HIGH-FIDELITY MODELLING OF COMPOSITE SPECIMENS MANUFACTURED WITH THE AUTOMATED FIBRE PLACEMENT TECHNIQUE

M. Vinot, L. Raps, N. Toso

Automated Fibre Placement
Process description

- Large increase of worldwide hydrogen needs in the next years
- High improvement potential through materials, manufacturing and design
- Automated fibre placement
  - → enable the production of type V linerless tanks
  - → increased tank recycling via thermoplastics
  - → increased design freedom (non-geodesic fiber orientations)

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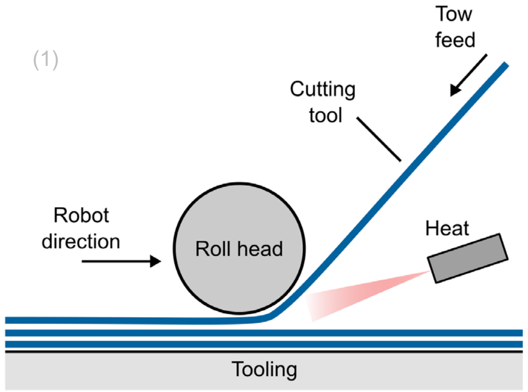
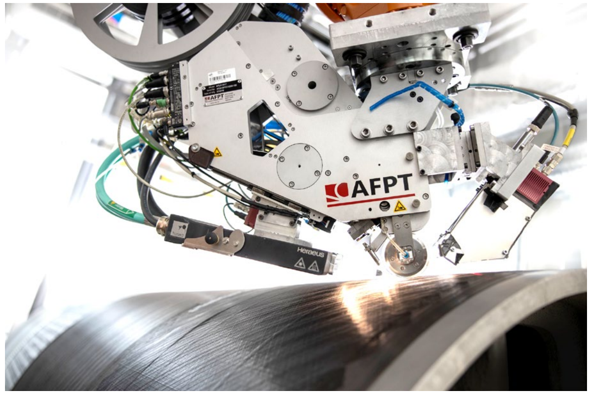
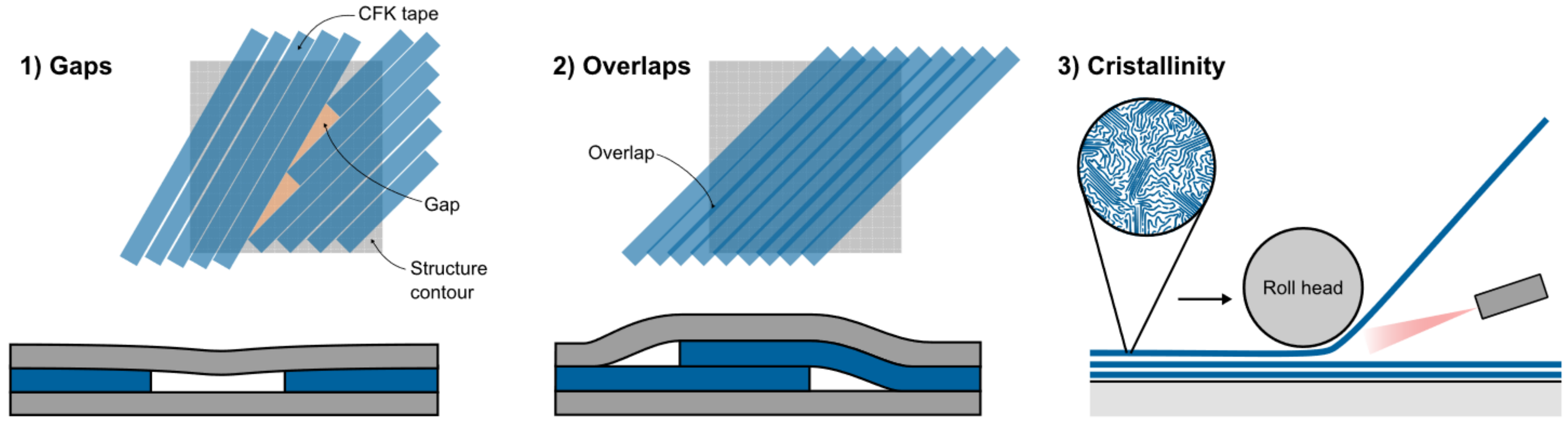




Automated Fibre Placement

Manufacturing effects and inherent defects

Potential influence of manufacturing parameters on the quality of the end product



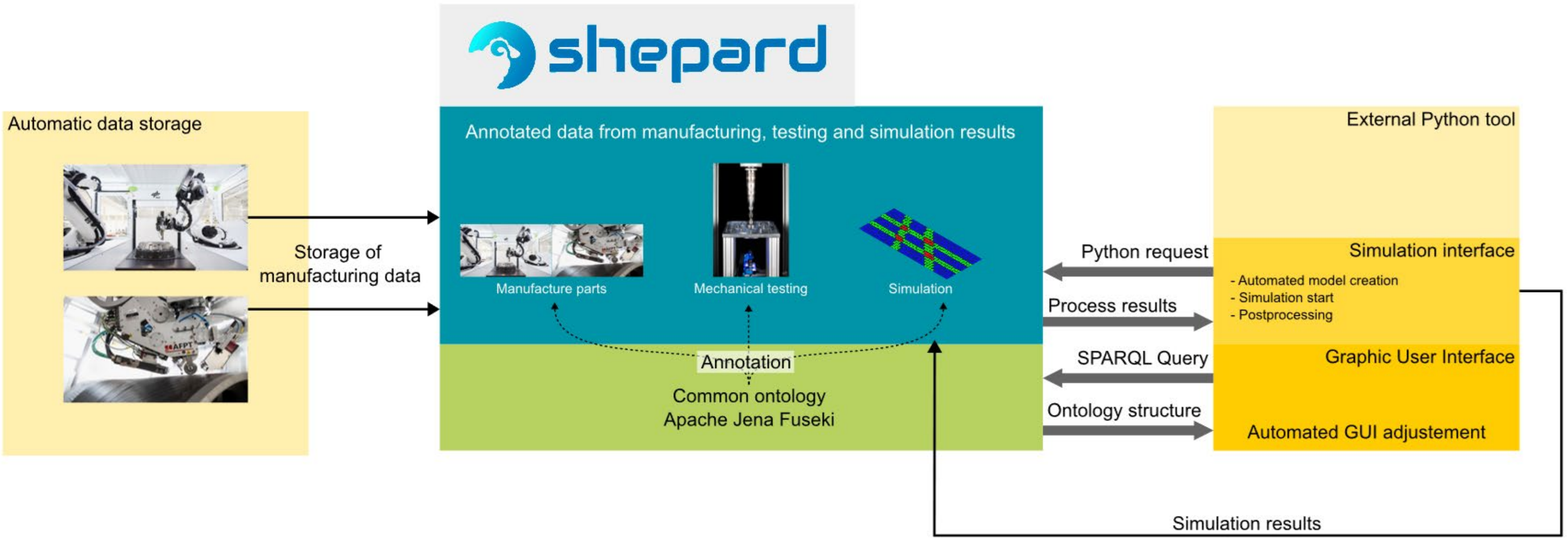
- Estimation of defects via direct measurement (robot data) or indirect measurement (derivation through data analytics, ultrasonic scans...)
- Structuring of data concerning manufacturing and defects via metadata and ontology

