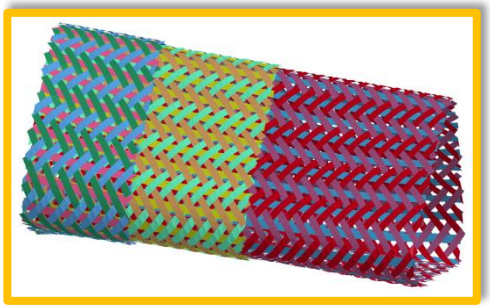

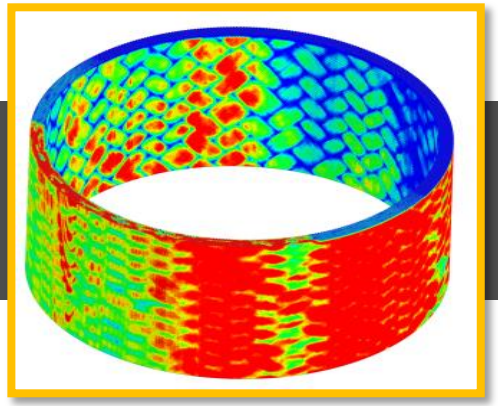

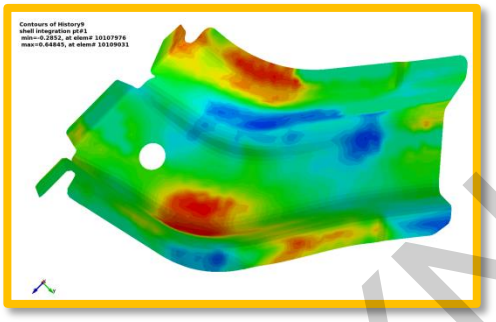

WORKSHOP ENVYO®: MAPPING AND DATA MANAGEMENT ALONG THE SIMULATION PROCESS CHAIN

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14. Deutsches LS-DYNA Forum ‘16
Bamberg, Germany

AGENDA

- „Historical“ Overview
- Workflow
- Mapping Capabilities
- Example
- Future Plans
- Questions & Answers

„Historical“ Overview

- In **2011**, with the start of the government funded research project T-Pult, first implementations were made to enhance the existing tool DYNAmat with mapping capabilities for **BEAM -> SHELL** mapping as well as to consider **CT-scan** data.

- Further inhancements led to the consideration of fiber orientations gained from draping simulations with *MAT_249 (*MAT_REINFORCED_THERMOPPLASTIC) on shell meshes with the **ORIENTATION -> SHELL** capability.

- Several material models for **draping** simulations (*MAT_034, *MAT_234 & *MAT_235) were considered for orientation mapping within the government funded research project SWIM-RTM.

- In 2013, the mapping capabilities were removed from the Fortran based DYNAmat – tool and transferred to an independet **C++** program.

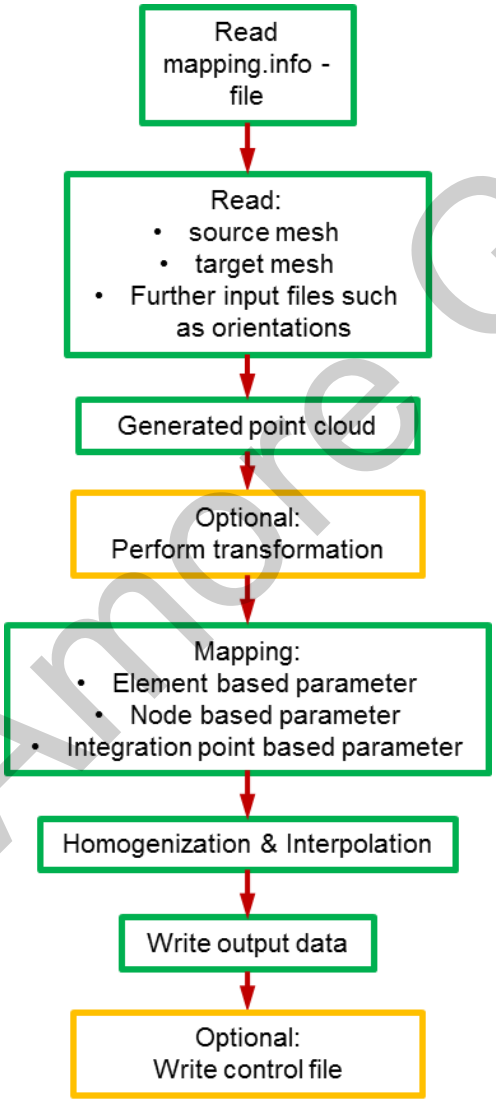
„Historical“ Overview

- several names existed – „Fibermap“ and „DYNAmap“ were the most common ones.
- with the start of the government funded research project ARNEA2036 in 2014, **further software tools** such as PAM-Crash, PAM-RTM, FiberSim can be considered within the mapping.
- a link to the **HDF5 binary data format** has been implemented.
- in **2015**, a lot of work went into the consideration of fiber orientations as well as resinuous areas which can be identified with **multi-layer draping** simulations.
- enhancements were made towards the homogenization of stiffness parameters for *MAT_157 for **short fiber reinforced composites**.

