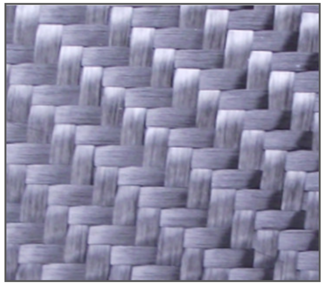
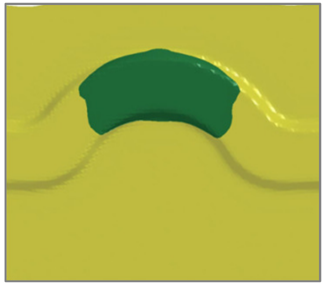




Recent developments for process simulations of composite structures in LS-DYNA

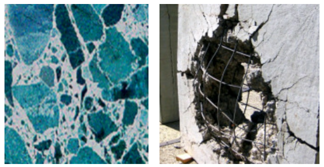
Dr. Thomas Klöppel, Christian Liebold, Dr. André Haufe

DYNAmore GmbH
Stuttgart

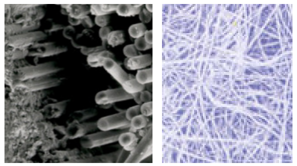
Composites: A rather broad term!

Definition

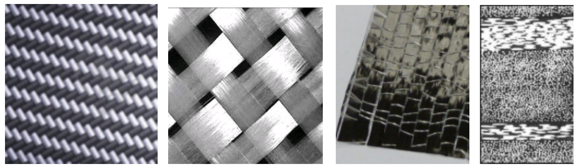
A **combination** of two or more **materials** (reinforcing elements, fillers, and composite matrix binder), differing in form or composition on a **macroscale**. The constituents retain their identities, i.e. they do not dissolve or merge completely into one another although they act in concert. The components can be physically identified and exhibit an interface between one another.



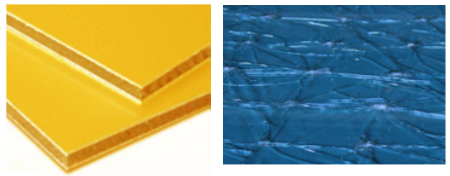
Concrete
(cement/stone/steel)



Short/long fiber reinforced polymers
(glass/PP)



Endless fiber reinforced polymers
(glass/carbon/PA/PP/EP)

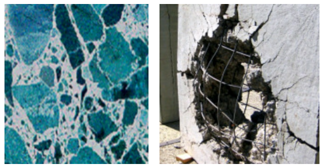


Sandwich/Laminates
(alloy/polymer/..glass/PVB/…)

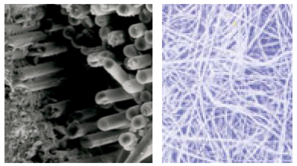
Composites: A rather broad term!

Definition

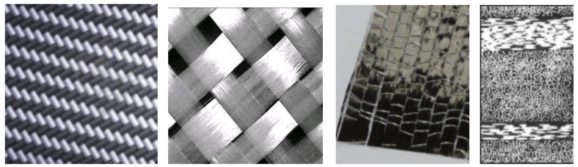
A **combination** of two or more **materials** (reinforcing elements, fillers, and composite matrix binder), differing in form or composition on a **macroscale**. The constituents retain their identities, i.e. they do not dissolve or merge completely into one another although they act in concert. The components can be physically identified and exhibit an interface between one another.



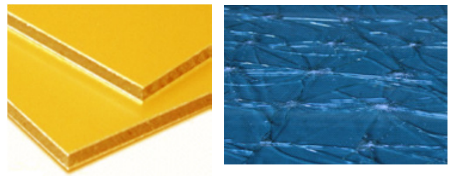
Concrete
(cement/stone/steel)



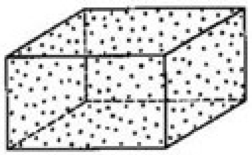
Short fiber reinforced polymers
(glass/PP)



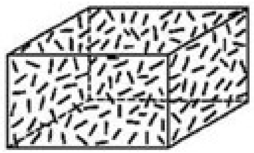
Long fiber reinforced polymers
(glass/carbon/PA/PP/EP)



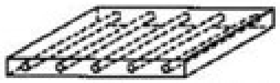
Sandwich/Laminates
(alloy/polymer/..glass/PVB/…)



particulate composite materials
(particles in a matrix)

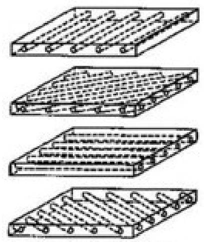


short fibers



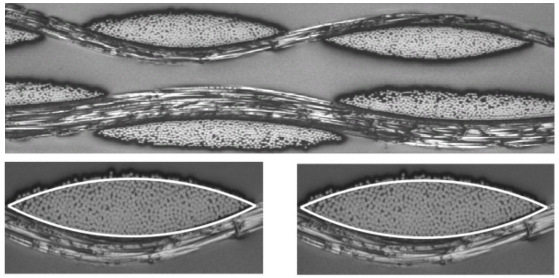
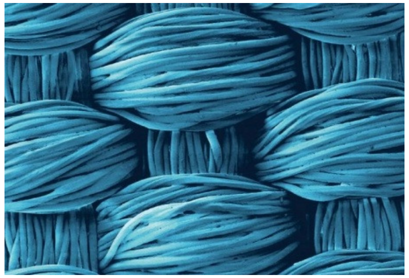
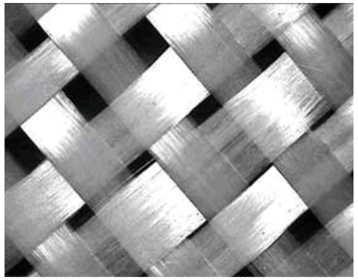
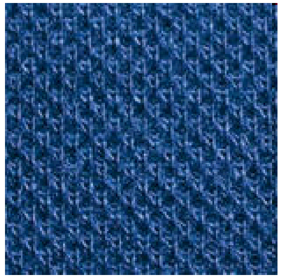
long fibers

fibrous composite materials
(fibers in a matrix)

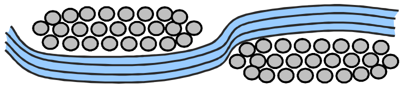


laminated composite materials
(layers of various materials)

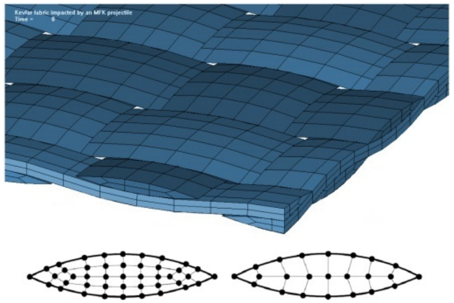
Process simulation: Motivation

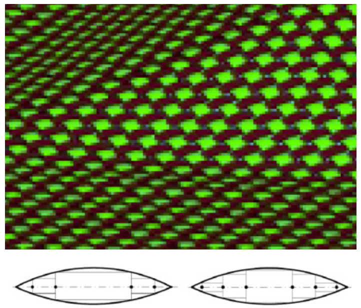
[μm] [mm] [cm] Length scale



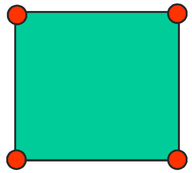
- Bundeled beam elements
- Automatic model setup
- Detailed studies



- Solid- or shell elements
- Automatic model setup
- Impact / draping simulation

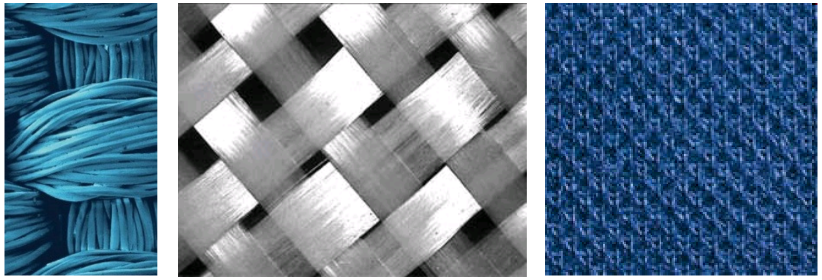


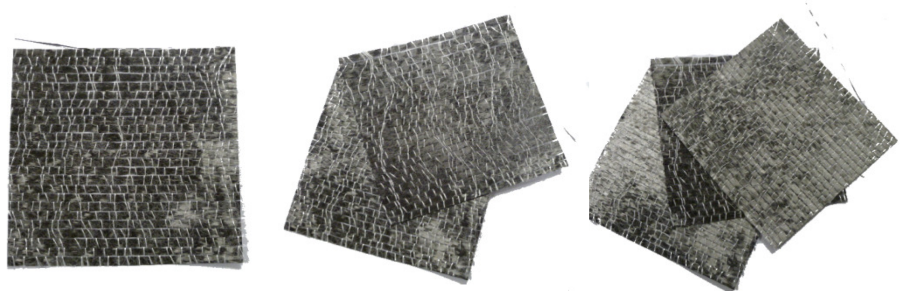
- Single shell elements
- Autom. Model setup
- Draping simulation



- Smeared modeling
- Production-/Processsim.
- Draping and wrinkles

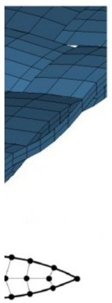
Process simulation: Motivation

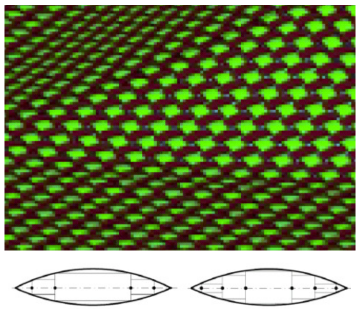




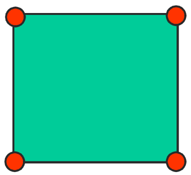
1 ply 2 plies 3 plies

[mm] [cm] Length scale

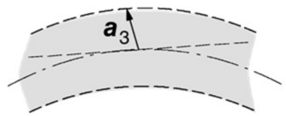




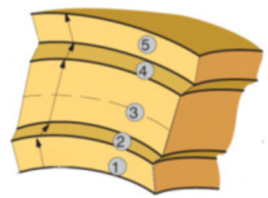
- Single shell elements
- Autom. Model setup
- Draping simulation



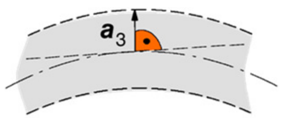
- Smeared modeling
- Production-/Processsim.
- Draping and wrinkles



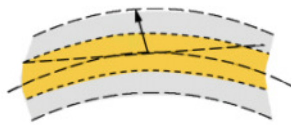
homogeneous shell



stacked solid or shell



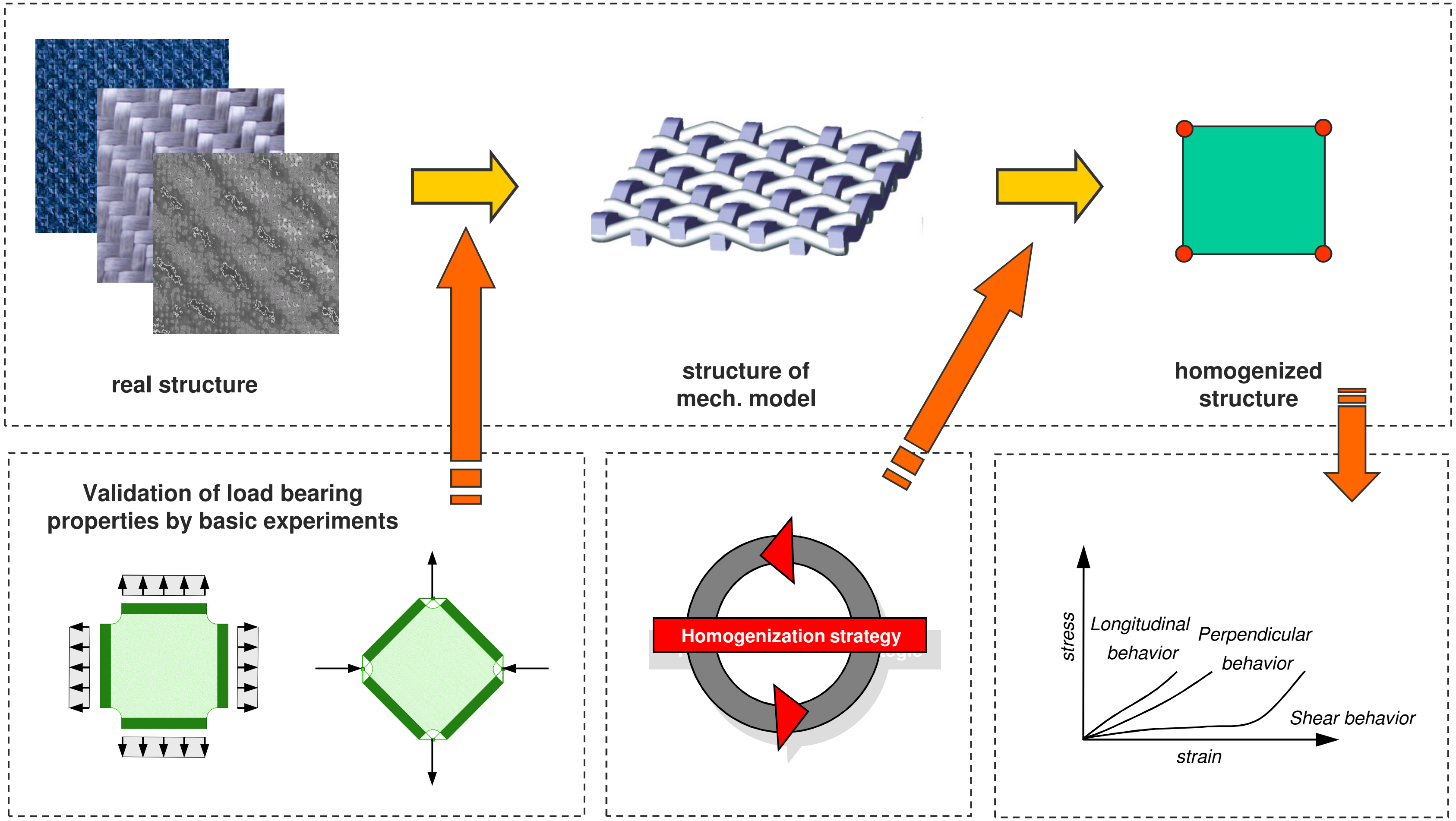
membrane



layered solid/shell

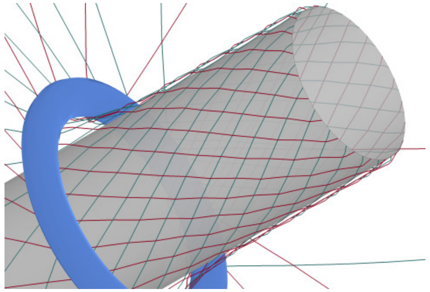
Simulation on cm-scale

Smeared approach: Homogenization of local structure and constitutive properties



Agenda

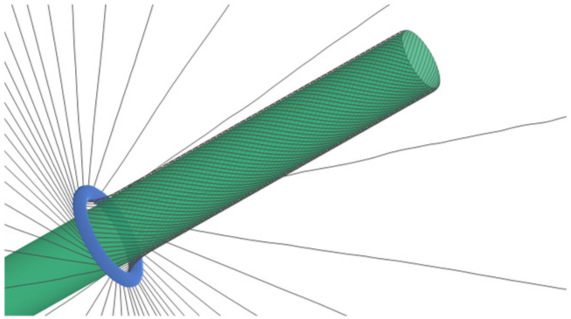
- Braiding
- Draping
- Organo sheets
- RTM
- Mapping



Braiding

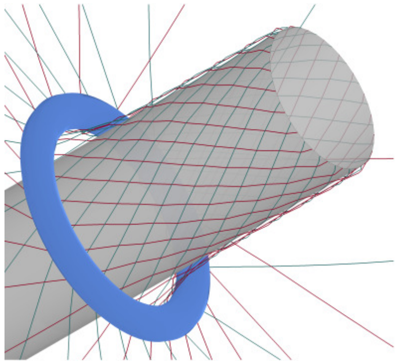
First steps for processing simulation

Filament winding simulation:



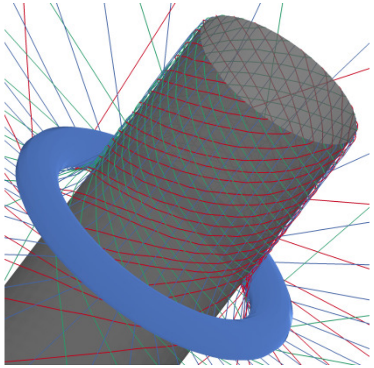
21 yarns
21543 Beam elements, 1 part
Simple rotation of the fibers and pushing of the braiding core through the braiding ring
Simple filament winding

Simple braiding simulation:

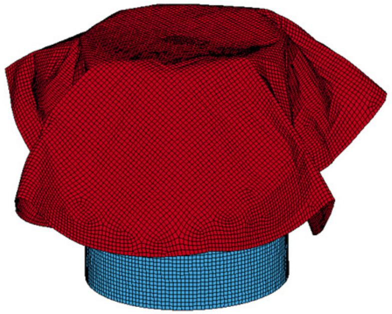


42 yarns
86172 Beam elements, 2 parts
Fibers are rotated and then moved up- and down to create the braiding-pattern
Braiding core is pushed through the braiding ring

Braiding simulation with UD reinforcement:



84 yarns
174348 Beam elements, 3 parts
Half the elements used as UD – reinforcement parts
Fibers are rotated and then moved up- and down to create the braiding-pattern
Braiding core is pushed through the braiding ring

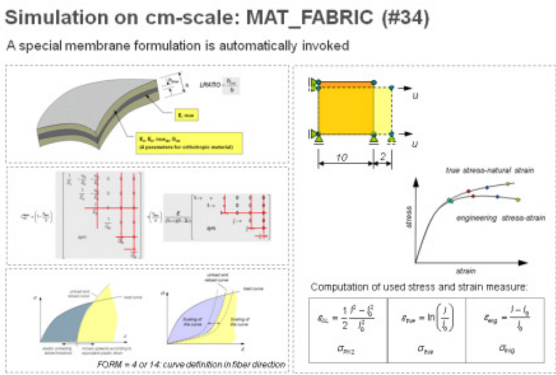


Draping

Modeling techniques on cm-scale:

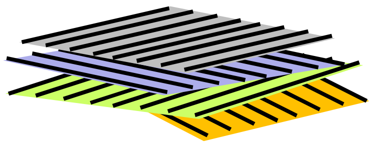
Fabric materials available for draping simulation

MAT_34



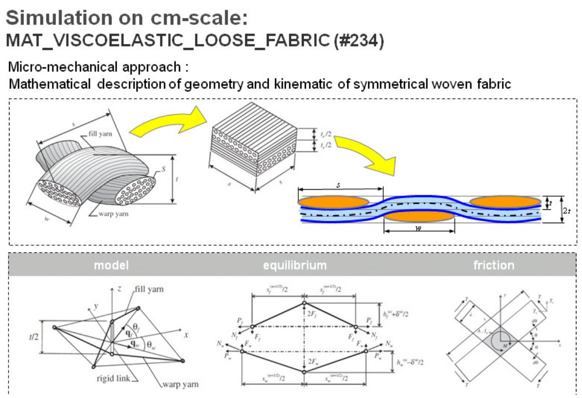
New in R7.0: bending stiffness

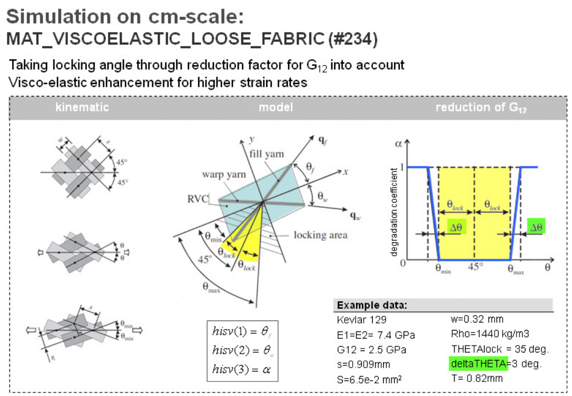
New: ACMD



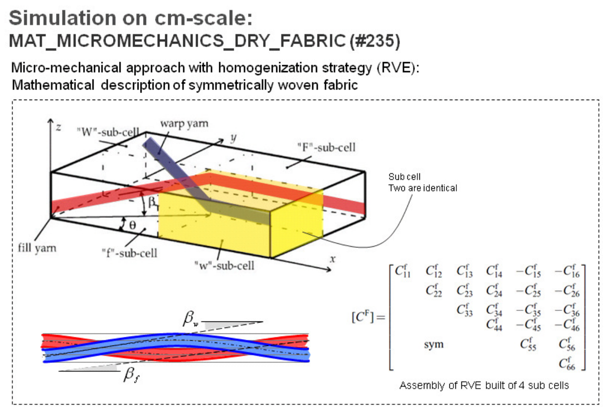
Anisotropic unidirectional layered constitutive model for draping NEW in future release.