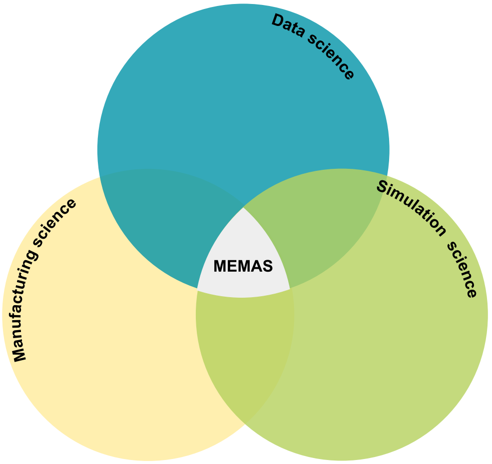
Manufacturing data and metadata in simulation

Multidisciplinary framework

MEMAS: Metadata Enriched Manufacturing data for Automated Simulation

- Framework to unite manufacturing, testing and simulation
- Acquisition and structured storage of manufacturing and test data/metadata
- Automatic generation of high-fidelity FE models based on manufacturing data



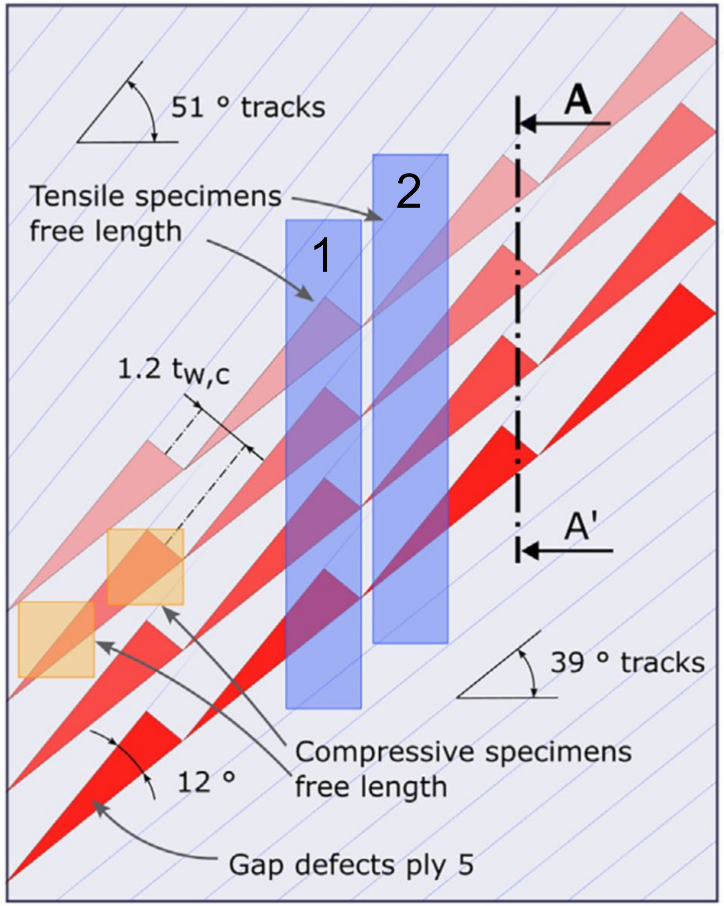


Experimental test campaign

Investigation of geometrical defects

Investigation of compression specimens

- Material: AS7/LM-PAEK 55 % fibre content
- Layout: $[0°/-45°/90°/(51°|39°)]_{2s}$
- Specimens extracted from CFRP plate
- Geometry: AITM 1–0008-A2
- Reference specimen without defects
- Two defect patterns (1, 2)
- Storage of tape paths for each ply into a research data management system



