PADERBORN UNIVERSITY

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MODELLING THE INTERFACE OF HYBRID METAL-FRP COMPONENTS JOINT BY FORM CLOSURES

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Agenda

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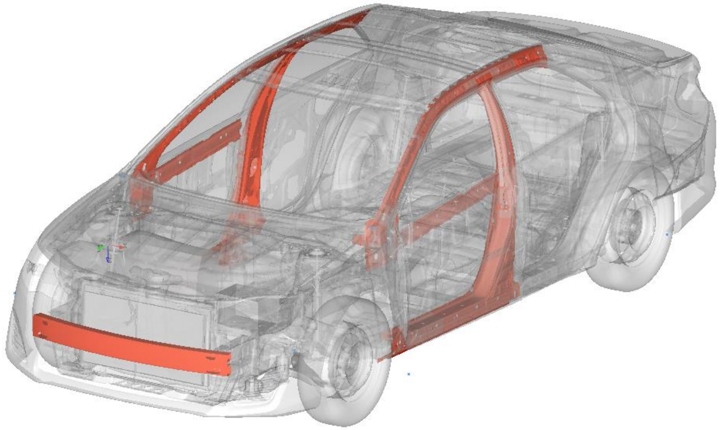
Introduction



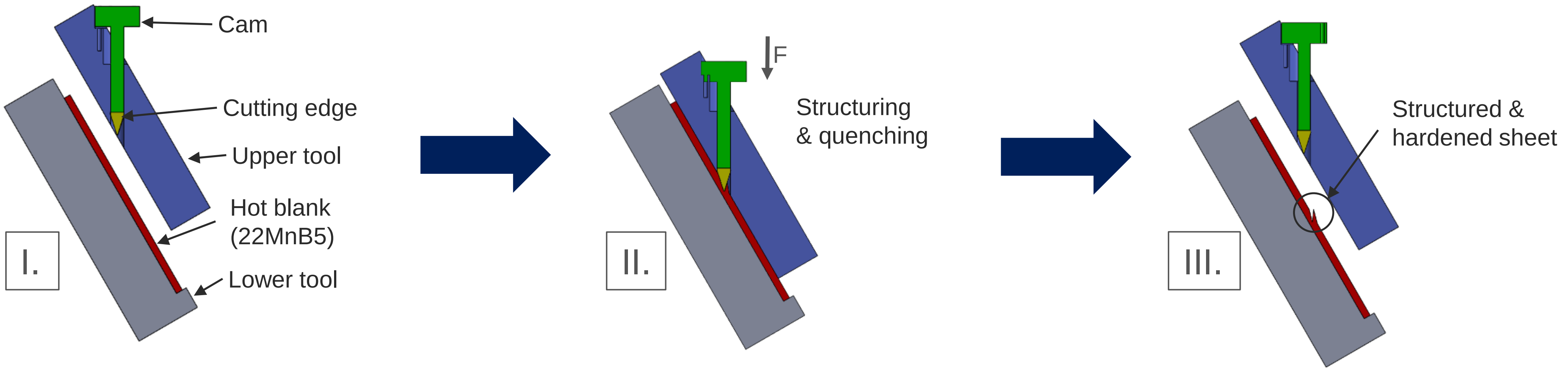
- Press hardening is state-of-art in the automotive industry to enable crash safety and lightweight at the same time for body-in-white components
- Nevertheless the achievable mass reduction is limited, because of the high density and buckling problems related to the reduction of sheet thicknesses
- A promising approach to achieve further weight reductions are multi-material components, e.g. consisting of metal and fiber-reinforced polymers (FRP)

- To create a better adhesive bonding the surface of these metal components usually will be treated in a separate process to create a bigger surface area, e.g. through laser-based surface treatment or sand-blasting
- Moreover a joining can be realized through mechanical fastening like riveting

Agenda

The HotStruc process

- At the Institute of Machine Tools and Production Technology and the Chair of Automotive Lightweight Design, a new approach is under development where macroscopic form closures will be created in the process of hot stamping ultra-high strength steels (e.g. 22MnB5)
- Due to *Dröder et al.* [1] it has been shown that these undercuts increase the transmittable tensile and shear forces of the interface between the metallic and FRP components



