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Karlsruher Institut für Technologie
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Investigation of Energy Absorption in Textile Composites with the Mapping Tool ENVYO

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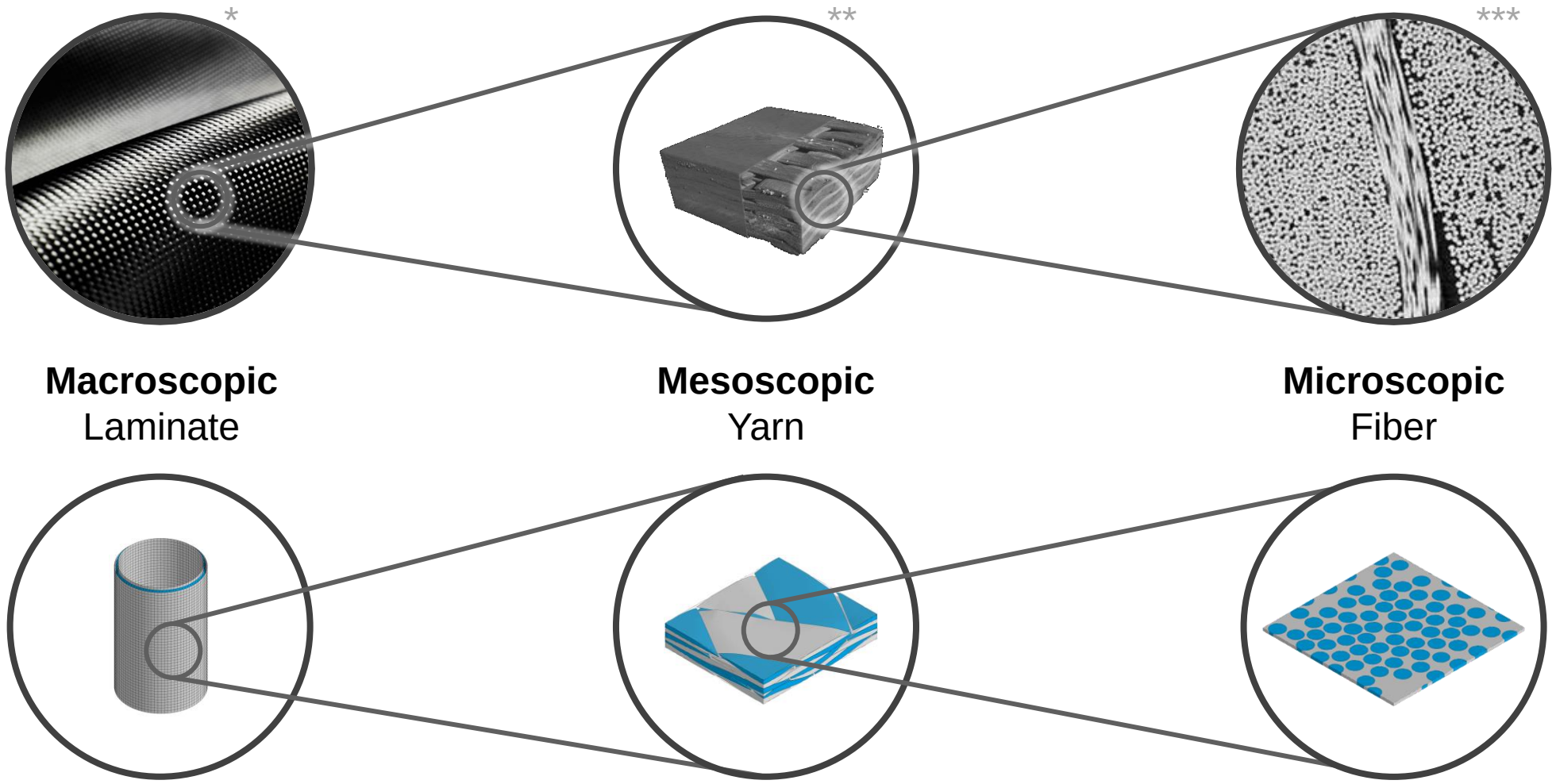
DLR

Multiscale simulations as a replacement to experimental tests

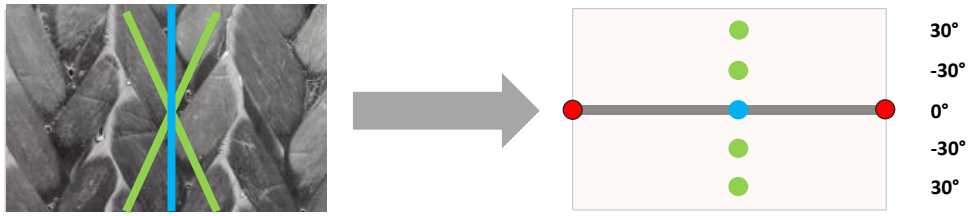


* http://www.sailingscuttlebutt.com
** https://www.nts.com/ntsblog/x-ray-computed-tomography-scanning-composite-materials/
*** http://www.azom.com

Investigation of textile composites - methodology

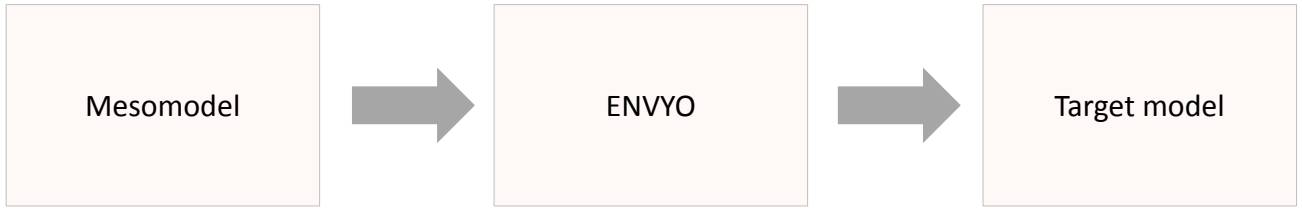
Reference approach

Modelling with UD-plies



Mapping approach

1. Generation of a realistic FE-Model on the mesoscale
2. Transfer of yarn orientations on a target mesh



Advantages

- „universal“ approach (weave / UD...)
- fast model generation
- low computing time

Drawbacks

- local effects are not considerated
- fibre architecture is not reproduced

Advantages

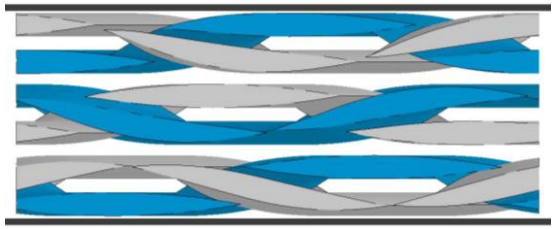
- realistic approach
- consideration of manufacturing effects

Drawbacks

- complex model generation
- increased computing time

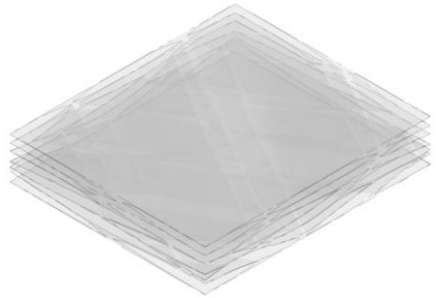
Modelling methodology for diverse textile composites

