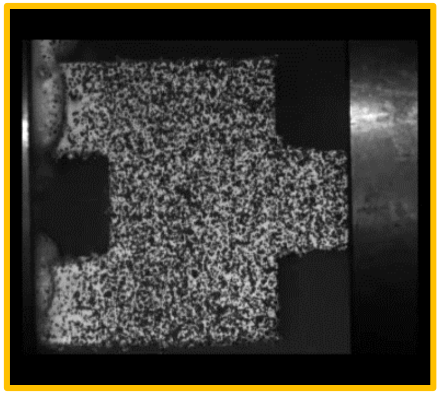
Evolution of specimen geometry

3 High dynamic interface testing
Results SHPB



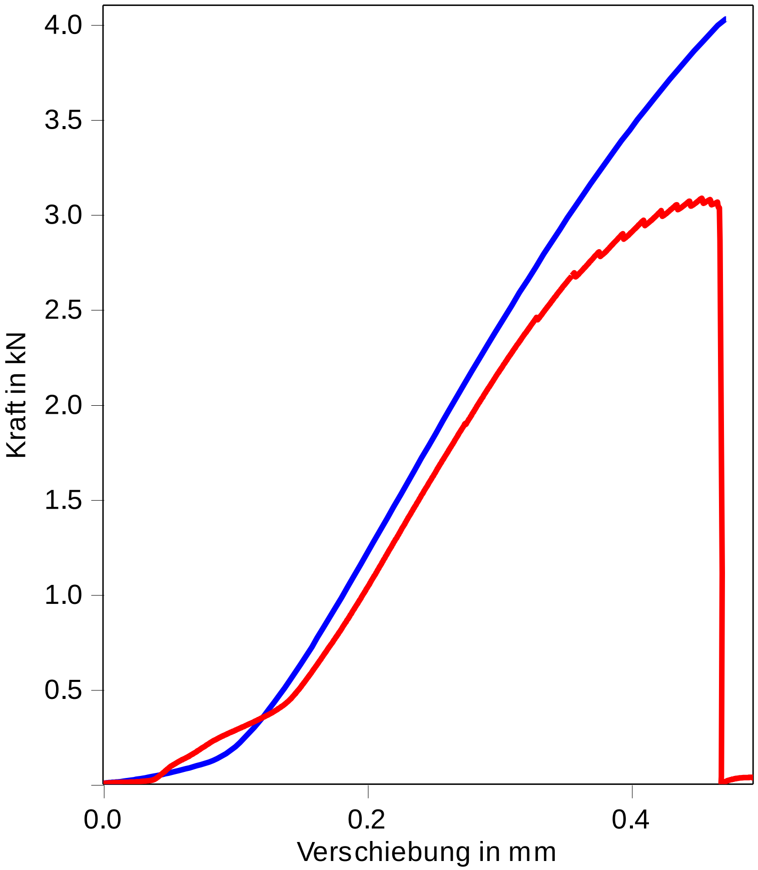






Specimen	Shear strength [MPa]
1	63
2	61
3	56

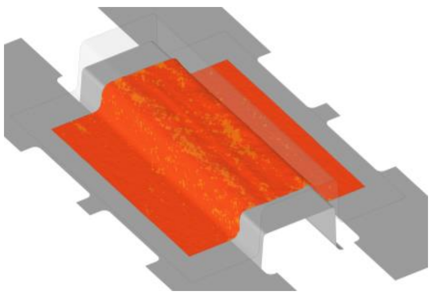
3 High dynamic interface testing
Results SHPB: quasi static vs. dynamic results



Testing speed (m/s)	Shear strength [MPa]
6	56 … 63
6x10^{-3}	32 … 38
6x10^{-6}	13 … 24

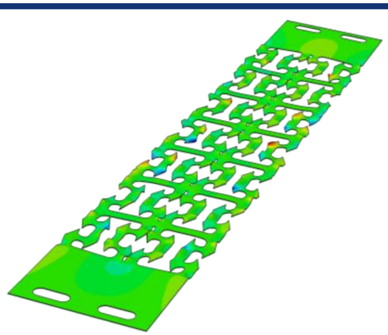
4 Finite element simulations considering the manufacturing history

- *Aim*: accurate numerical simulations due to the consideration of the manufacturing history



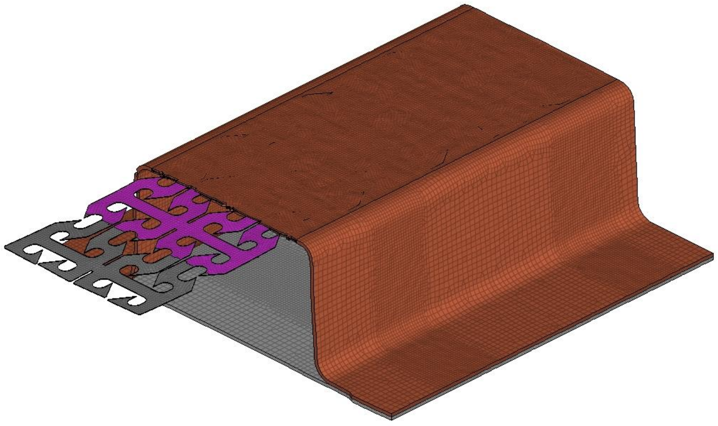
- Geometry
- Fiber volume content
- Fiber orientation
- Local thickness