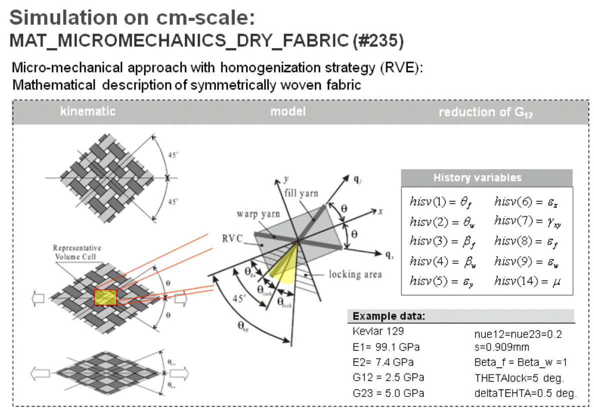
MAT_234





MAT_235

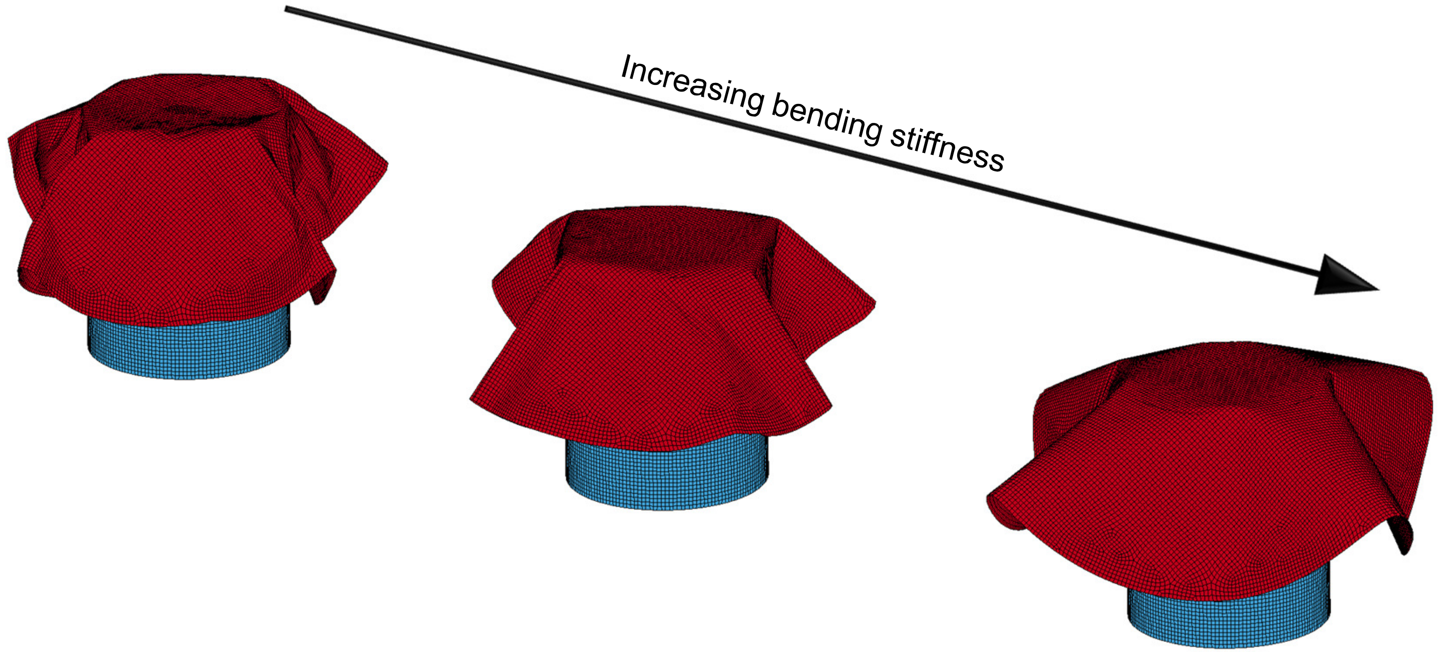




Enhancements in MAT_FABRIC (MAT34) starting with LS-DYNA R7.0

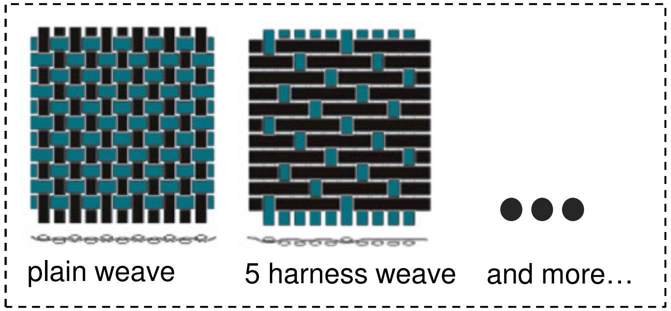
- Material describes an orthotropic material behavior
- Requires discretization with membrane elements
- Allows to add a bending resistance by defining an additional elastic coating in the material card

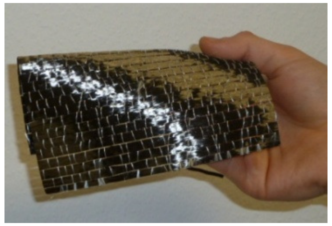
Example: Tablecloth with varying coating stiffness

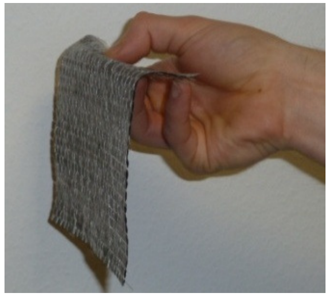


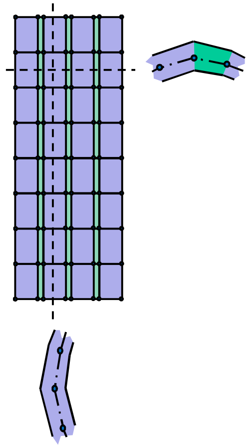
Process simulation: Draping with strong anisotropy

Some fabrics (preforms) show extreme orthotropic behavior. Here modeling with shell elements using different constitutive models is possible:

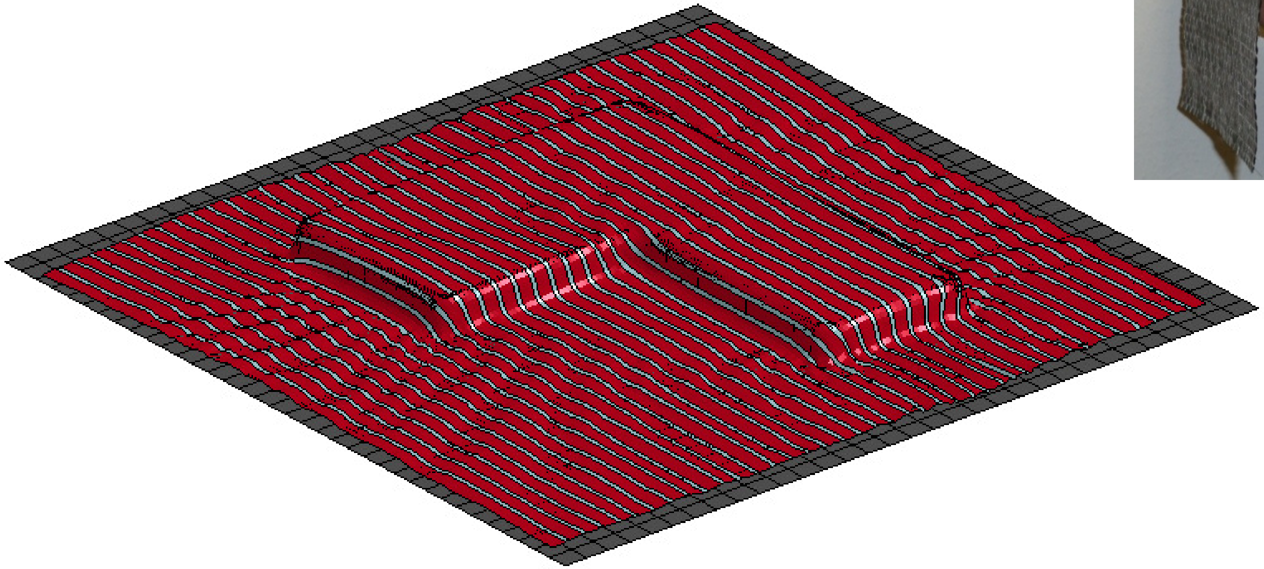






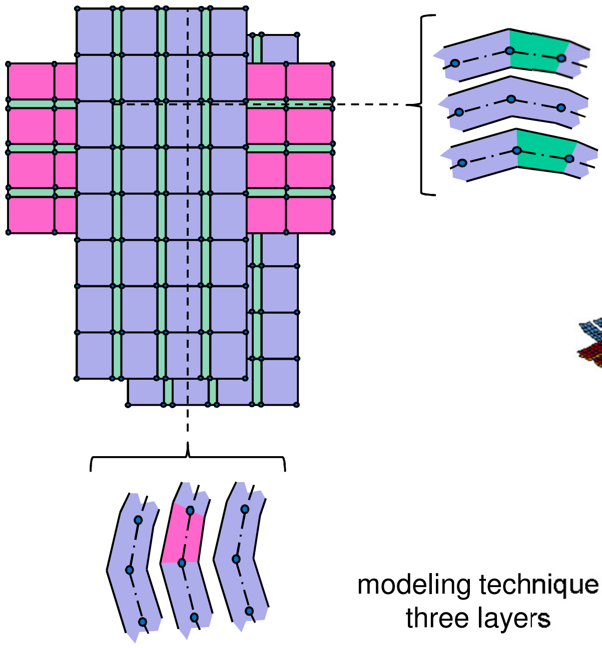


modeling technique
single layer

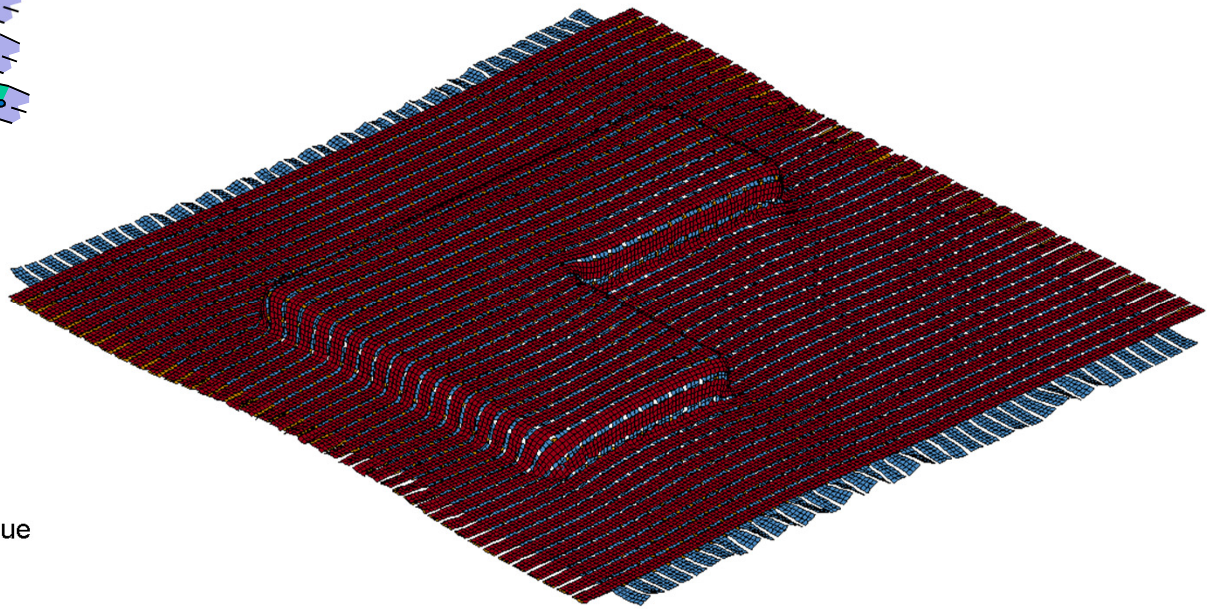


Process simulation: Draping with strong anisotropy

Some fabrics (preforms) show extreme orthotropic behavior.
Here modeling with shell elements using
different constitutive models is possible.
For stacked preforms a similar approach
in finite element modeling is of course
possible: Multiple layers of shell elements.

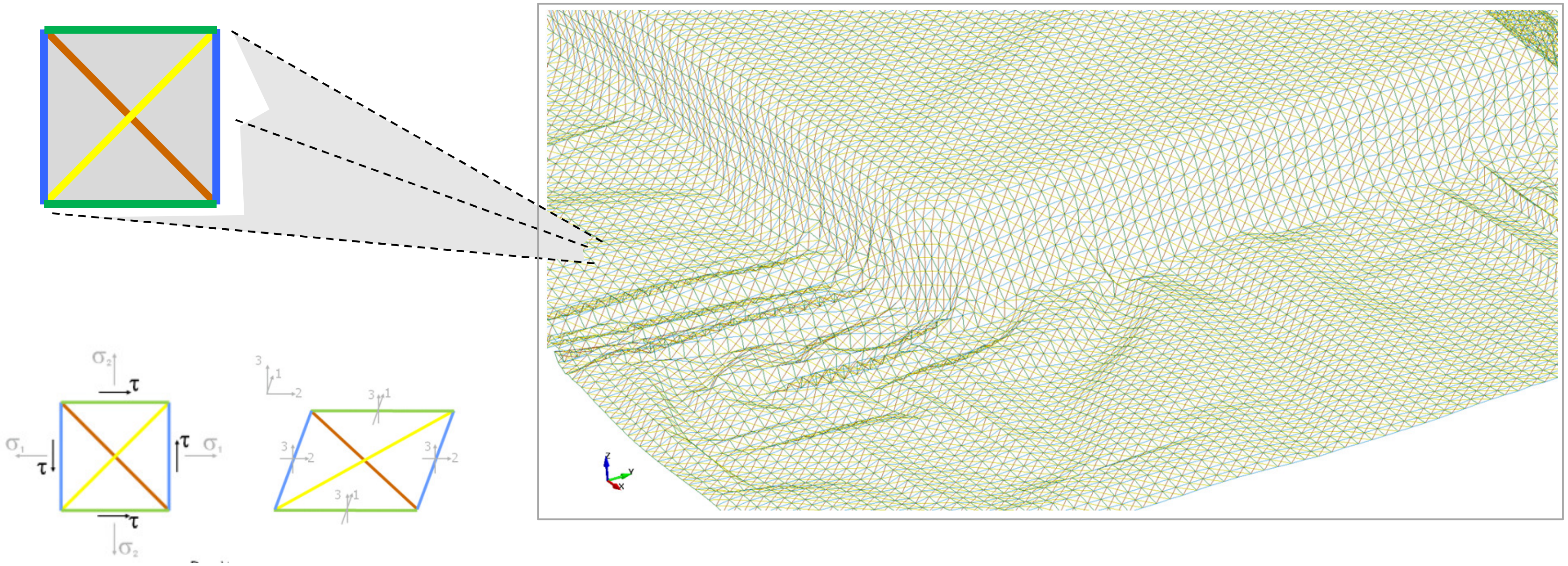


modeling technique
three layers



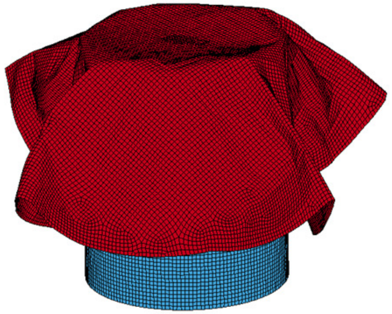
Draping: Using discrete elements for strong anisotropy

Modeling woven fabrics with beam elements:
Warp and weft direction *MAT_LINEAR_ELASTIC_DISCRETE_BEAM (MAT_066)
Diagonal behavior modeled with *MAT_CABLE_DISCRETE_BEAM (MAT_071)



This approach allows also to model positive and negative shear loading.

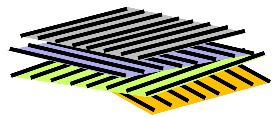
Optional matrix may be represented with shell elements and elastic/plastic material.



Draping –
New Material model

Beta status
(could be enhanced for organo sheets)

New anisotropic constitutive model for draping (ACMD)



- Hyperelastic, anisotropic material formulation, accounting for *n* discrete fiber families in *each* integration point
- Normalized initial fiber directions $\vec{m}_i^0$ are defined w.r.t. to material direction
- Current state of fiber $\vec{m}_i$ is given by $\vec{m}_i = \underline{F}\vec{m}_i^0$ with length λ_i
- Response of the fibers according to a function $f(\lambda_i)$ of current length $\vec{m}_i$ of the fiber defined by a load curve
- Stresses due to elongation of the individual fibers families are then computed as

$$\underline{\sigma} = \sum_{i=1}^{n} \tfrac{1}{J} f(\lambda_i)\, \vec{m}_i \otimes \vec{m}_i$$

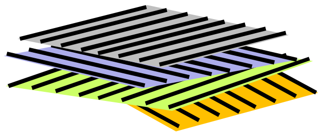
- Interaction between neighboring fiber families can be accounted for by

$$\underline{\sigma} = \sum_{\substack{i,j \\ i \neq j}} \tfrac{1}{J} g(\vec{m}_i \cdot \vec{m}_j)\, \vec{m}_i \otimes \vec{m}_j$$

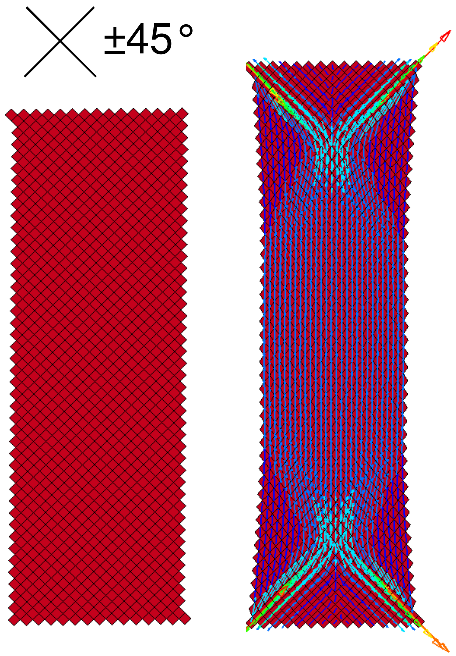
where function g can again be provided as a load curve

- For the sake of stability, a linear relation between transverse shear stresses σ_{31}, σ_{32} and the corresponding components of the bulk strain tensor is additionally assumed

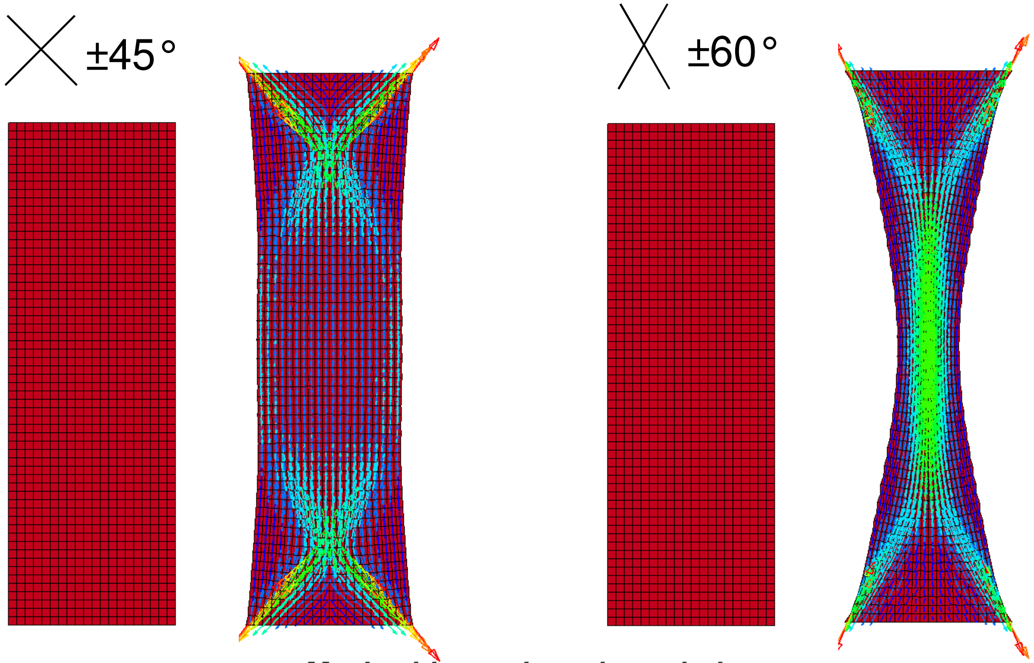
Example: tensile test specimen (ACMD)



- Prescribed motion of top nodes
- Arrows indicate the principal stresses



Mesh aligned with fiber directions

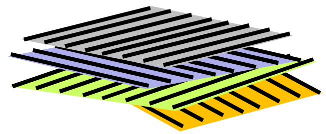


Mesh with specimen boundaries

Results show that

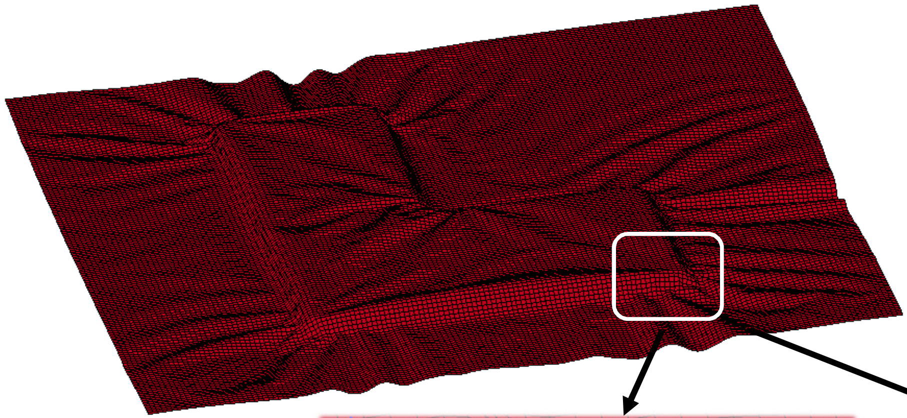
- stress orientations are independent of element orientations
- material definition accounts correctly for anisotropic (non-orthotropic) material behavior

Example ACMD: Draping simulation (0 /90)

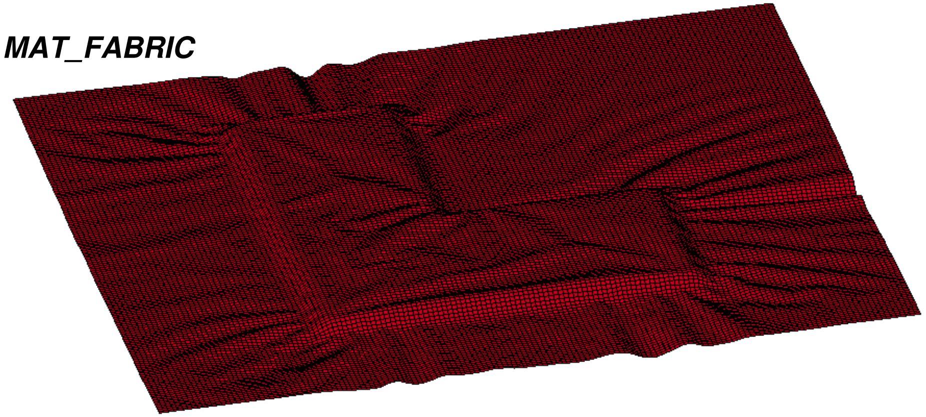


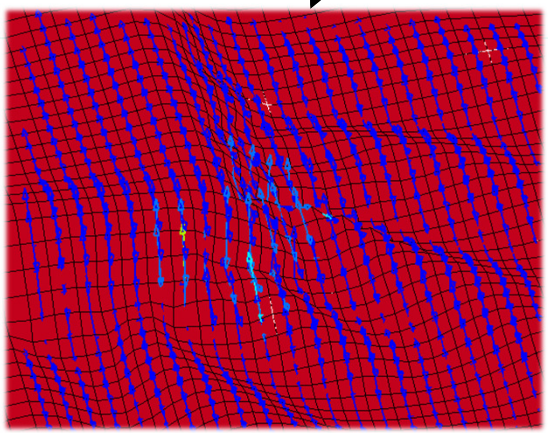
Comparison with LS-DYNA standard material MAT FABRIC (MAT 034)

New anisotropic constitutive model

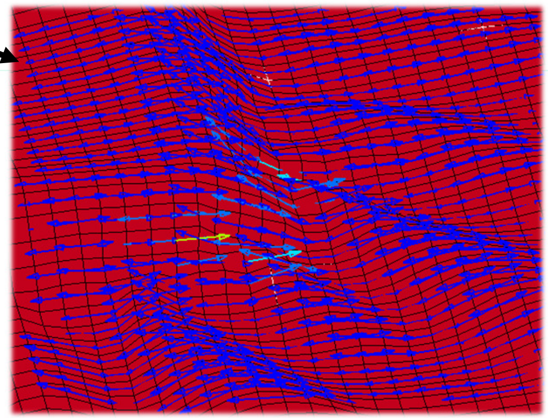


MAT_FABRIC



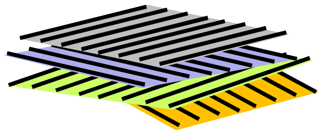


Fiber 1



Fiber 2

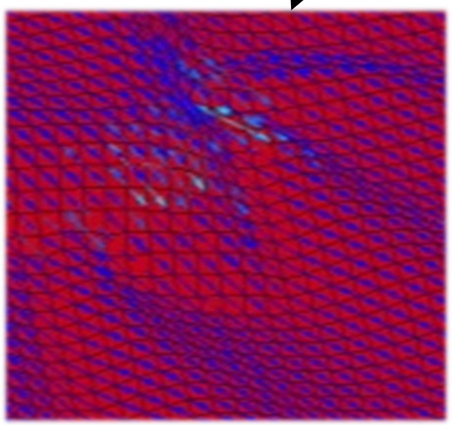
Example ACMD: Draping simulation (-45 /+45)

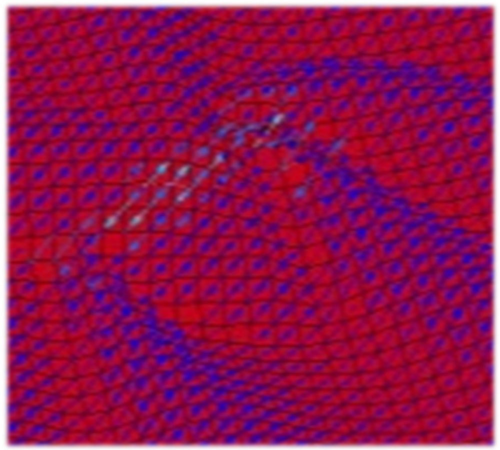


Comparison with LS-DYNA standard material MAT_FABRIC (MAT_034)