TexGen	Textile modelling
Python	Export of .dyn file
LS-DYNA	Textile compaction
LS-DYNA	Mesh generation
LS-DYNA	Generation of specimen
LS-DYNA	RVE simulation
Database	Composite database

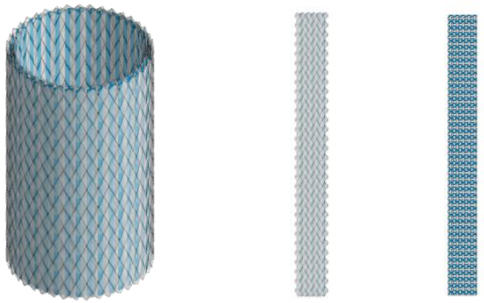


Compaction of the dry textile

Yarn geometry after compaction



Matrix mesh

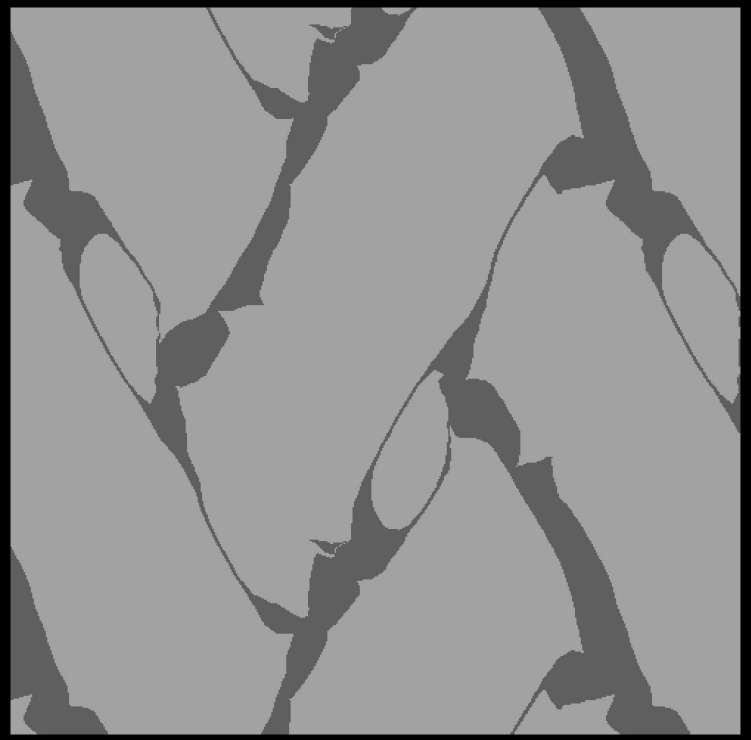


Specimen meshes from unit cells

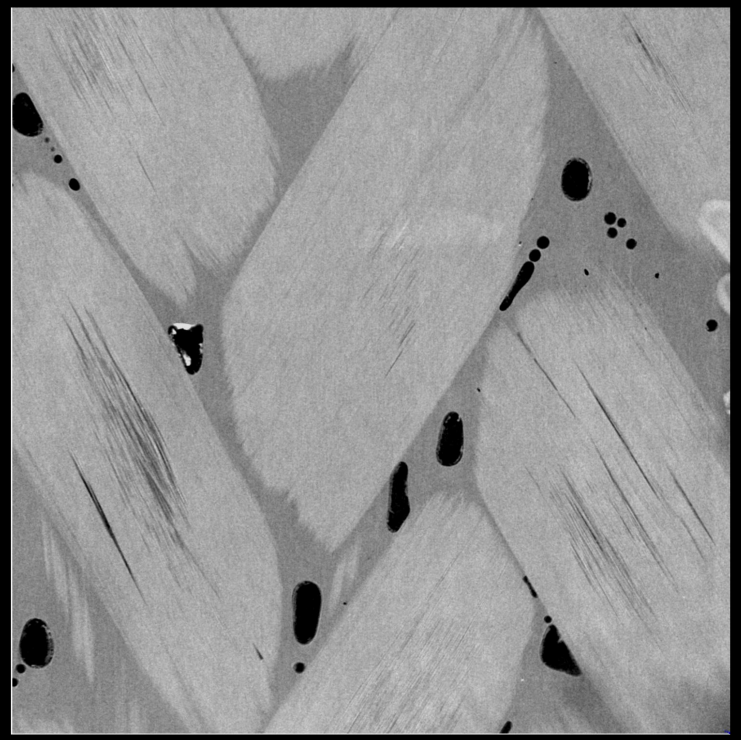
Validation of the yarn architecture in unit cells with CT-scans