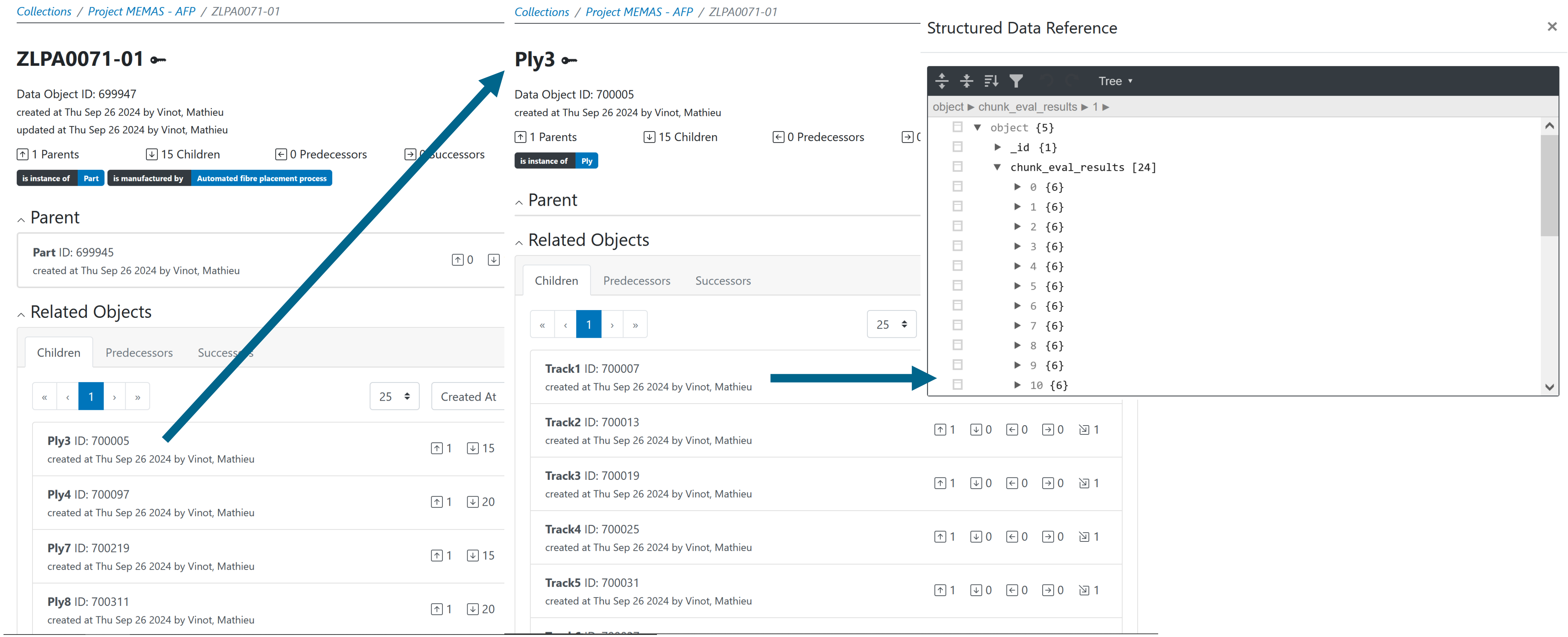
Lukas Raps, Fynn Atzler, Ashley R. Chadwick, Heinz Voggenreiter, In-situ automated fiber placement gap defects filled by fused granular fabrication, Manufacturing Letters,

Structured storage of manufacturing data

Research data management system shepard (https://gitlab.com/dlr-shepard)

DLR

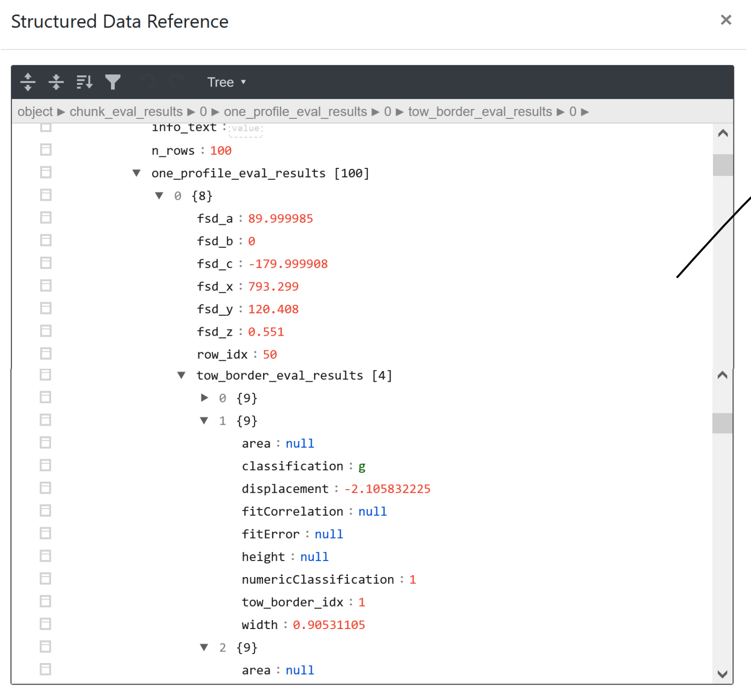
Structured storage for efficient data analysis and referencing



Model generation based on manufacturing data

Mapping procedure and model generation

Mapping of tape information from database on elements with closest point algorithm