New anisotropic constitutive model

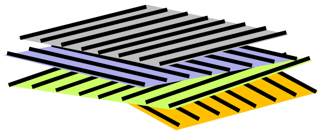
MAT_FABRIC



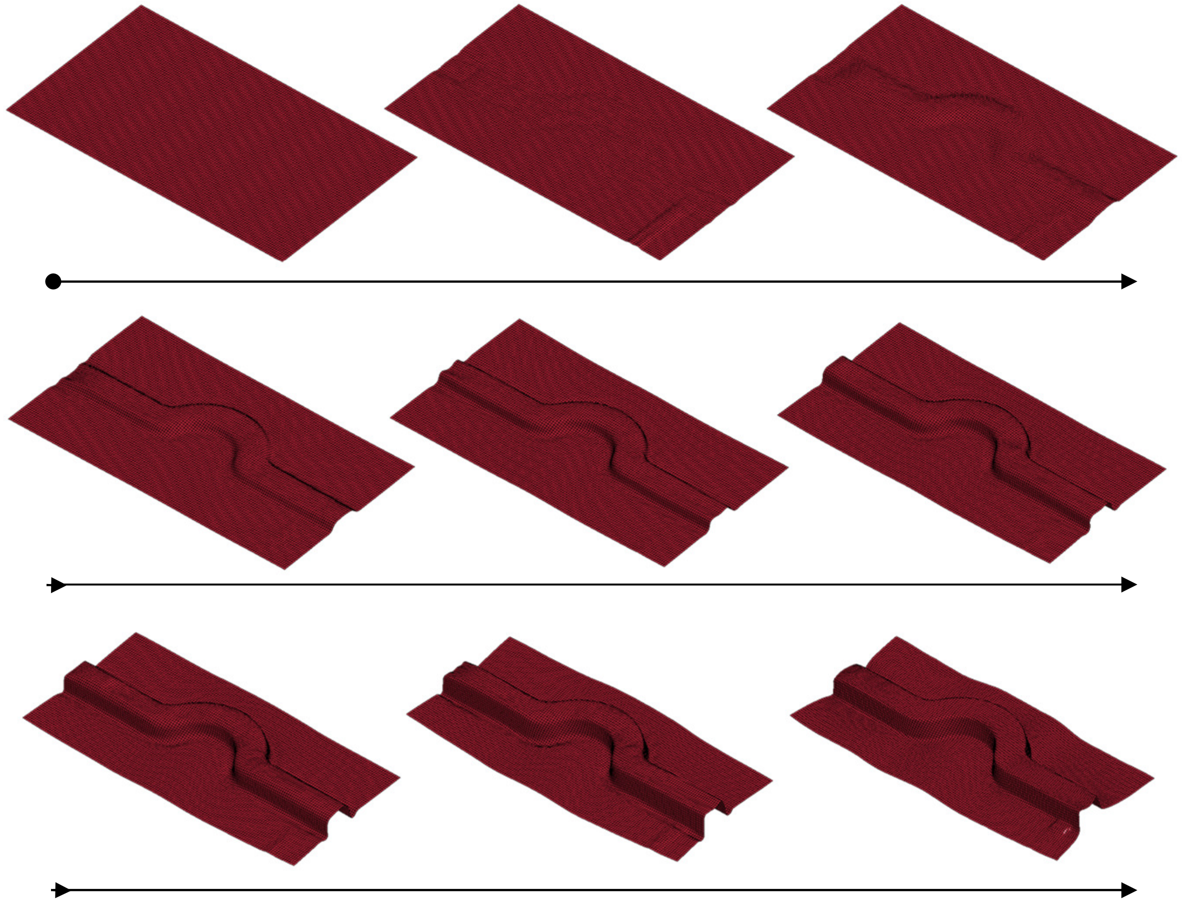


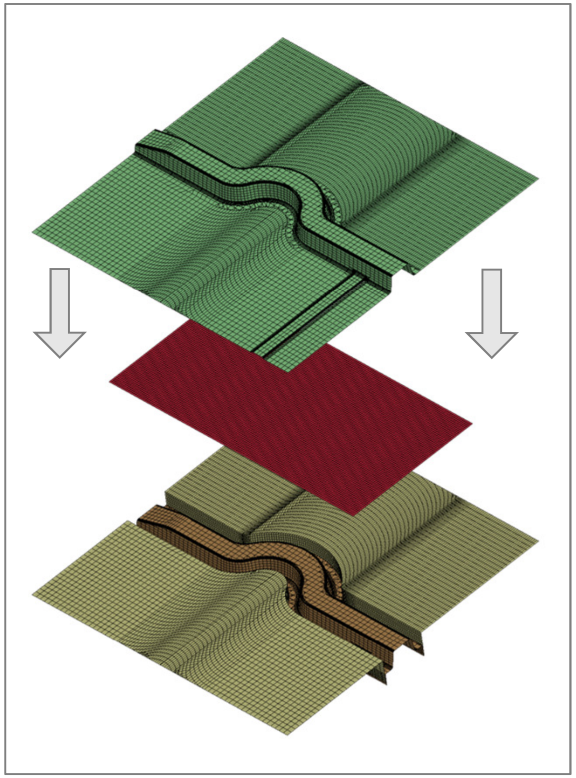
Fiber 2

Draping example: S-Rail



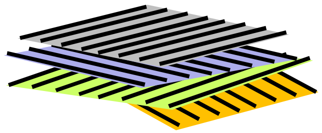
Process simulation



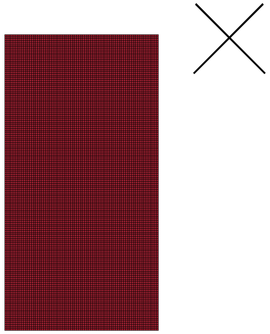


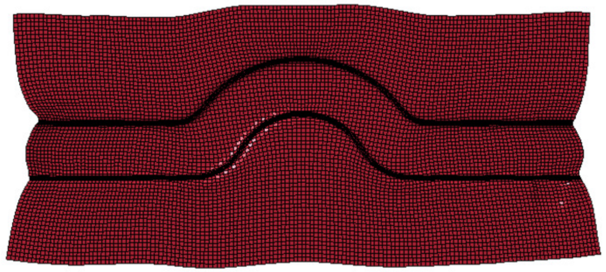
[geometry provided by Benteler-SGL]

Draping example: S-Rail

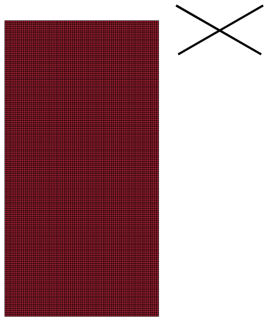


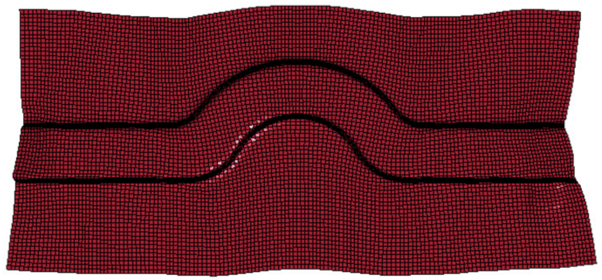
- Fiber angle ±45°, final state





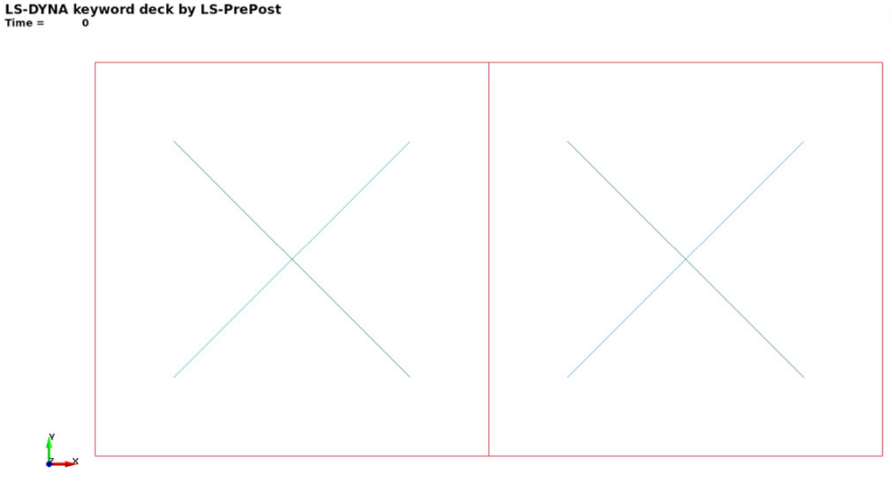
- Fiber angle ±60°, final state

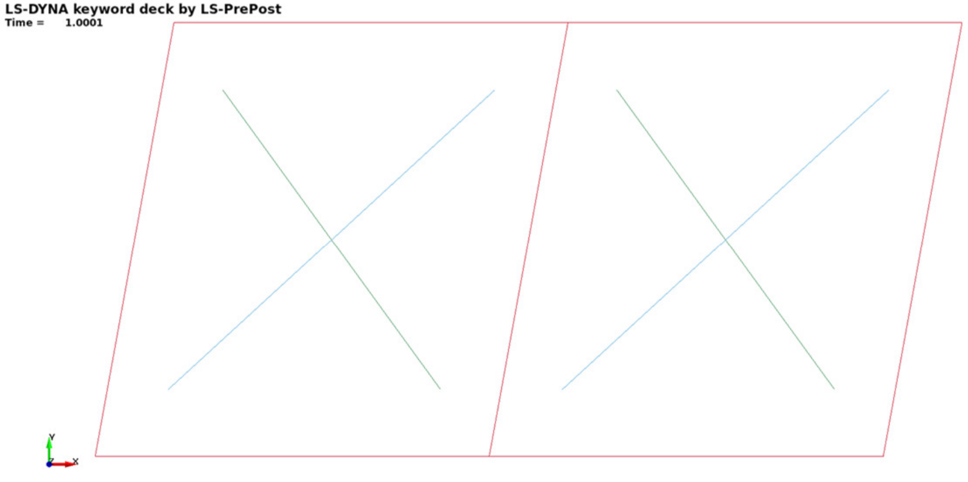




Outlook: Output of composite related data

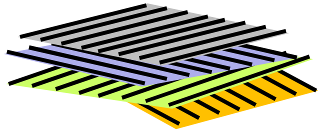
- **Write separate output file including information about**
  - Ply-ID the IP under consideration belongs to
  - Fiber directions
  - Damage
  - …
- **Output in binary LSDA-format**
- **First implementations made in LS-DYNA for the User Material and in LSPP**



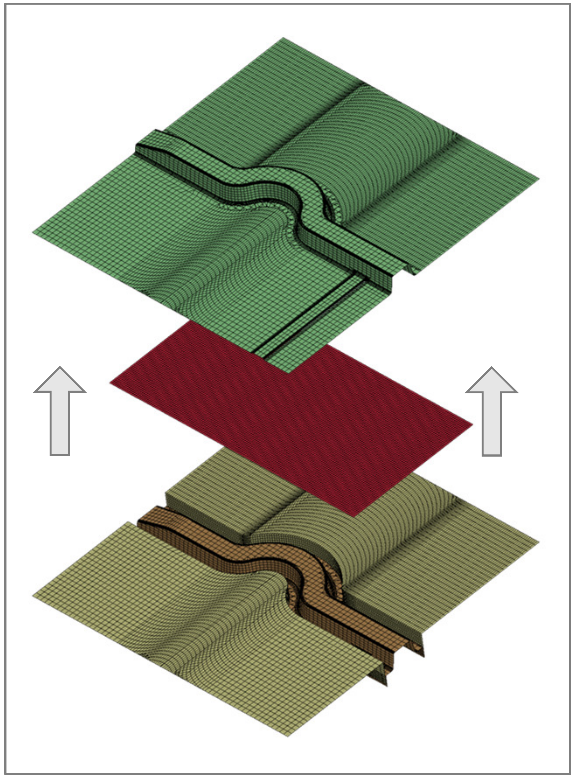


- **Next steps: implementation for LS-DYNA standard materials**

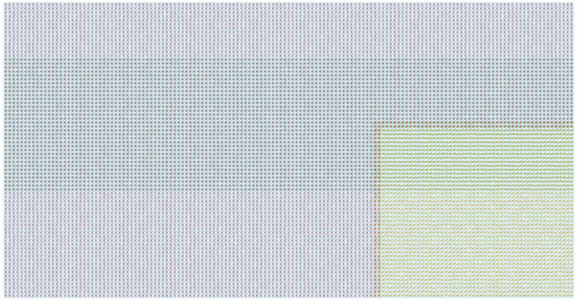
Draping example: S-Rail

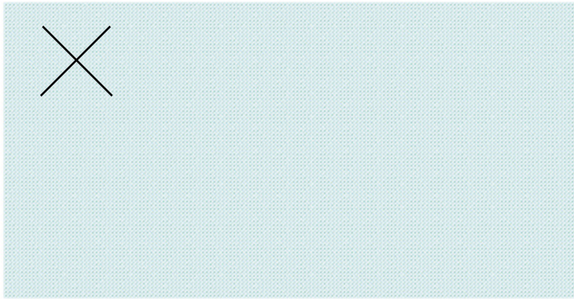


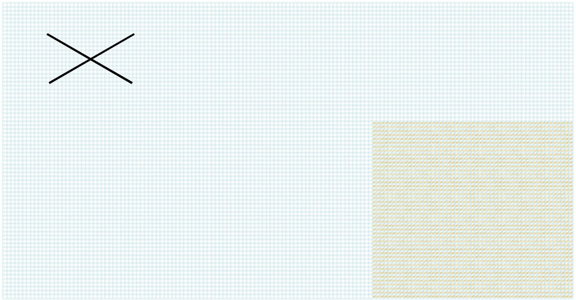
Process simulation

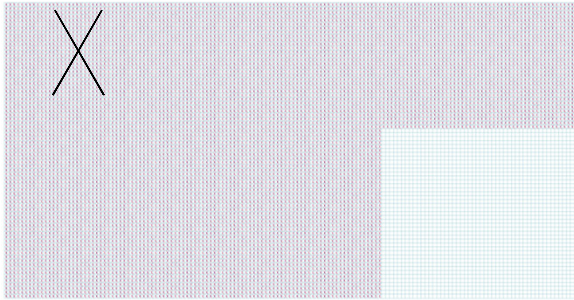


[geometry provided by Benteler-SGL]

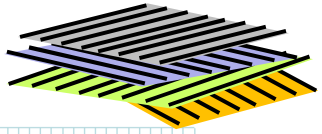




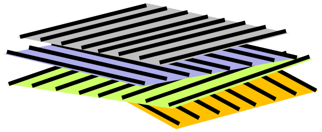


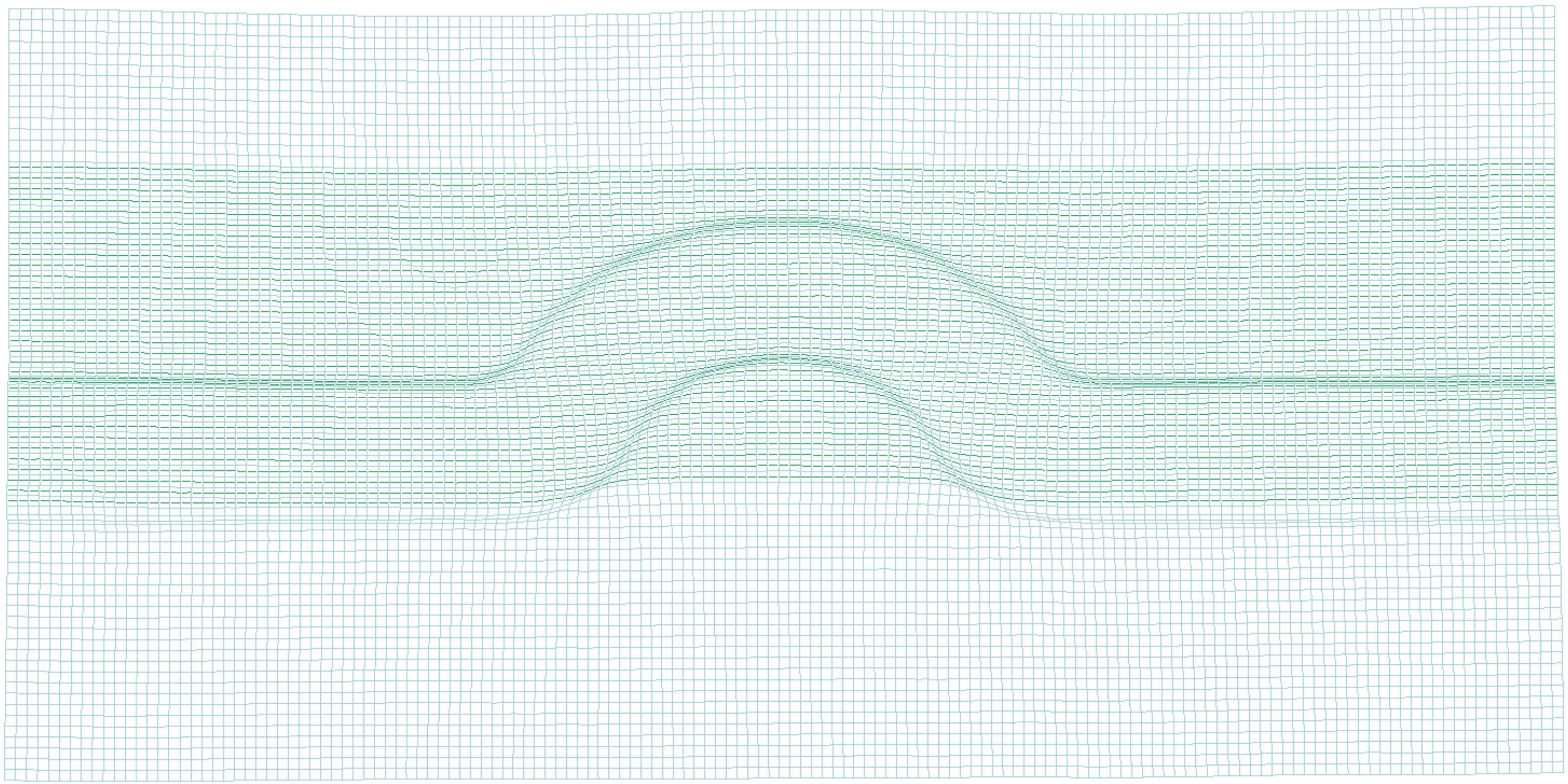


0°- Layer

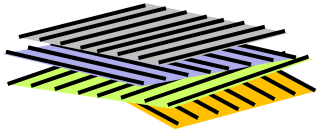


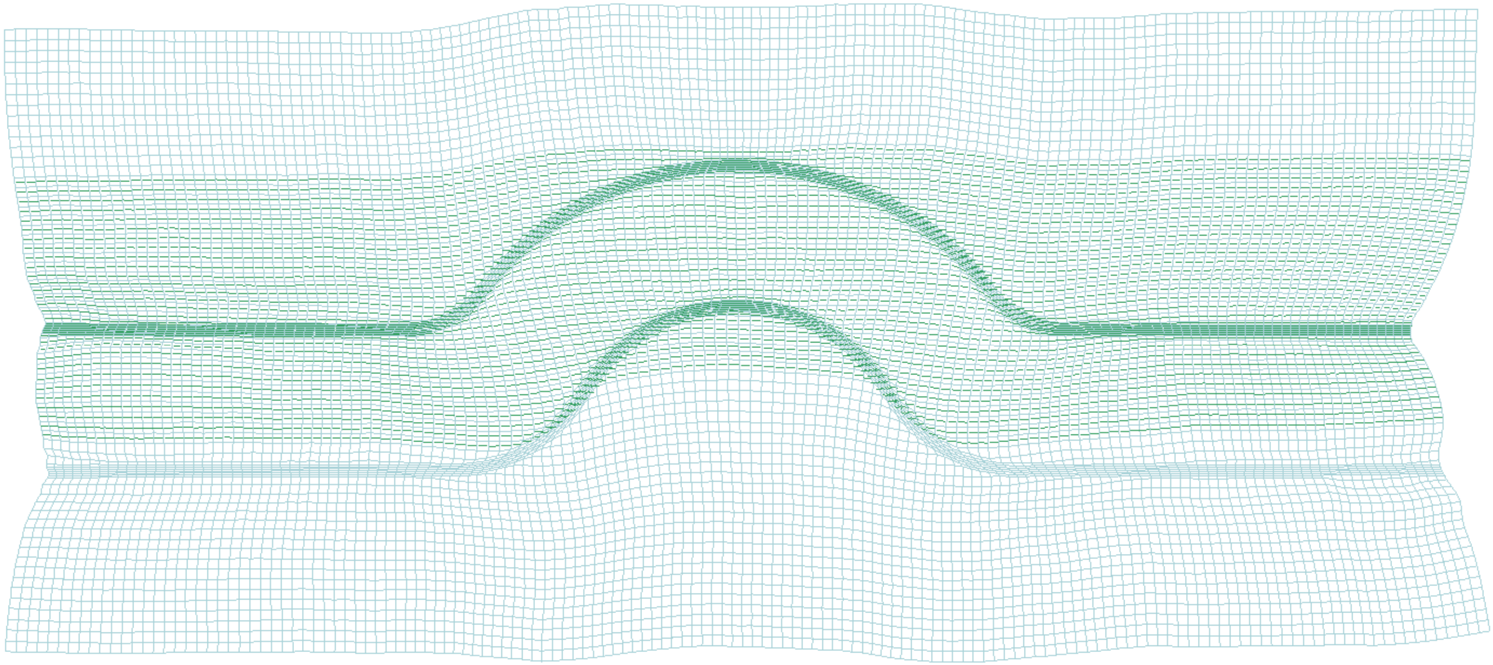
0°- Layer





0°- Layer





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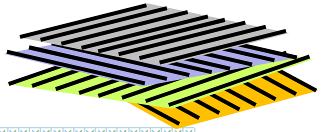
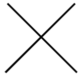
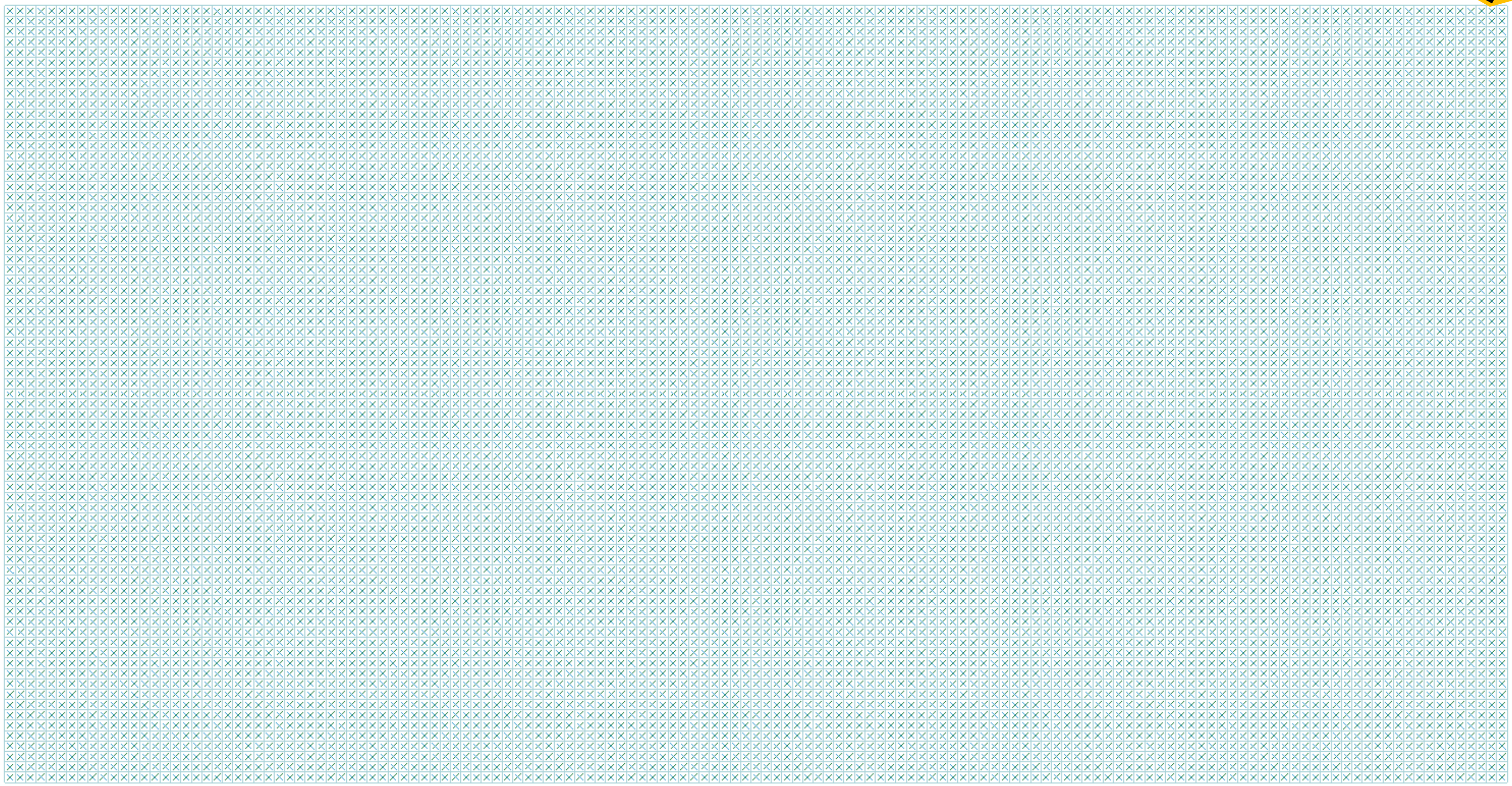
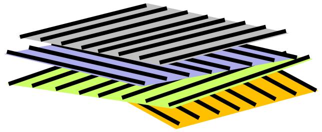
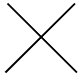