„Historical“ Overview

- in **2016**, the consideration of eff. plastic strain resulting from a forming simulation for damage estimation in the **GISSMO** *MAT_ADD_EROSION failure and damage model has bee implemented.
- results from forming simulations using shell meshes can be used to **generate solid meshes** for springback analysis and thickness post-processing.
- a tool to generate vector files for the post-processing of various spring back analysis as been implemented.
- the mapping tool is officially named **Envyo®** is introduced to the public at the 14th German LS-DYNA User‘s Meeting in Bamberg, Germany.

Workflow

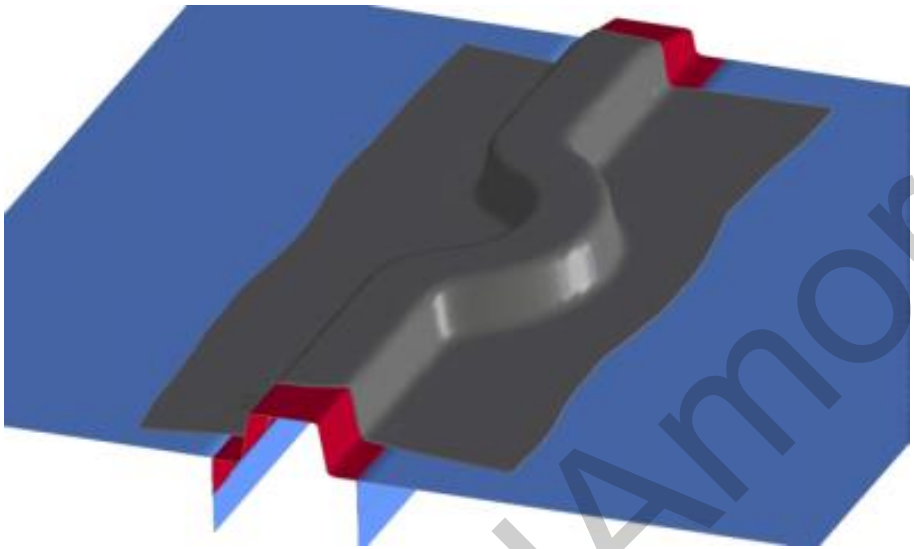


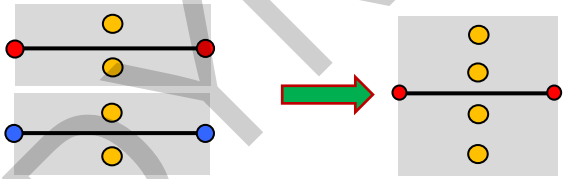
Mapping Capabilities

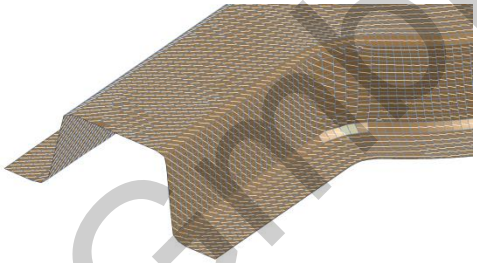
- ORIENTATION -> SHELL
- ORIENTATION -> ALE_MESH
- SHELL -> STACKED_SHELL
- SOLID -> SOLID
- STACKED_SHELL -> SOLID
- BEAM -> ALE_MESH
- SHELL -> SOLID
- SHELL -> THICK_SHELL
- STACKED_SHELL -> STACKED_THICK_SHELL
- SHELL -> SHELL
- SHELL -> SOLID (GENERATION)
- MOLDFLOW -> SHELL
- MOLDFLOW -> SOLID
- MOLDFLOW -> SHELL (with plasticity curve interpolation)
- Moldflow visualization
- CT-Scan -> SHELL
- CT-Scan Visualization
- CT-Scan -> Through Thickness Curves
- MOLDFLOW -> Through Thickness Curves
- MOLDFLOW3D -> Through Thickness Curves
- HDF5-Input
- Springback Analysis

Mapping Capabilities

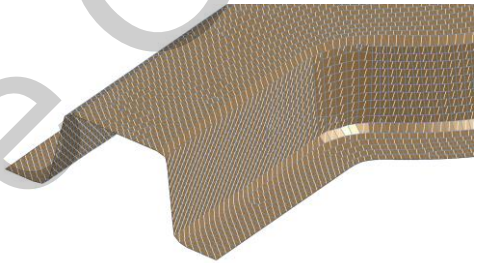
- ORIENTATION -> SHELL







Layer #1:



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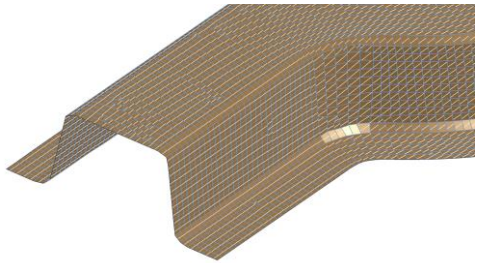
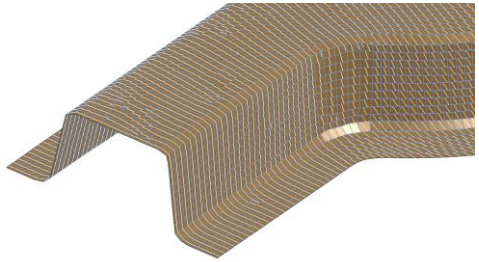