FE-model of a 30°-triaxial braid

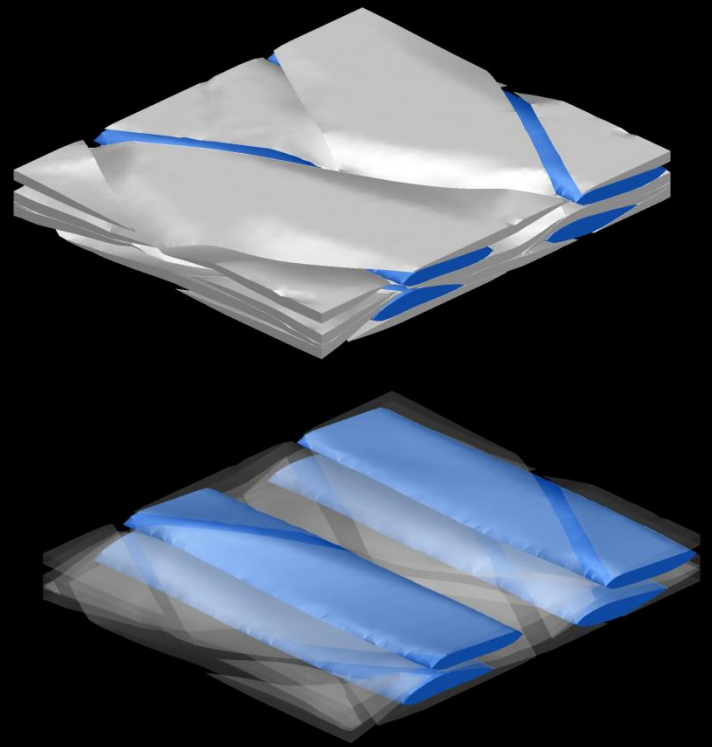
Simulation



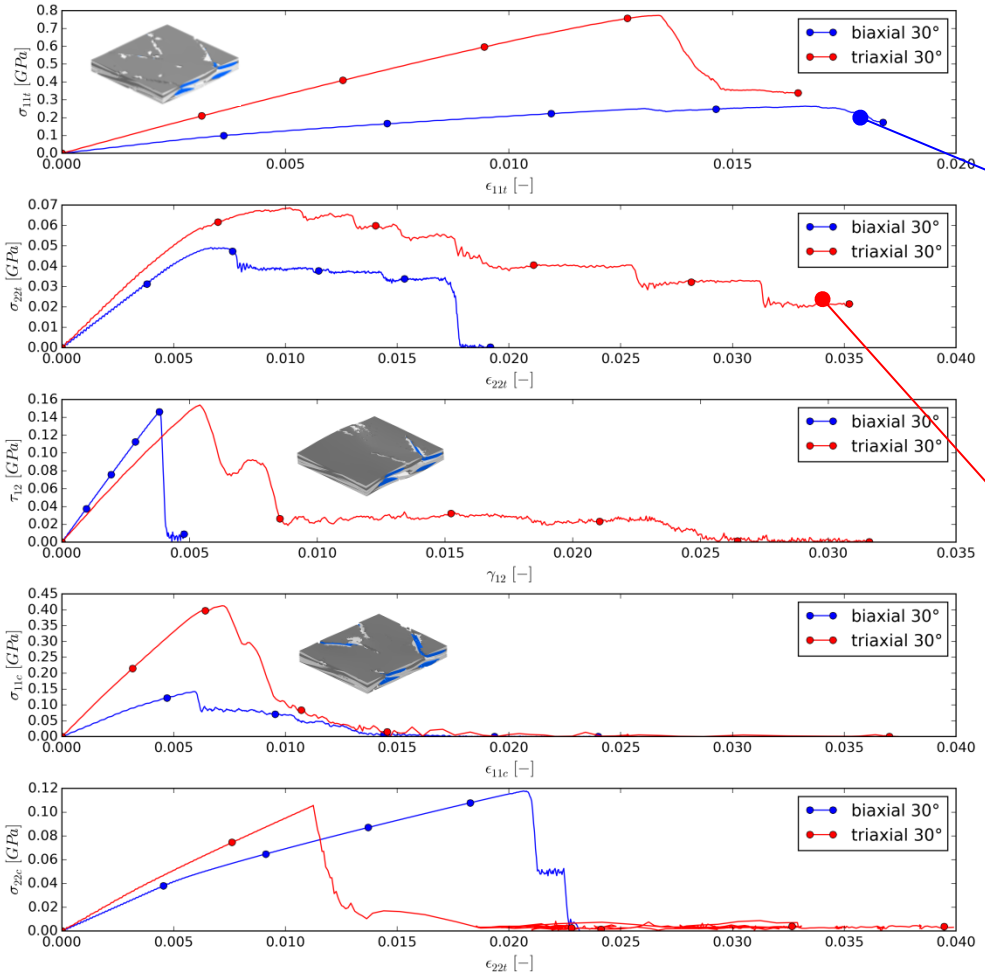
CT-Scan



Simulation



Results of the simulation on the mesoscale




```
$
$ Material card for B30 braided composite
$
*MAT_ENHANCED_COMPOSITE_DAMAGE
$#     mid        ro        ea        eb        (ec)      prba      (prca)    (prcb)
       230   1.6e-06     25.83      8.19                  0.83
$#     gab       gbc       gca       (kf)      aopt      2way
     26.17                                       2
$#      xp        yp        zp        a1        a2        a3     mangle
                                                           1
$#      v1        v2        v3        d1        d2        d3     dfailm    dfails
                                                                   0.007     0.004
$#   tfail      alph      soft      fbrt     ycfac     dfailt    dfailc       efs
                                                         0.017     0.006
$#      xc        xt        yc        yt        sc      crit      beta
     0.142     0.264     0.118     0.049     0.147
$#     pel      epsf      epsr      tsmd     soft2
$#  slimt1    slimc1    slimt2    slimc2     slims     ncyred     softg
      0.88      0.19      0.68      0.48      0.15
$
$ Material card for T30 braided composite
$
*MAT_ENHANCED_COMPOSITE_DAMAGE
$#     mid        ro        ea        eb        (ec)      prba      (prca)    (prcb)
       330   1.6e-06     66.11     10.36                  0.84
$#     gab       gbc       gca       (kf)      aopt      2way
     65.75                                       2
$#      xp        yp        zp        a1        a2        a3     mangle
                                                           1
$#      v1        v2        v3        d1        d2        d3     dfailm    dfails
                                                                   0.01      0.005
$#   tfail      alph      soft      fbrt     ycfac     dfailt    dfailc       efs
                                                         0.013     0.007
$#      xc        xt        yc        yt        sc      crit      beta
     0.413     0.773     0.106     0.069     0.154
$#     pel      epsf      epsr      tsmd     soft2
$#  slimt1    slimc1    slimt2    slimc2     slims     ncyred     softg
      0.54      0.18       0.6      0.05      0.16
```

Result on the mesoscale → Material card for the macroscale

Mapping algorithms in ENVYO

3+1 algorithms are available in the latest version of ENVYO

Closest Point
Direct transfer of fiber orientations from the source mesh to the target mesh, part after part

Element Size Search Radius
Use of element size of target mesh as a search radius for the mapping
Mapping of matrix-rich regions possible

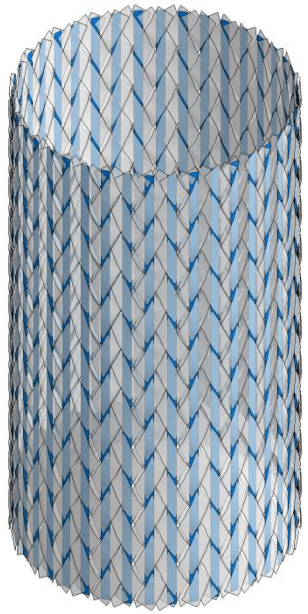
Consider Ondulation
Transfer of orientations starting from the target mesh
Consideration of fiber ondulation possible
Mapping of matrix-rich regions possible

