GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

BETREUT VOM
PTKA Projektträger Karlsruhe
Karlsruher Institut für Technologie

FORSCHUNGS CAMPUS
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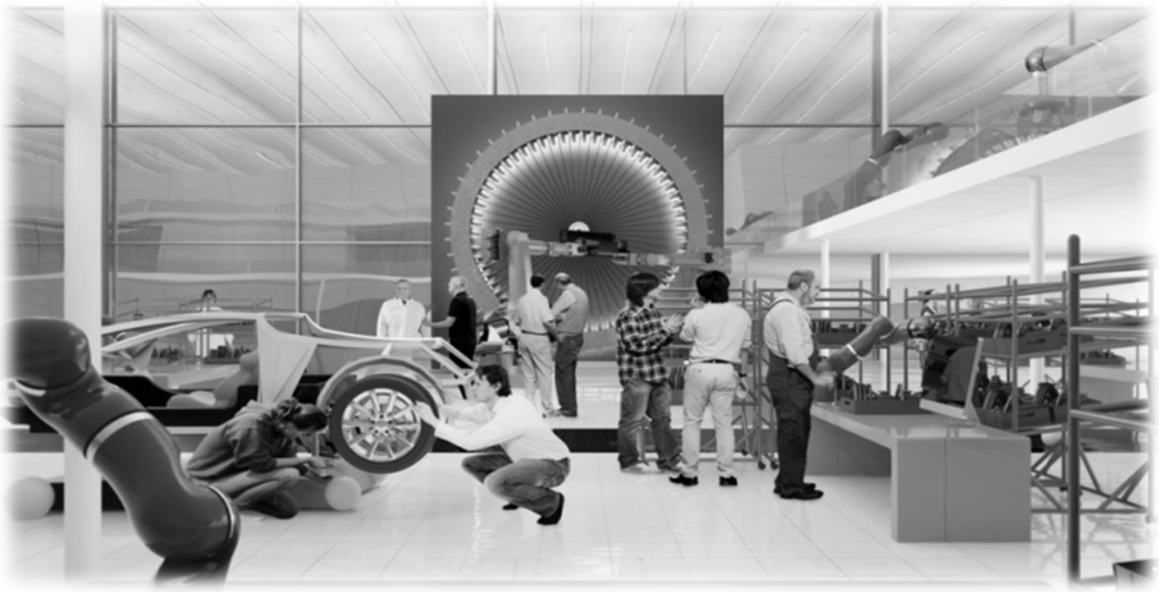
ARENA2036 DigitPro

M. Holzapfel, M. Vinot – German Aerospace Center
C. Liebold – DYNAmore GmbH

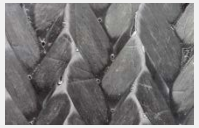


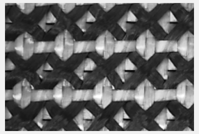
Strategic partnership for new innovations and research on a new level

- closed, numerical process chain
- from the presizing to the final product
- **simulation on the meso- and macroscale**
- various simulation tools
- HDF5 format