Layer #3:



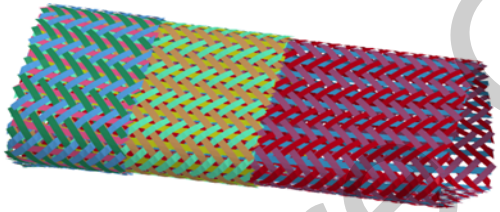
Layer #4:

Mapping Capabilities

- ORIENTATION -> ALE_MESH

Mapping Capabilities

- SHELL -> STACKED_SHELL



Layer #1:

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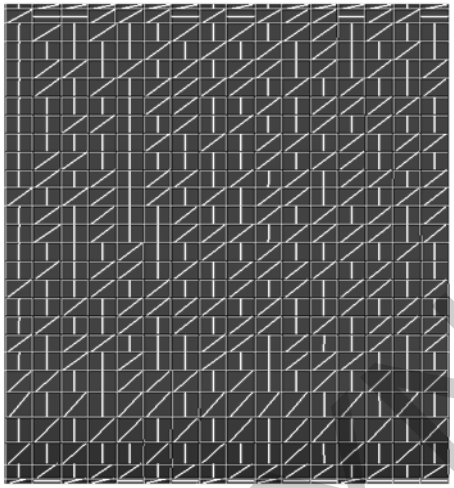
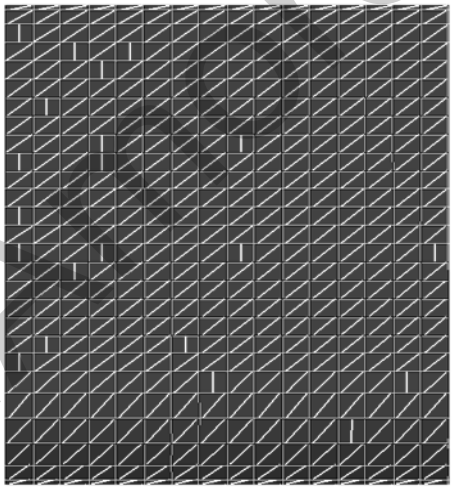
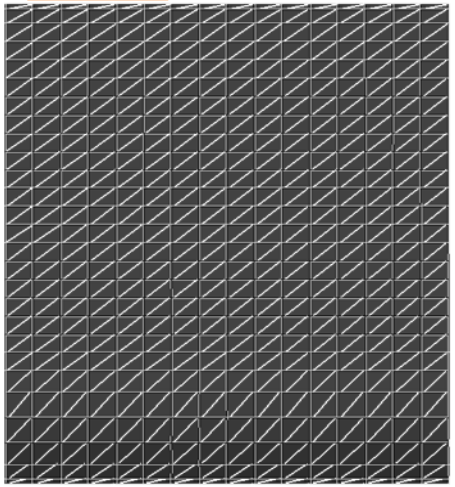