Structured Data Reference

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info_text : value
n_rows : 100
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▼ 0 {8}
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fsd_b : 0
fsd_c : -179.999908
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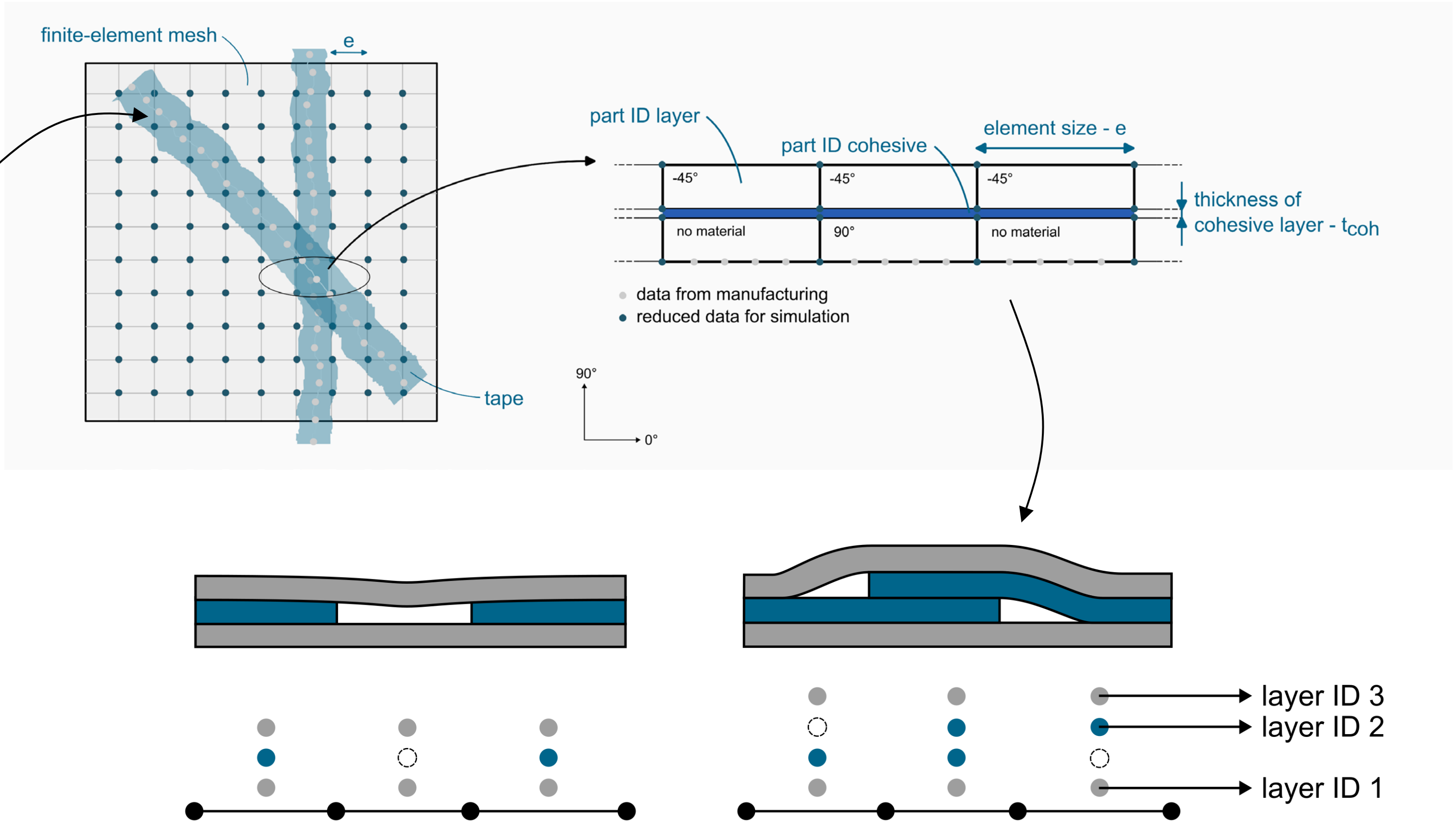
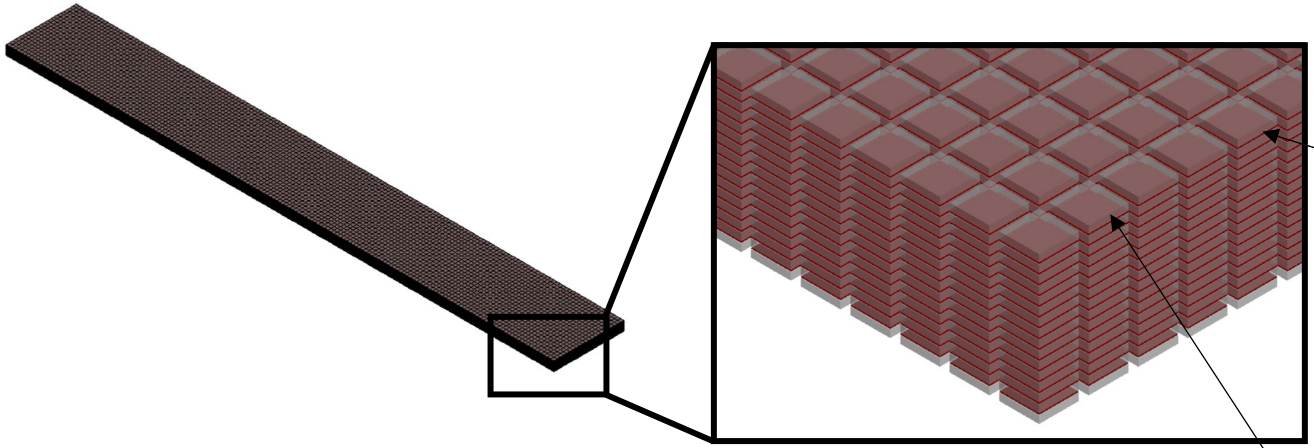
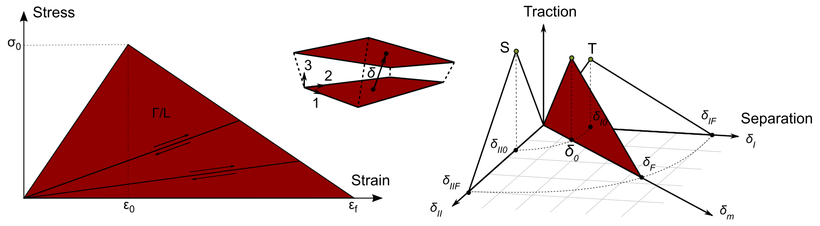


*ELEMENT_SHELL_BETA_OFFSET_COMPOSITE_LONG

Modelling strategy and material models

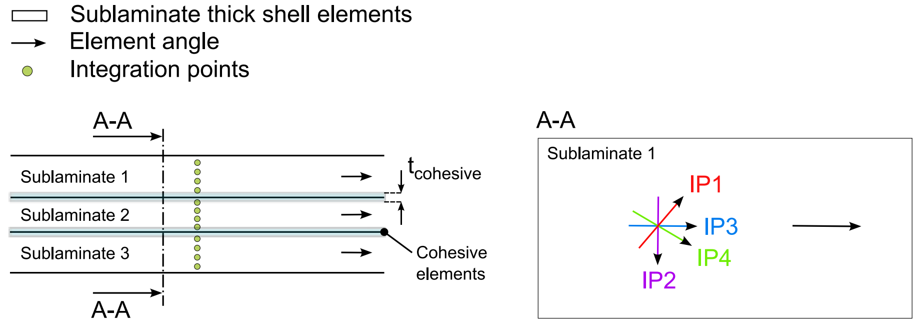
Mapping of tape information from database on elements with closest point algorithm