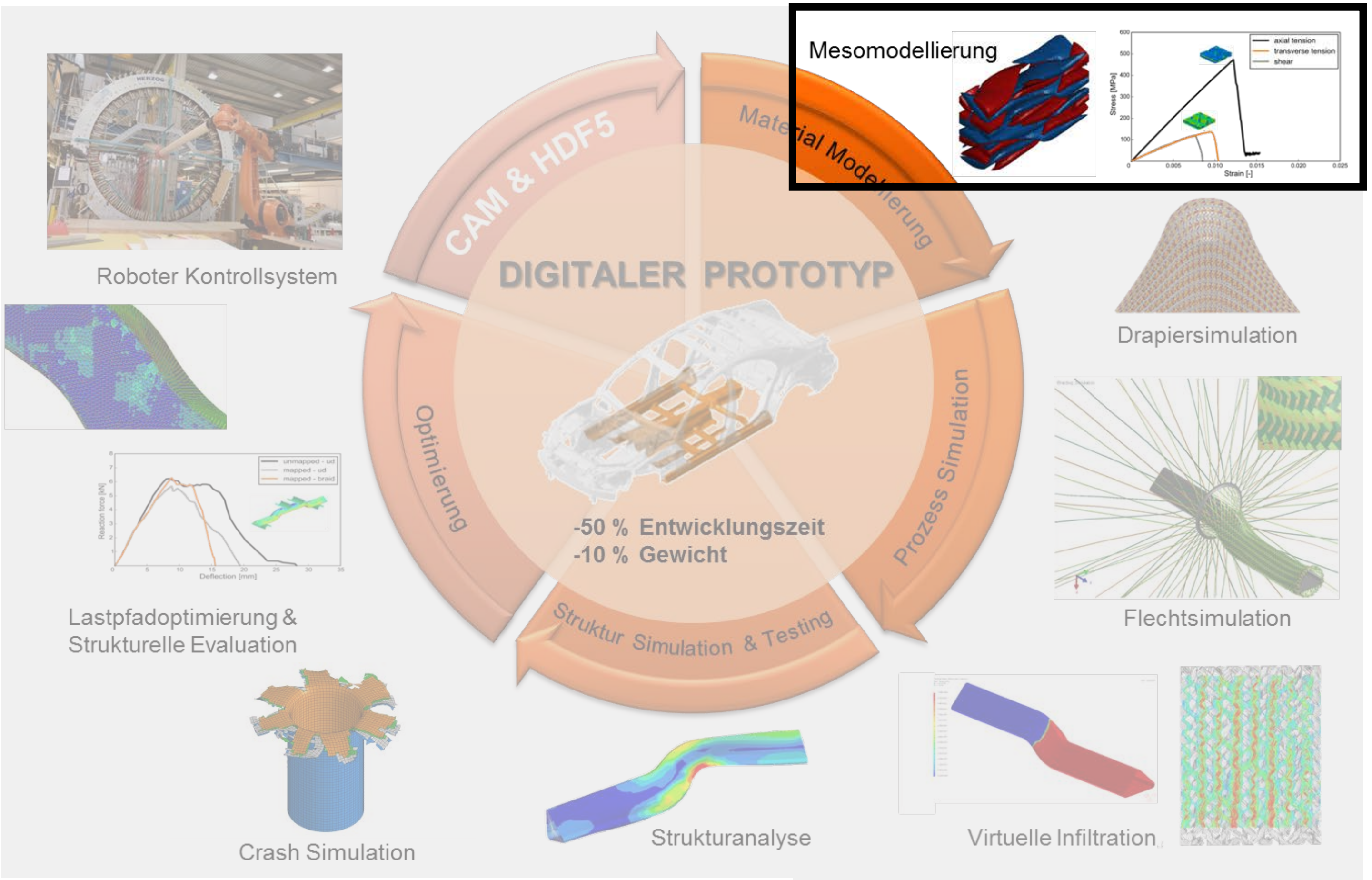
– braided structures

– **O**pen-**R**eed-**W**eaving parts





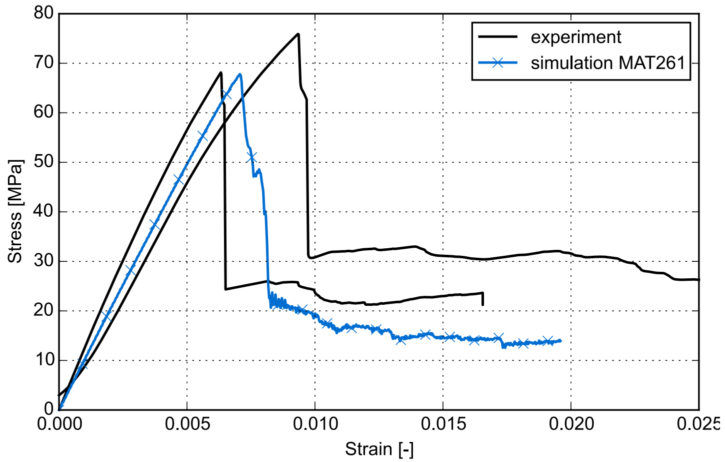
-50% development time
-10% weight (minimum)

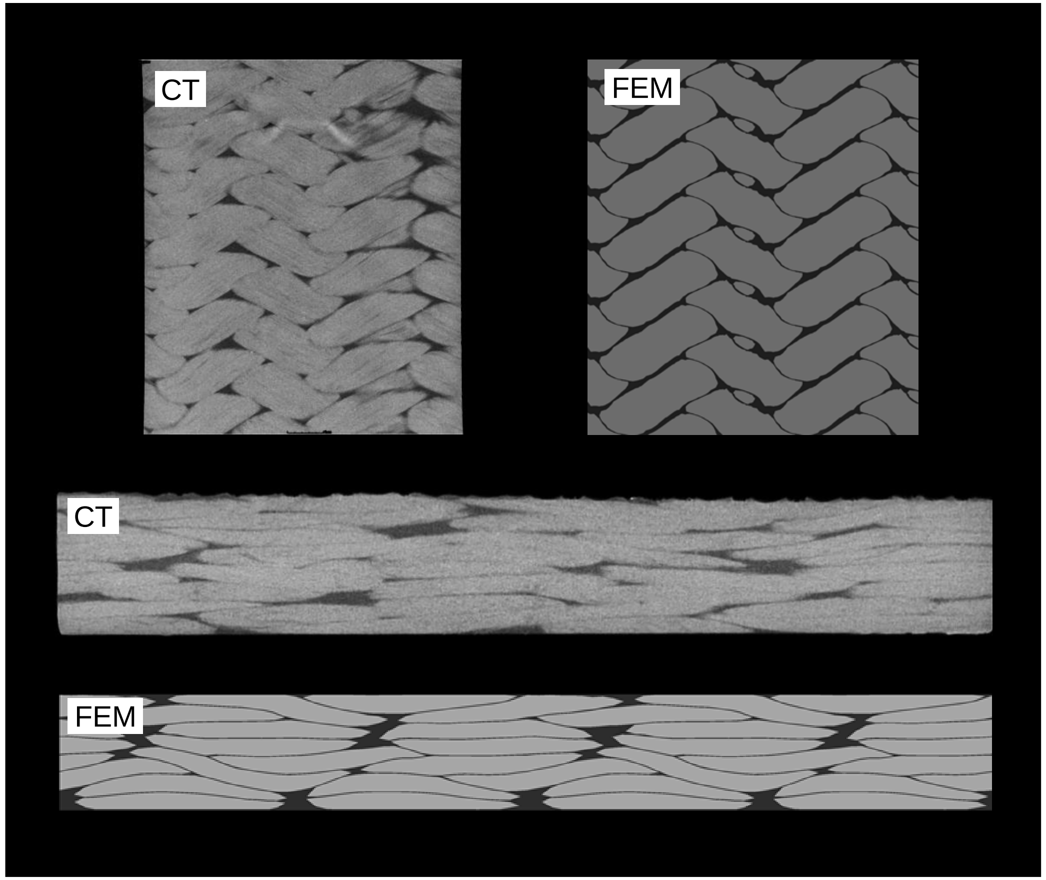


Numerical process chain to support the product design of textil-based composite structures.

Results presented on the last European LS-DYNA Conference

- Presentation of a numerical approach for the modelisation and virtual testing of **braided composites** on the mesoscale.
- Validation of the generated fibre architecture with CT-scans.
- Validation of the braids behaviour in tension with insitu CT-scans.

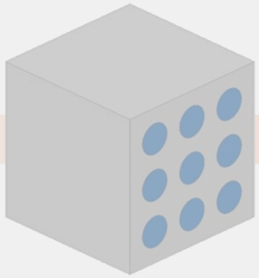




Comparison of the roving‘s structure in the braid between the experiment and the simulation

Validation of the approach for the generation and simulation of unit cells for braided composite.