The HotStruc process

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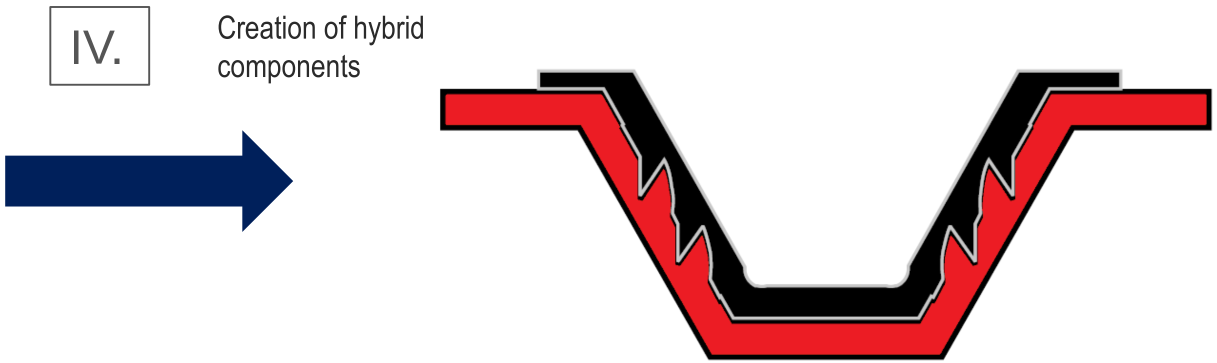
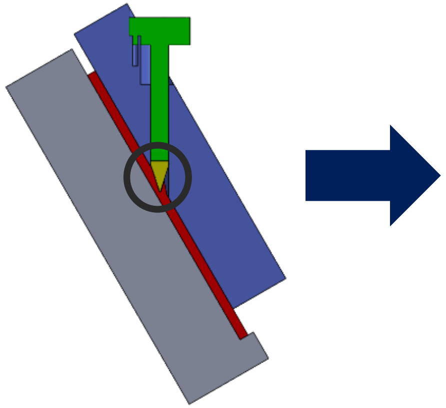
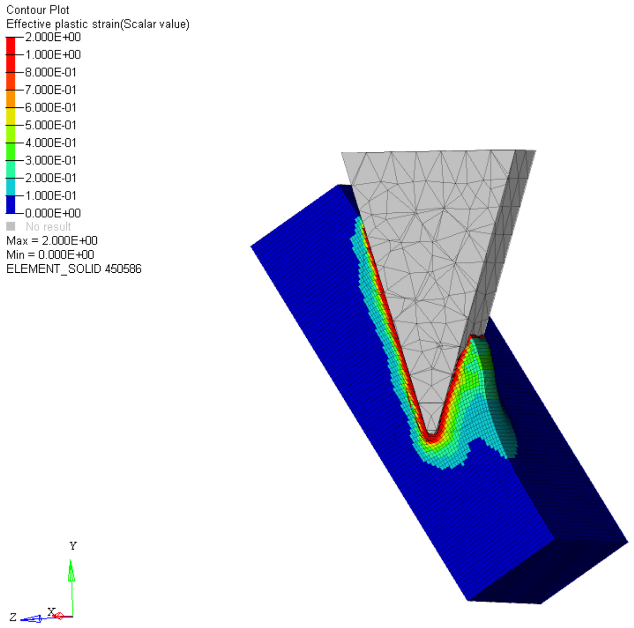


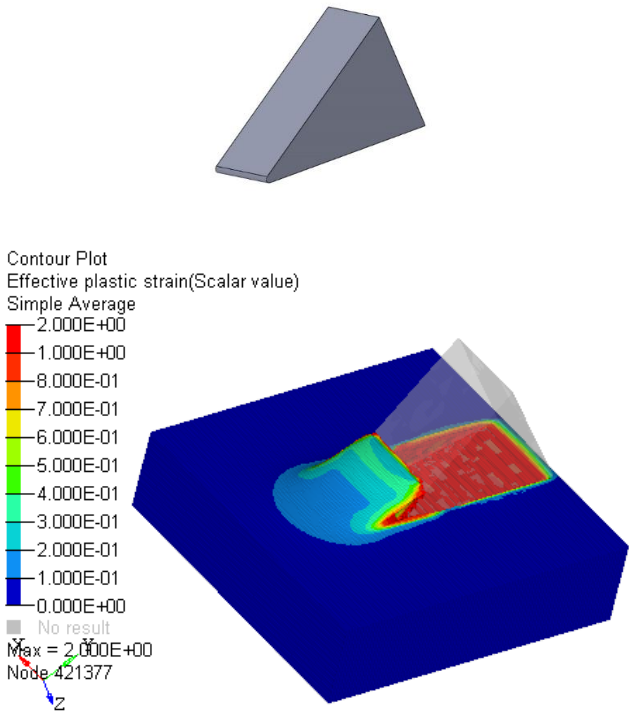
The HotStruc process – Forming simulation