Cohesive zone model *MAT_240
- strain-rate independent strengths and fracture toughness
- independent on fibre angle of bound layers

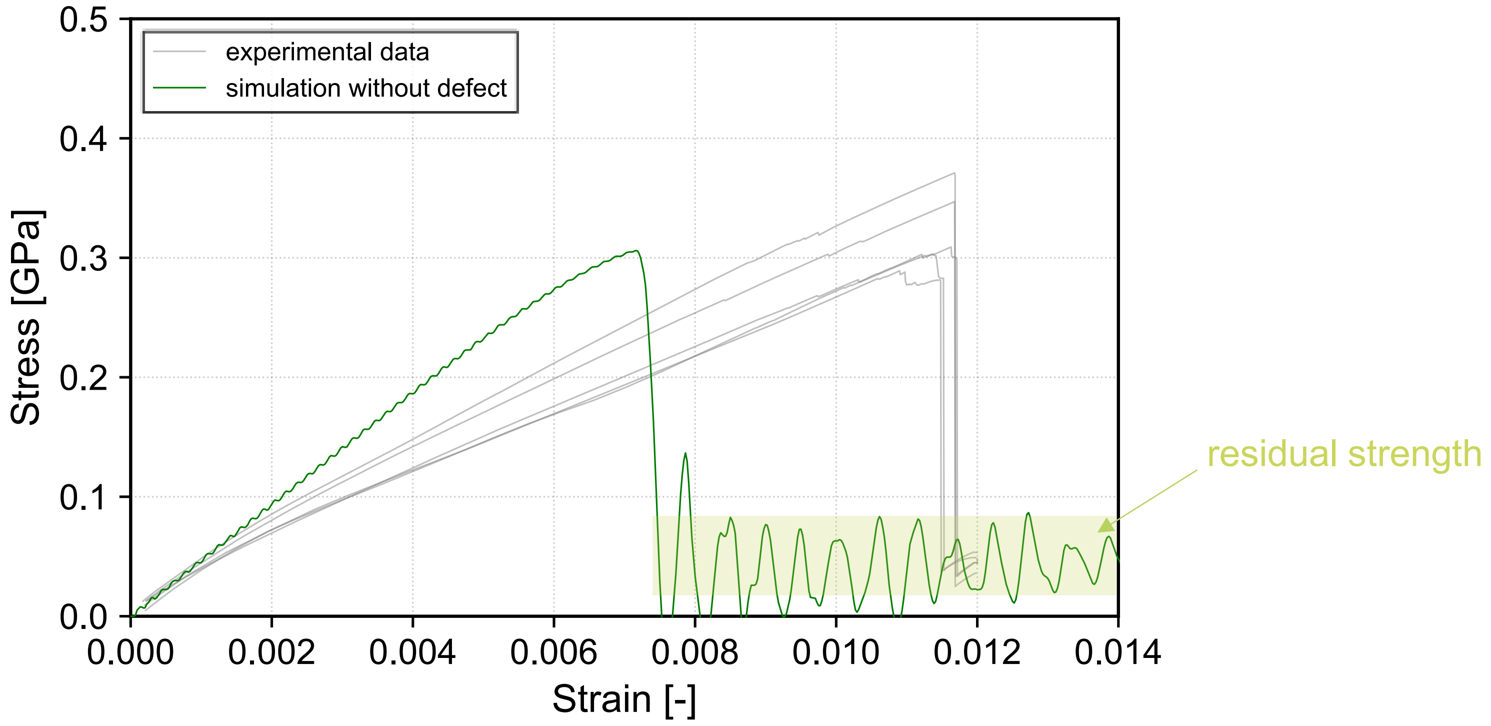
Orthotropic continuum damage model from Camanho *MAT_262
- strain rate dependent strengths and fracture toughnesses
- physically-based failure and damage criterion



Virtual compression tests

Validation of reference model – preliminary results

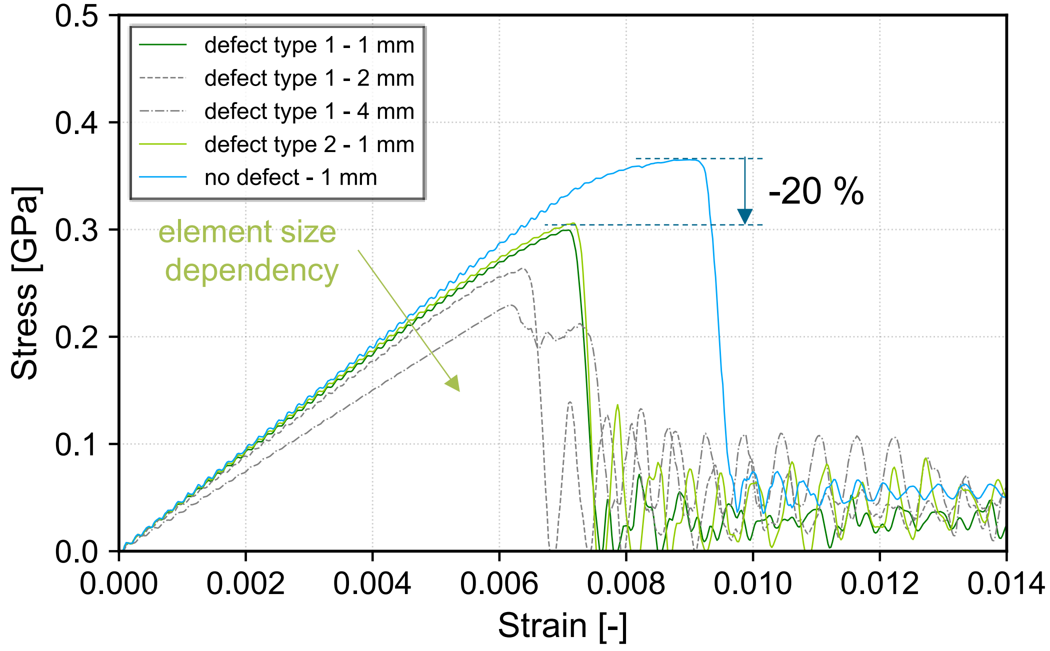
- Initial stiffness before first ply failure accurate
- Good correlation of compression strength and residual strength for pristine samples
- Non-linear behaviour of the specimen not accurately reproduced