SF = 1.0

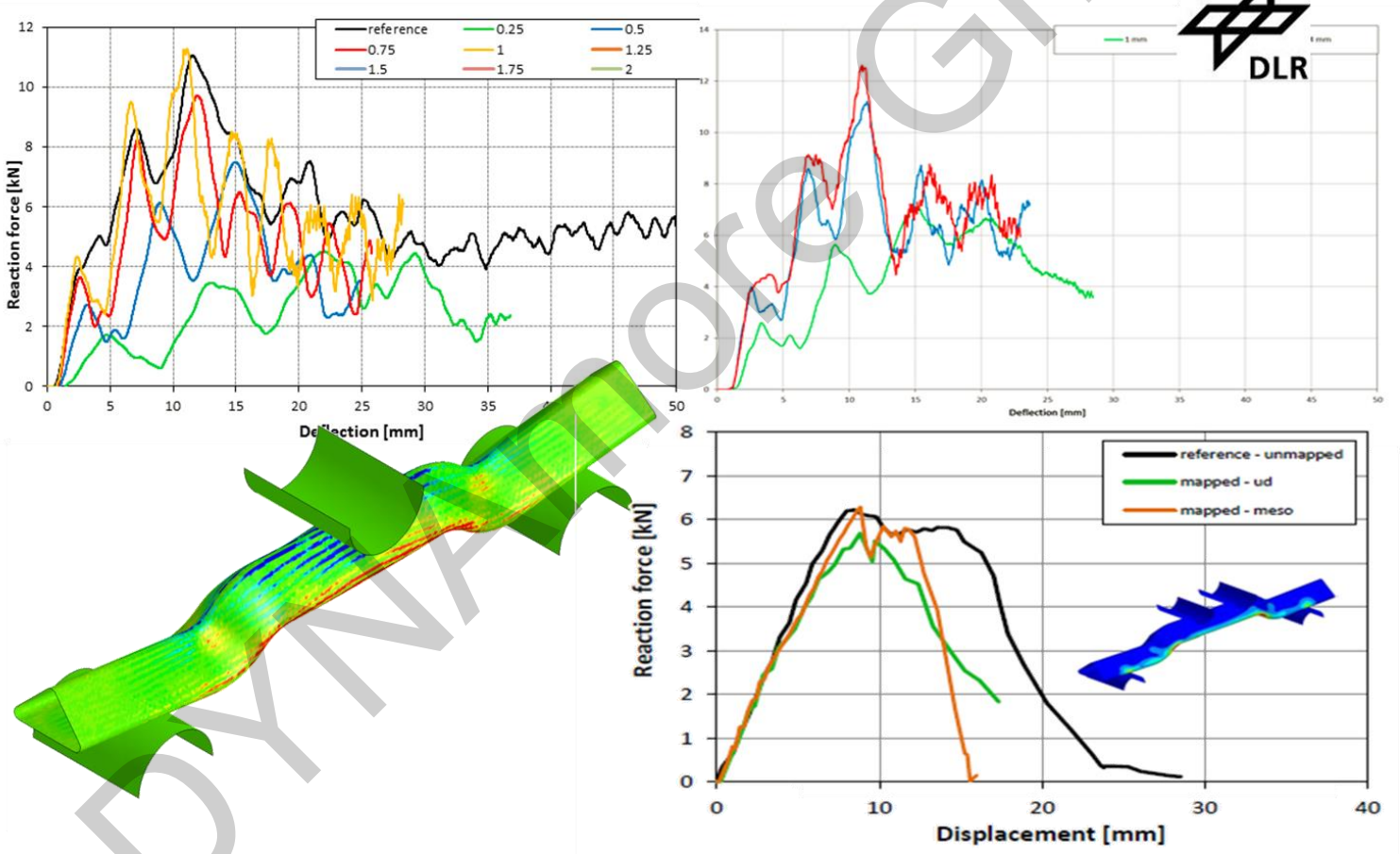


SF = 2.0



Mapping Capabilities

- SHELL -> STACKED_SHELL



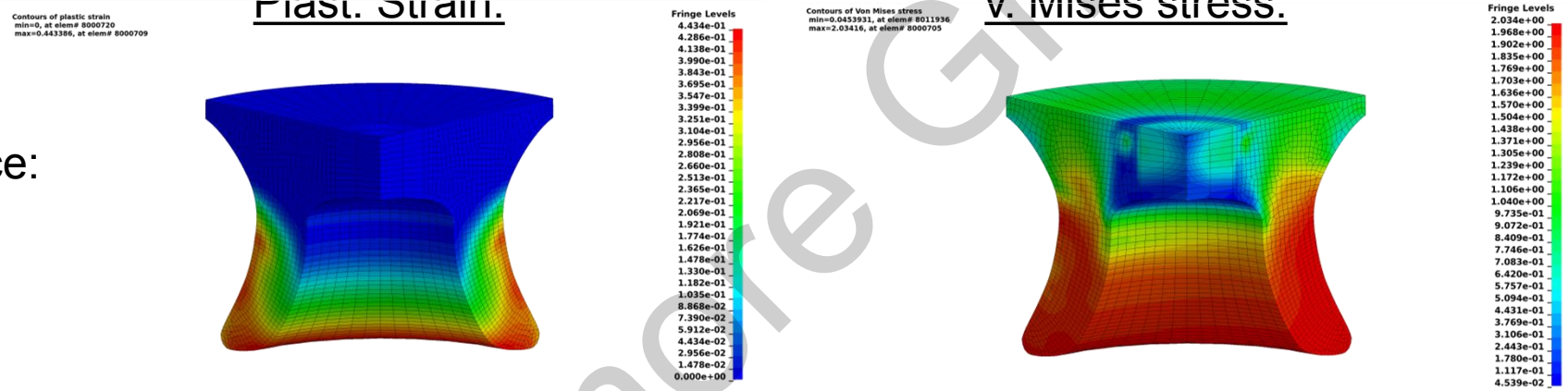
Mapping Capabilities

- SOLID -> SOLID

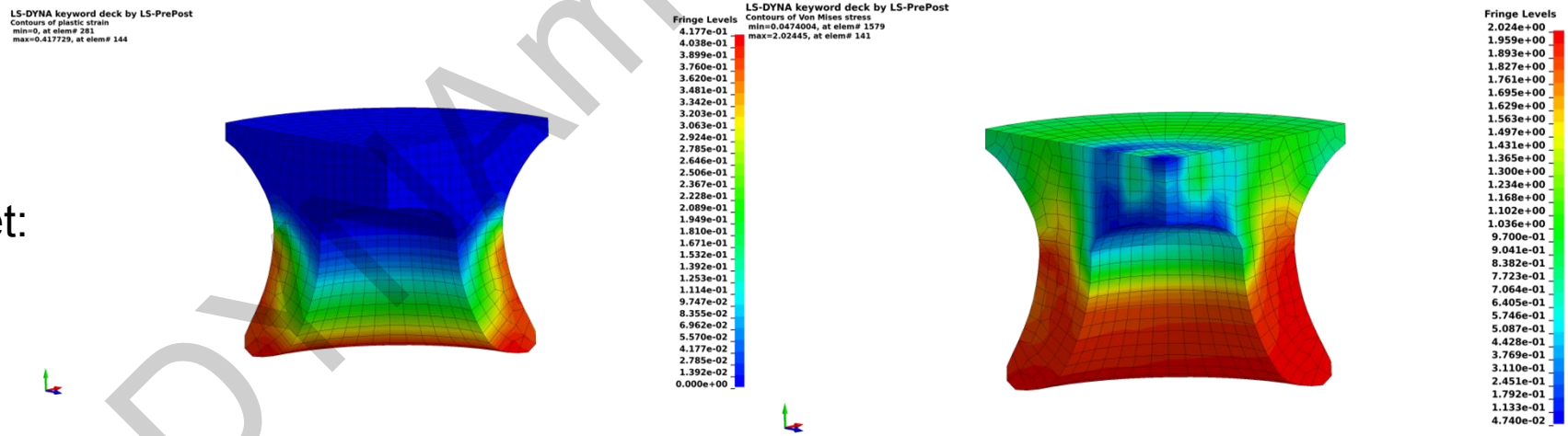
Plast. Strain:

v. Mises stress:

Source:



Target:



Mapping Capabilities

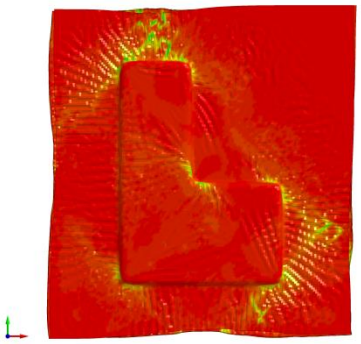
- STACKED_SHELL -> SOLID

Mean strain:

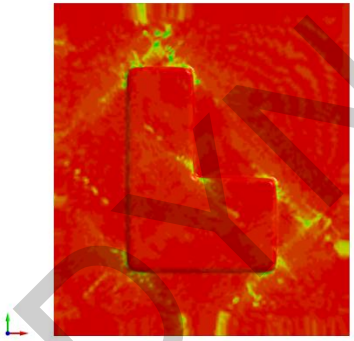
HISV #1:

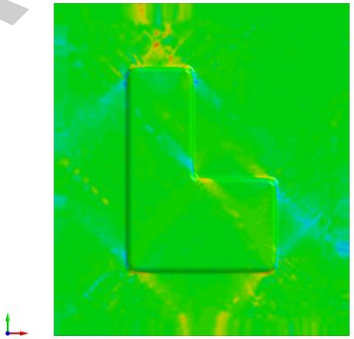
Fiber orientation output:

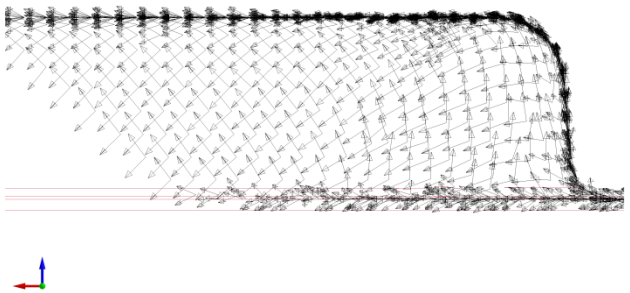
original:



target:



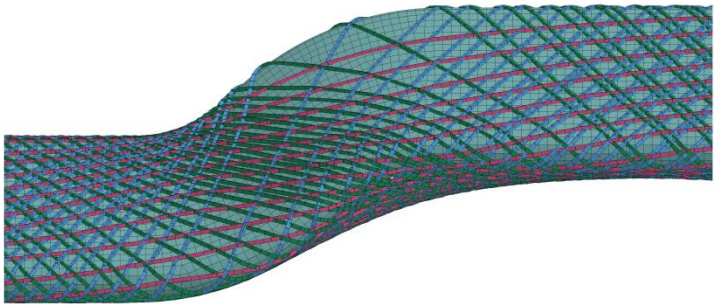




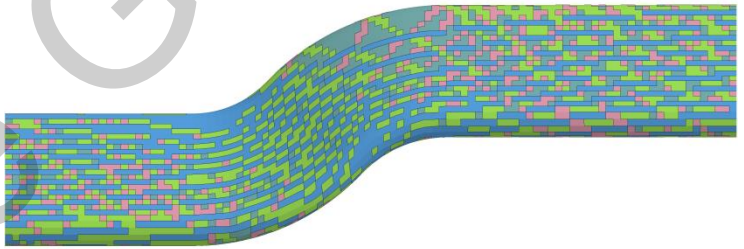
Mapping Capabilities

- BEAM -> SHELL

Source – Mesh:



Scale factor = 5.0:



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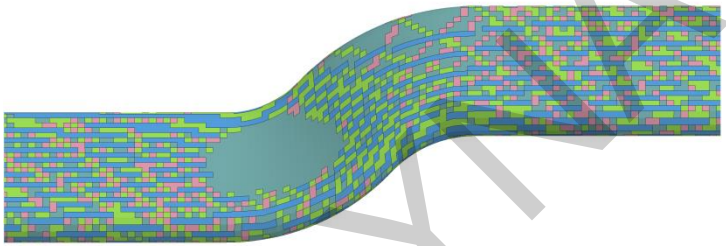
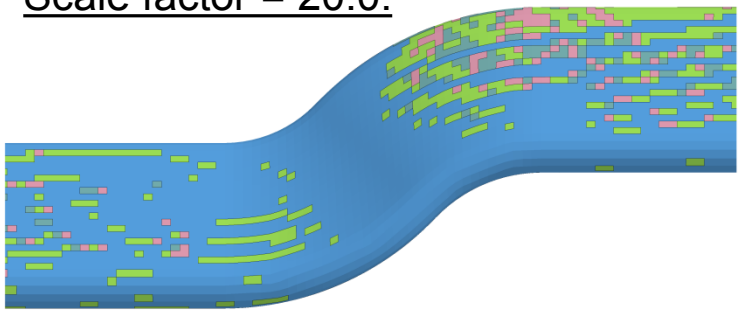