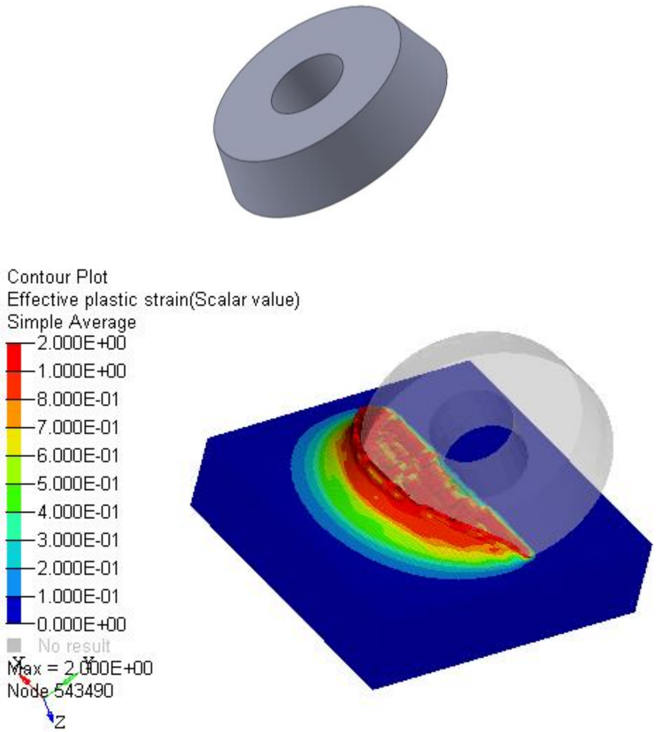


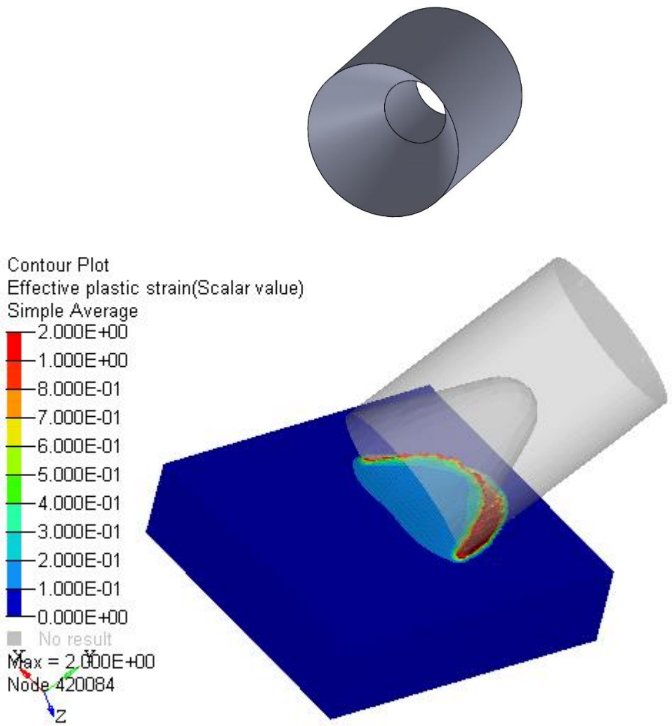


- Simulation of the forming process by an isothermal explicit FEA
- The flow curve (700° C) for 22MnB5 has been taken from *Hochholdinger* [2]
- Fine solid element mesh with l_e = ~50 µm, respectively 550.000 elements for 80 mm³ volume of steel sheet
- The cutting edges are considered to be rigid
- For the steel sheet **`*MAT_024`** is combined with DIEM (**`*MAT_ADD_EROSION, IDAM = -1`**) to account for material separation
- Ductile damage initiation (**`DETYP = 1`**) is based on triaxility over plastic strain
- For the DIEM a fracture energy based ductile failure criteria is used (**`IDAM = -1, DETYP = 1, G_f = 20 [N/mm]`**)

The HotStruc process – Structuring







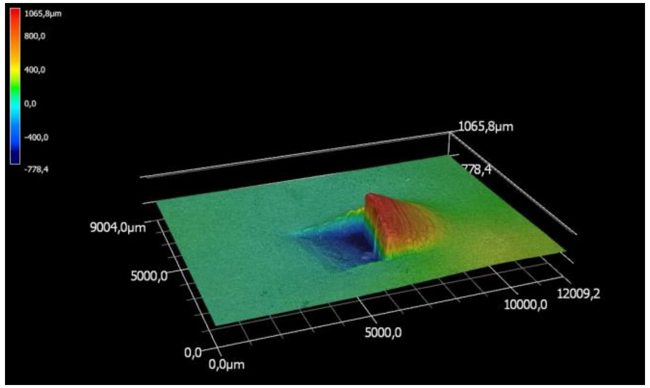
- Consideration of different carbide end cutting edge geometries
- Variation of process parameters like cutting and impact angle or immersion depth

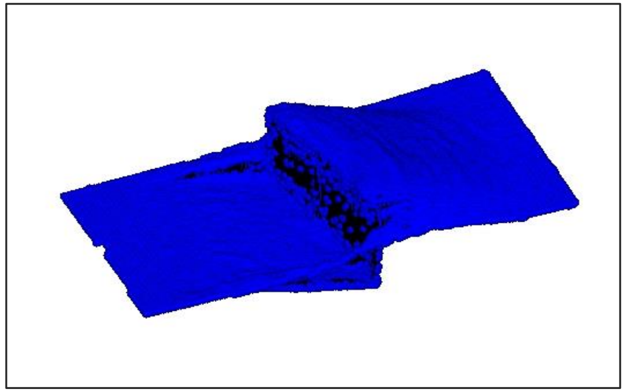
The HotStruc process – Experimentel evaluation forming

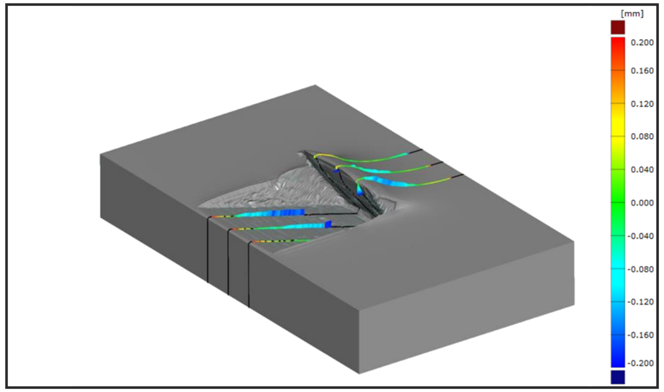
Scanning of the resulting surface with an optical 3D profilometer