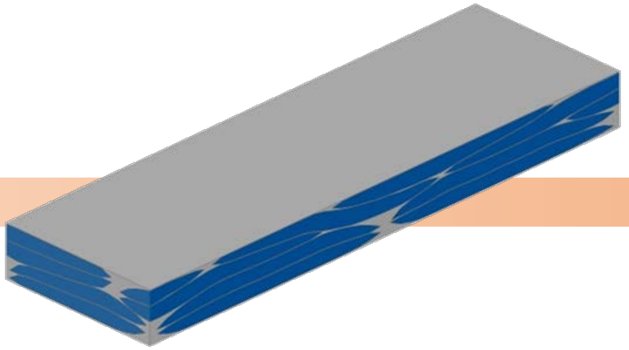
microscale



+ determination of rovings properties

- influence of the fibre distribution
- interface properties a priori unknown

mesoscale



+ determination of composite properties
+ parametrisable geometry
+ reduction of experimental testing

- potentially high computing time

macroscale

+ determination of structure behaviour
+ low computing time

- no account for local phenomena

investigated scales in DigitPro

Investigation of ORW-composites on the mesoscale and on the macroscale in DigitPro.

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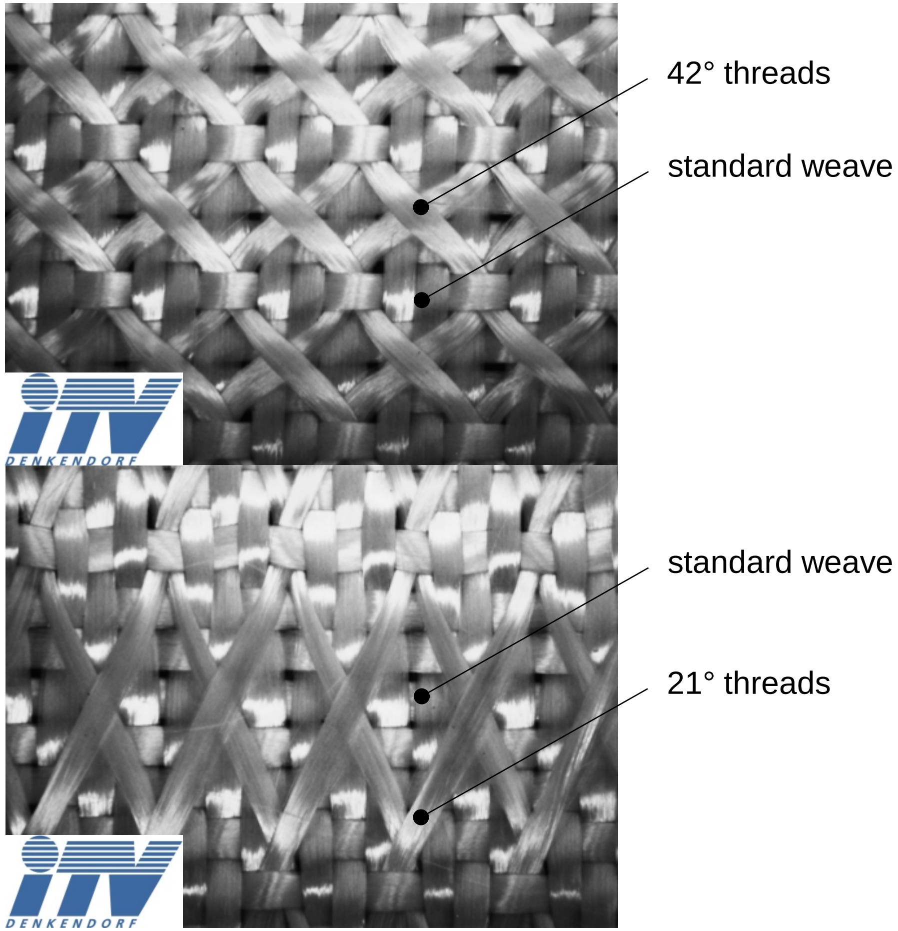
- new weaving process developped by DORNIER GmbH
- reinforcement of a standard weave with additional threads
- large band of reinforcement angles and materials (GFK, CFK...)
- weight reduction potential

https://www.lindauerdornier.com/en/weaving-machine/open-reed-weave-orw-technology



ORW textiles offer reinforcement possibilities and weight saving possibilities for composite structures.