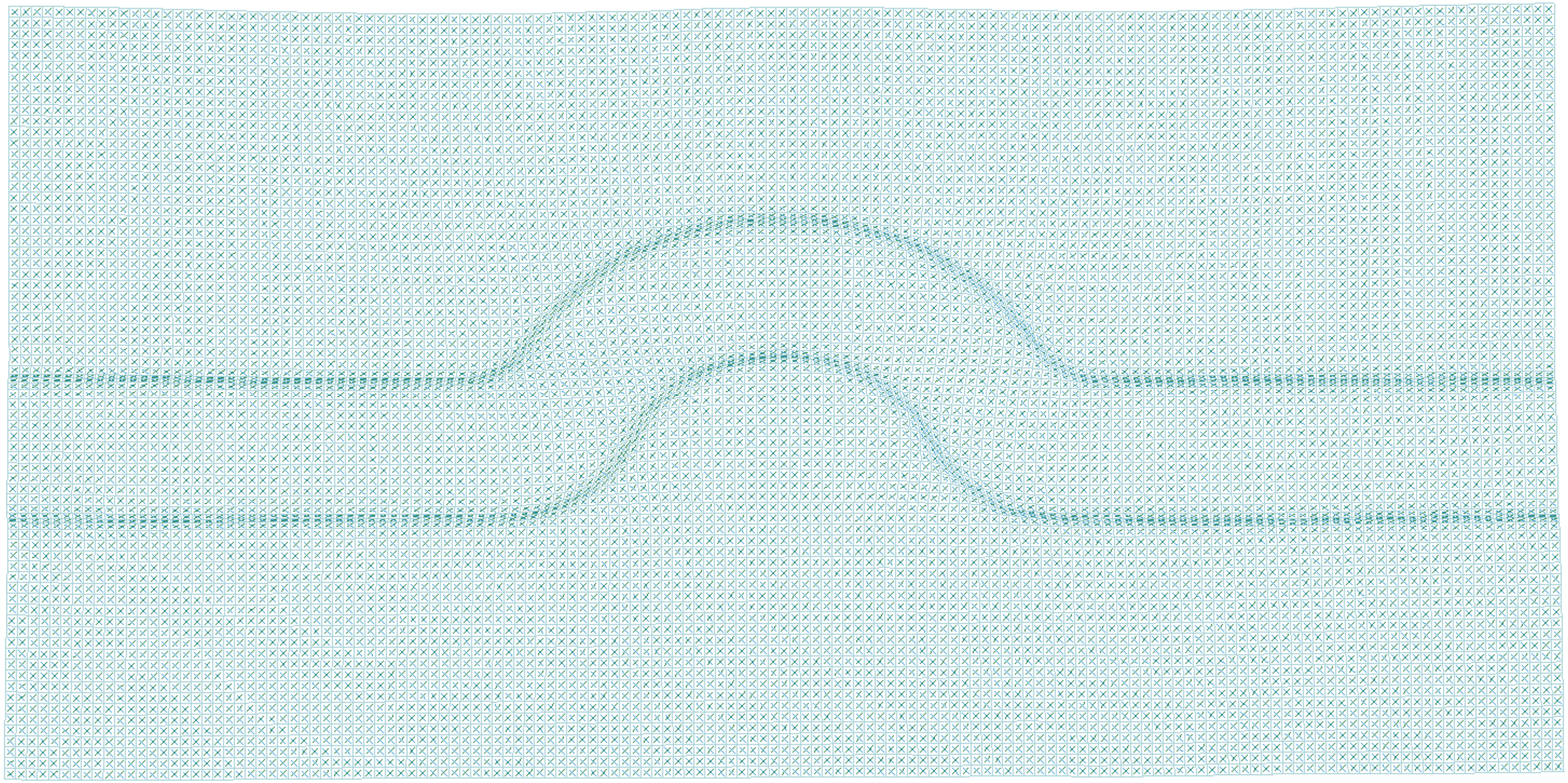




±45° - Layer







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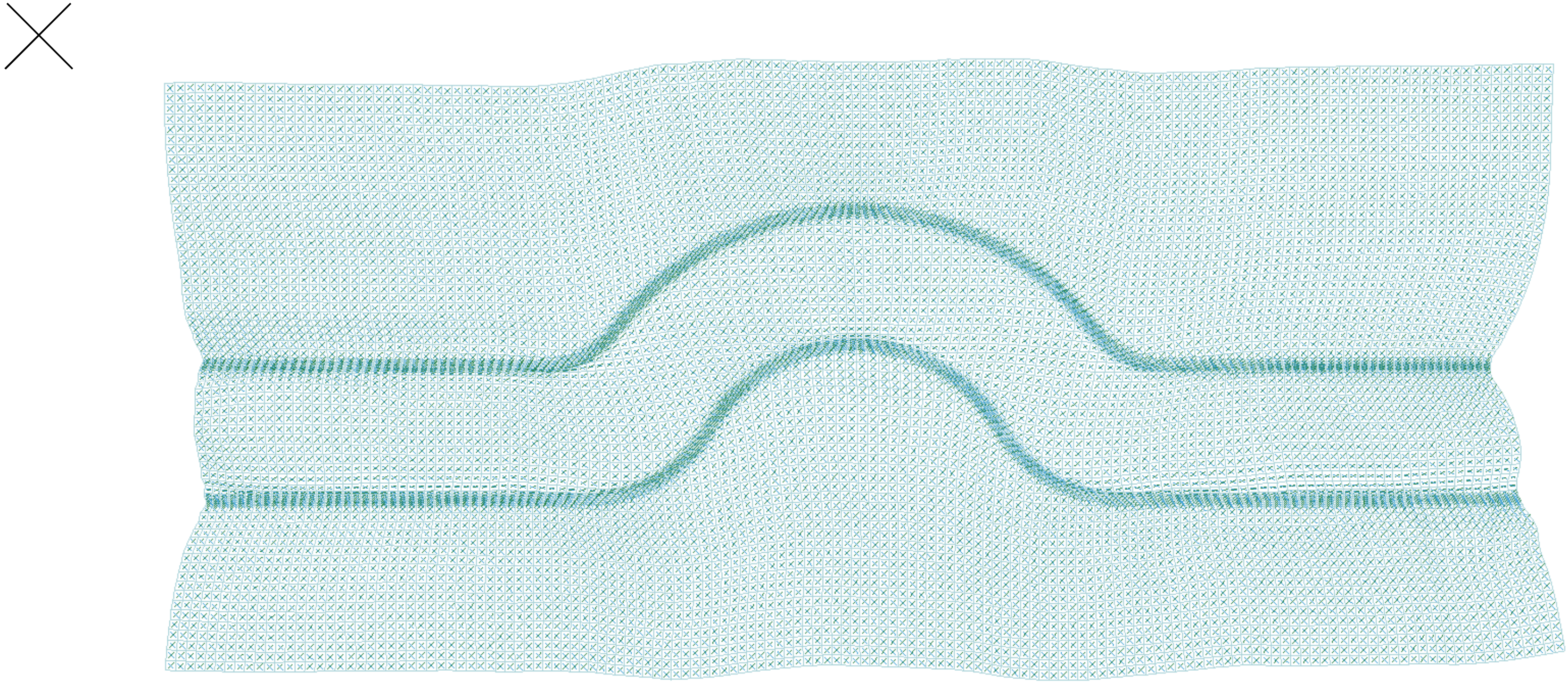
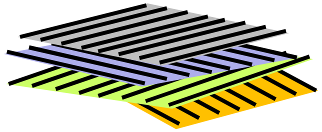
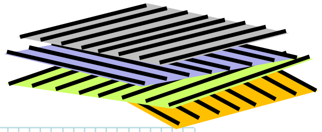
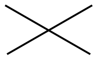
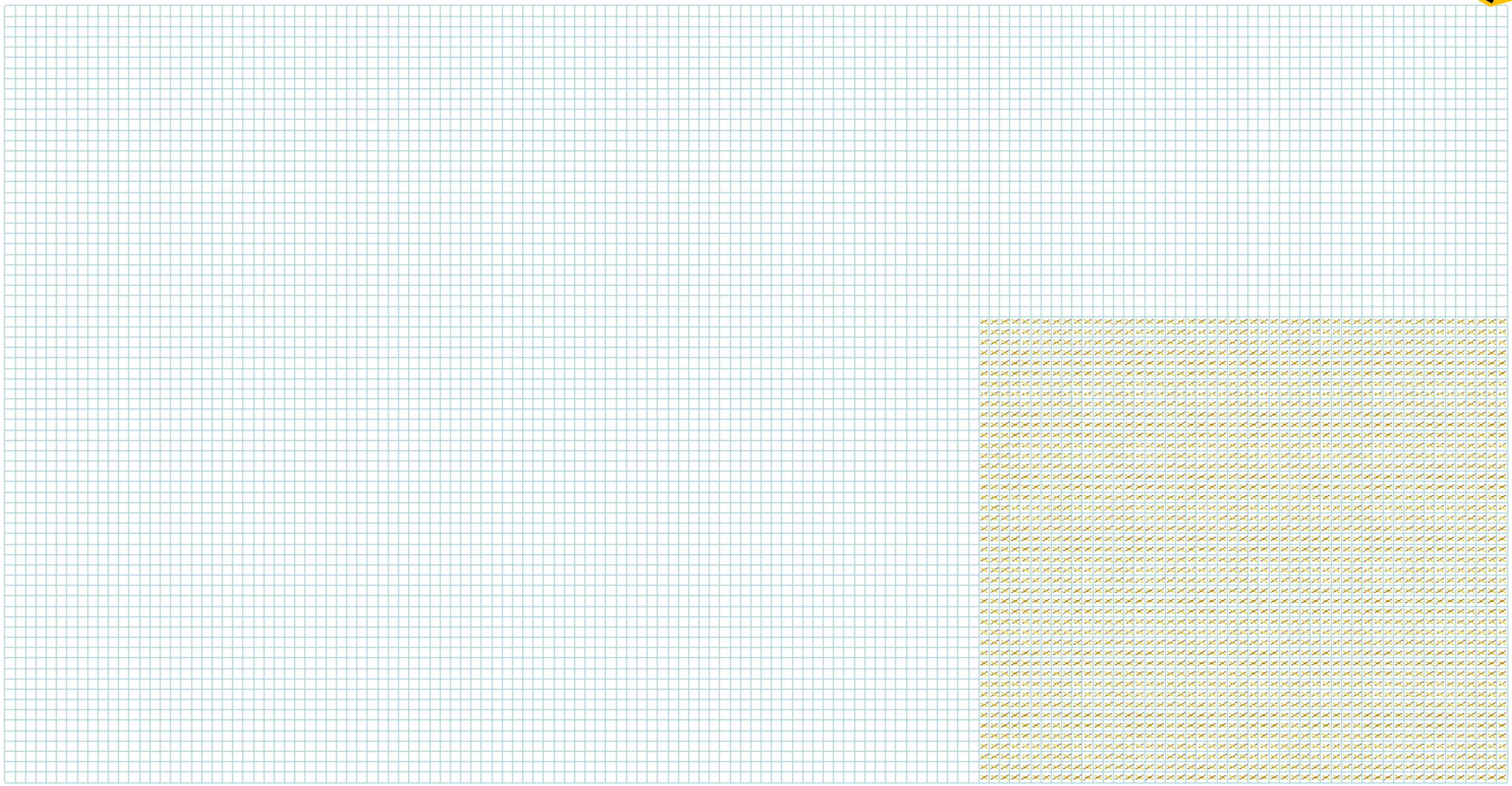




±30° - Layer







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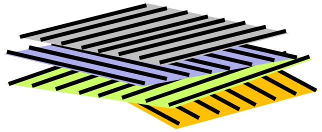
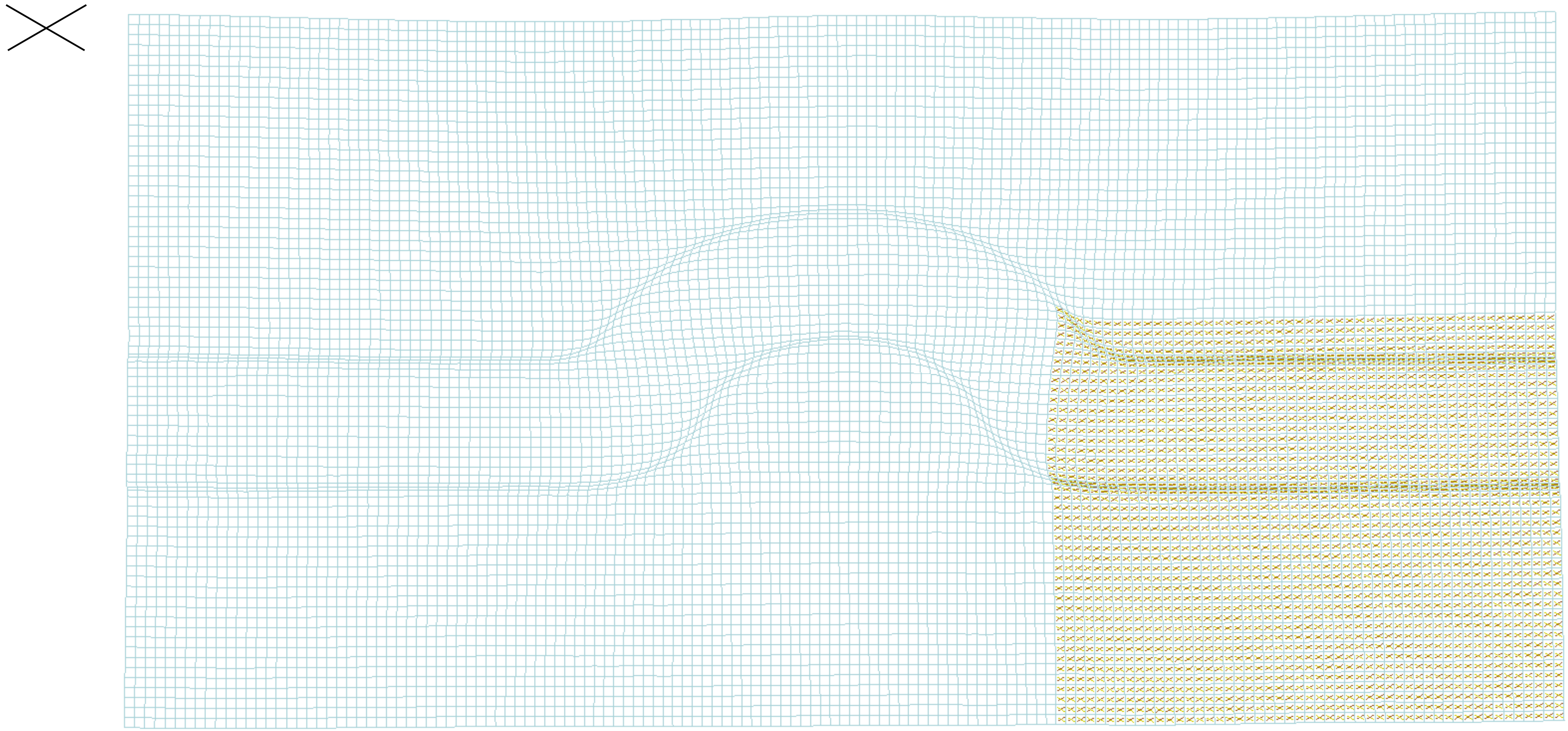
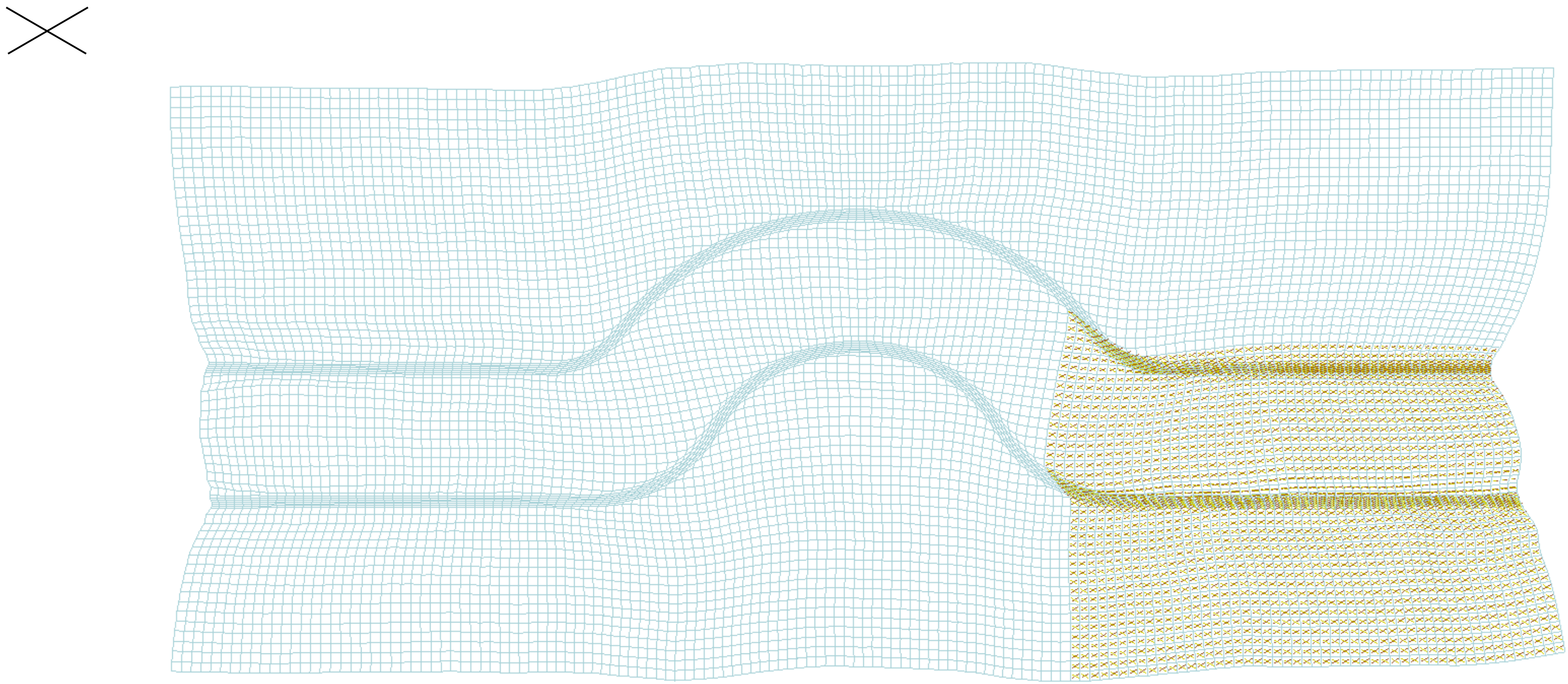
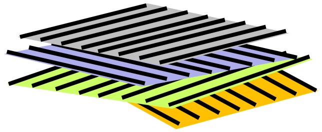