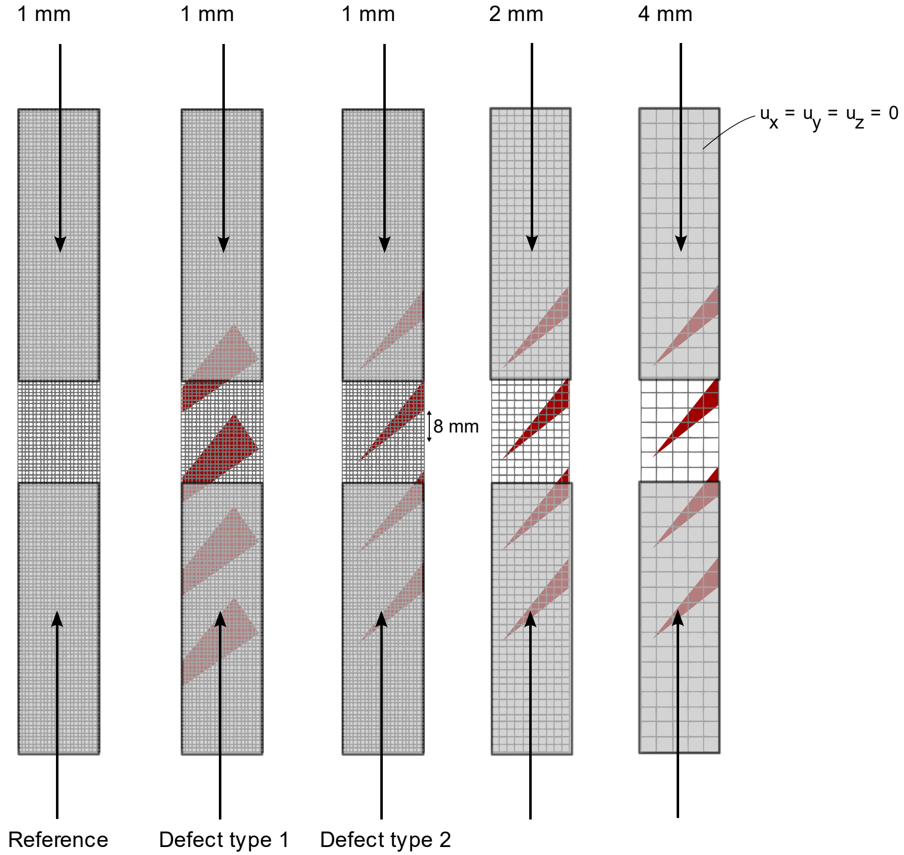


Virtual compression tests

Investigating the effect of defects on global mechanical behaviour

- Investigation of element size effects on predicted mechanical response
- Investigation of defect size
- For the moment, no investigation of the defect position