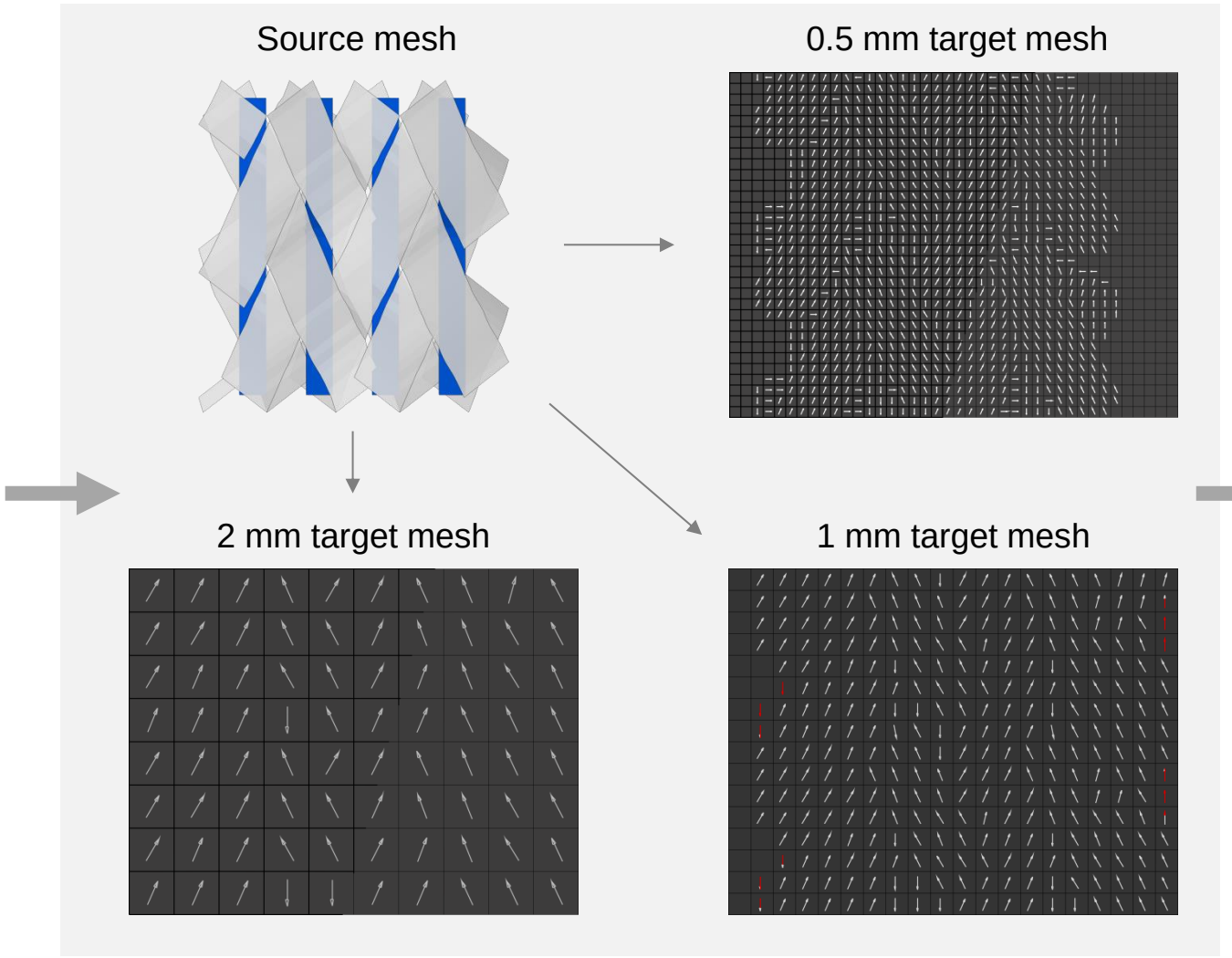
→ Information transfer

Mapping RVE
Clustering of the source mesh in region with constant fiber architecture → Information simplification

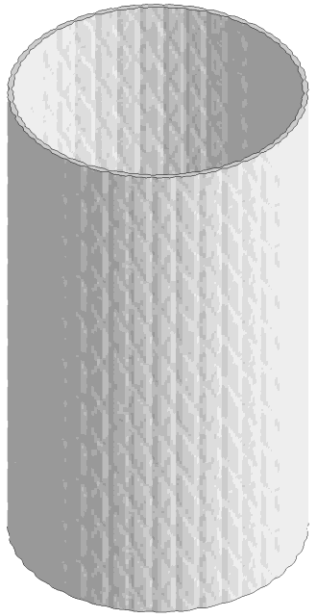
Mapping of orientations with „ConsiderOndulation“

Source mesh





Mapped tube

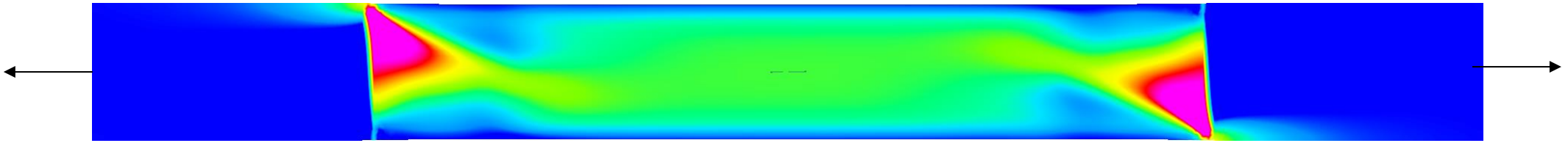


Mapping of orientations with „ConsiderOndulation“

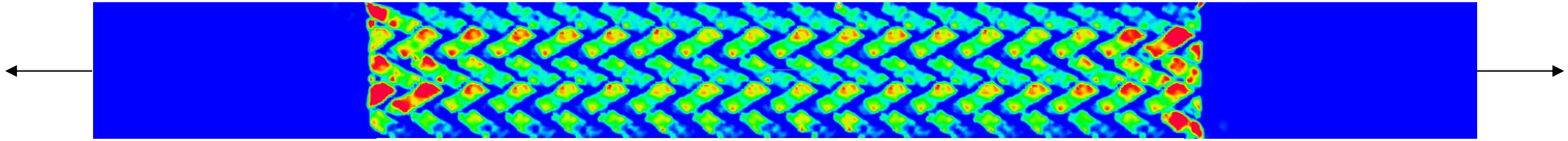
Simulation of a tensile braided specimen

- local strain and stress fields are well predicted
- stiffness and strength prediction are more reliable with the mapping approach

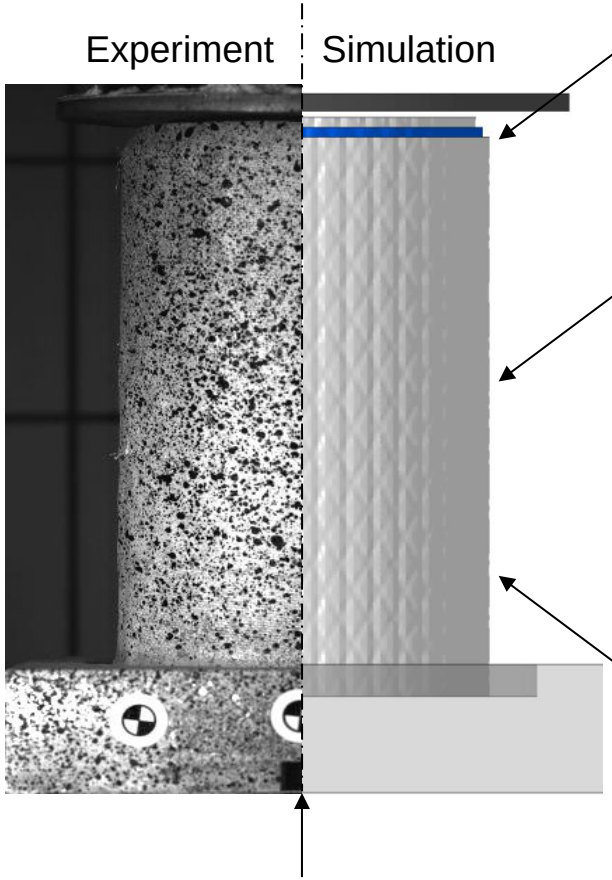
State of the art reference simulation



Simulation with the new mapping approach



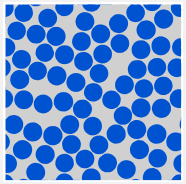
Crash tube – modelling approach

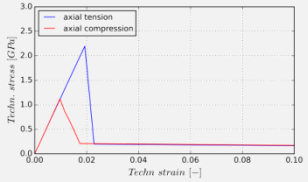


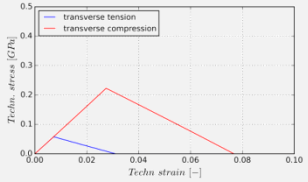
Modelling of 45°-trigger with offset of the three layers