Reverse engineering of CAD data

Comparison of the simulated geometry with the experimental data



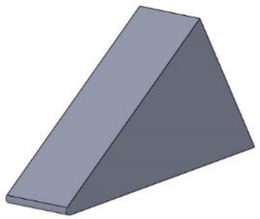


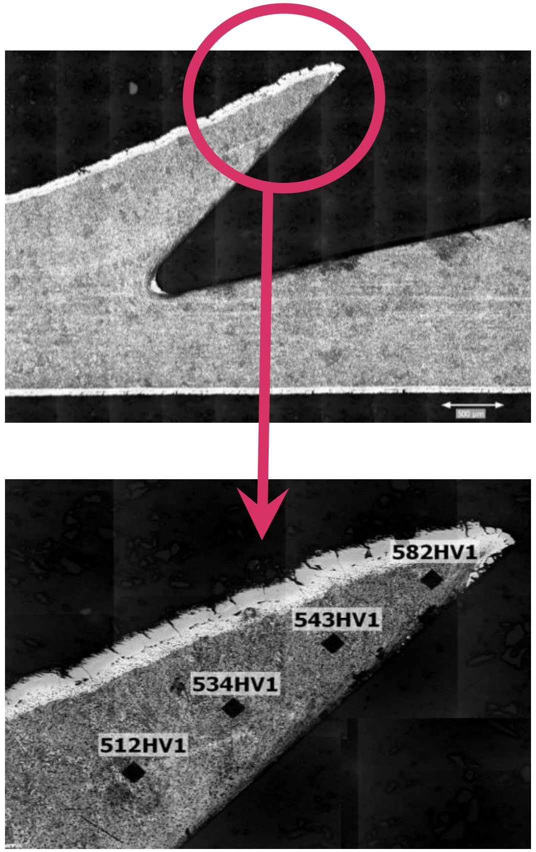


The HotStruc process – Experimentel evaluation of achieveable hardness

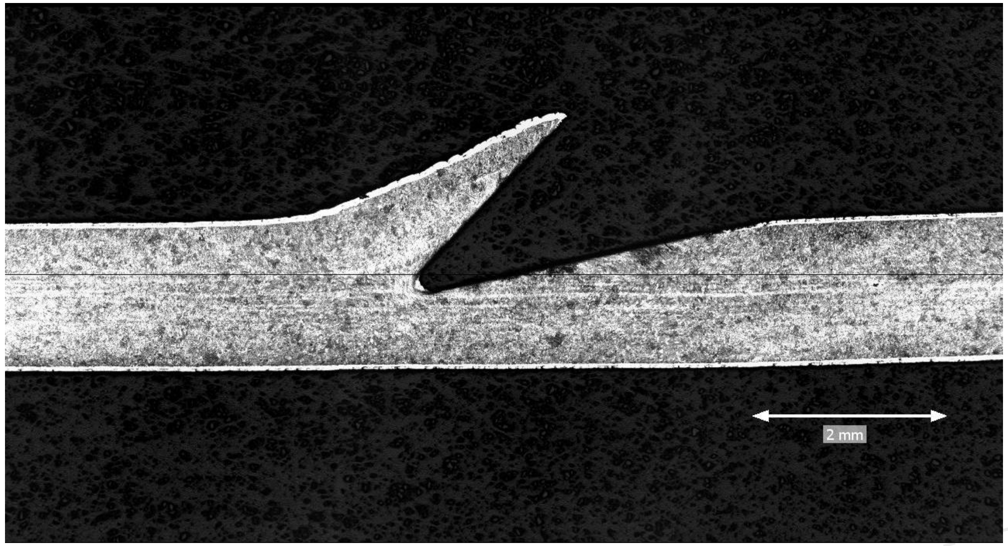
- The process showed his ability to structure and harden the 22MnB5 sheets simultaneously

Considered cutting edge (indexable insert)



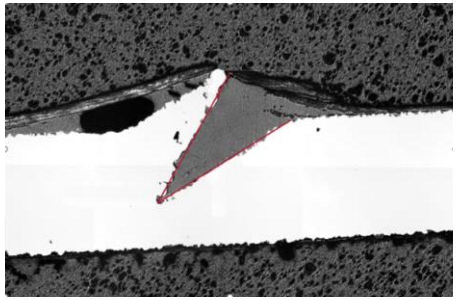


Average hardness:	493HV1
MIN:	448HV1
MAX:	582HV1

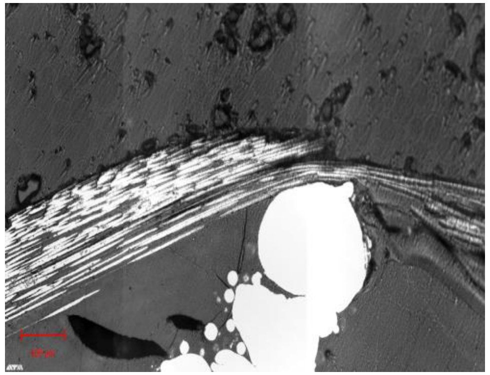


The HotStruc process – Composites

Epoxy & Carbon-fibers 0°

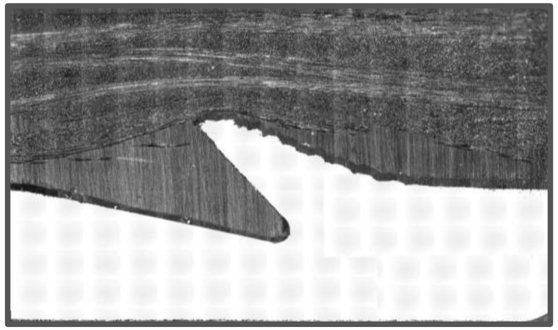


→ Epoxy: Good adhesion without surface treatment
→ Long process time

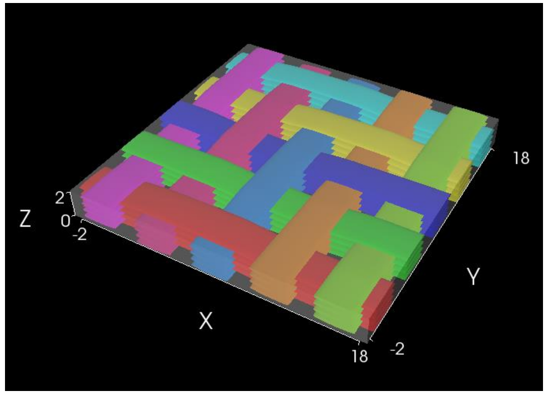


→ Pores
→ Fracture initiation from structures
→ Consideration of 90° layers in structure area

PA6 & Glassfiber twill 2/2



→ PA6: Nearly no adhesion without surface treatment
→ Quick process time
→ Easy formability