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textile parameters

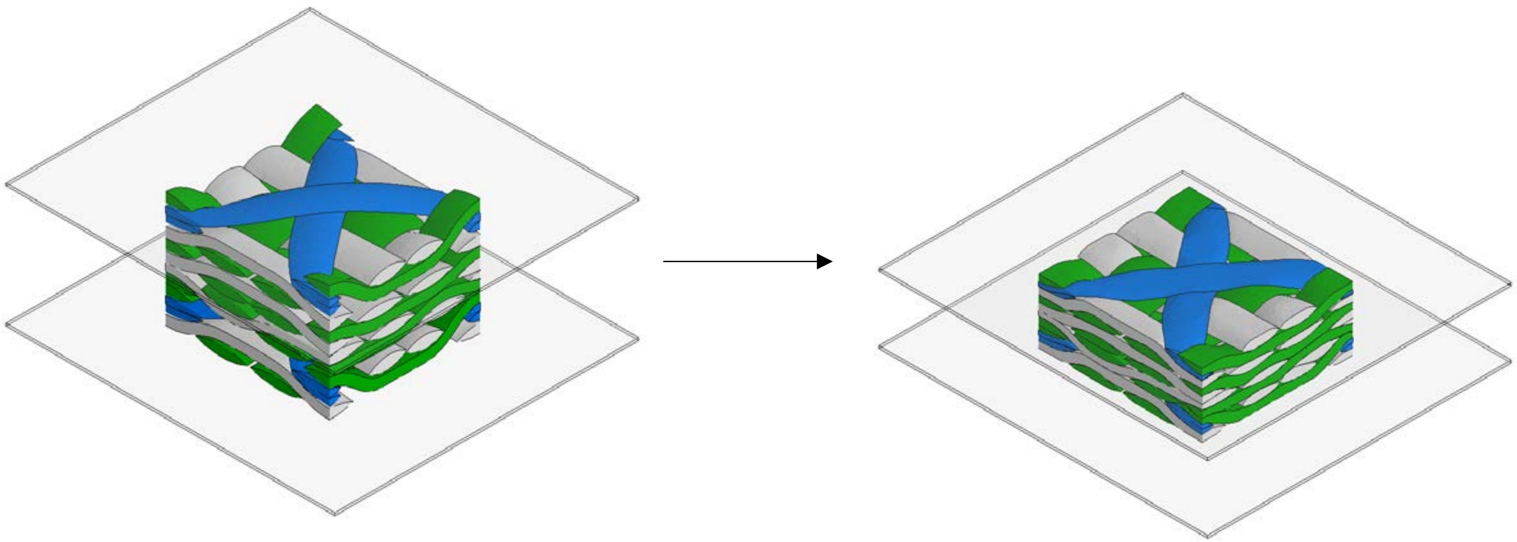
textile modelling in TexGen

textile compaction in LS-DYNA

unit cell simulation in LS-DYNA

material database

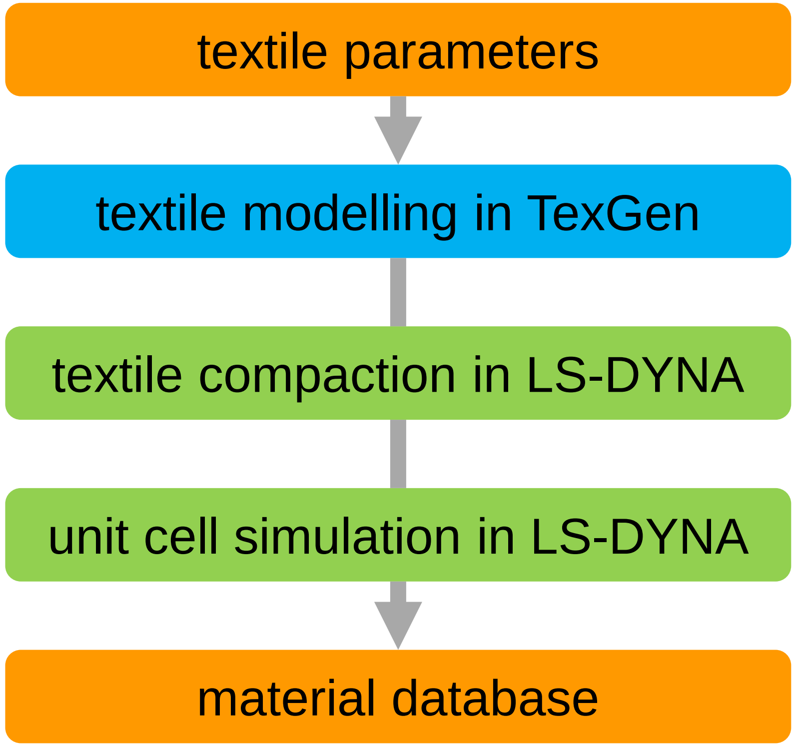
Compaction of the dry ORW textile



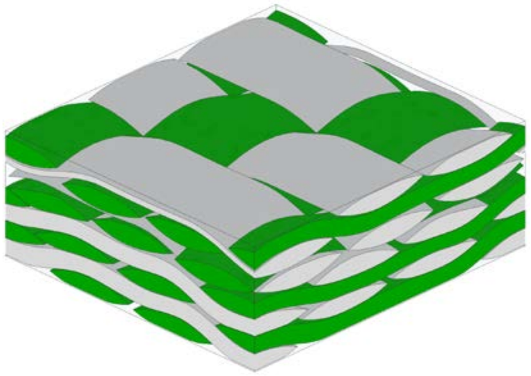
The methodic has been validated for braided composite, as shown in:
M. Vinot, R. Jemmali, *Numerical investigation of carbon braided composites at the mesoscale: using computer tomography as a validation tool*, European LS-DYNA Conference 2015

Automatised model generation for weaves and ORWs based on the software TexGen and the Python language.

Generating unit cells for a standard weave and an ORW

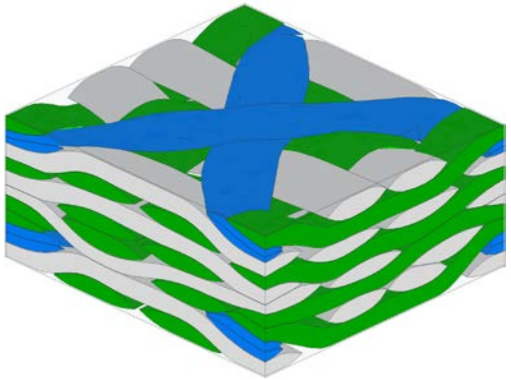


standard weave



- $[0/90]_4$
- overall fibre content of 50%
- yarn fibre content of 65%

ORW



- $[0/90/\pm42, 0/90]_s$
- overall fibre content of 50%
- yarn fibre content of 65%
- fibre content 42° yarns of 8%

The methodic has been validated for braided composite, as shown in:
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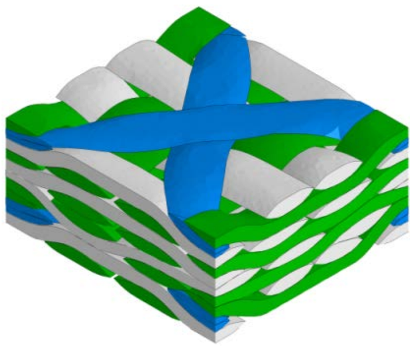
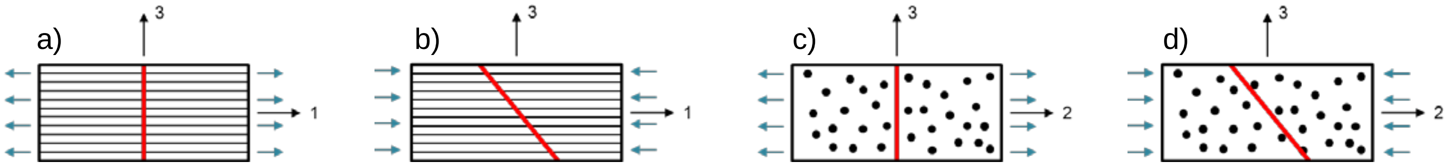
Material card for glas rovings