UD material properties for the yarns calculated with microscopic models

*MAT_262_LAMINATED_FRACTURE_DAIMLER_CAMANHO

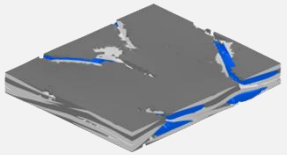


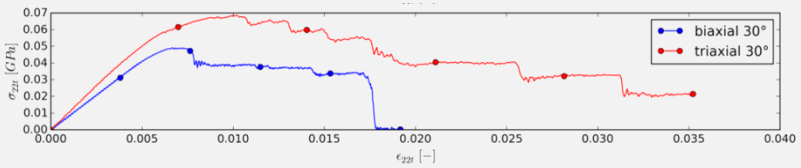




1. approach

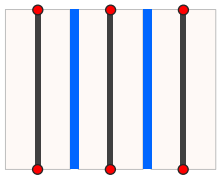
Material properties of textile calculated with mesoscopic models





2. approach

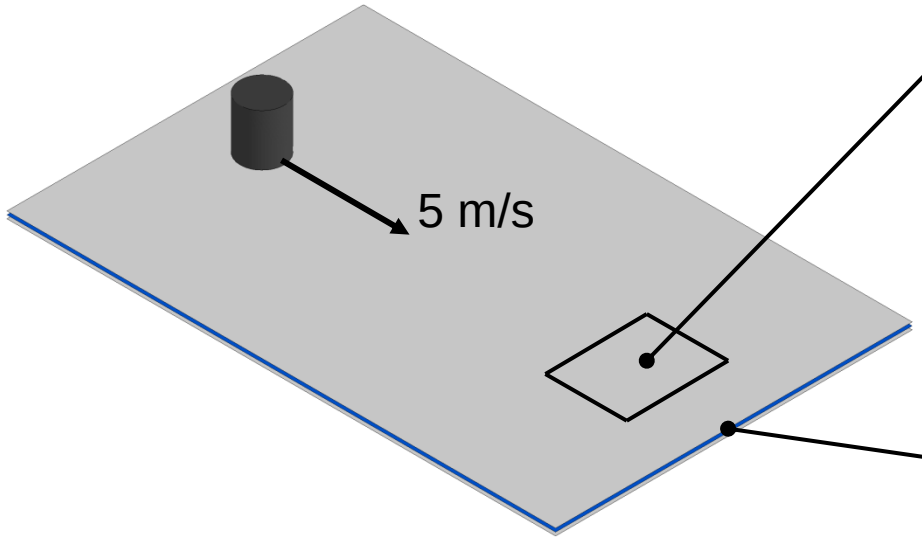
Modelling of the laminate with 3 layers, tied with TIEBREAK contact

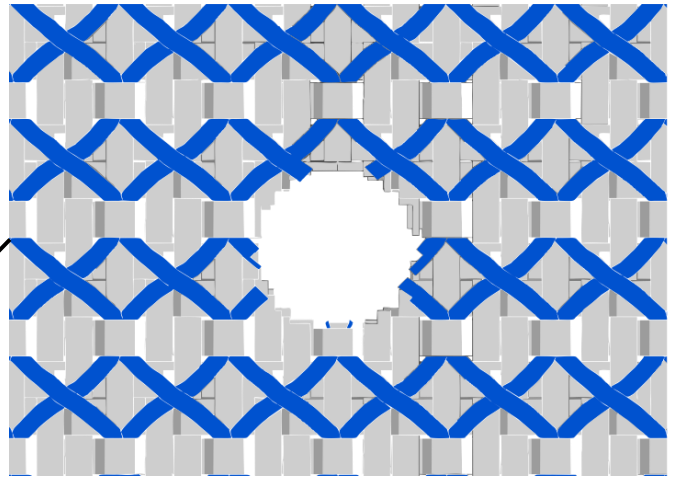


shell element

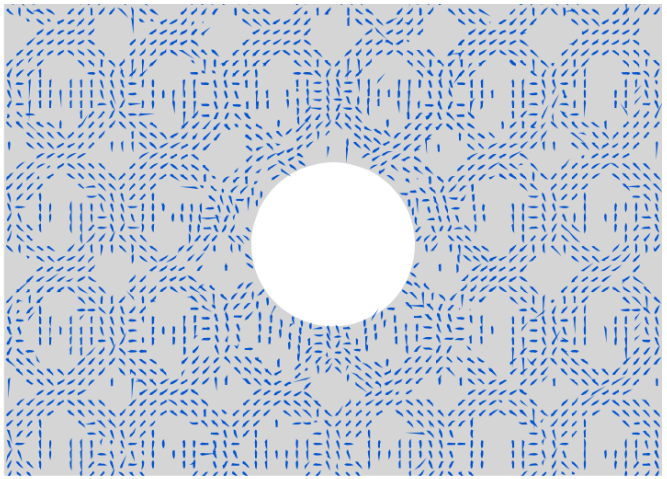
cohesive contact

Bearing test specimen – modelling approach



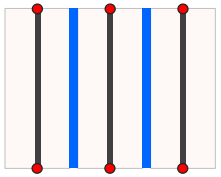


real fiber architecture



mapping result

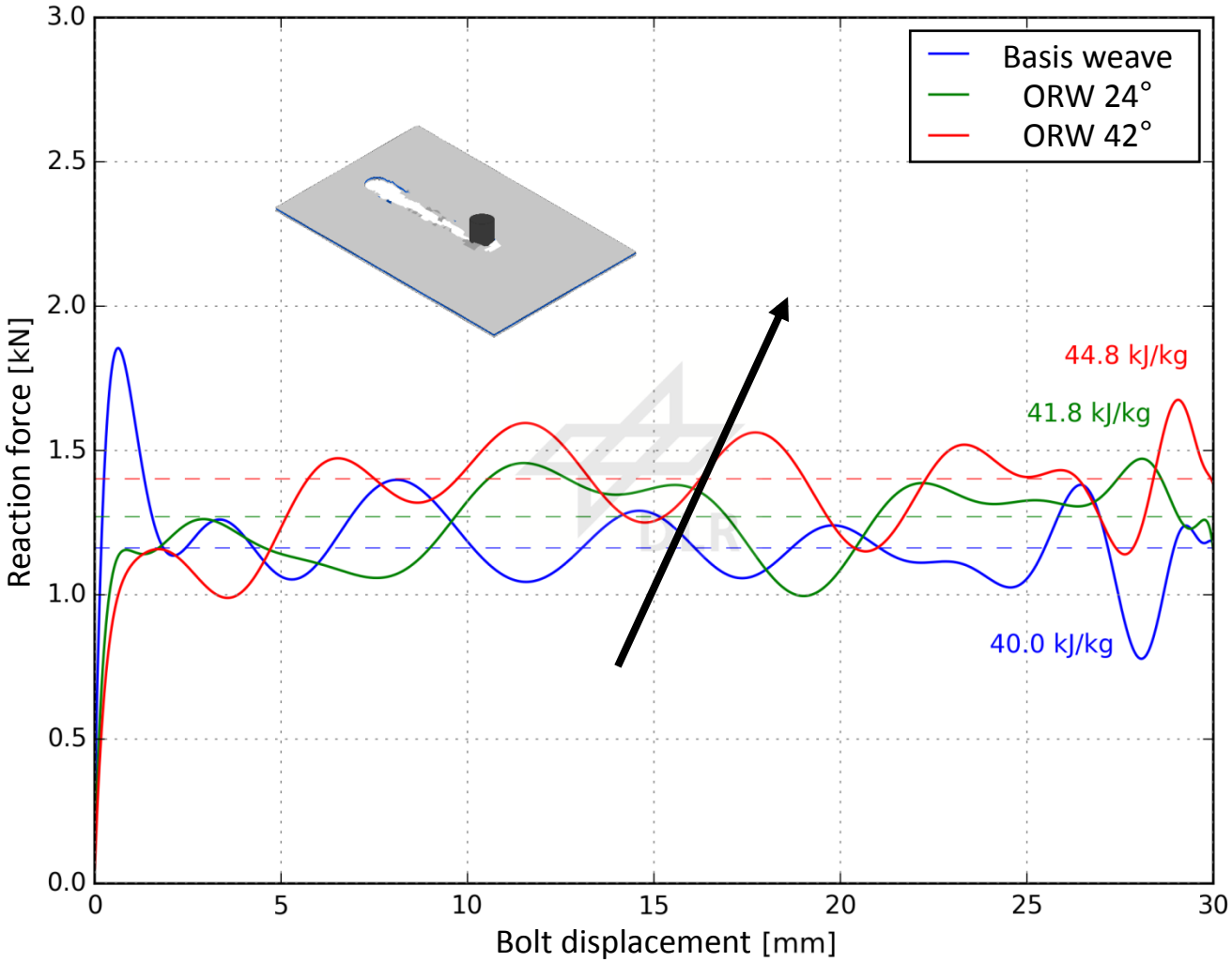
Modelling of the laminate with 3 layers, tied with TIEBREAK contact