thermoforming



- Geometry
- Local thickness
- Hardening
- Damage

sheet metal forming

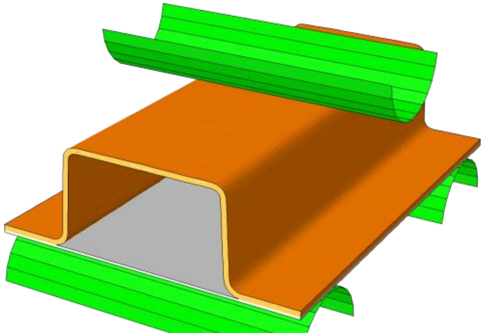


finite element model

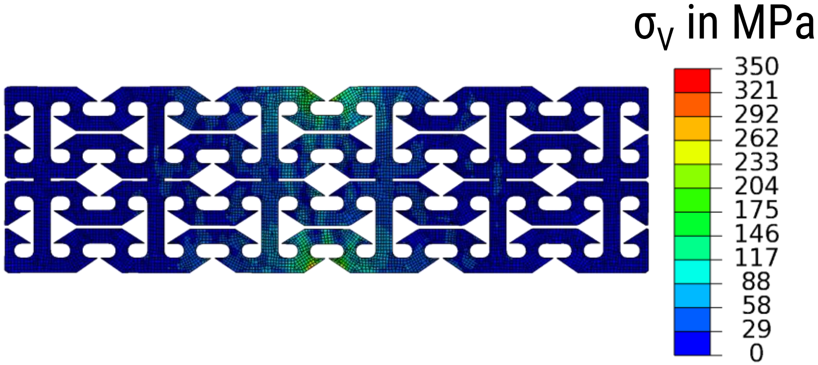
Riemer; Kießling et al.: On the development of finite element model to analyze the behavior of hybrid composites considering manufacturing history. IDDRG 2018