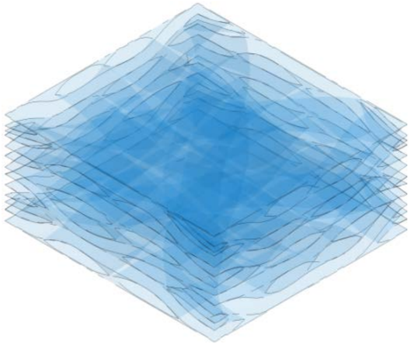
*MAT_LAMINATED_FRACTURE_DAIMLER_PINHO (*MAT_261)

- evaluation of mechanical properties of the roving with the rule of mixtures
- fibre and matrix failure criteria in tension and compression



loading case for fibre (a, b) and matrix (c, d) failure in MAT_261

Material card for pure resin



*MAT_PLASTICITY_COMPRESSION_TENSION + *MAT_ADD_EROSION

- use of experimental values as input for the material cards
- **two independent stiffnesses, strengths and failure strains** in tension and compression
- use of the triaxiality for the failure criterium

Modelling of the direction-dependent material behaviour of the epoxid resin.

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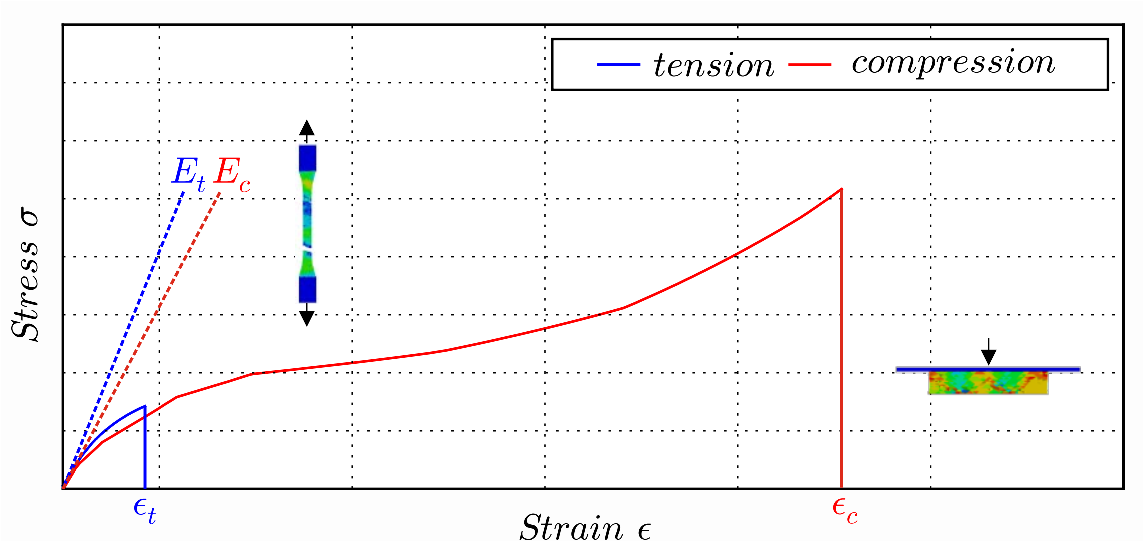
- tension test according to ISO 527-2
- compression test according to ISO 604
- testing speed v = 5 mm/min
- test performed up to total failure of the specimens

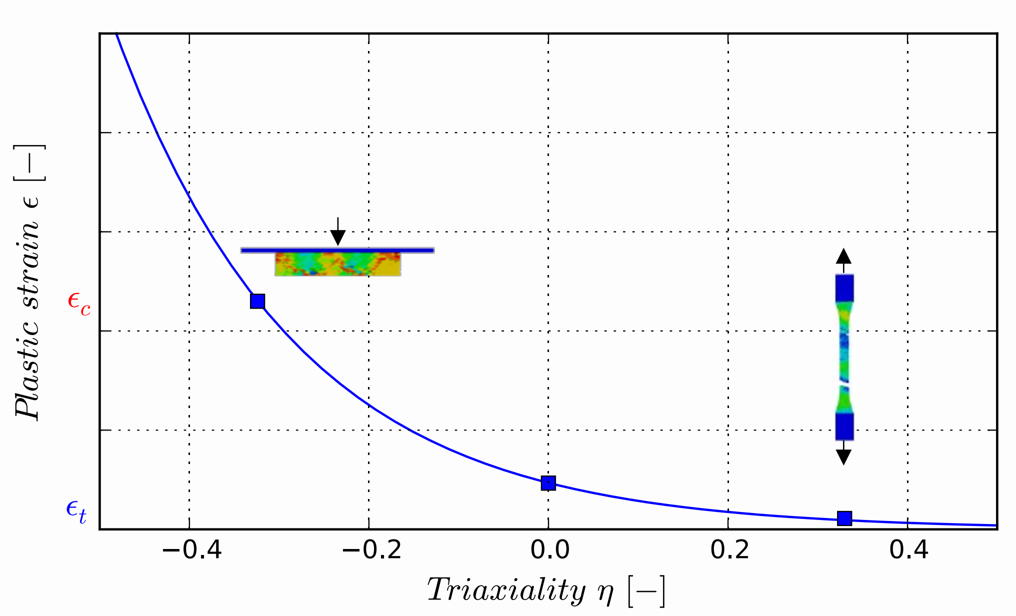
$$\eta = \frac{\sigma_{hydrostatic}}{\sigma_{von\ mises}} = \frac{1/3 \cdot (\sigma_1 + \sigma_2 + \sigma_3)}{1/\sqrt{2} \cdot \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}}$$