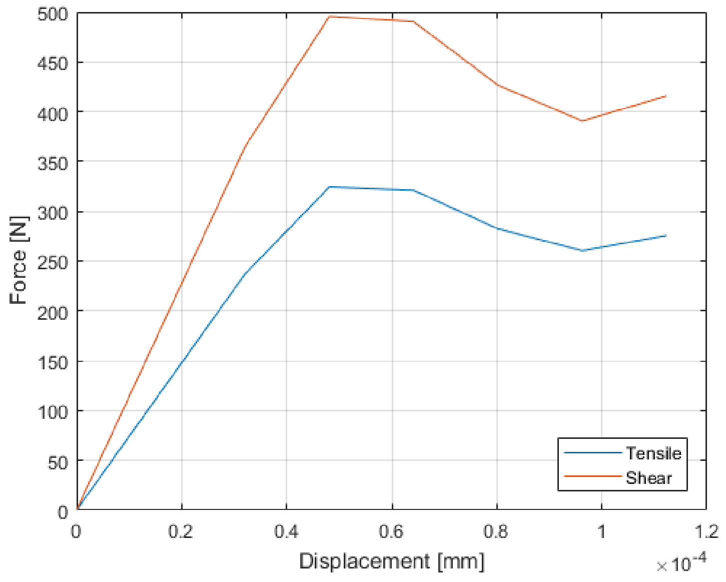
Created with TexGen

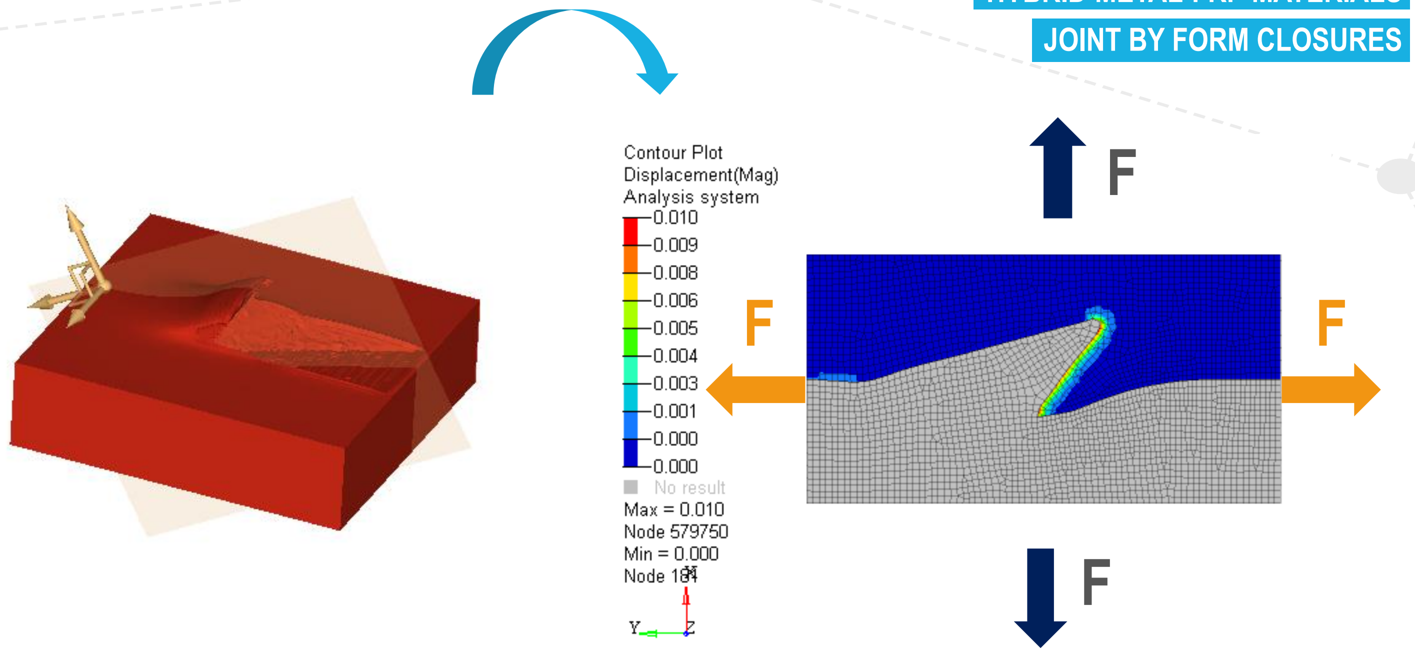
→ Isolated influence of the form closures can be investigated

The HotStruc process – Reaction forces

Aim: Find an optimal geometry for the form closure with good shear and tensile properties

Reaction forces polymer – plain strain simulation



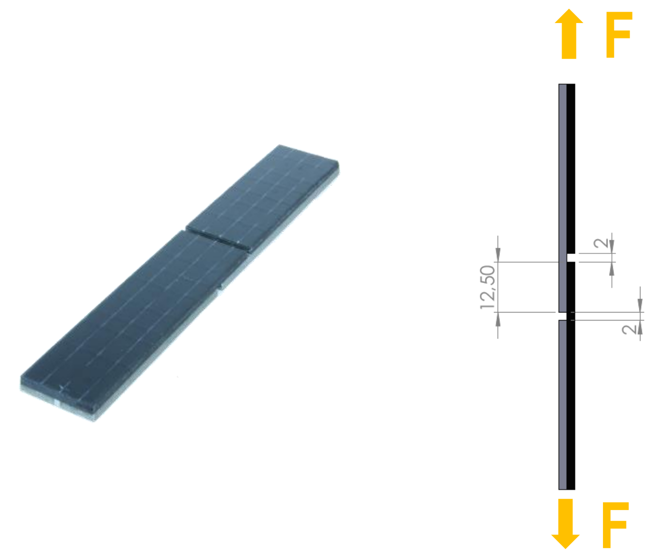


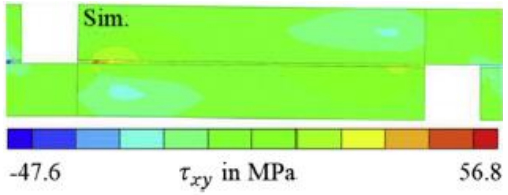
- Use of the predicted geometry from the explicit forming simulation
- 2-dimensional plain strain elements **ELFORM = 13**