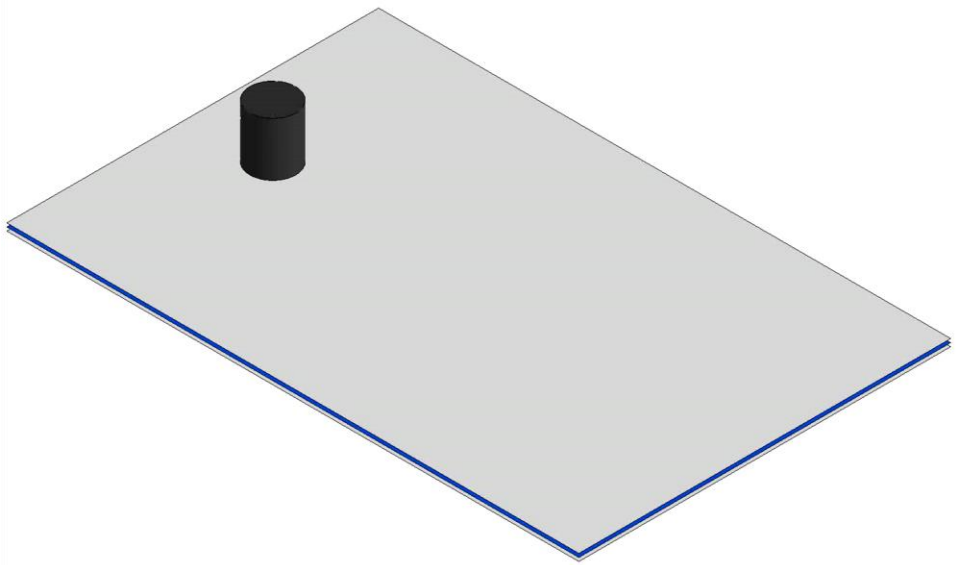
shell element

cohesive contact

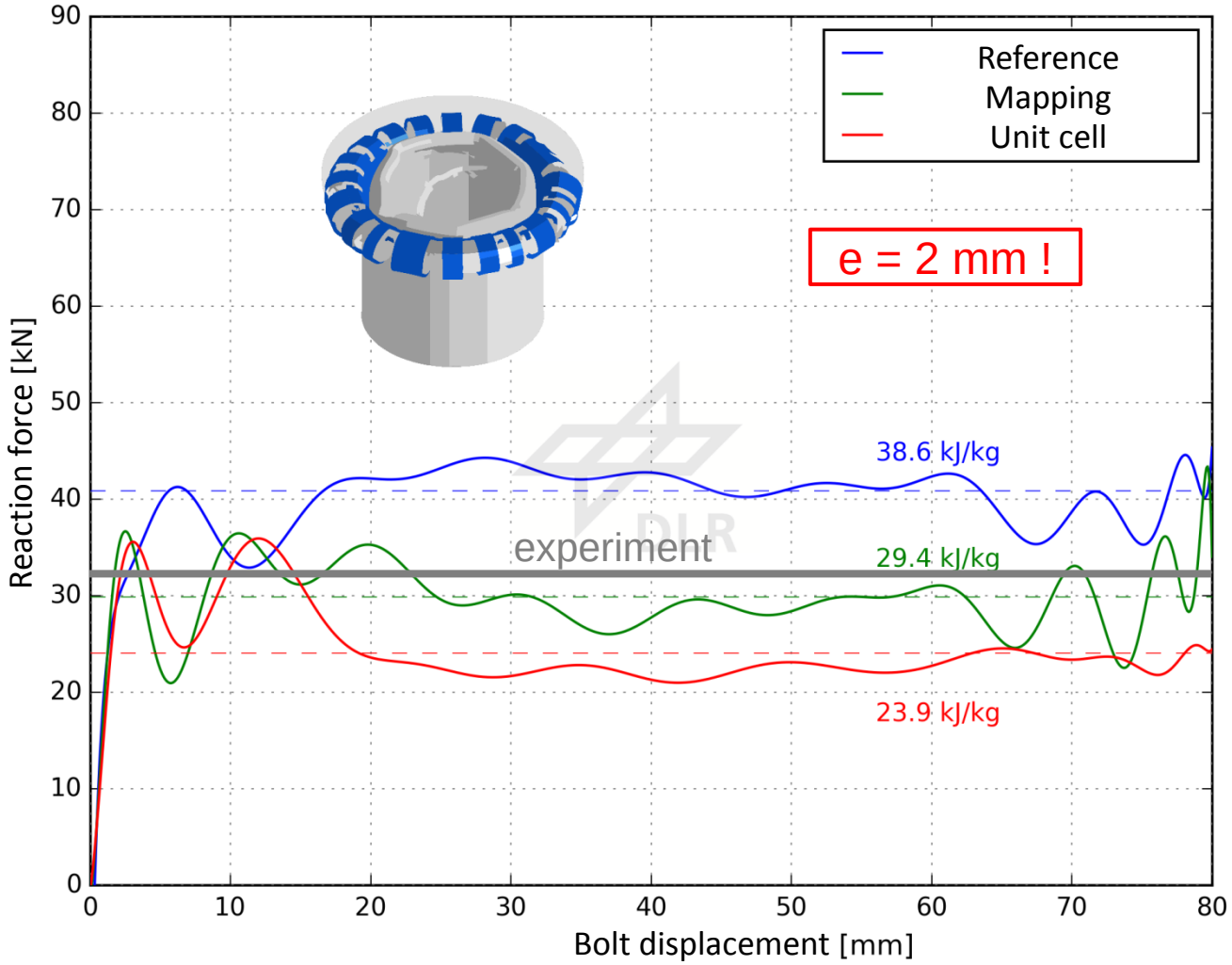
Bearing test – numerical results

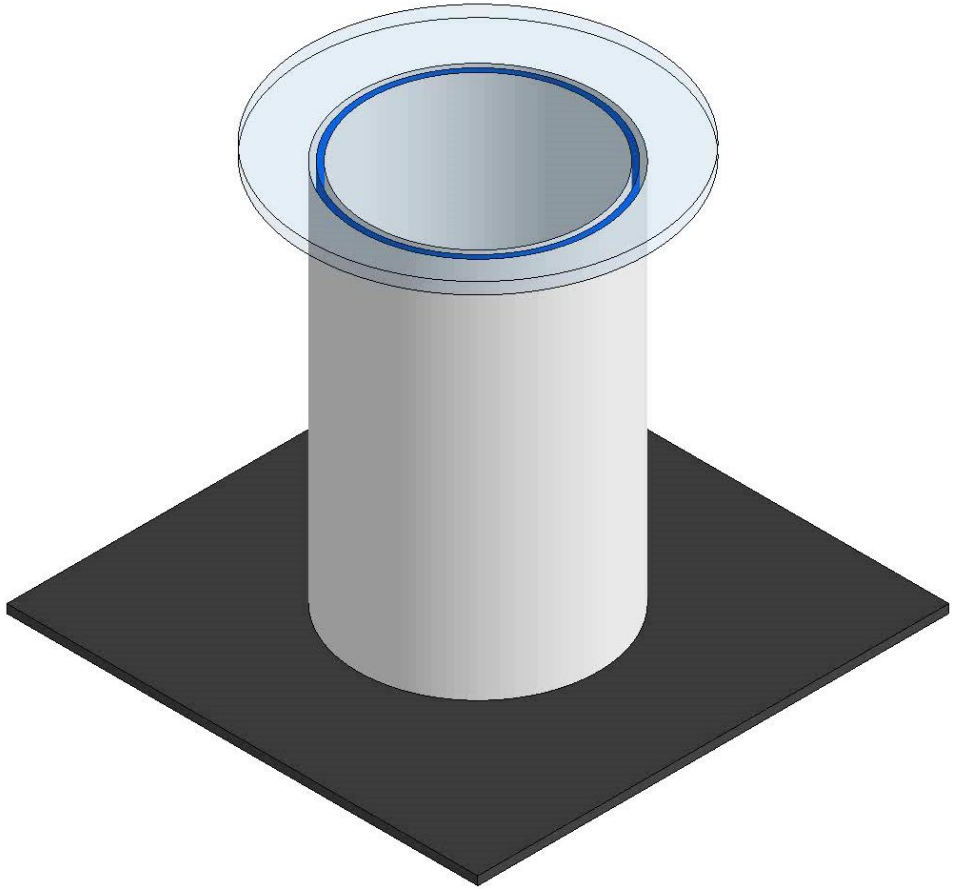


- very local fibre reinforcement
- relative low weight increase of 2% and 3%
- SEA increase of 4.5% and 12%



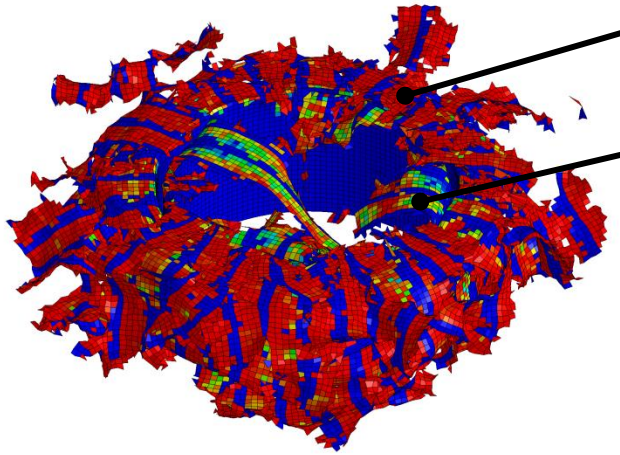