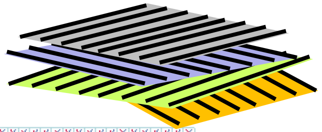


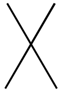
±30° - Layer

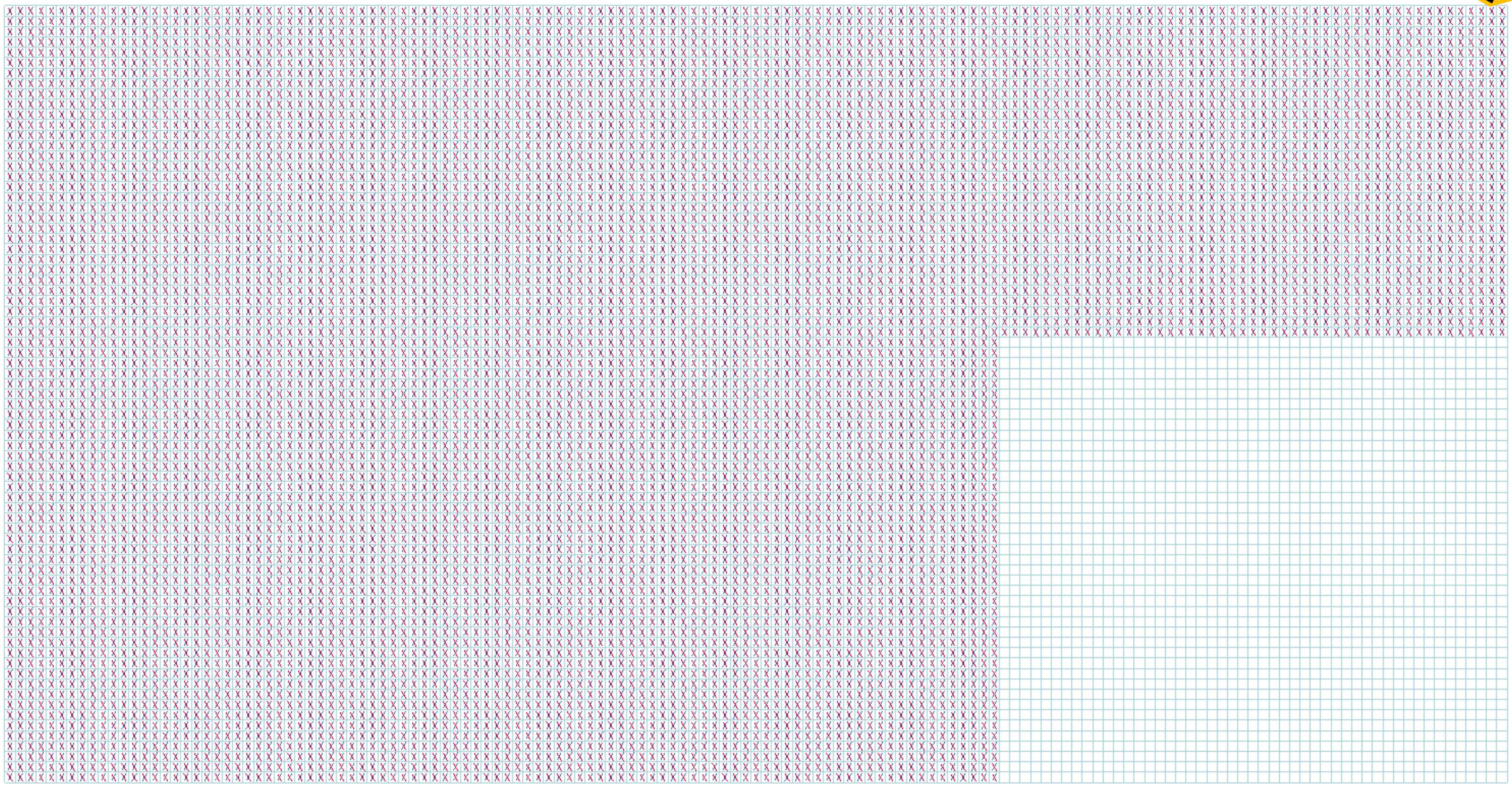




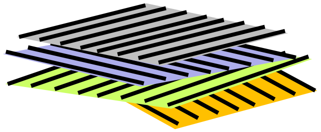
±60 ° - Layer

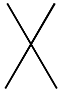


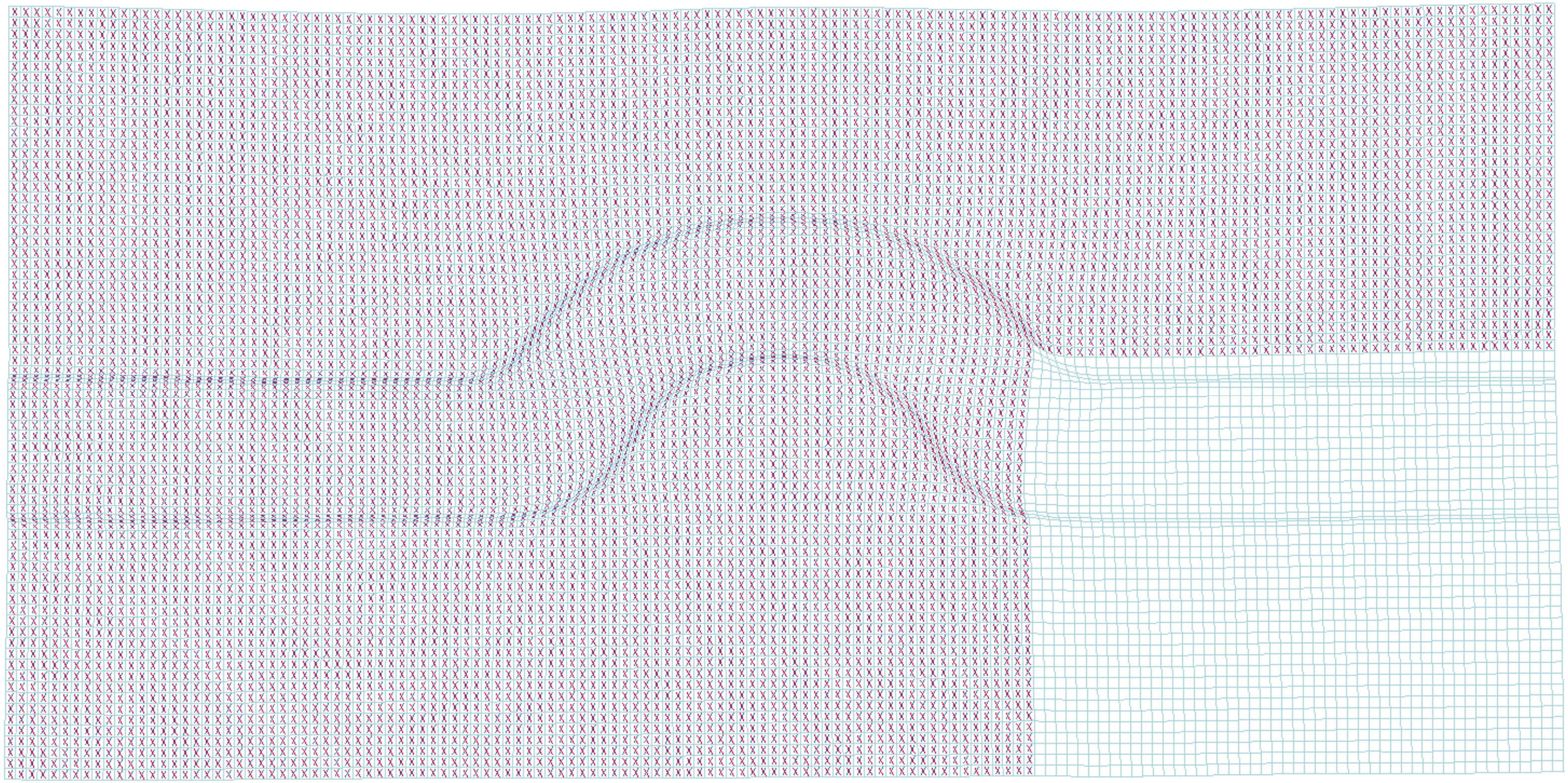




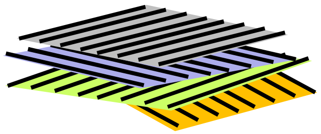
±60° - Layer

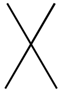


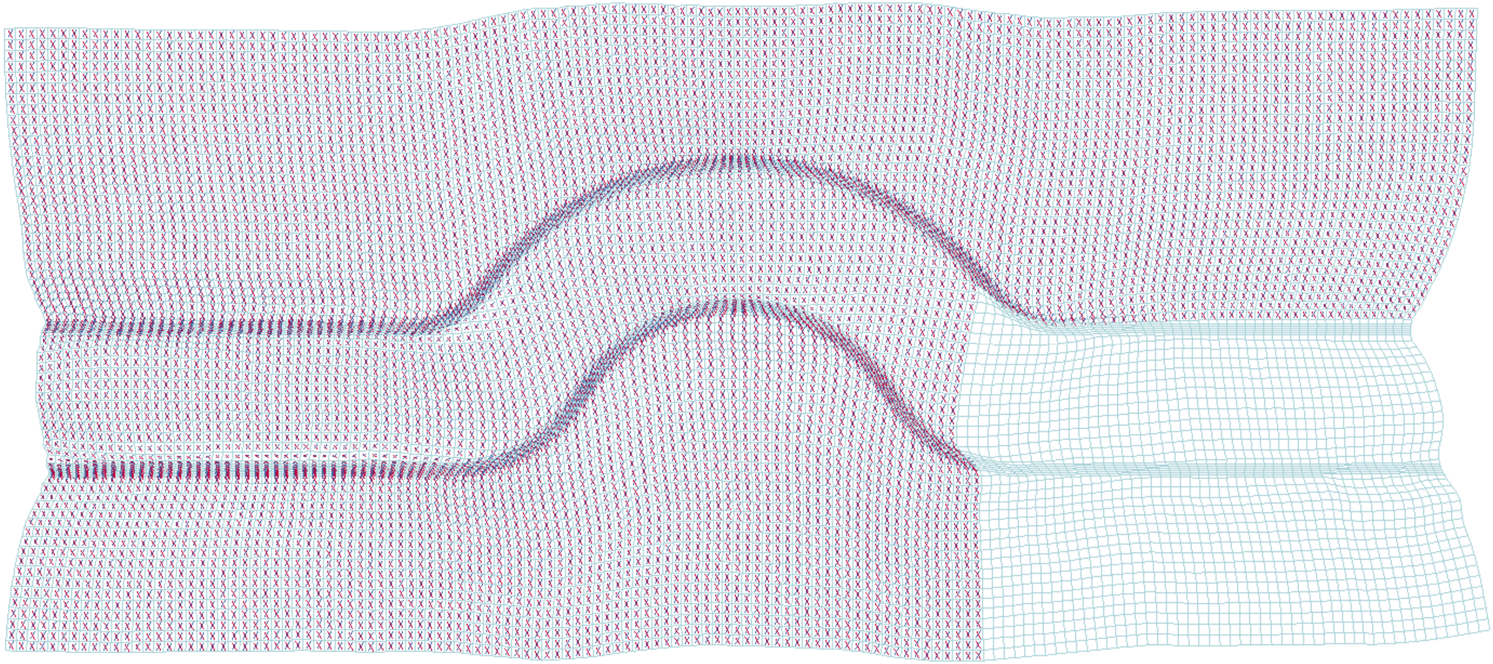




±60 ° - Layer

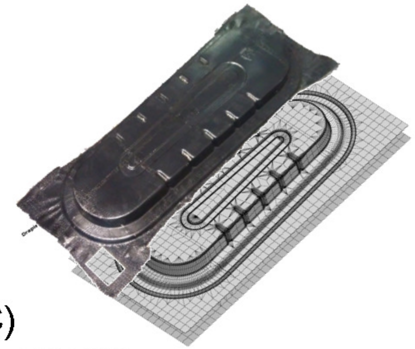




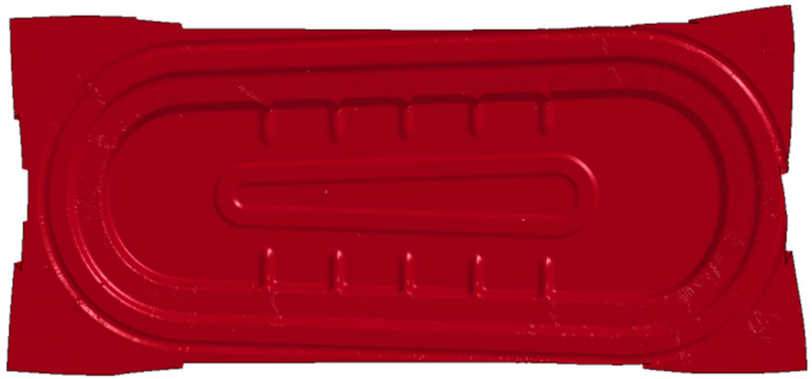


Organo sheet

Process simulation: Organo sheet

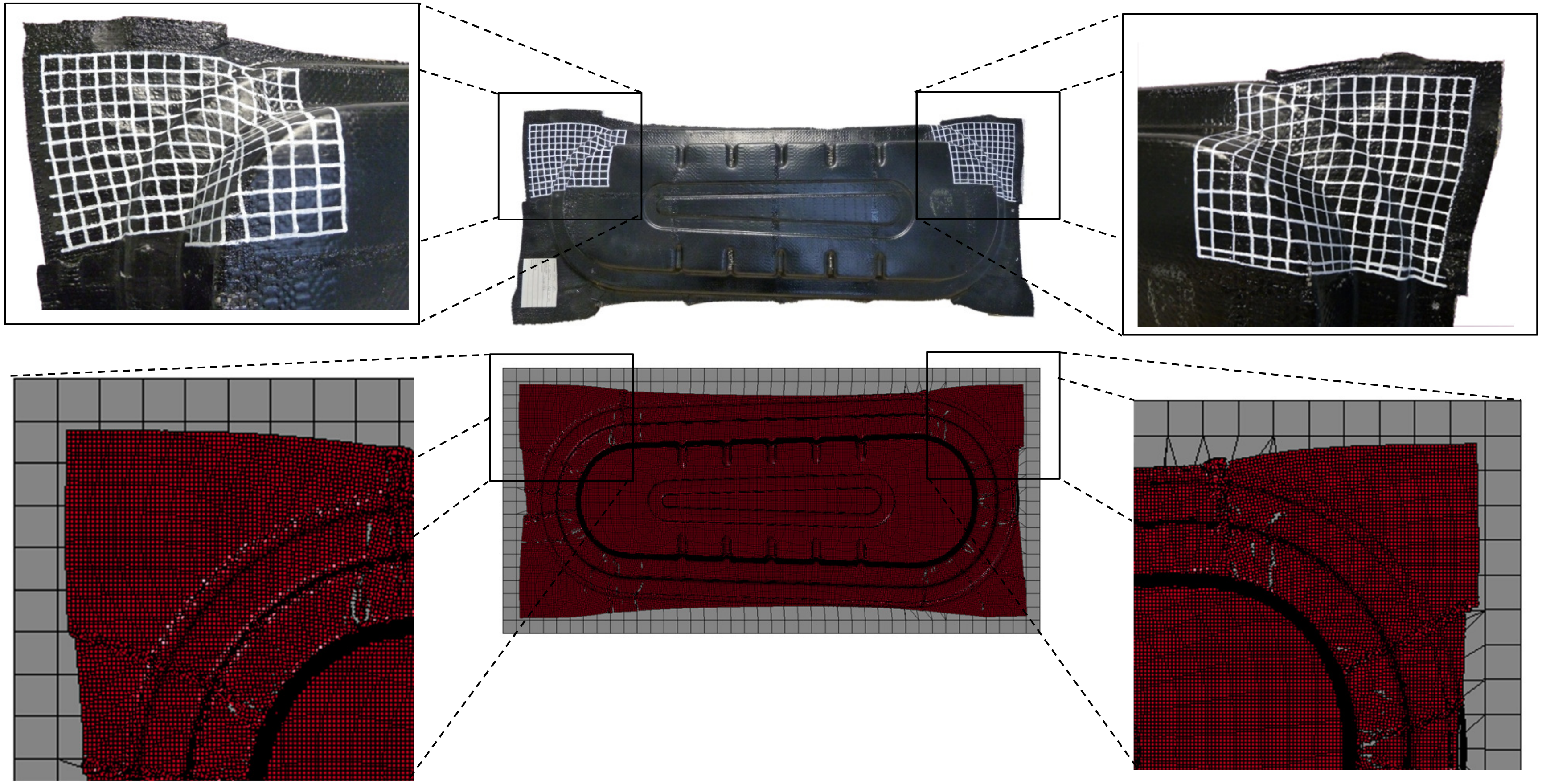


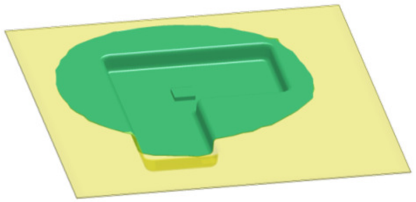
Single layer of woven fabric that is coated on both sides with PA6, t=1.5mm
The forming process is done at 250-300 C.
Modeling: Layered shell with *PART_COMPOSITE defining
plastic material for PA6 at the outsides (*MAT_PLASTIC_KINEMATIC)
and orthotropic material for woven fabric (*MAT_ORTHOTROPIC_ELASTIC)



Process simulation: Organo sheet

Optical comparison of fiber directions (aligned with mesh)



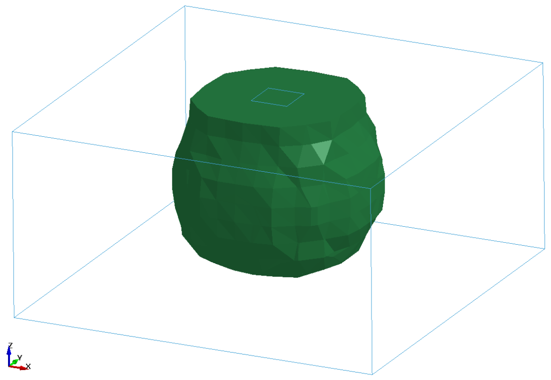


Resin transfer moulding (RTM)

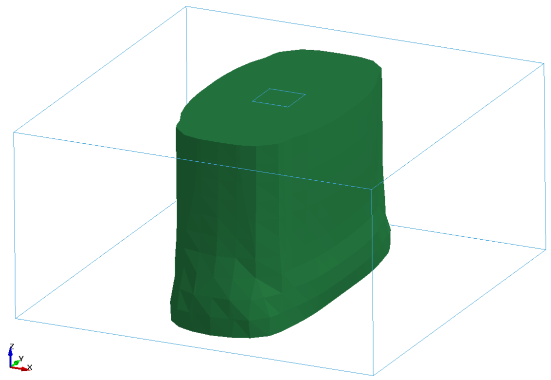
Injection of Resin

- Infiltration is a 3D flow problem through a porous media
- Porosity depends on the packing density of the fibers
- Fiber orientation results in an anisotropic porosity

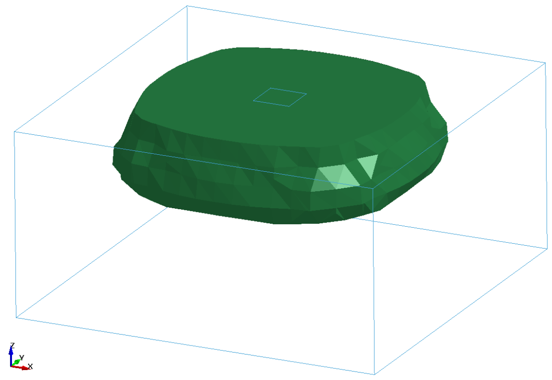
- Flow through porous media can be modeled in LS-DYNA using the CONSTRAINED_LAGRANGE_IN_SOLID keyword



same porosity in all directions

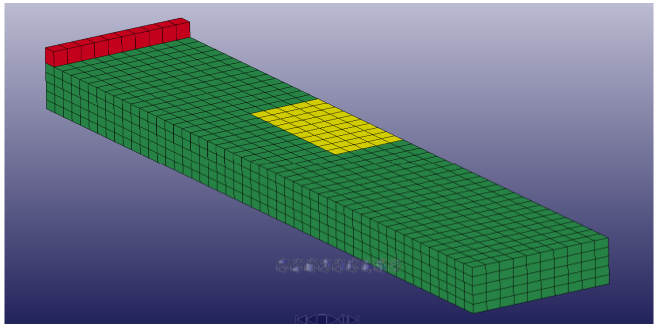


Low porosity in x-direction



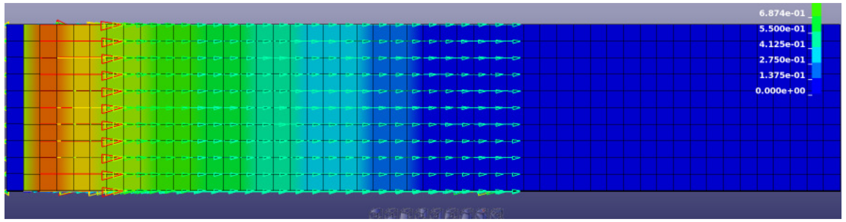
Low porosity in z-direction

Simple test example

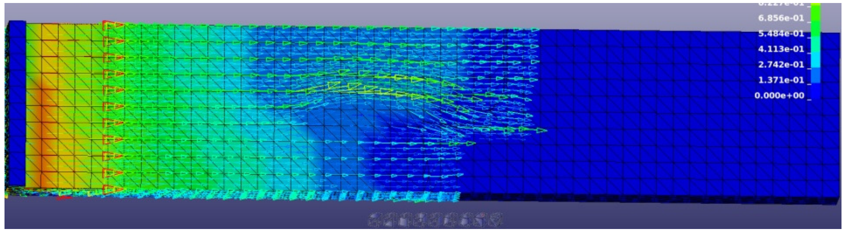


Box with an inclusion
Inflow defined at red elements
Main material (green) and inclusion (yellow) have same/different viscous coefficients.

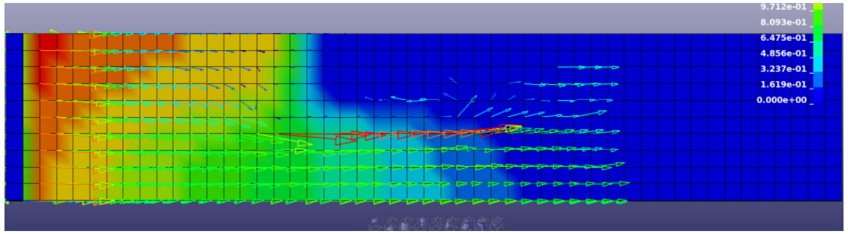
Same porosity coefficients



Inclusion has higher porosity

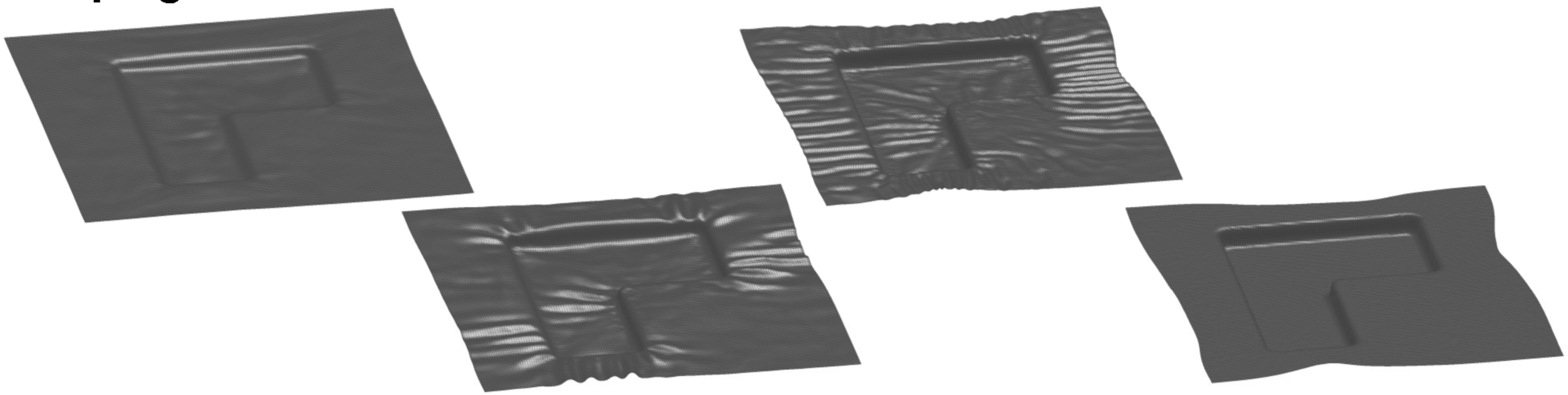


Main material has higher porosity

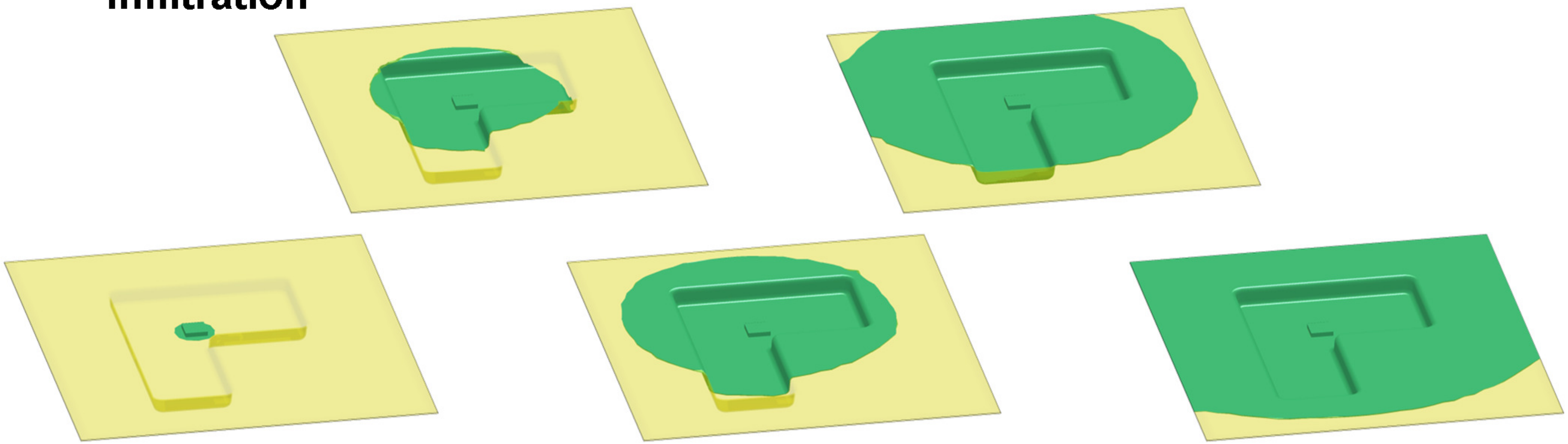


Example: L-Shape

- Draping

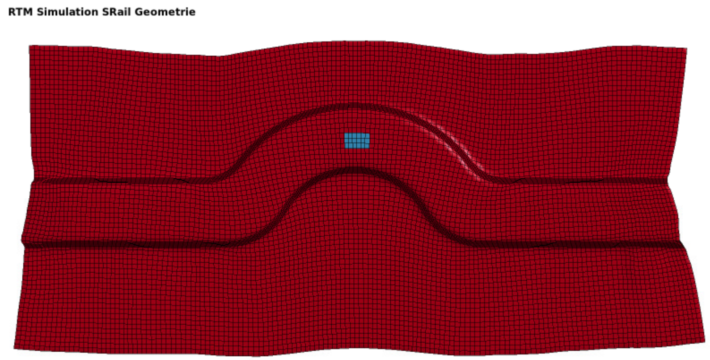


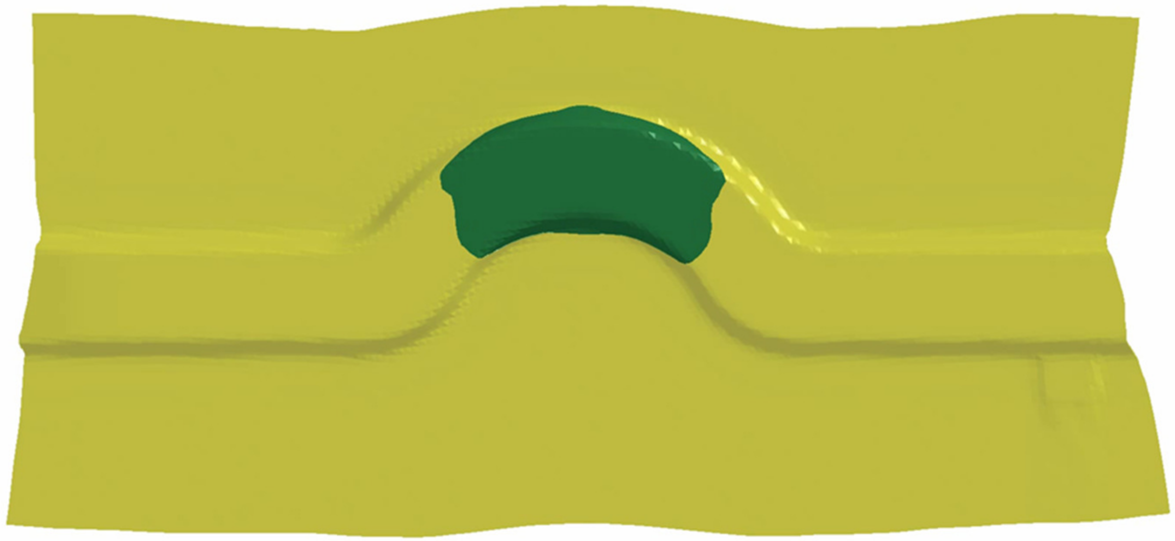
- Infiltration



S-Rail example: Isotropic porosity

- Mesh obtained from draping simulation
- Flow induced by pressure inlet
- One injection point for resin
  is considered (blue)