- Simulation of the resulting reaction forces in shear and tensile direction
- The steel has been considered rigid and for the FRP component an isotropic PA6 (***MAT_024**) material is applied
- Investigation on the influence of the different cutting parameters

The HotStruc process – Hybrid material testing

Single lap joint





Zinn et al. [5]

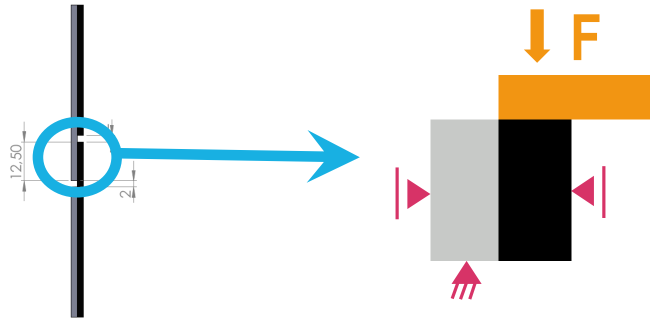
How to test the shear strength of hybrid materials?

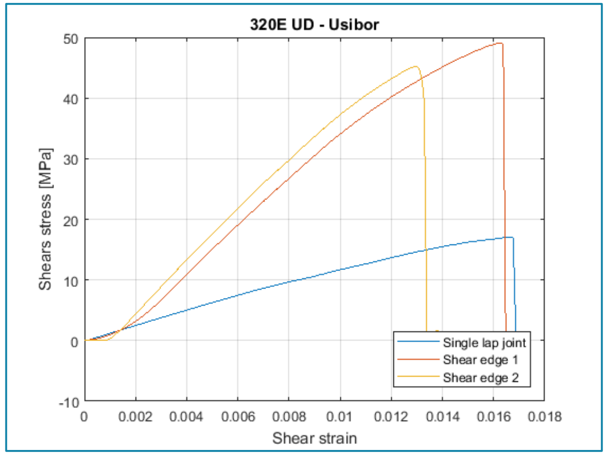
- Most of the testing of hybrid materials is based on the norms DIN 65148 (intralaminar shear strength of composites) or DIN EN 1465 (shear strength of adhesives)
- Classic testing methods like the single lap joint suffer from the following:
- Residual stresses ⬇
- Loading induced bending (even more pronounced due to different stiffnesses) ⬇
- Material intensive ⬇
- Resource consuming manufacturing (finishing work: waterjet cutting and milling) ⬇

→ Through single lap joint testing only apparent shear stresses can be obtained

The HotStruc process – Hybrid material testing

The shear edge test





How to test the shear strength of hybrid materials?

- Based on the work of *Weidenmann et al. [4]*
- Advantages of the shear edge test:
- Better force transmission ⬆
- Less bending problems ⬆
- Simple production and sparsely material usage ⬆

→ The testing results show about 300 % higher apparent shear stresses for the samples of the shear edge test

The HotStruc process – Material characterization

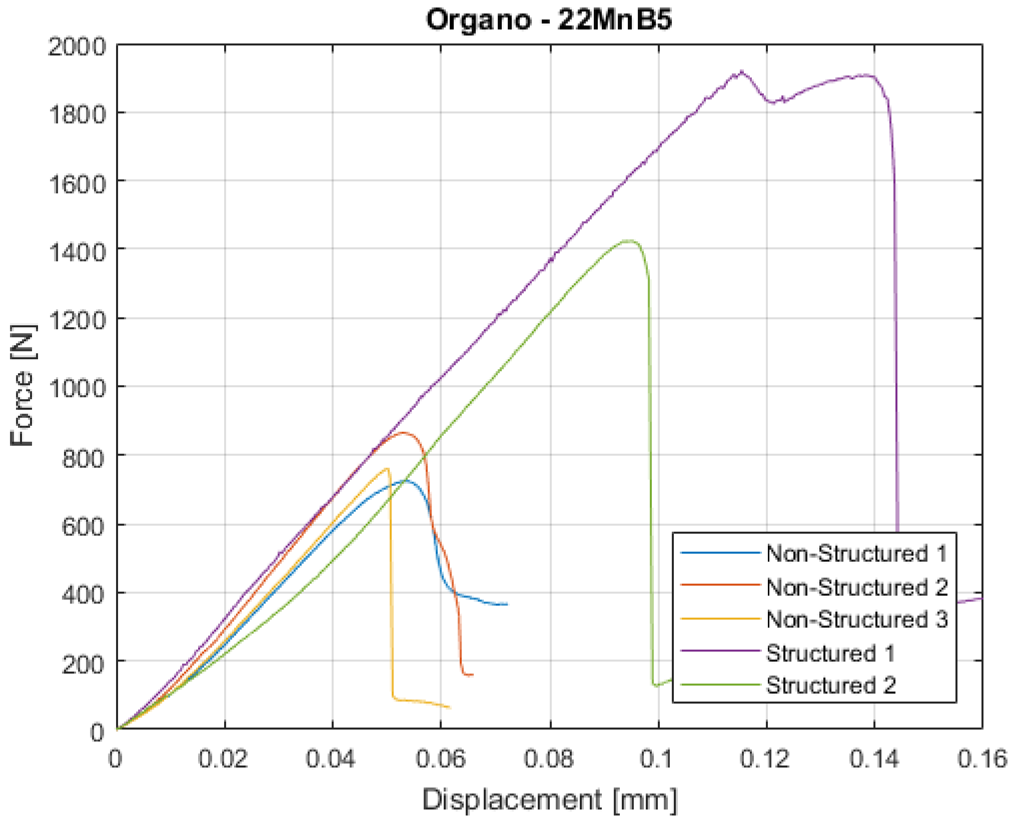
Testing Procedure

Characterization of the adhesion of the non-structured 22MnB5 with AlSi coating

Evaluation of the structured samples under different loading angles and directions