Crash tube – comparison of mapping methods on triaxial braid 30°





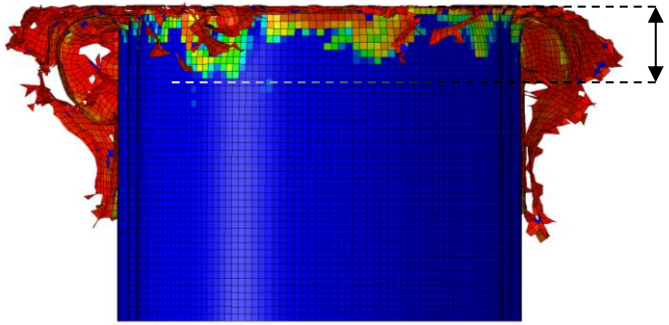
Crash tube – benefits of the mapping approach

fibre failure in compression
(history variable 6)



completely failed axial fibre under compression

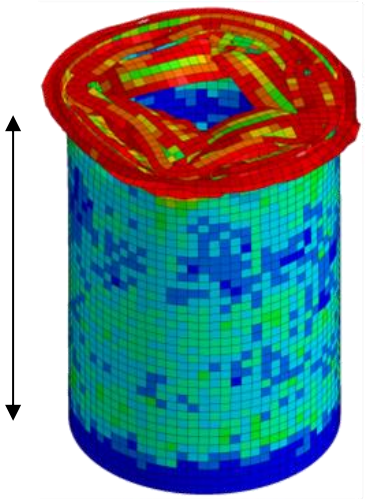
partially damaged axial fibre under bending