$\eta = 0.33 \rightarrow \textit{uniaxial tension}$

$\eta = 0 \rightarrow \textit{pure shear}$

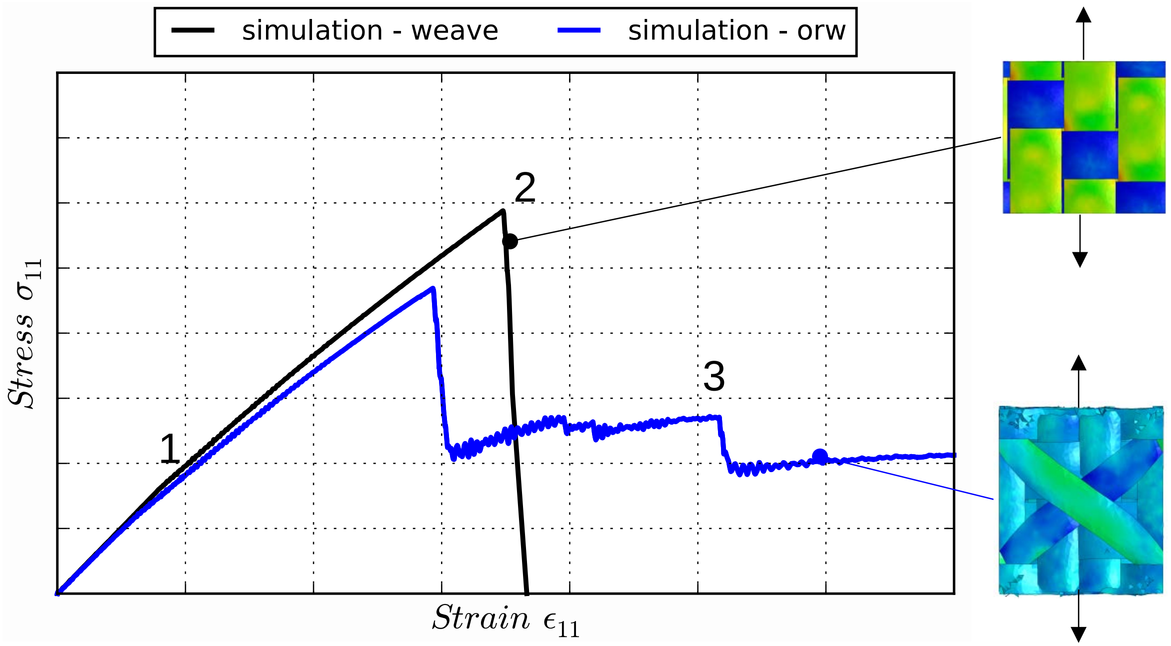
$\eta = -0.33 \rightarrow \textit{uniaxial compression}$





Modelling of the direction-dependent material behaviour of the epoxid resin.

- periodic boundary conditions are implemented
- test of the RVEs in tension
- numerical testing speed v = 0.5 mm/ms



Standard weave

1. matrix failure in the weft yarns
2. global failure due to fibre failure in the warp yarns

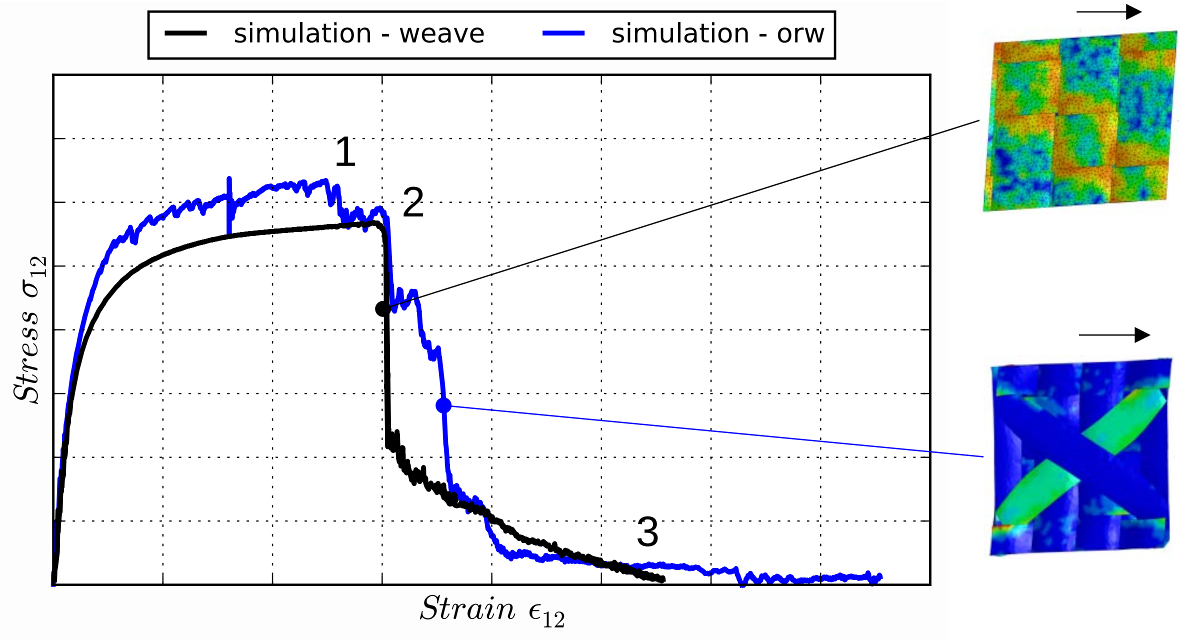
ORW

1. matrix failure in the weft yarns
2. global failure due to fibre failure in the warp yarns
3. second load path through shear loading of the ORW yarns

→ <u>higher energy absorption post-failure</u>

Virtual testing of the standard weave and the ORW in LS-DYNA

- periodic boundary conditions are implemented
- test of the RVEs in shear
- numerical testing speed v = 0.5 mm/ms



Standard weave

2. global failure due to shear failure of the warp yarns

ORW

1. failure due to tensile failure of the +42° yarns
2. shear failure of the warp yarns
3. realignment and failure of the -42° yarns