Implementation of suitable abstraction models to represent the hybrid material interface for full-vehicle simulations

Evalution of the raw cleaned surface, before considering e.g. bonding agents foils



Increase of the transmittable forces up to 100 %

Agenda

Abstraction of the interface – Modelling strategies

Modelling of the from closures by beam material model
*MAT_NONLINEAR_ELASTIC_DISCRETE_BEAM/
*MAT_067

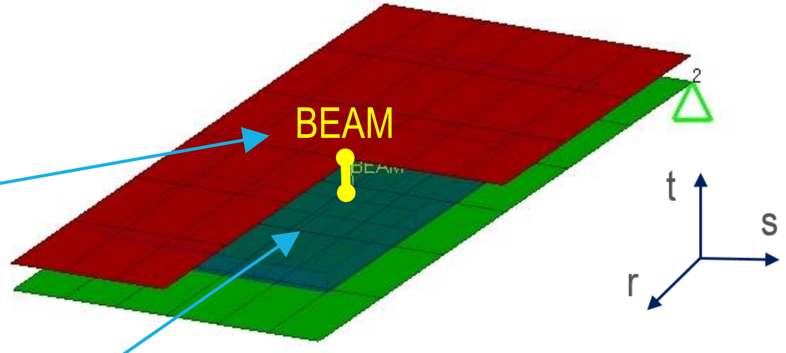
MAT_067

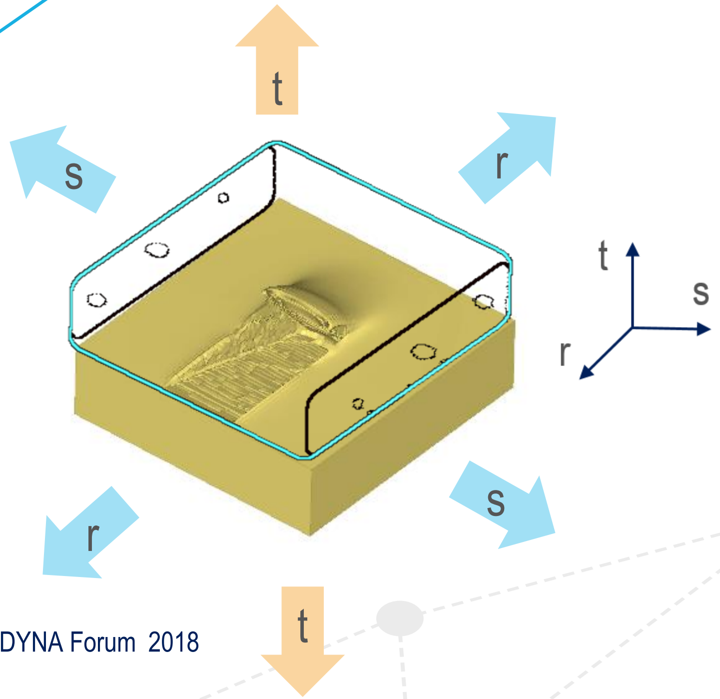
→ Force over displacement curves for local r,s,t- directions
→ Failure forces *FFAIL

Modelling of the polymer adhesion by cohesive zone elements
*MAT_COHESIVE_GENERAL/
*MAT_186

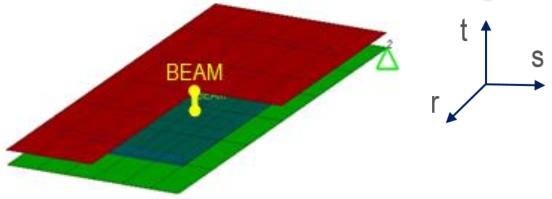
*MAT_186

→ Alternative: *CONTACT_TIEBREAK to increase computational efficiency and avoid element distortion in crash simulations