4 FE simulation considering the manufacturing history

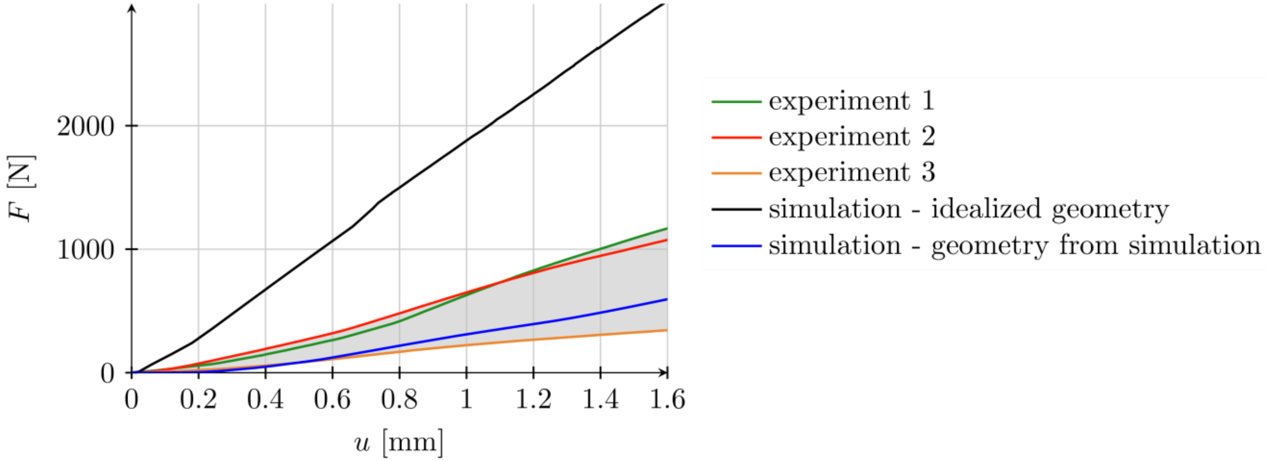
Comparison with experimental results



FE - Modell

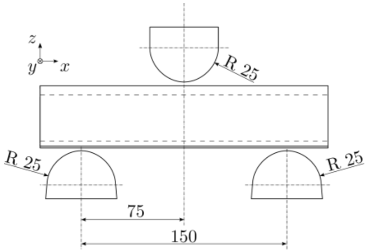


Stress distribution insert



5 Mechanical testing of the demonstrator part

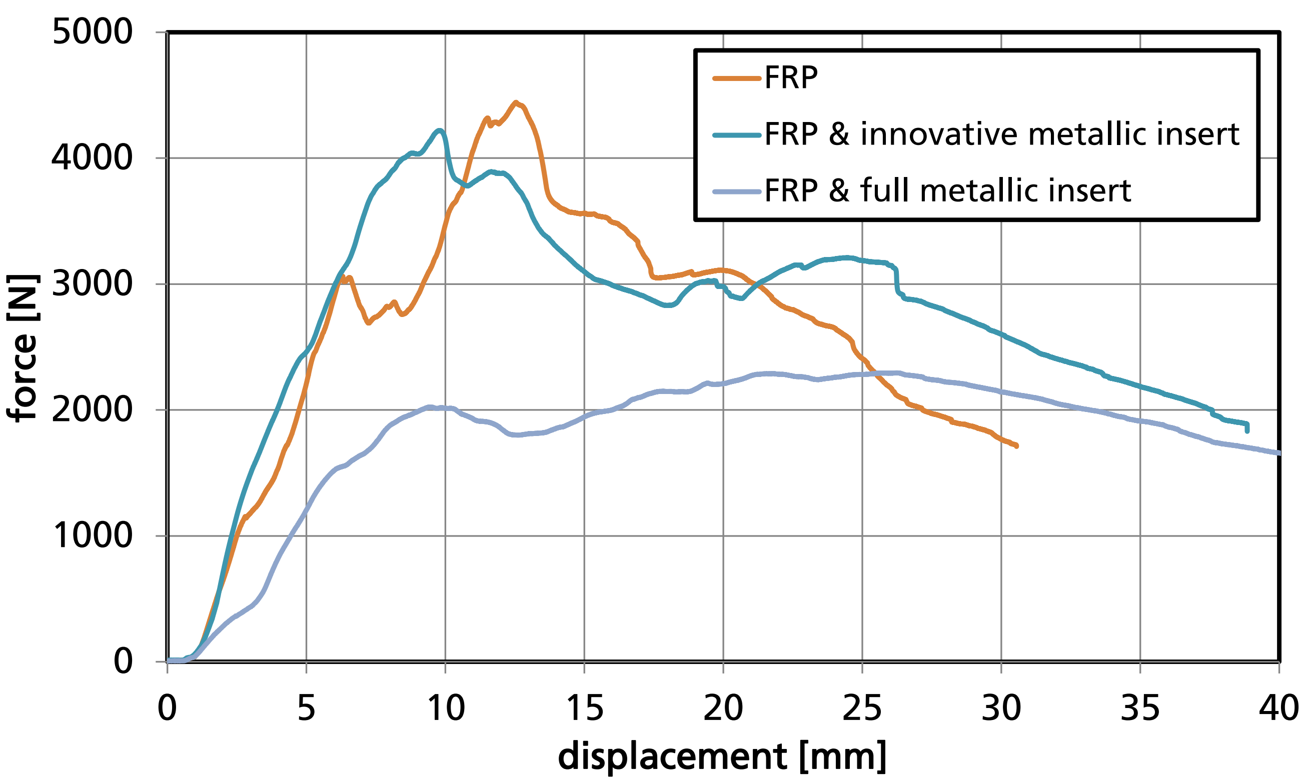
three point bending test

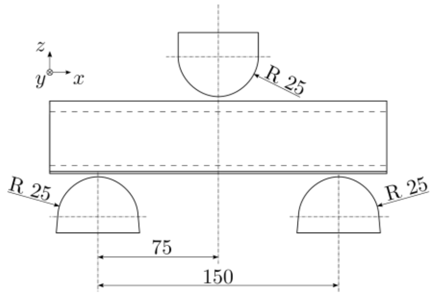


Testing Speed: ca. 2 m/s

5 Mechanical testing of the demonstrator part

three point bending test





Testing speed: ca. 2 m/s

6 Summary and outlook

- Intrinsic manufacturing process for crash relevant structures has been developed
- Combination of adhesive bonding and mechanical interlock is realized in a one-step manufacturing process
- Improved adhesive bonding and corrosion resistance based on sol-gel coating
- Advanced strategy for modelling the part behavior of hybrid composites considering the manufacturing history has been developed.
- specimen development for interface characterization under high dynamic load
- mechanical tests show the potentials of the concept

Further work:

- further testing of the demonstrator part
- Investigation of further materials for the metallic insert

Thank you for your kind attention!

Production – Fraunhofer IWU

Mechanics – FKM TU Chemnitz

Material science – IWW TU Chemnitz

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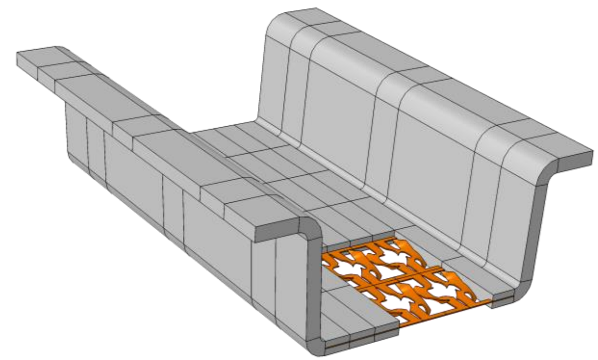

Acknowledgements

The authors want to thank the German Research Foundation (DFG) for the financial support of the project “Intrinsic hybrid composites for crash-relevant structural parts processed by forming” in the priority programme 1712 “Intrinsic cfrp-metal composites for lightweight structures”.

SPP1712

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