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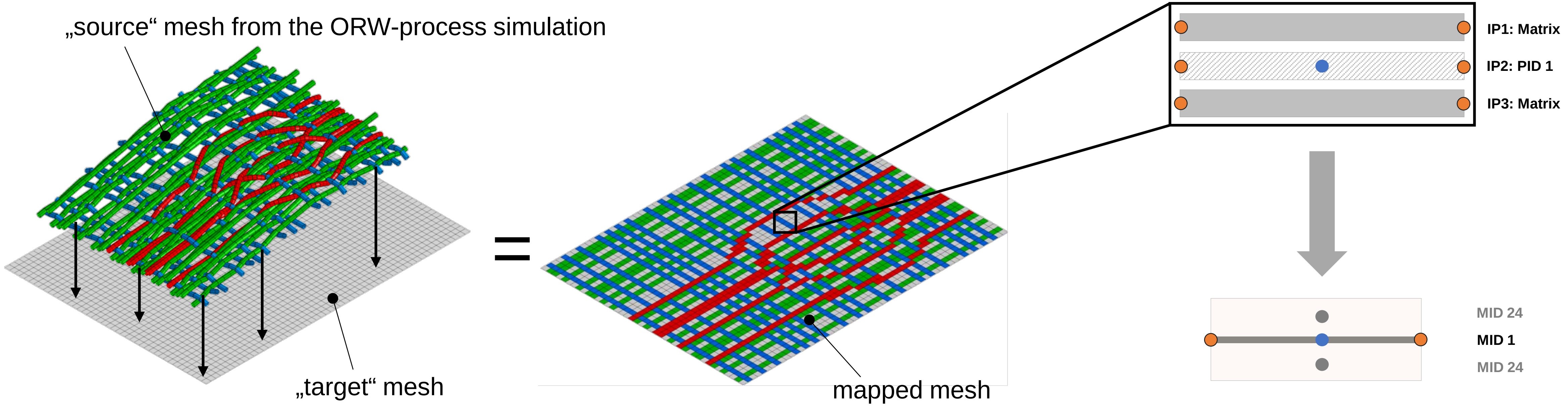
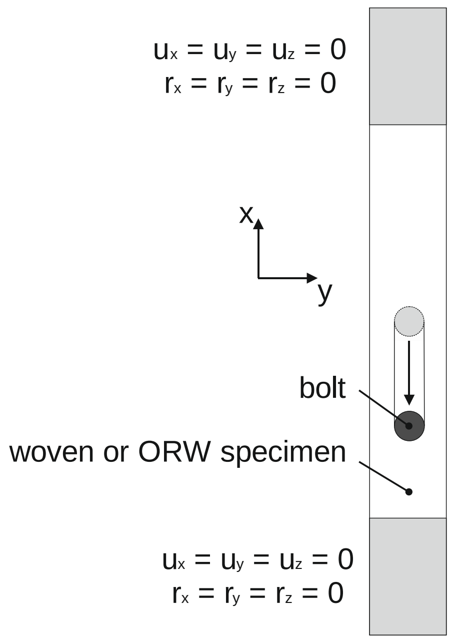
Principle of the algorithmus

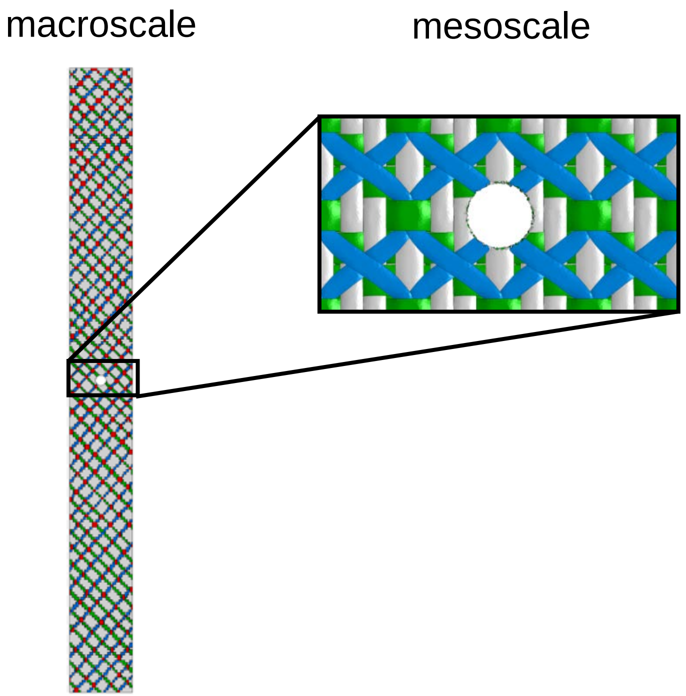
- mapping of the orientations on a target mesh
- beam-to-shell or shell-to-shell mapping have been implemented
- zones with orientation can be mapped as matrix-rich zones



The mapping algorithmus as a bridge between process simulation and structure simulation.

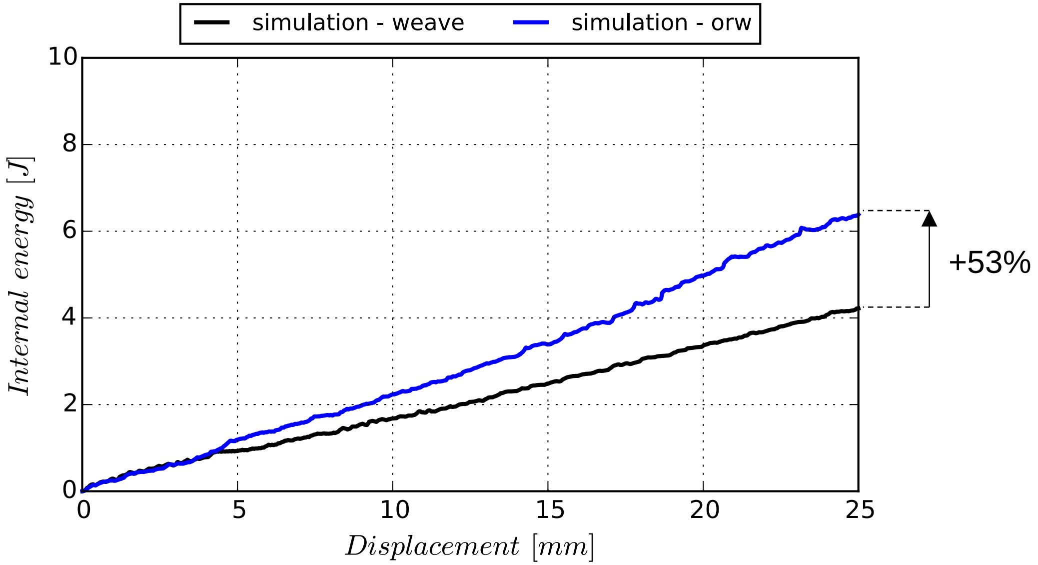
- mapping of the 42°-ORW fibre architecture on the specimen mesh for bearing strength simulation
- bolt (4 mm Ø) with a speed of 5 m/s
- after having reached the material strength, energy is absorbed through composite crushing