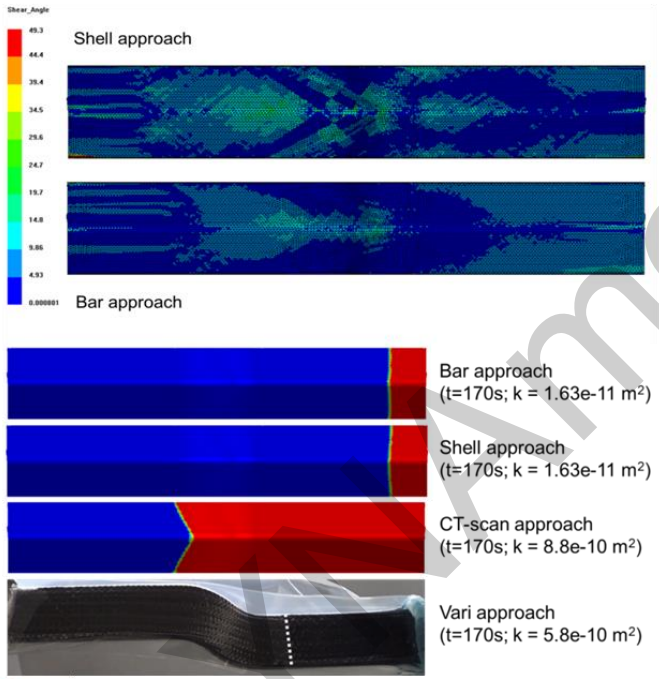
Scale factor = 20.0:



Mapping Capabilities

- BEAM -> SHELL

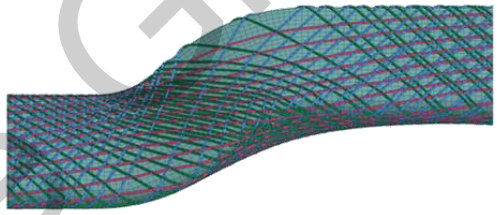
Infiltration Simulation



IFB

Universität Stuttgart

Source – Mesh:



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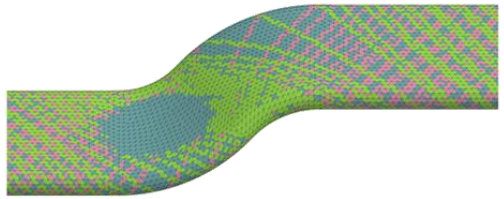

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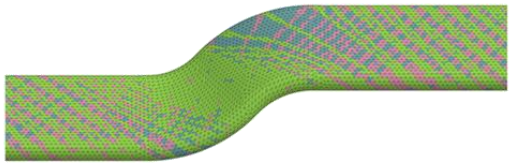
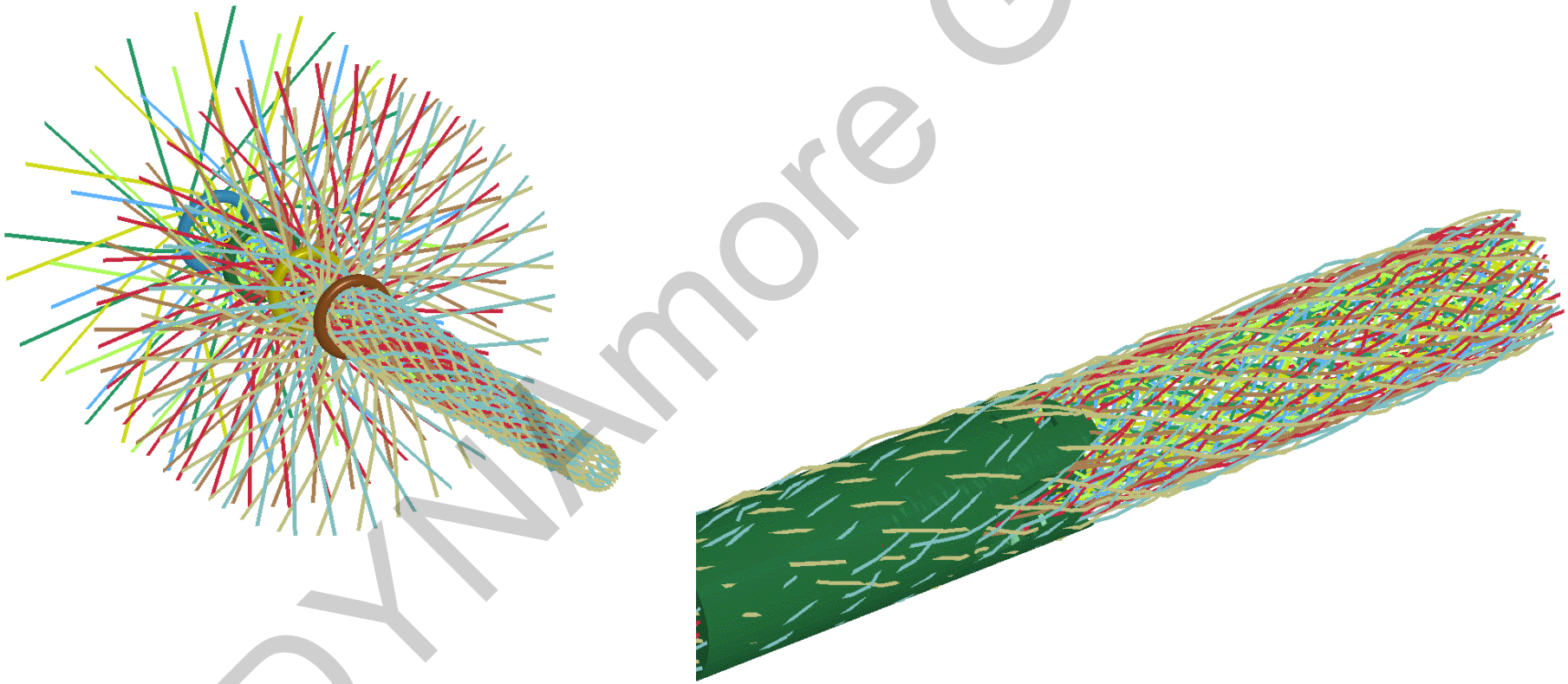