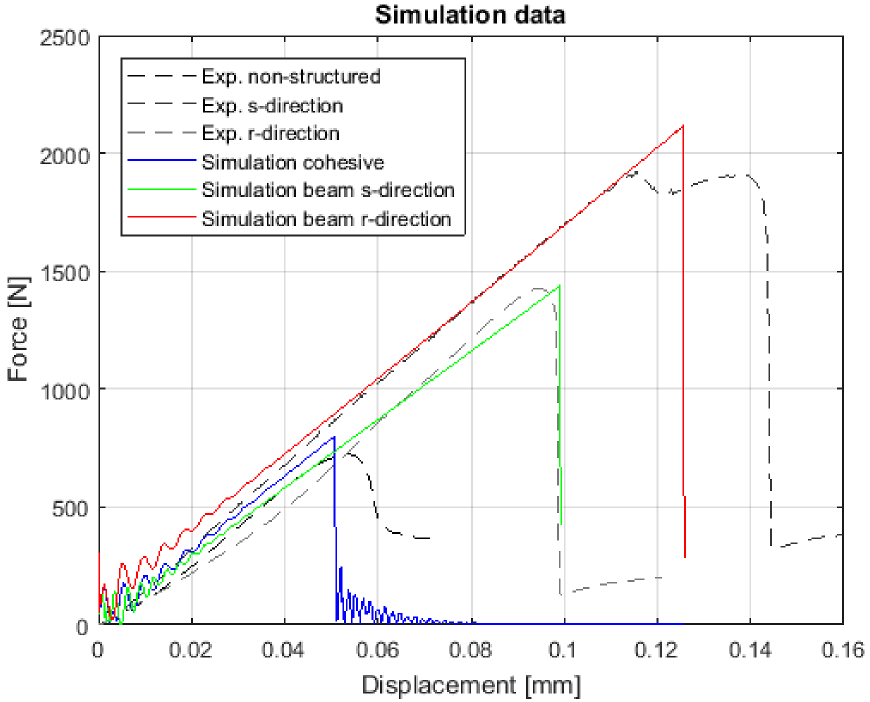


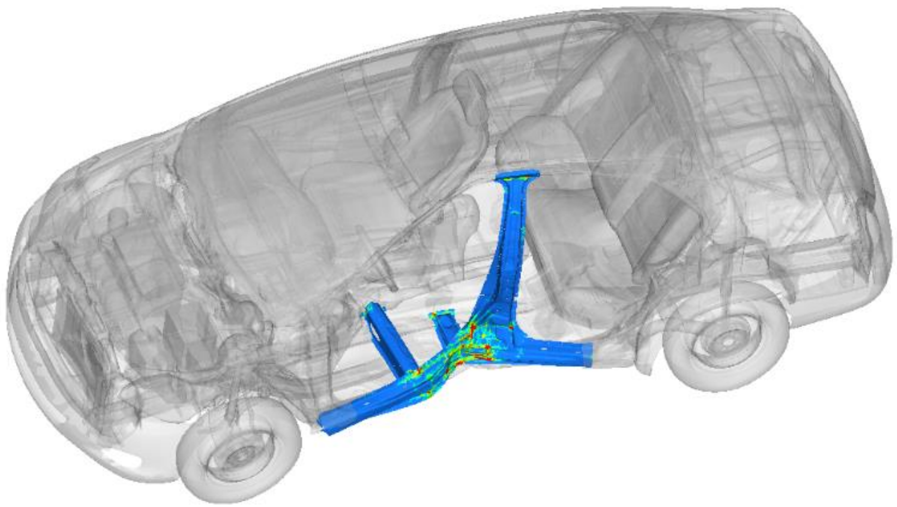
Abstraction of the interface – Modelling strategies



Build up suitable abstraction models which then can be used for component and full-vehicle crash simulations

Investigation of application fields of characterized hybrid materials





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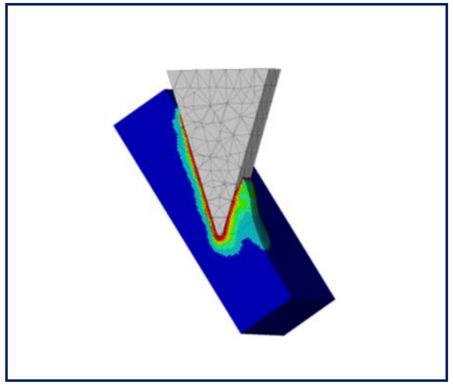
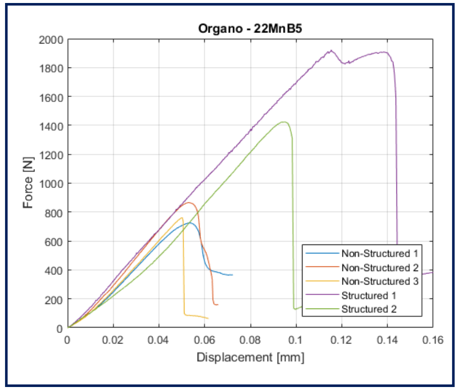
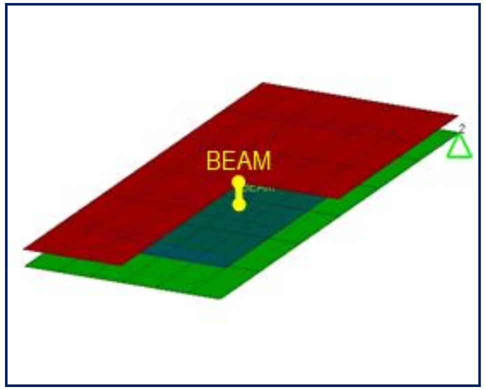
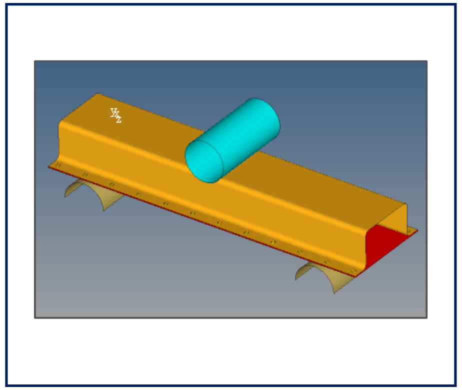
Summary and outlook

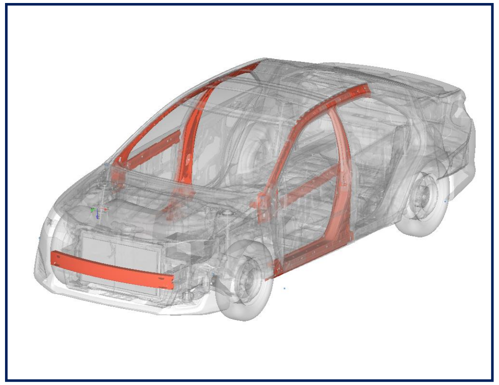
Process → Hybrid testing → Abstraction models → Component testing → Application fields











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FOSTA

AiF

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