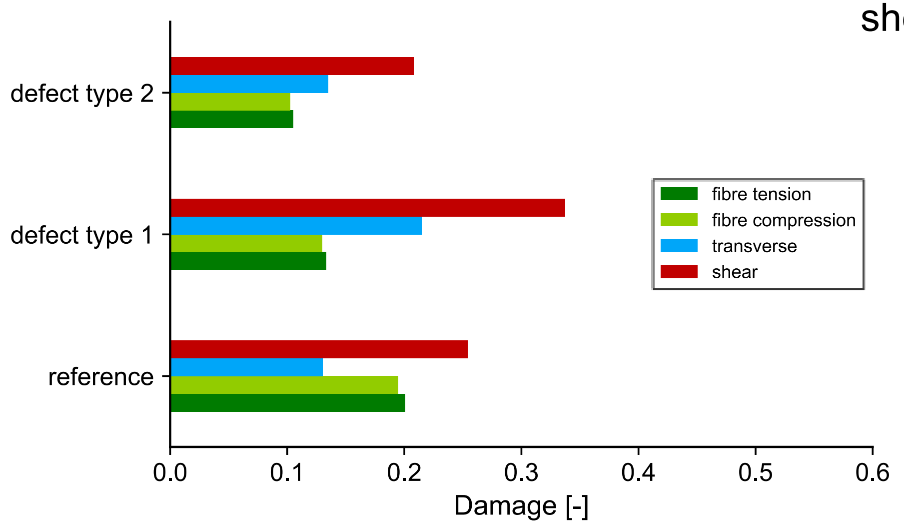


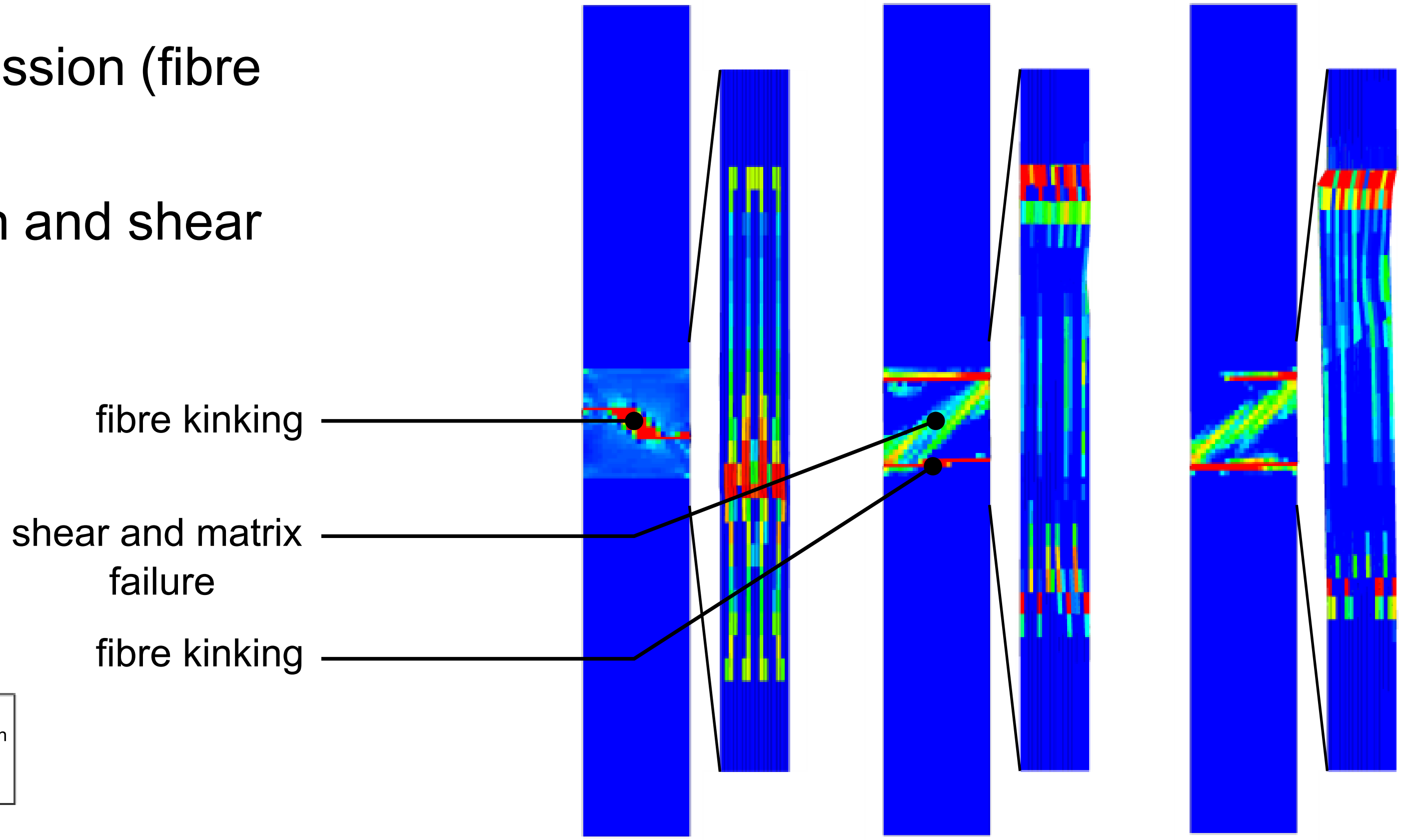


Virtual compression tests

Investigating the effect of defects on failure patterns

- Global failure under fibre compression (fibre kinking) in the pristine specimen
- Shift towards matrix compression and shear failure in the defect specimens