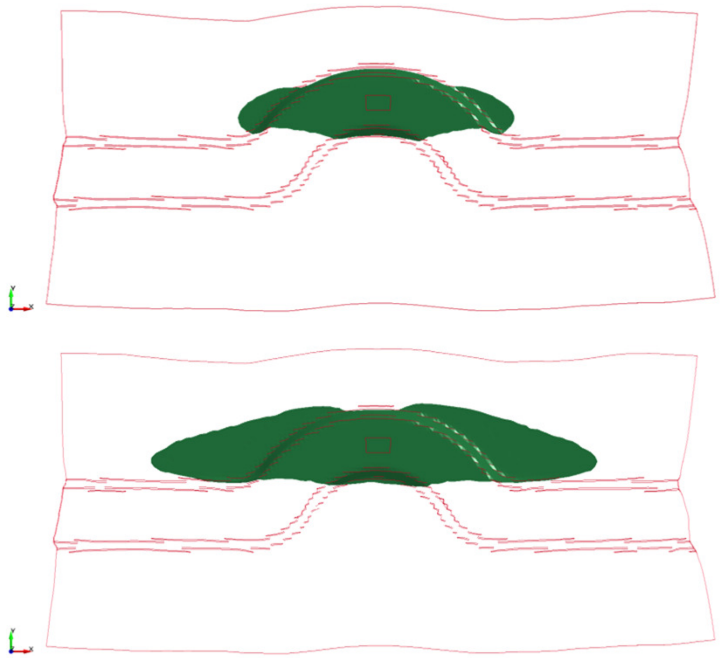




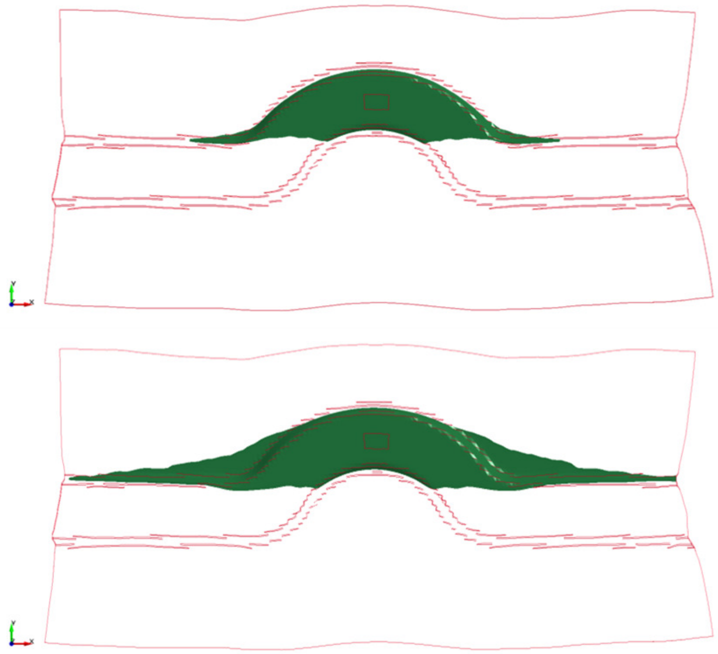
S-Rail example: Anisotropic porosity

- **LS-DYNA allows to define the porosity with respect to the element coordinate system:**
  - Easy to specify a porosity in thickness direction even for curved geometries
  - Important if the geometry results from a previous draping simulation

High porosity in global x-direction



High porosity in element x-direction



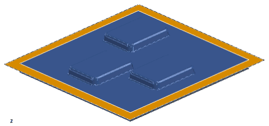
Agenda

- Braiding
- Draping
- Organo sheets
- RTM
- Mapping

Composite process chain: Producibility2Servicability

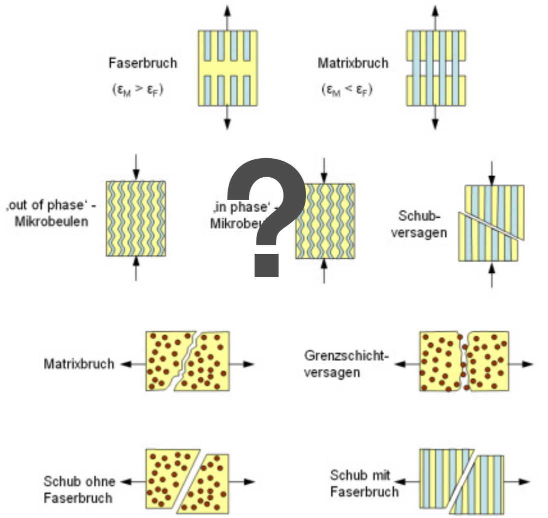
Problem: Different applications use different modeling techniques, constitutive models, standards and validation procedures.

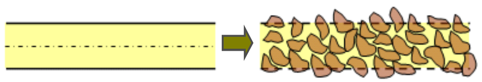
Producibility



GMT, SMC, BMC
LMC or Prepreg?

Anisotropy and inhomogeneity





Length scale?

Const. model mapping

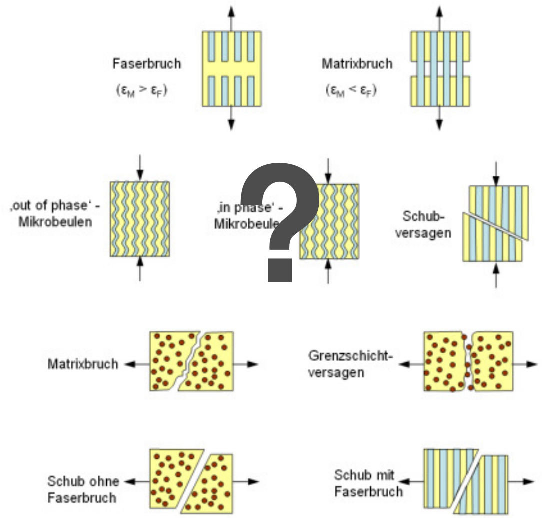
Geometrical mapping

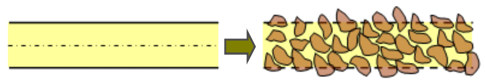
LSTC Livermore Software Technology Corp.

Fraunhofer SCAI Institute Algorithms and Scientific Computing

Serviceability

Anisotropy and inhomogeneity

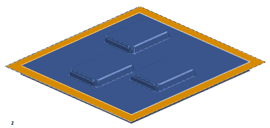




Composite process chain: Producibility2Servicability

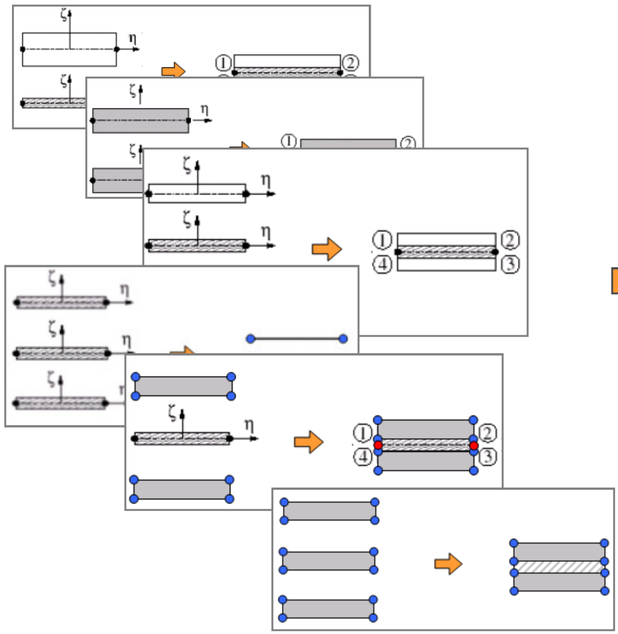
Problem: Different applications use different modeling techniques, constitutive models, standards and validation procedures.

Producibility



GMT, SMC, BMC
LMC or Prepreg?

Anisotropy and inhomogeneity



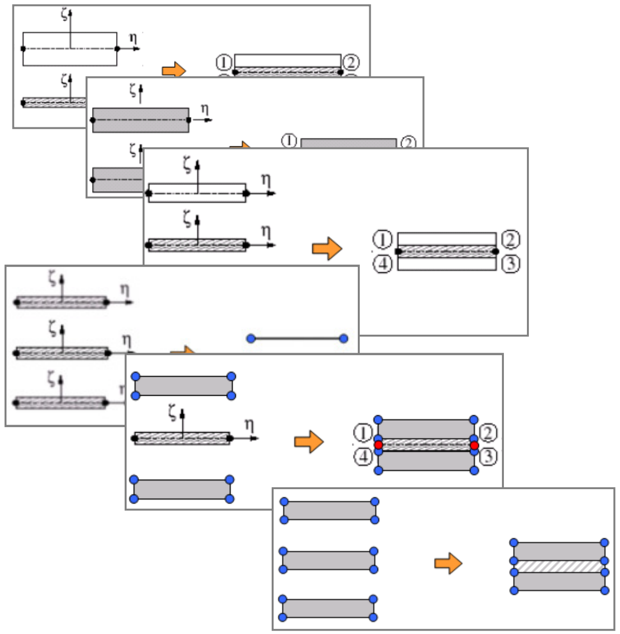
Modeling technique

Const. model mapping

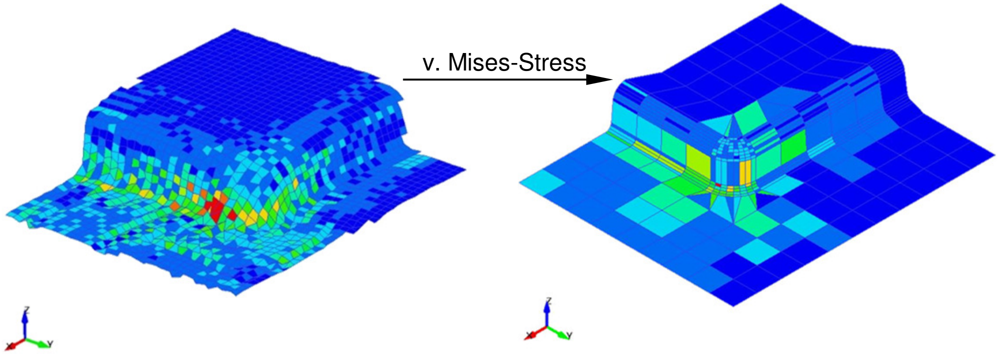
Geometrical mapping

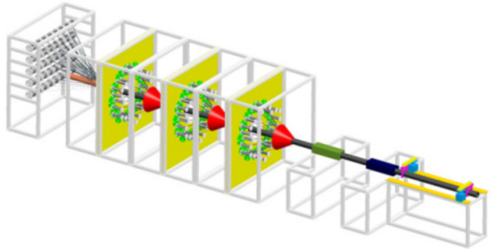
Serviceability

Anisotropy and inhomogeneity



Project TPult





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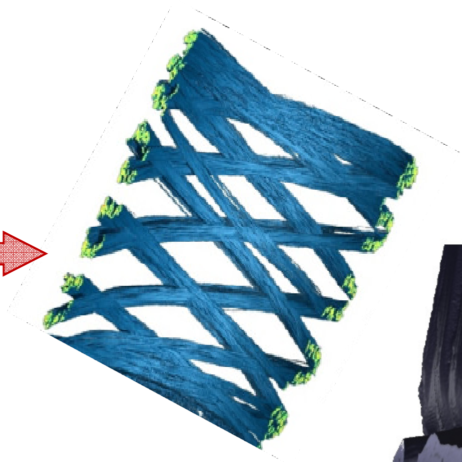
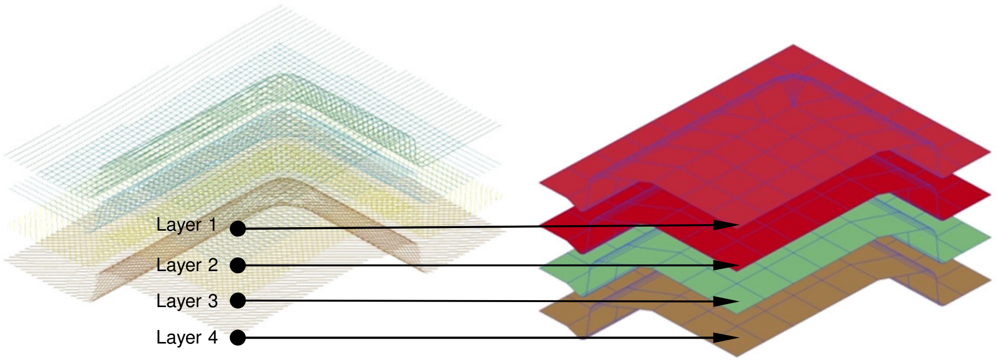
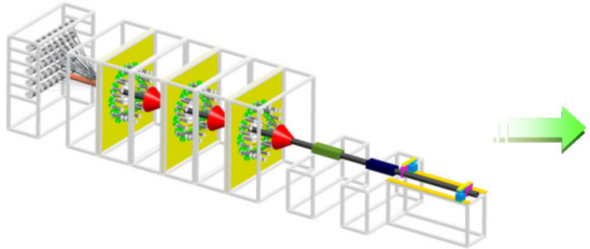


[H. Finkh: ITV Denkendorf]

Project TPult





ITV DENKENDORF

DYNA MORE

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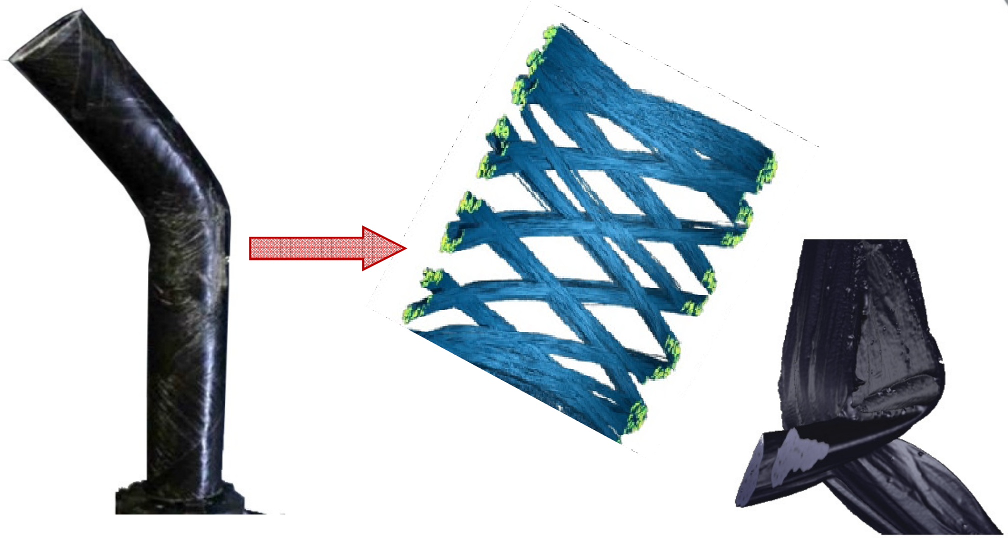
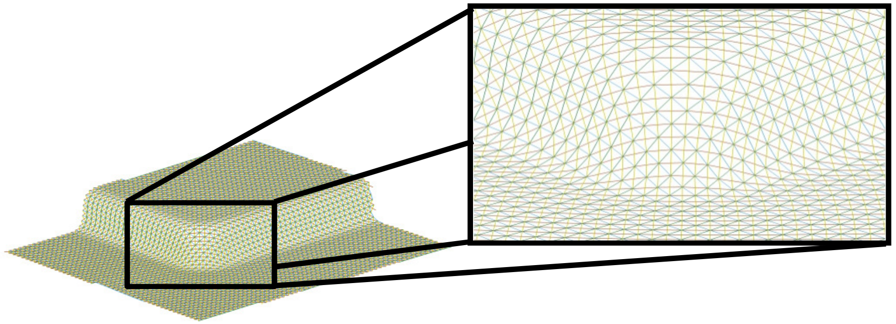
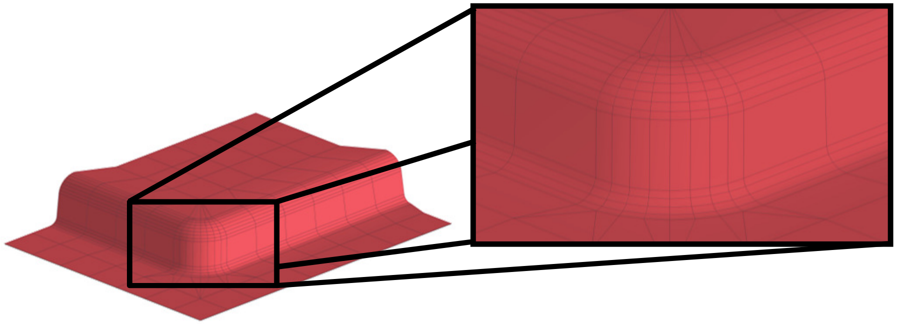


[H. Finkh: ITV Denkendorf]

Homogenization strategies

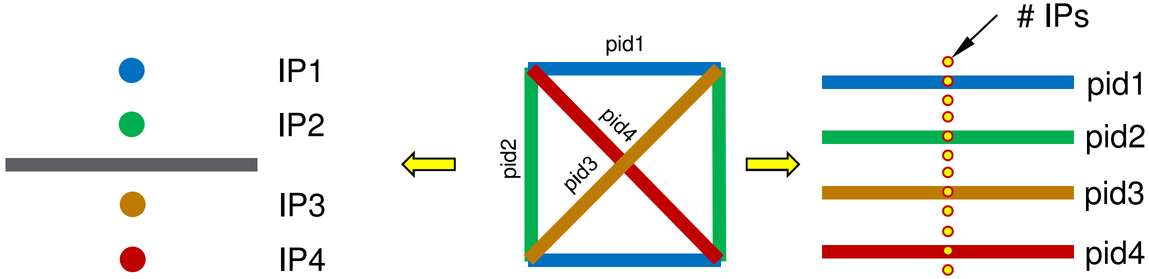


Source Mesh:
four Parts
10461 Beam Elements
avg. length: 1.65 – 3.30 mm

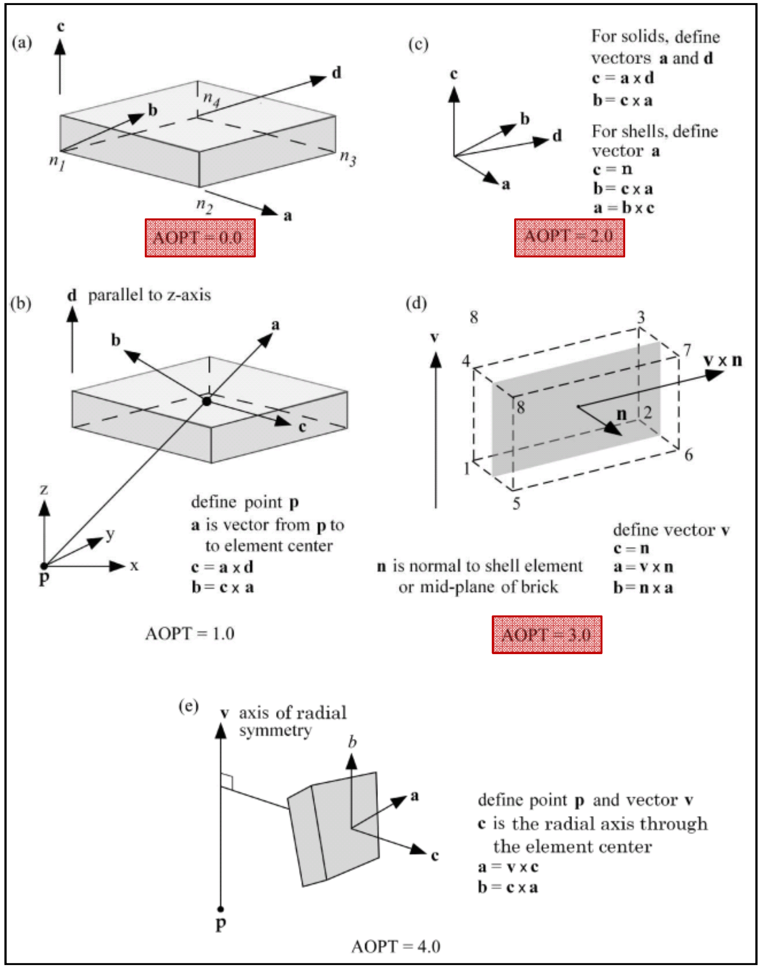


Target Mesh:
one or four Parts
4x 300 Shell Elements
avg. length: 1.80 – 18.40 mm

Homogenization strategies:

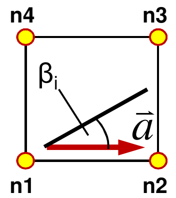


Fiber orientation definition



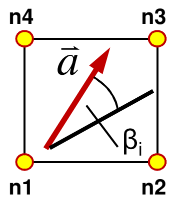
AOPT considered so far…

AOPT = 0



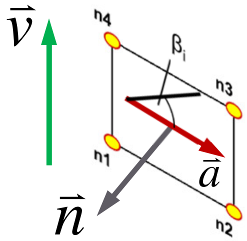
No further user-input required
Main fiber direction determined by the element's main axis (n1 -> n2)
β_i can be varied by *ELEMENT_SHELL_-COMPOSITE or *PART_COMPOSITE

AOPT = 2



Vector $\vec{a}$ has to be user-defined
β_i can be varied by *ELEMENT_SHELL_-COMPOSITE or *PART_COMPOSITE

AOPT = 3



Vector $\vec{v}$ has to be user-defined
Main fiber direction $\vec{a} = \vec{v} \times \vec{n}$
β_i can be varied by *ELEMENT_SHELL_-COMPOSITE or *PART_COMPOSITE

***PART_COMPOSITE(_TSHELL)**

```
Composite Lay up
$--------1---------2---------3---------4---------5---------6---------7---------8
$      PID|   ELFORM|     SHRF|     NLOC|    MAREA|     HGID|    ADOPT|
$     MID1|   THICK1|    BETA1|              MID2|   THICK2|    BETA2|
$     MID3|   THICK3|    BETA3|              MID4|   THICK4|    BETA4|
                                 .
                                 .
                                 .
```

***ELEMENT_(T)SHELL_COMPOSITE**

```
Composite Lay up
$------1-------2-------3-------4-------5-------6-------7-------8-------9------10
$    EID|    PID|     N1|     N2|     N3|     N4|     N5|     N6|     N7|     N8|
$     MID1|   THICK1|    BETA1|              MID2|   THICK2|    BETA2|
$     MID3|   THICK3|    BETA3|              MID4|   THICK4|    BETA4|
                                 .
                                 .
                                 .
```

***ELEMENT_(T)SHELL_BETA**

```
Composite Lay up
$------1-------2-------3-------4-------5-------6-------7-------8-------9------10
$    EID|    PID|     N1|     N2|     N3|     N4|     N5|     N6|     N7|     N8|
$          THICK1|         THICK2|         THICK3|         THICK4|          BETA|
```

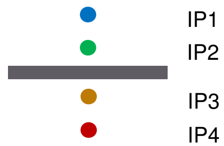
***MAT_ORTHOTROPIC_ELASTIC**

```
$--------1---------2---------3---------4---------5---------6---------7---------8
$      MID|       RO|       EA|       EB|       EC|     PRBA|     PRCA|     PRCB|
$      GAB|      GBC|      GCA|     AOPT|
$       XP|       YP|       ZP|       A1|       A2|       A3|     MACF|
$       V1|       V2|       V3|       D1|       D2|       D3|     BETA|      REF|
```

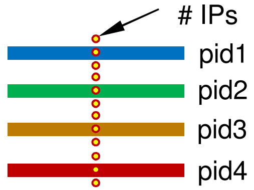
Fiber orientations as a result of a combination of AOPT &

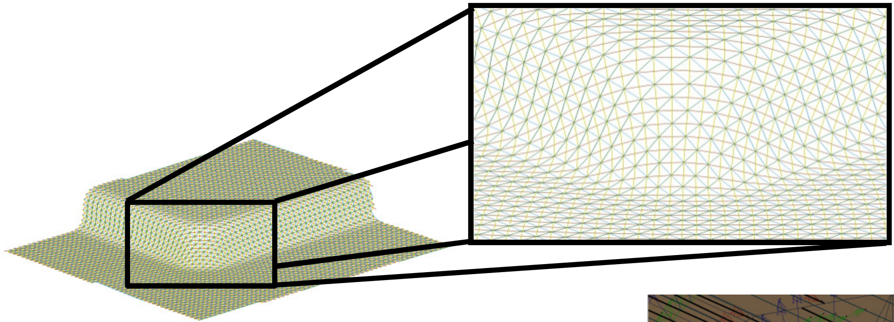
$$\theta_i = \beta + \beta_i$$

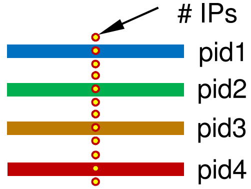
*Part_Composite
*Element_Shell_Composite
Diff. Materials for each integration point conceivable