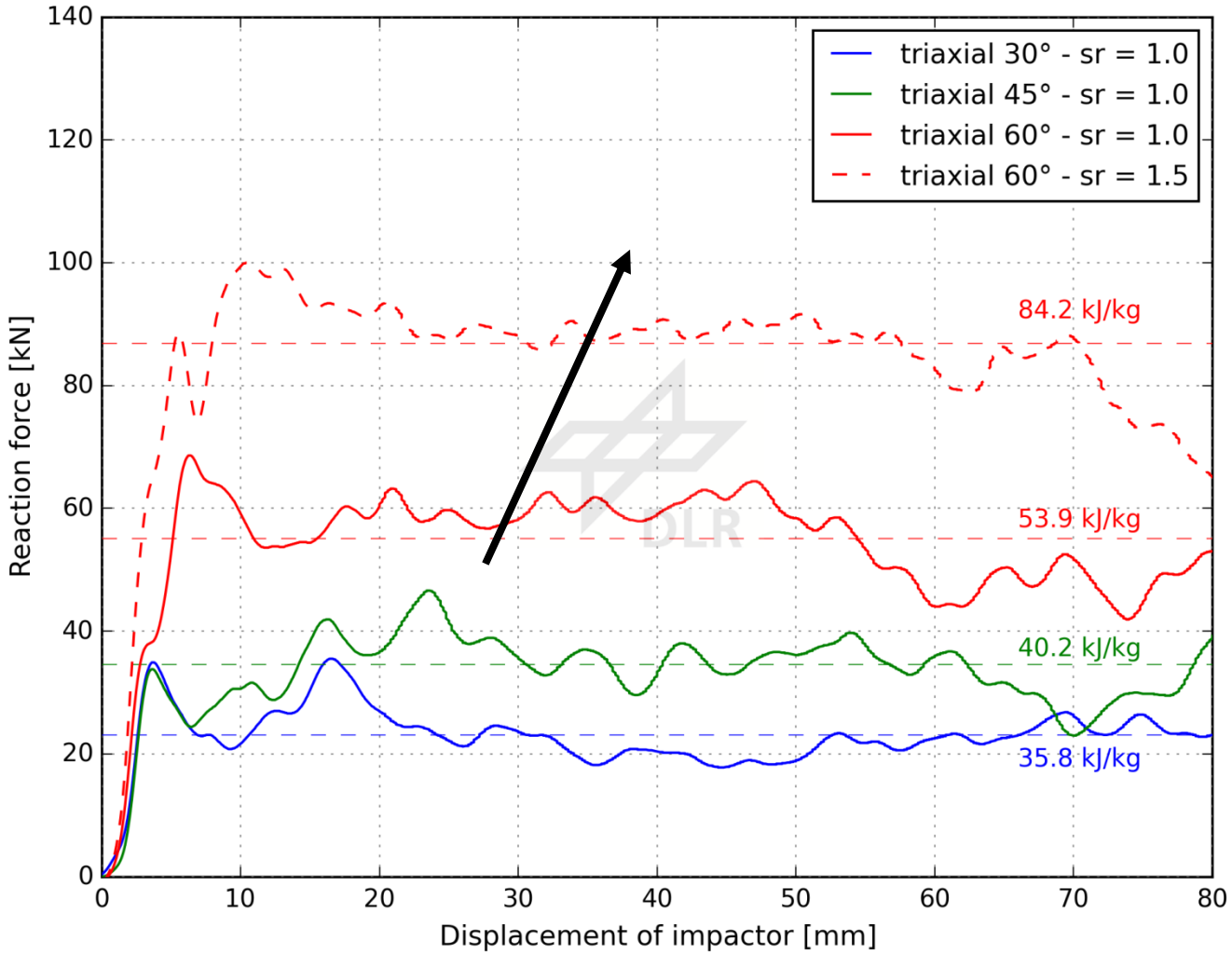
damage propagation up to 8 mm from the crash front

damage propagation along the entire tube

reference approach



Crash tube – influence of braiding angle

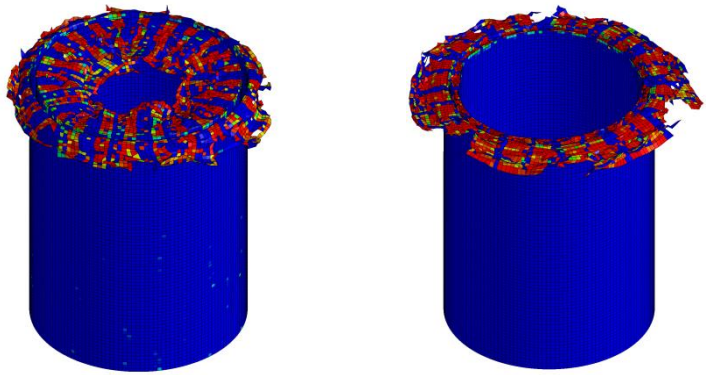


strong influence of the search radius

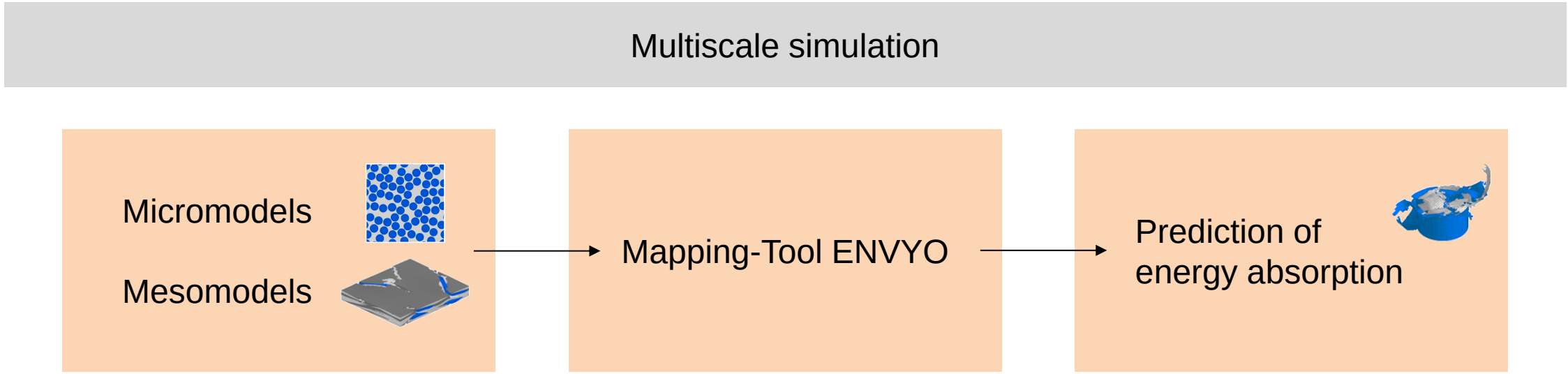
increase of the search radius

↓

increase of axial yarn content



Conclusion



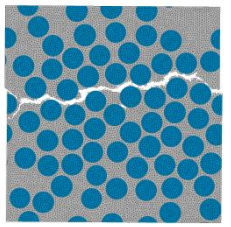
- The simulation approaches on the multiscale have been studied and validated on crash tubes and bearing specimens.
- The failure mechanisms are realistically reproduced through the mapping with ENVYO.
- The methodology should be more accurately investigated on different specimen geometry and textiles.
- The mapping requires experience and a good understanding of the parameters.

Outlook

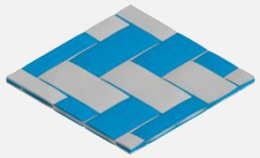
Sizing tool for composite materials
stiffness/strength/energy absorption
fatigue/probability of default

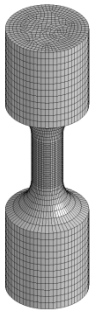
Material properties

Material card for structure simulation
und
and prediction of lifespan

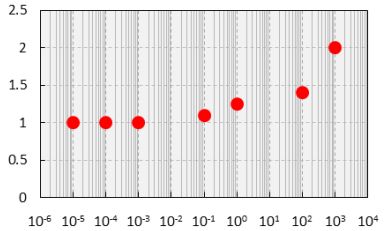


Simulation on the microscale

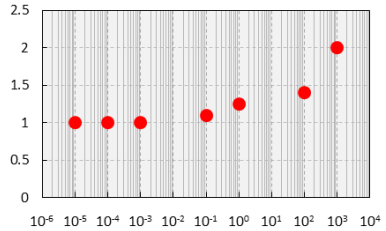




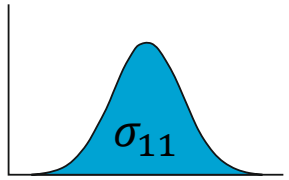
Resin properties



Strain rate dependency



Thermal dependency



Stochastic material properties

Thank you for your attention

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