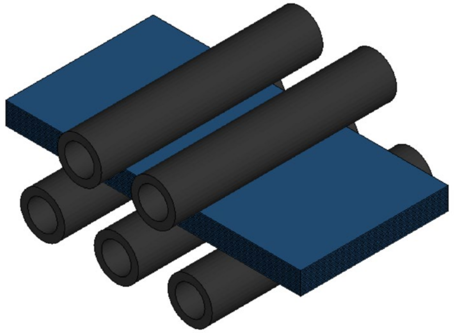


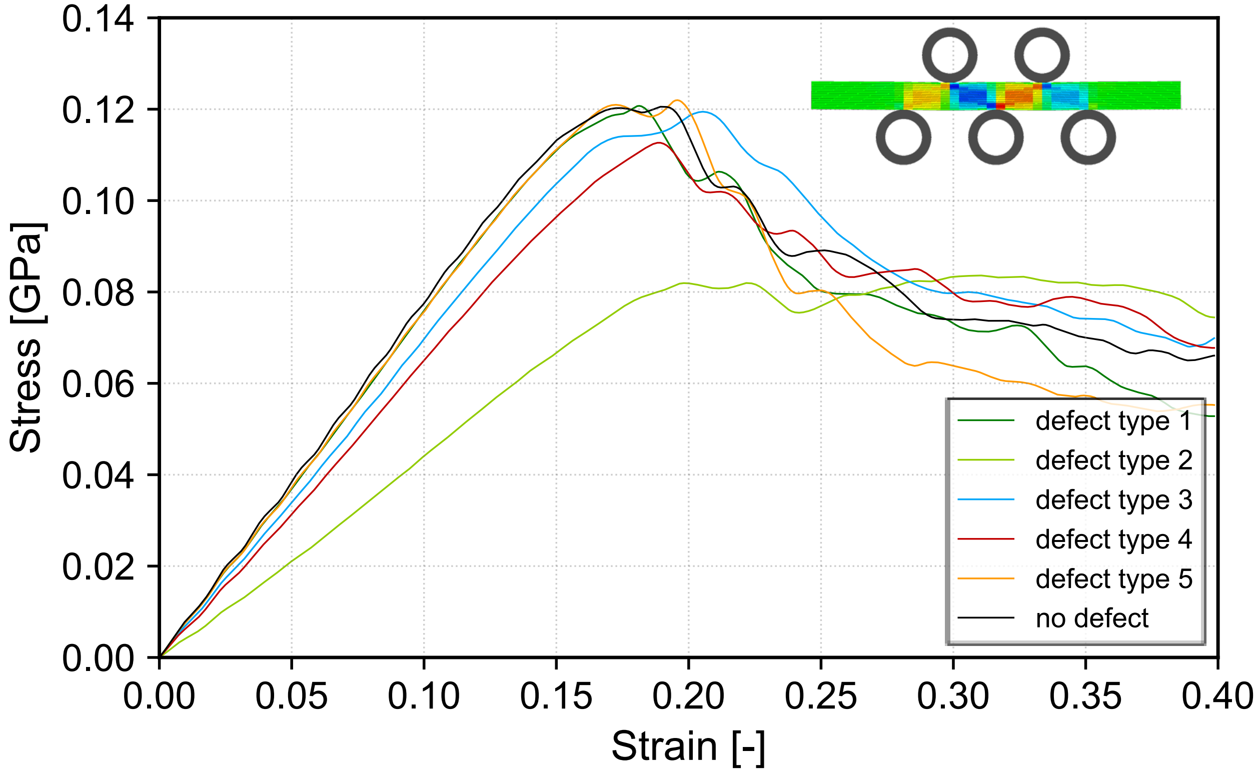


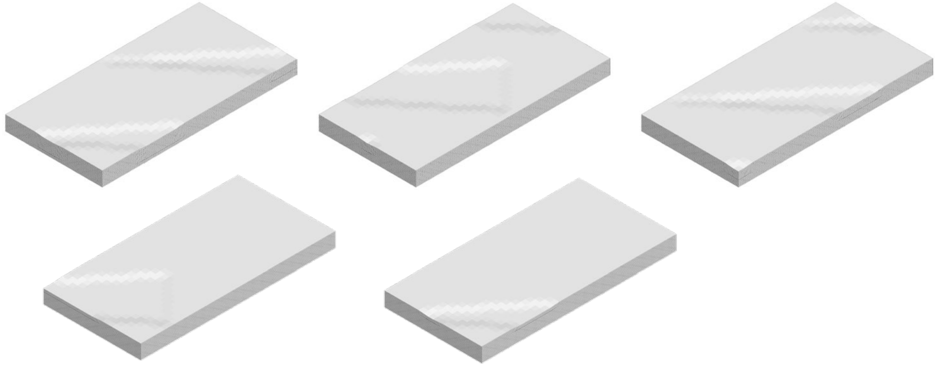
Extension to more loading cases

Estimating the interlaminar shear strength (ILSS) of thermoplastic materials

- Double beam shear test to measure ILSS of composites
- Property strongly dependent on sample quality (planarity, defects etc.)





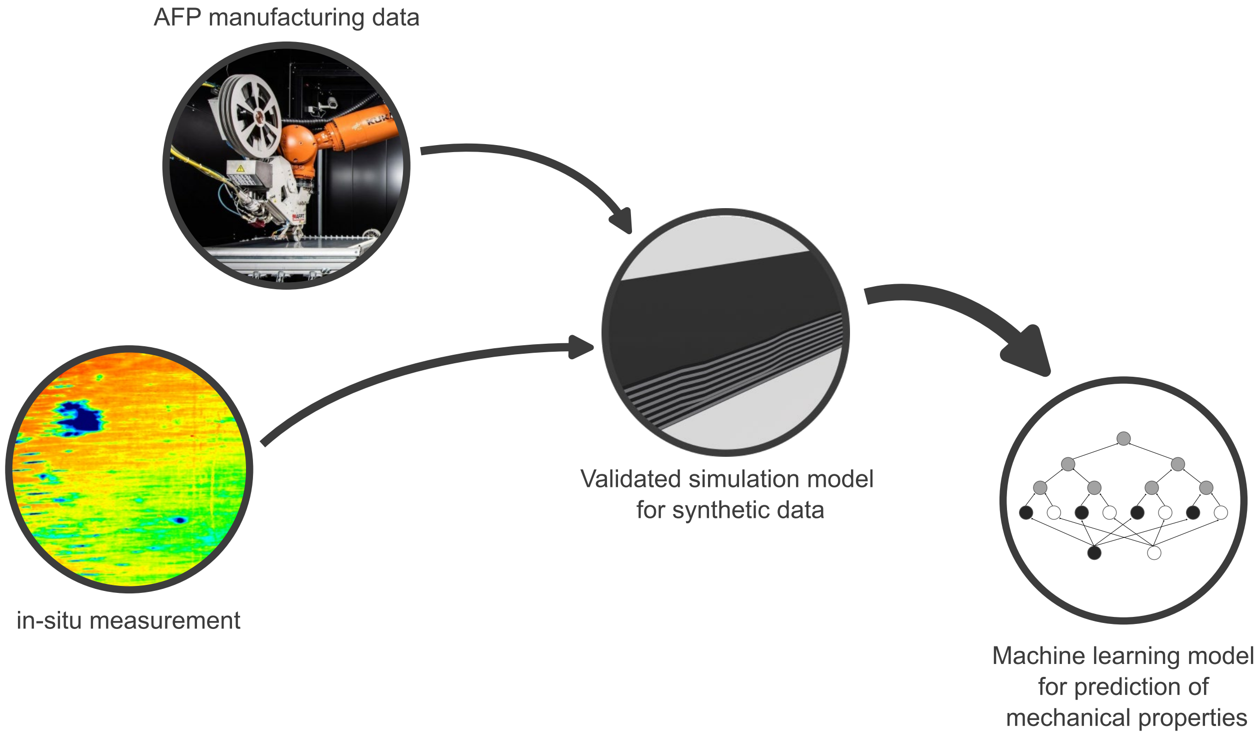


Conclusion and outlooks

- Digital framework for storage and further use of manufacturing data in simulation
- Simulation approach for prediction of thermoplastic materials with manufacturing defects
- Partial validation under compression loading

What is to come?

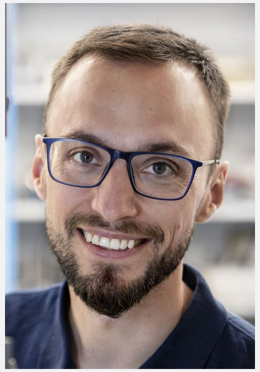
- Extensive experimental validation
- Training of machine learning model for live performance prediction



Thank you for your attention!

BT-SIN – department for structural integrity

Ground-based transportation systems



Tobias Behling
Research scientist

Nicole Betz
Research scientist

Sanghyun Yoo
Research scientist

Mathieu Vinot
Team leading

Nathalie Toso
Head of department

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Vinot Mathieu
Institute of Structures and Design, Stuttgart
Departement for Structural Integrity
mathieu.vinot@dlr.de

Imprint

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Author: Mathieu Vinot

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