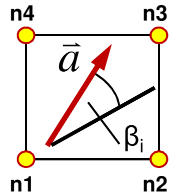
Stacked *Element_Shell_Beta
*Element_Shell & diff. Materials
Cohesive Elements/*Tiebreak Contact modeling required







AOPT = 2



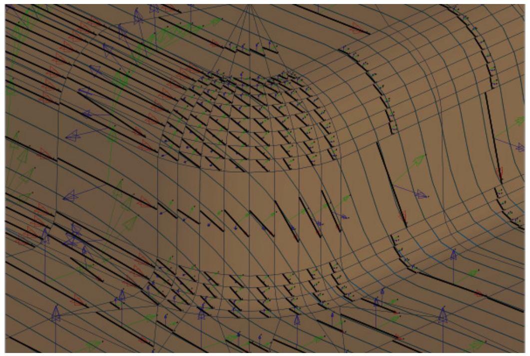
Vector $\vec{a}$ is given directly by the orientations of the beam elements

*ELEMENT_SHELL_COMPOSITE or *PART_COMPOSITE

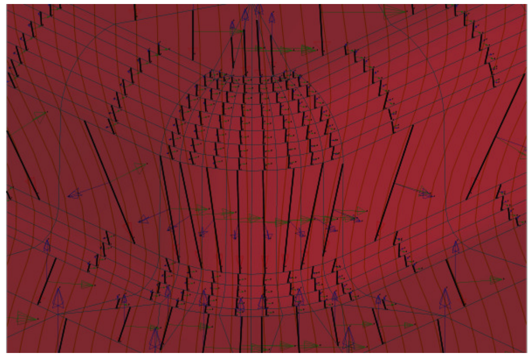
Main disadvantage:

- Each element get's an assigned material card -> 300 elements eq. 300 diff. material cards
- good as a first tryout, but not relevant for any kind of simulation

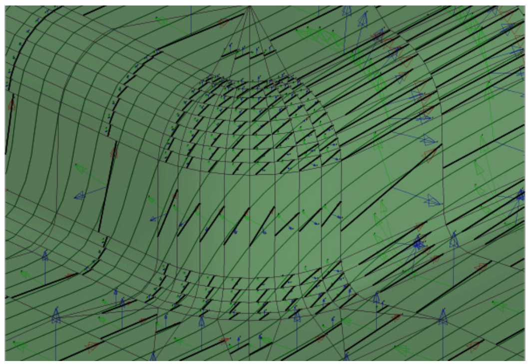
Layer 1



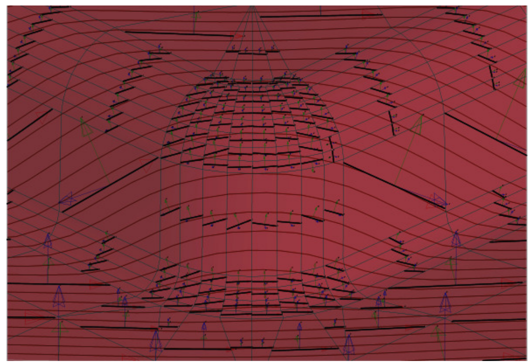
Layer 3



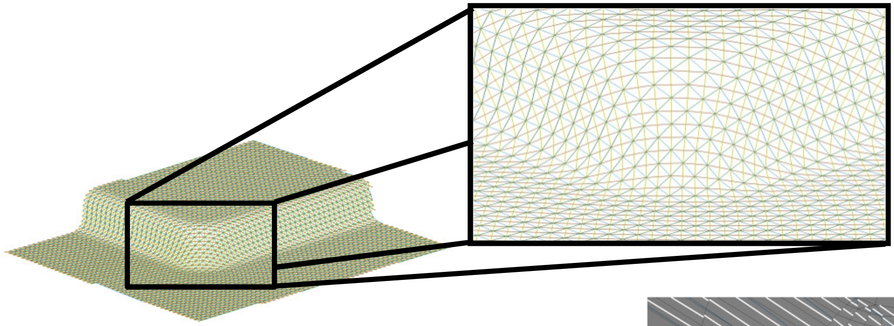
Layer 2



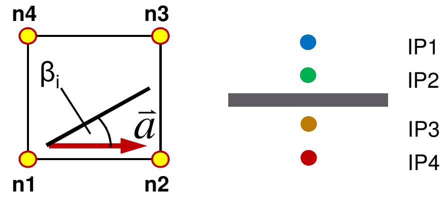
Layer 4

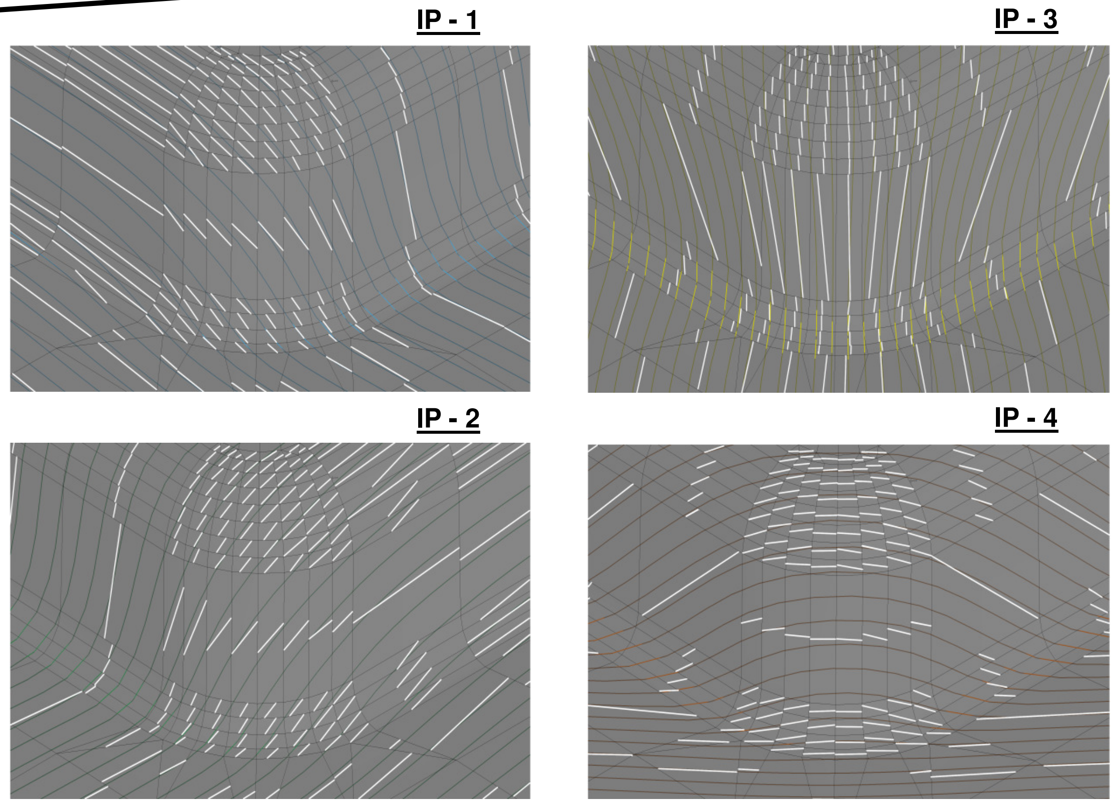


Usage of Element-Direction:



AOPT = 0





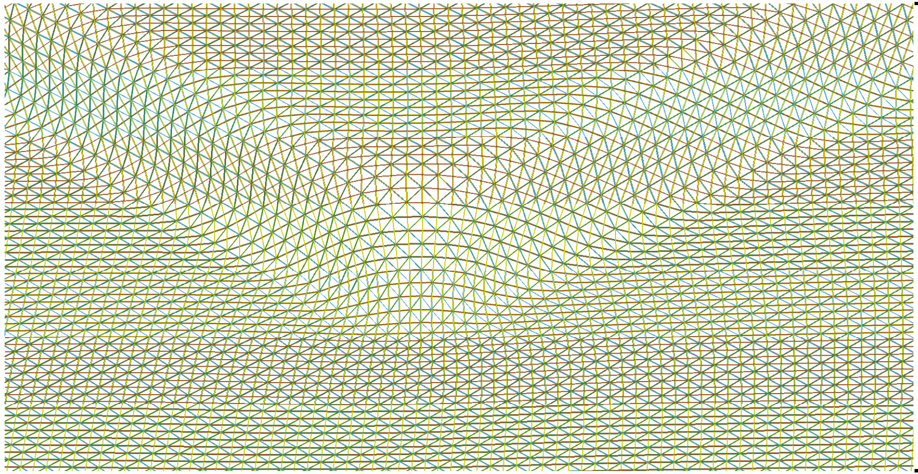
Vector $\vec{a}$ is given directly by the element orientation

*ELEMENT_SHELL_COMPOSITE or *PART_COMPOSITE

Identifiaction of β_i is a little bit more complicated than writing fiber orientation directly into the material card

Only one material card per part! Relevant for crash simulations…

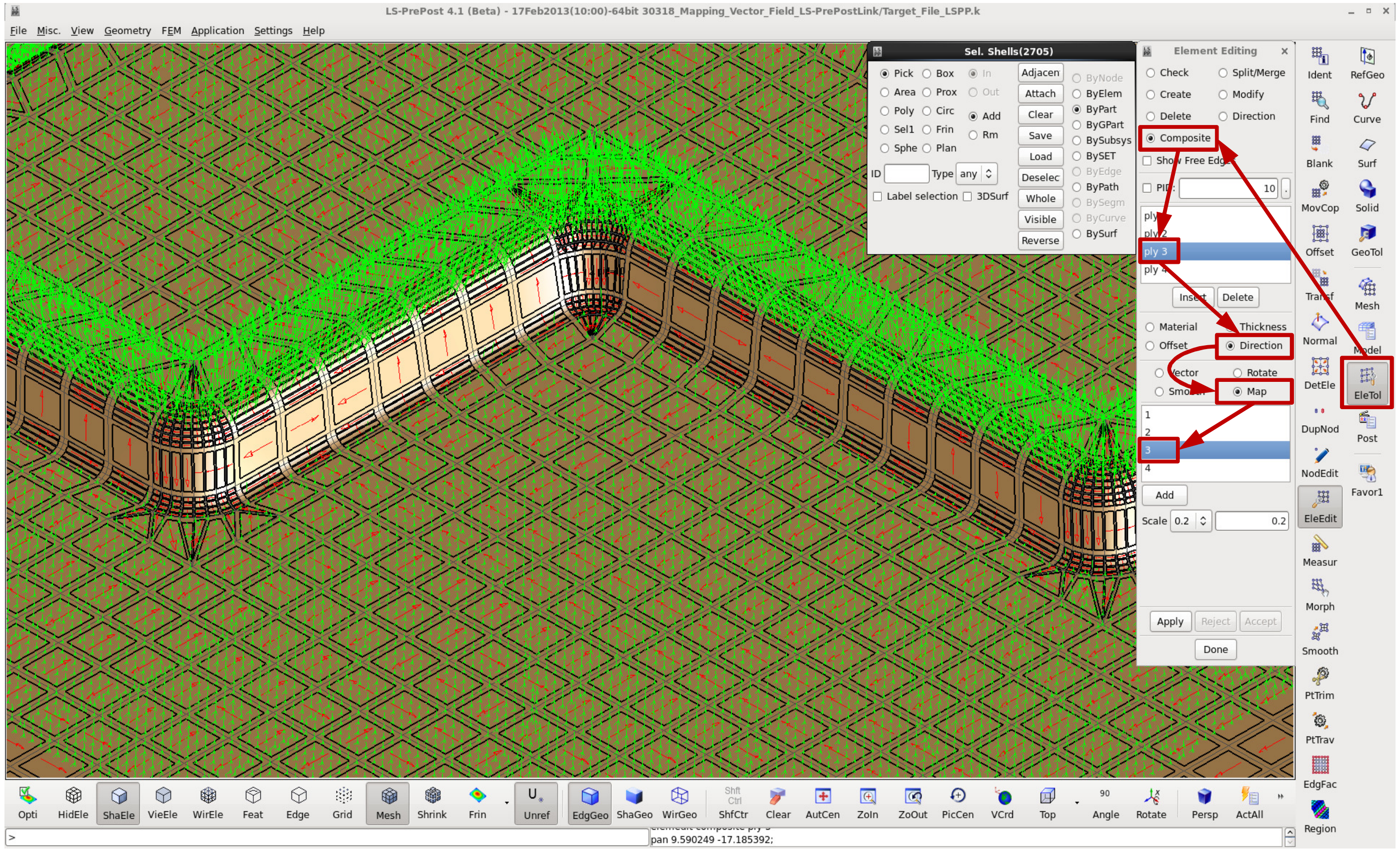
Mapping with LS-PrePost



Generate vector fields for each main fiber direction (four in this case)
*.dvm - File

Origin	Direction
0.291E+03 0.316E+03 0.506E+02	-0.110E-01-0.200E+01 0.000E+00
0.287E+03 0.316E+03 0.506E+02	-0.106E-01-0.200E+01 0.000E+00
0.283E+03 0.316E+03 0.506E+02	-0.970E-02-0.200E+01 0.800E-05
0.279E+03 0.316E+03 0.506E+02	-0.858E-02-0.200E+01 0.000E+00
0.275E+03 0.316E+03 0.506E+02	-0.714E-02-0.200E+01-0.400E-05
0.271E+03 0.316E+03 0.506E+02	-0.546E-02-0.200E+01 0.000E+00
0.267E+03 0.316E+03 0.507E+02	-0.369E-02-0.200E+01 0.000E+00
0.263E+03 0.316E+03 0.507E+02	-0.180E-02-0.200E+01 0.000E+00
0.259E+03 0.316E+03 0.506E+02	-0.600E-04-0.200E+01 0.530E-04
0.256E+03 0.316E+03 0.506E+02	0.160E-02-0.200E+01 0.221E-03
0.252E+03 0.316E+03 0.506E+02	0.310E-02-0.200E+01 0.511E-03
0.248E+03 0.316E+03 0.506E+02	0.454E-02-0.200E+01 0.881E-03
0.244E+03 0.316E+03 0.506E+02	0.580E-02-0.200E+01 0.129E-02

Mapping with LS-PrePost



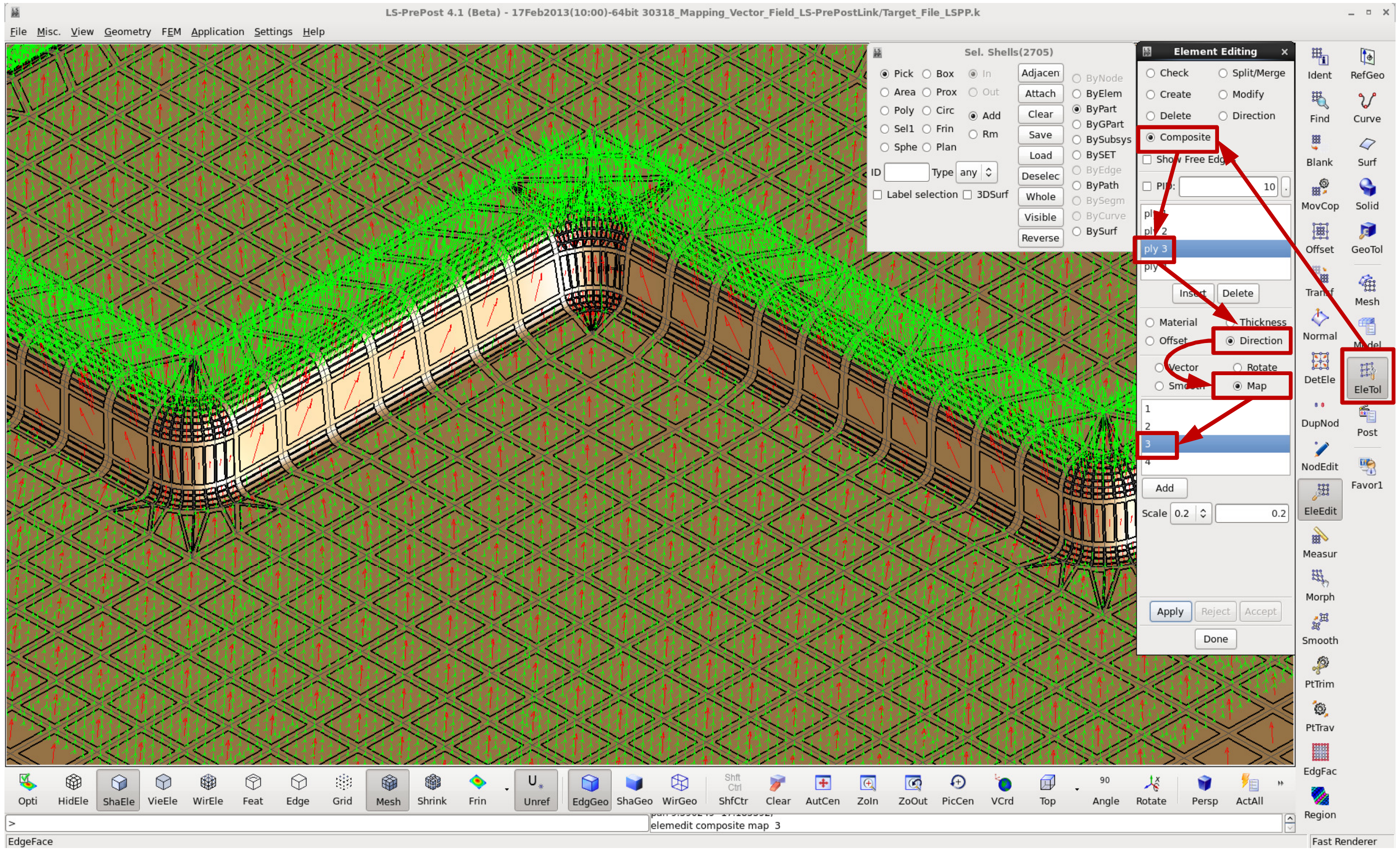
Load vector field into LS-PrePost using the Composite-Modeling feature:

Eletol -> Composite -> Map

For each ply, fiber directions can be mapped

Output will be *ELEMENT_-SHELL_COMPOSITE for LS-DYNA input deck

Mapping with LS-PrePost



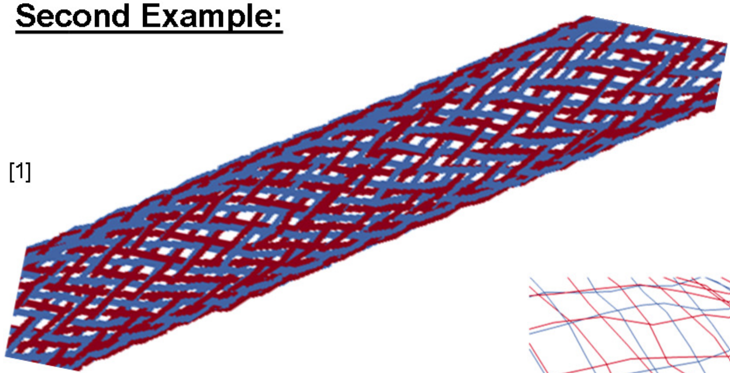
Load vector field into LS-PrePost using the Composite-Modeling feature:

Eletol -> Composite -> Map

For each ply, fiber directions can be mapped

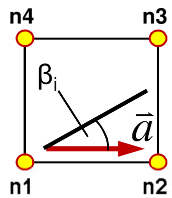
Output will be *ELEMENT_-SHELL_COMPOSITE for LS-DYNA input deck

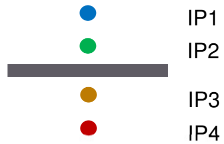
Second Example:



[1]

AOPT = 0





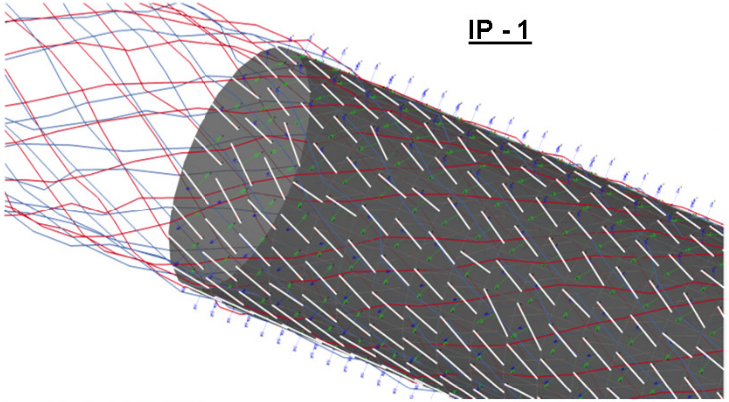
Vector $\vec{a}$ is given directly by the element orientation

*ELEMENT_SHELL_-COMPOSITE or *PART_COMPOSITE

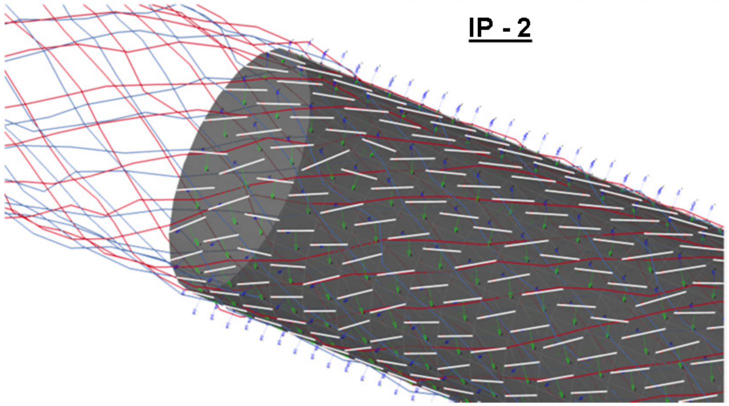
Identifiaction of β_i is a little bit more complicated than writing fiber orientation directly into the material card

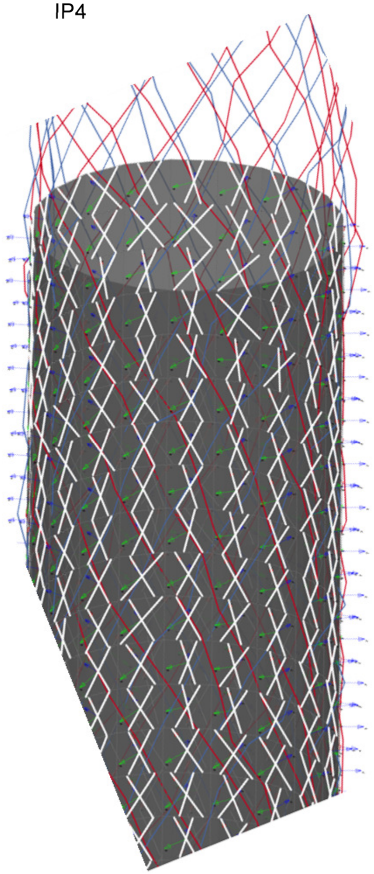
Only one material card per part! Relevant for crash simulations…

IP - 1



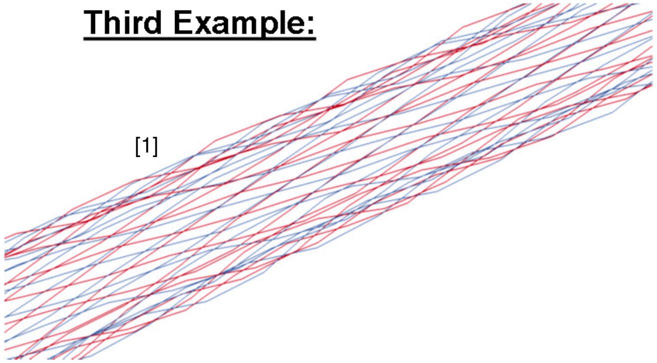
IP - 2



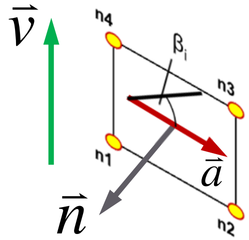


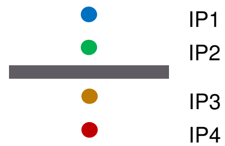
[1] H. Finckh, ITV Denkendorf

Third Example:



AOPT = 3





Vector $\vec{a}$ is given directly by the element orientation

*ELEMENT_SHELL_-COMPOSITE or *PART_COMPOSITE

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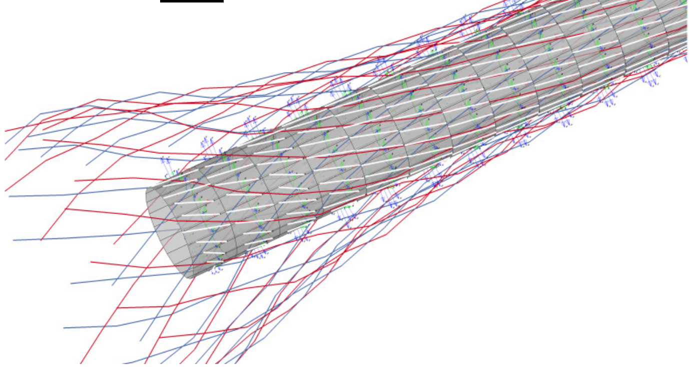
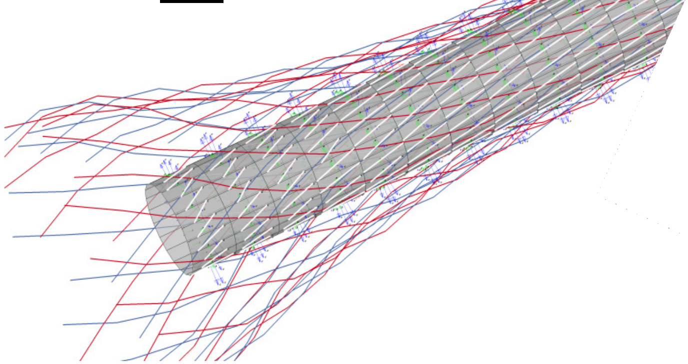
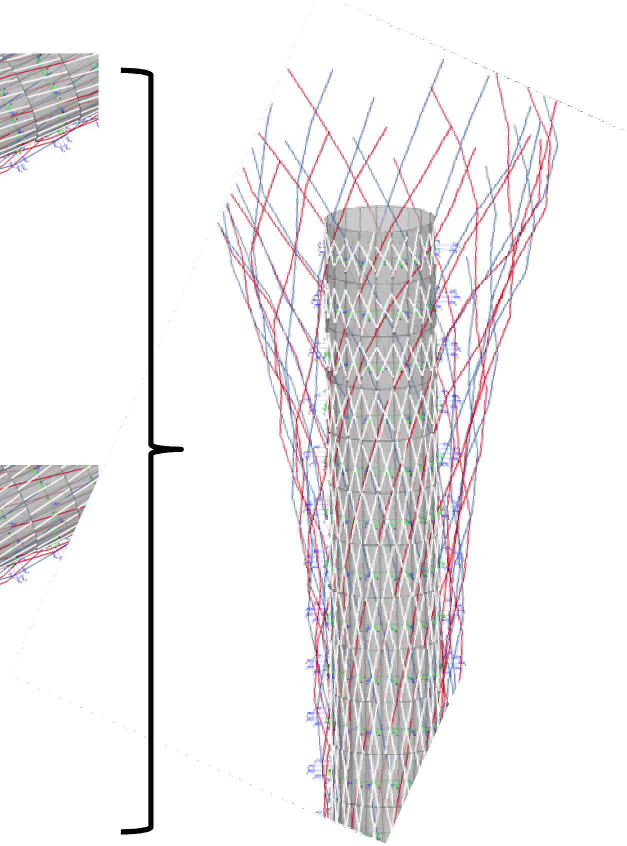
IP - 1



IP - 2





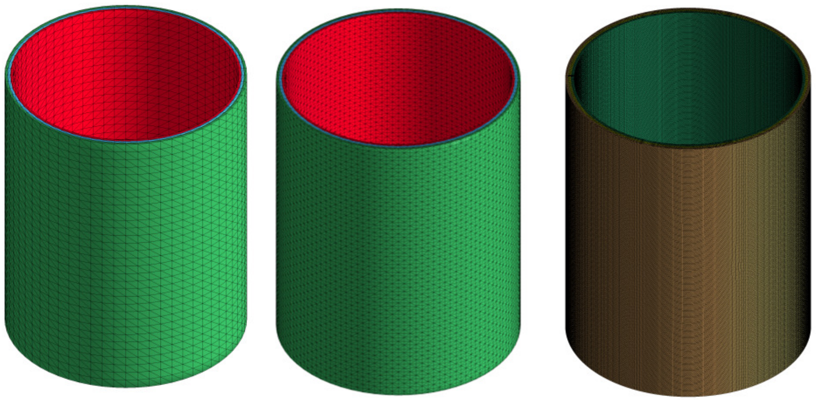
[1] H. Finckh, ITV Denkendorf

Mapping from experimental data

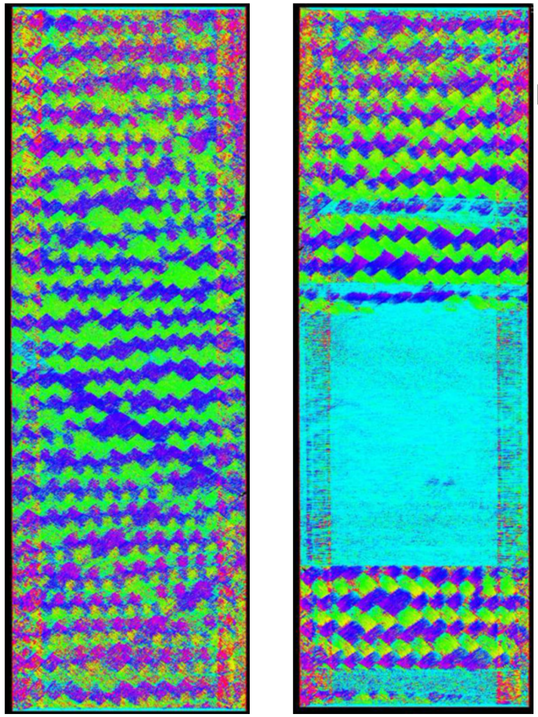
so far: transfer of fiber orientation-tensors onto a LS-DYNA mesh
Input: patran-format mesh, output: csv-file containing orientation tensor & fiber-volume ration per element, transfer as *INITIAL_STRESS_SOLID data for visualization purposes only
Three different mesh sizes considered so far: Coarse, Mean, Fine
Example-part: 3-layered braided tupe with 0-deg reinforcement fibers
Further enhancements supposed to work with Hexa-elements, maybe with (T)shell elements

	Num. of Elements	Layers	Element-Size
Coarse Mesh	38420	1	0,3 - 1,25 mm
Mean Mesh	150039	2	0,15 - 0,62 mm
Fine Mesh	15078400	4	0,075 - 0,1 mm

Coarse Mesh **Mean Mesh** **Fine Mesh**



First Layer **Second Layer**



[1]

[1] H. Finckh, ITV Denkendorf

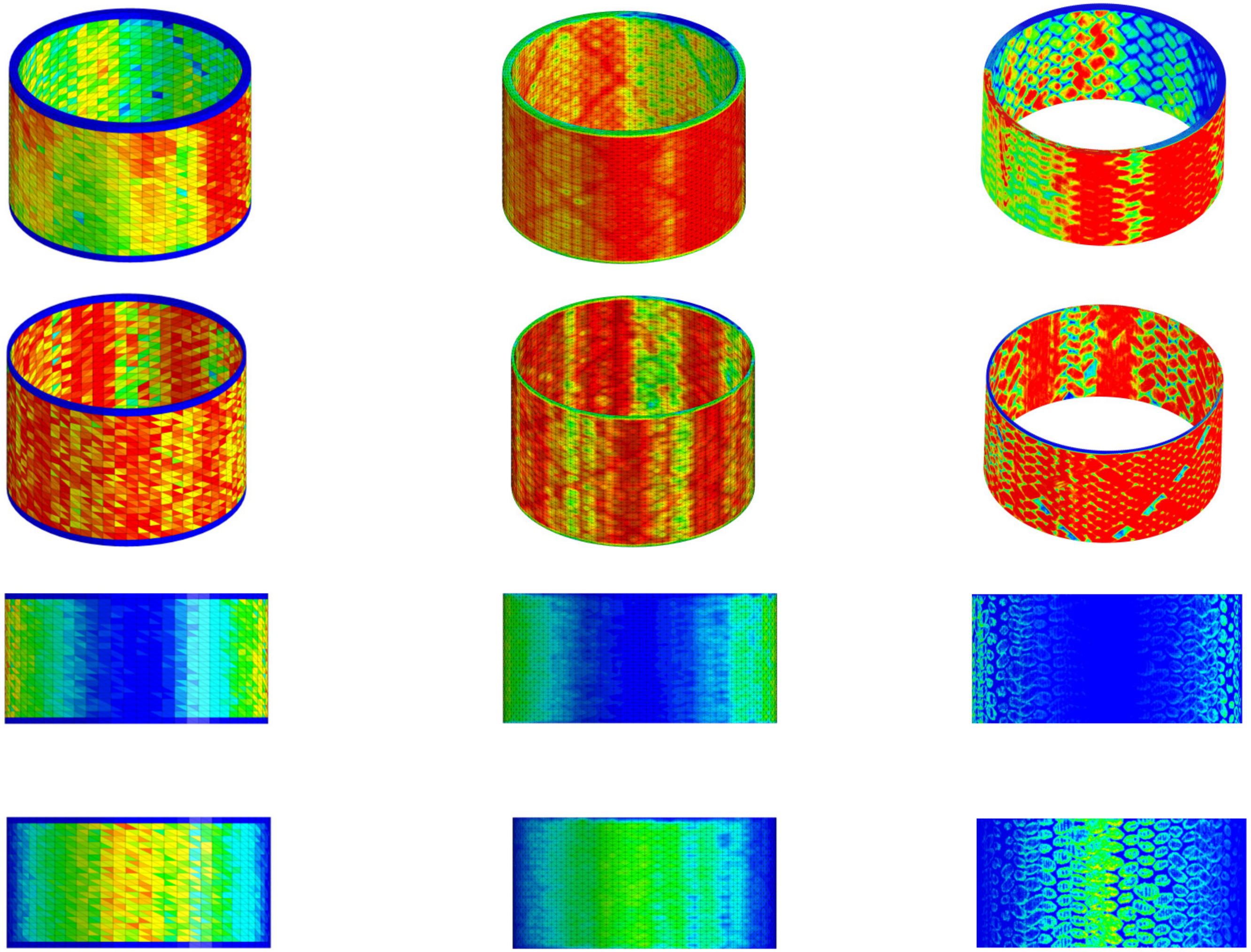
Mapping from experimental data

Fiber-Volume Fraction:

z-Orientation – Layer 2:

x-Orientation:

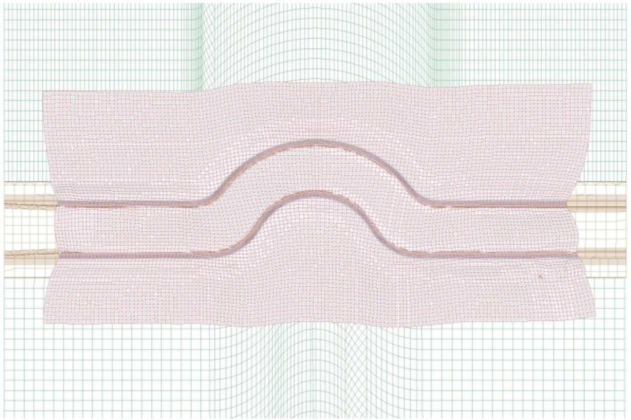
y-Orientation:



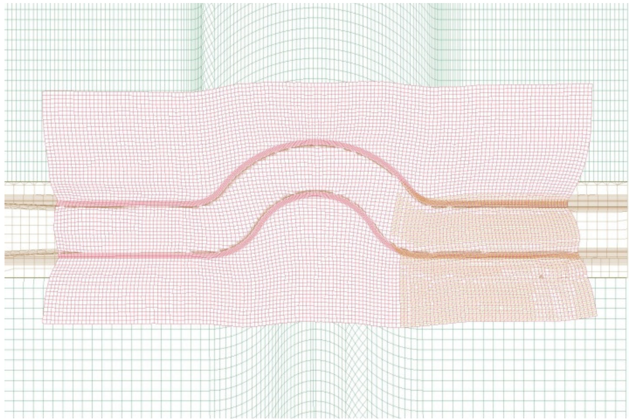
Coarse Mesh | **Mean Mesh** | **Fine Mesh**

Mapping from LSDA output

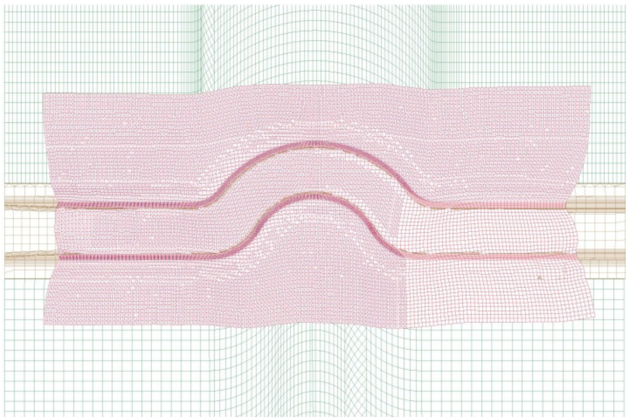
PlyID #1



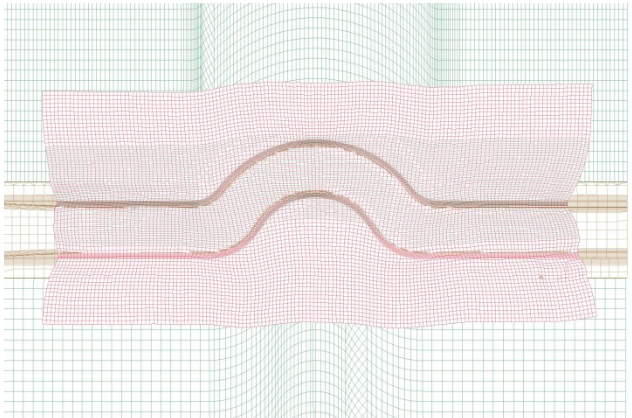
PlyID #3



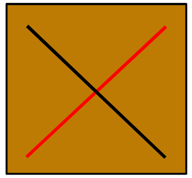
PlyID #5



PlyID #7



PlyID #1



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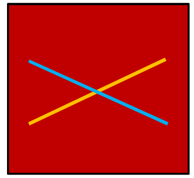
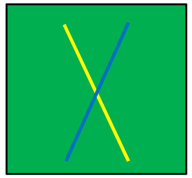
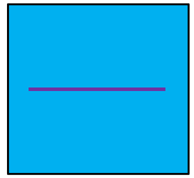


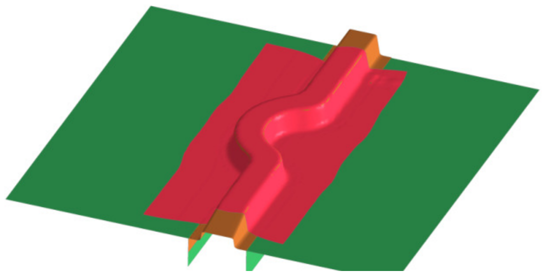
PlyID #5

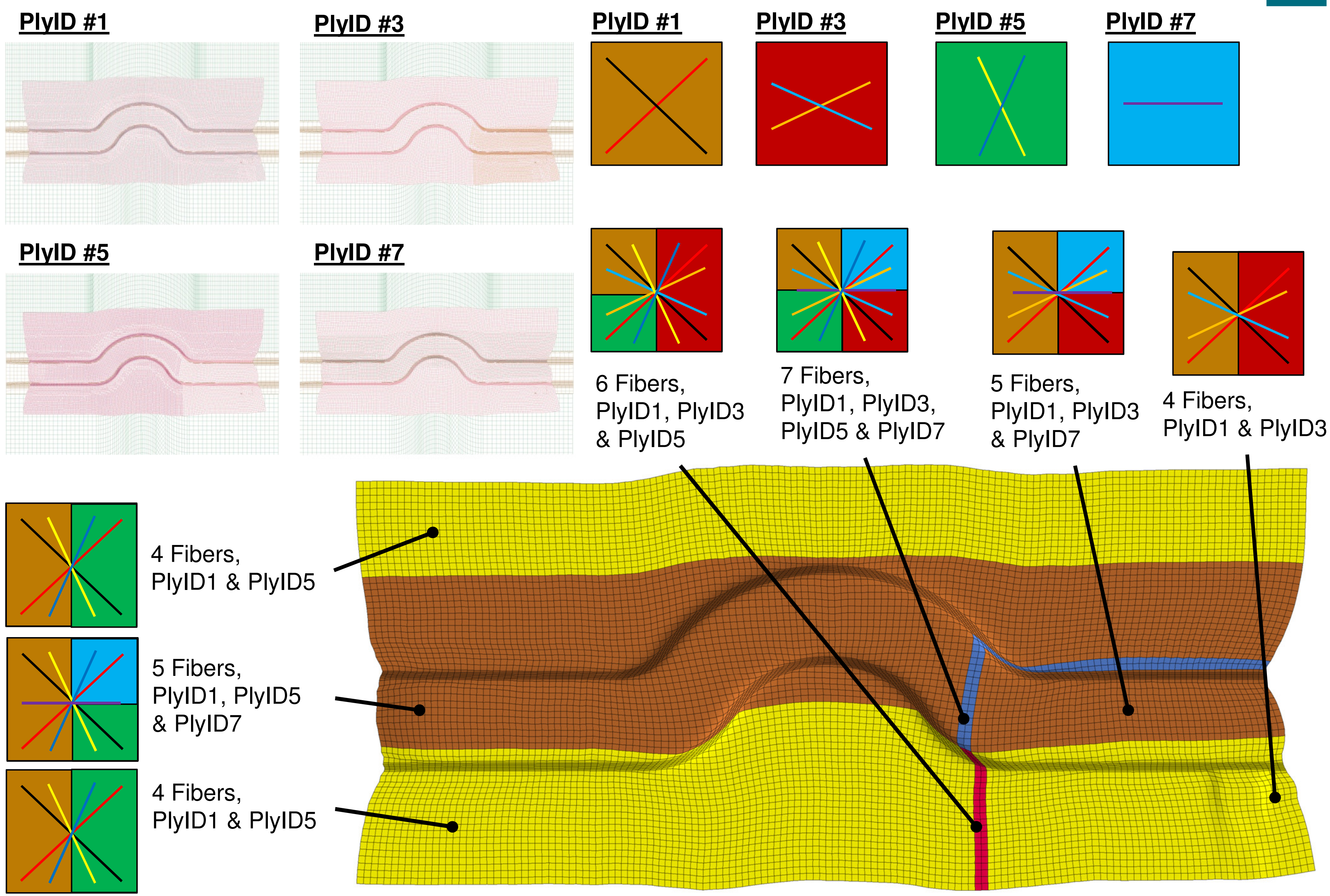


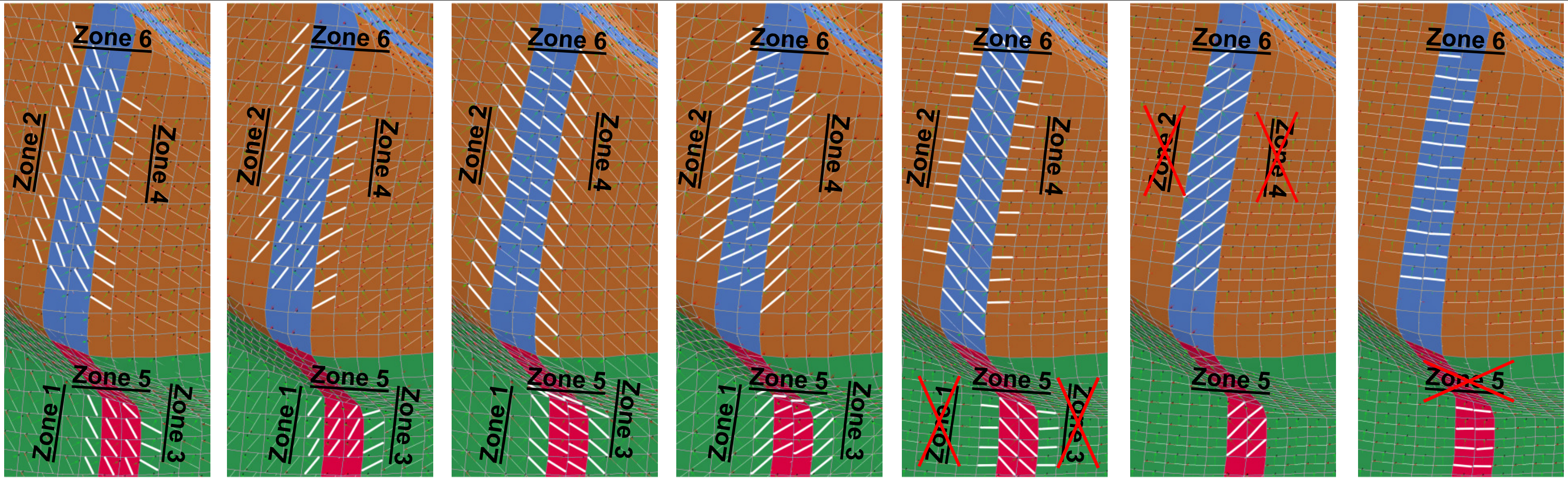
PlyID #7



Schichtaufbau:
PlyID #5
PlyID #3
PlyID #1
PlyID #7




PlyID #1
PlyID #3
PlyID #5
PlyID #7
PlyID #1
PlyID #3
PlyID #5
PlyID #7
6 Fibers, PlyID1, PlyID3 & PlyID5
7 Fibers, PlyID1, PlyID3, PlyID5 & PlyID7
5 Fibers, PlyID1, PlyID3 & PlyID7
4 Fibers, PlyID1 & PlyID3
4 Fibers, PlyID1 & PlyID5
5 Fibers, PlyID1, PlyID5 & PlyID7
4 Fibers, PlyID1 & PlyID5



Zone 1 Zone 2
PlyID #5 PlyID #5
PlyID #1 PlyID #1
PlyID #7

Zone 3 Zone 4
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

Zone 5 Zone 6
PlyID #5 PlyID #5
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

IP #1

Zone 1 Zone 2
PlyID #5 PlyID #5
PlyID #1 PlyID #1
PlyID #7

Zone 3 Zone 4
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

Zone 5 Zone 6
PlyID #5 PlyID #5
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

IP #2

Zone 1 Zone 2
PlyID #5 PlyID #5
PlyID #1 PlyID #1
PlyID #7

Zone 3 Zone 4
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

Zone 5 Zone 6
PlyID #5 PlyID #5
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

…

Zone 1 Zone 2
PlyID #5 PlyID #5
PlyID #1 PlyID #1
PlyID #7

Zone 3 Zone 4
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

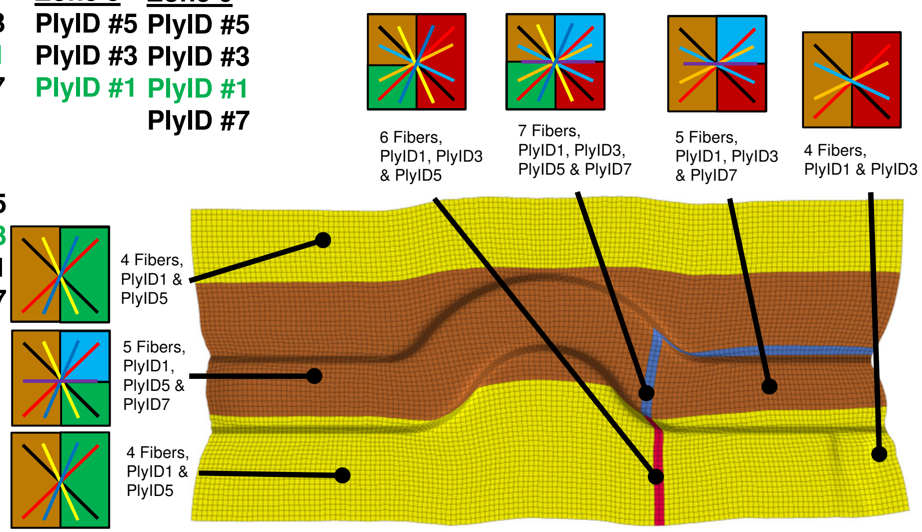
Zone 5 Zone 6
PlyID #5 PlyID #5
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

Zone 2 Zone 4
PlyID #5 PlyID #3
PlyID #1 PlyID #1
PlyID #7 PlyID #7

Zone 5 Zone 6
PlyID #5 PlyID #5
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

Zone 5 Zone 6
PlyID #5 PlyID #5
PlyID #3 PlyID #3
PlyID #1 PlyID #1
PlyID #7

Zone 6
PlyID #5
PlyID #3
PlyID #1
PlyID #7



Vielen Dank!