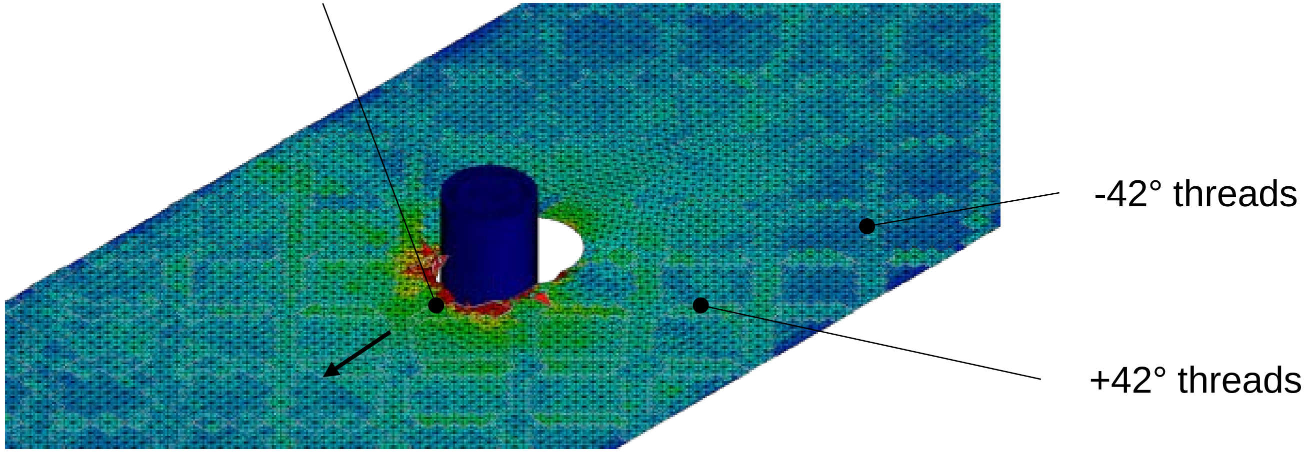
Simulation of a mapped ORW-specimen on the macroscale.

- use of MAT_261 for the integration points with fibre properties
- use of MAT_124 for the integration points with matrix properties
- increase of the energy absorption potential through ORW threads
- weight increase of only 7%



crushing zone

- failure of warp rovings in compression
- matrix failure in compression



Damage parameter in tension

Increase of the energy absorption potential through the ORW architecture.

- several investigation scales within the closed process chain
- the different scales are linked with the mapping tool Envyo
- the results for ORWs still must be validated experimentally

Mesoscale

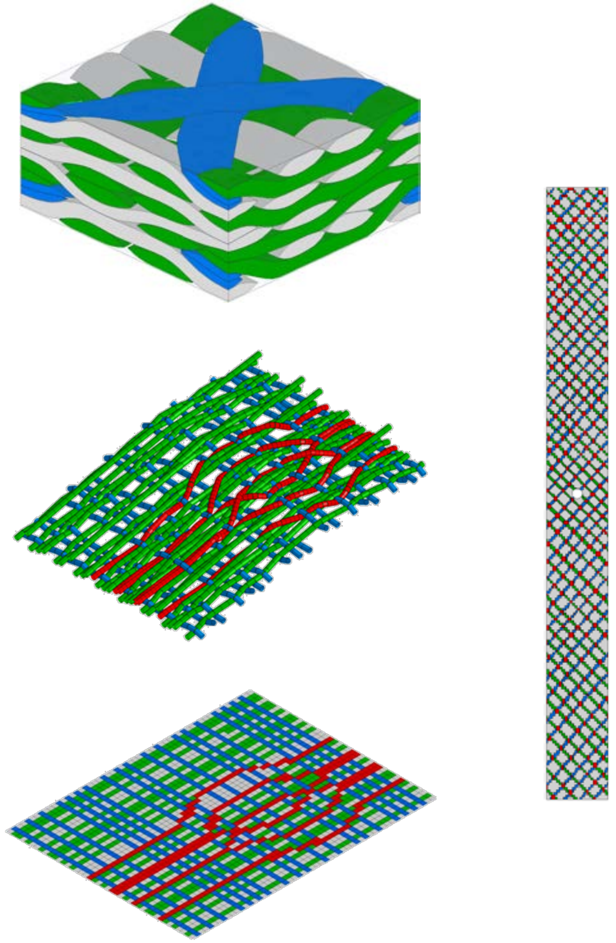
- virtual testing of composites
- reduction of experimental effort
- relative high CPU time

Envyo ⟷

Macroscale

- structure simulation
- consideration of local effects
- relative low CPU time

HDF5 format



Higher understanding of the behaviour of composite parts and increased predicting capabilities with the process chain

Thank you very much for your attention!

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PTKA
Projektträger Karlsruhe
Karlsruher Institut für Technologie

Martin Holzapfel
martin.holzapfel@dlr.de

Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Pfaffenwaldring 38-40
70569 Stuttgart