Mapping Capabilities

- BEAM -> ALE_MESH



Mapping Capabilities

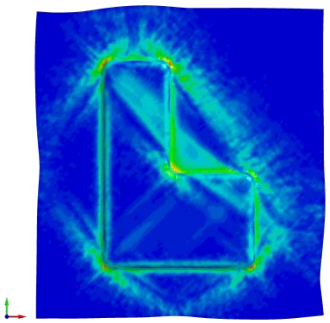
- SHELL -> SOLID

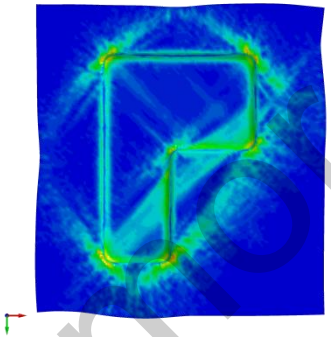
vMises IP1:
(top view)

vMises IP4:
(bottom view)

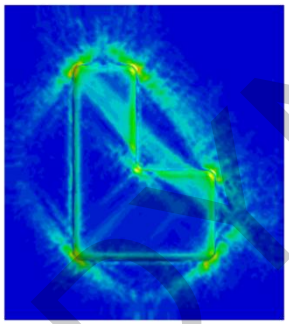
Fiber orientation output:

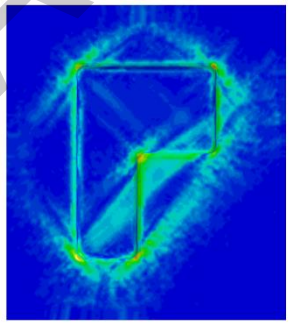
original:

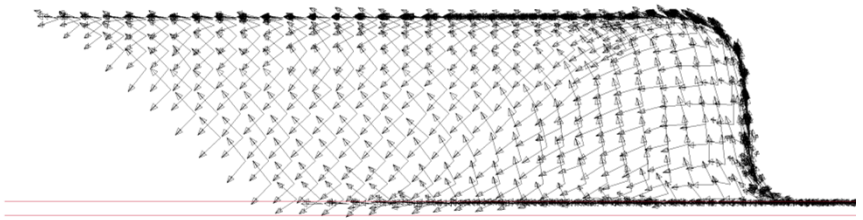




target:

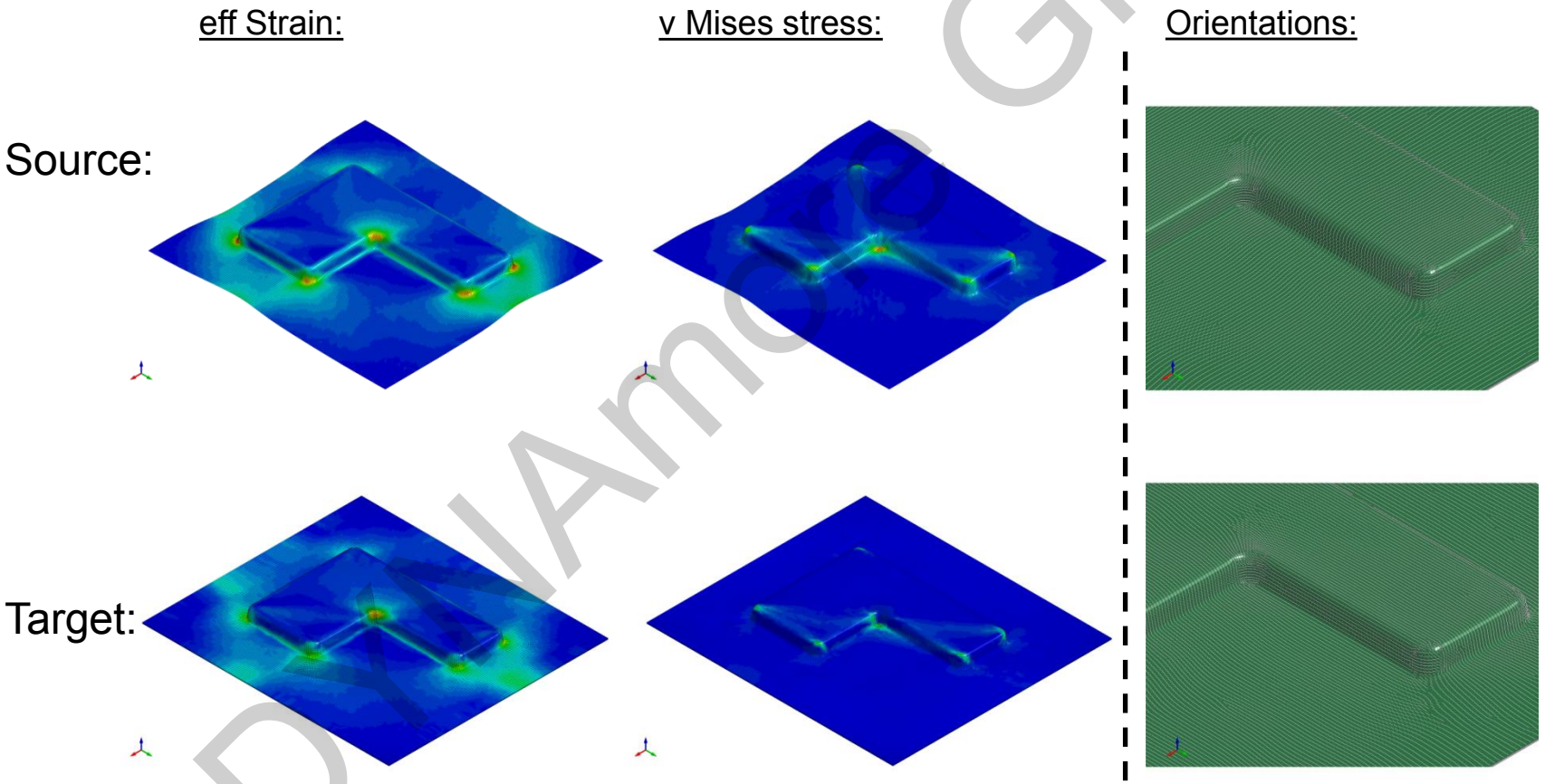






Mapping Capabilities

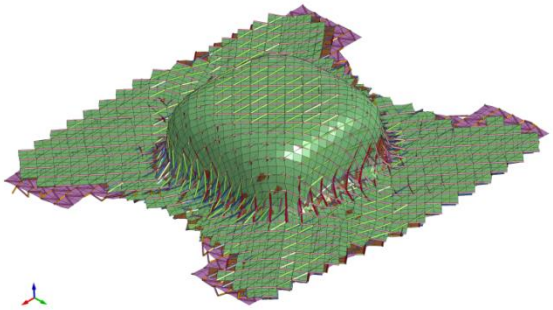
- SHELL -> THICK_SHELL



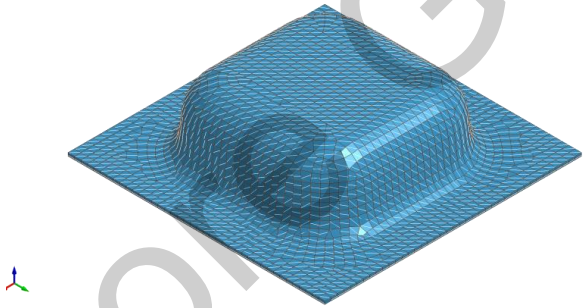
Mapping Capabilities

- STACKED_SHELL -> STACKED_THICK_SHELL

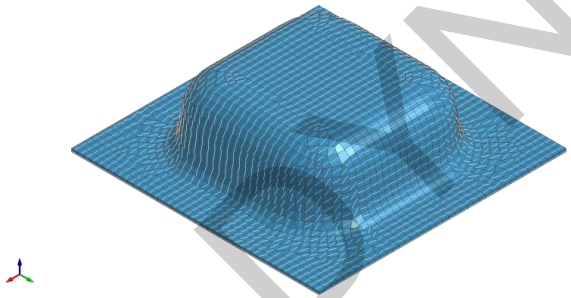
Source – Mesh -Stacked Shells (5 Layers):



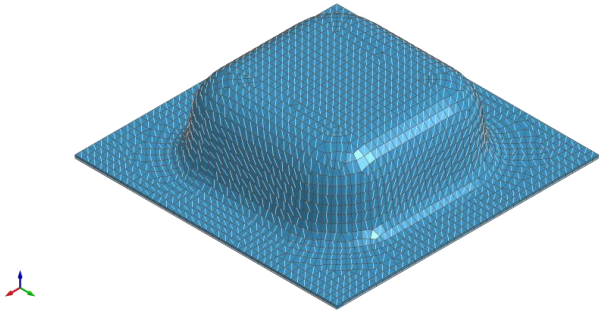
Orientations IP#3:



Orientations IP#1:

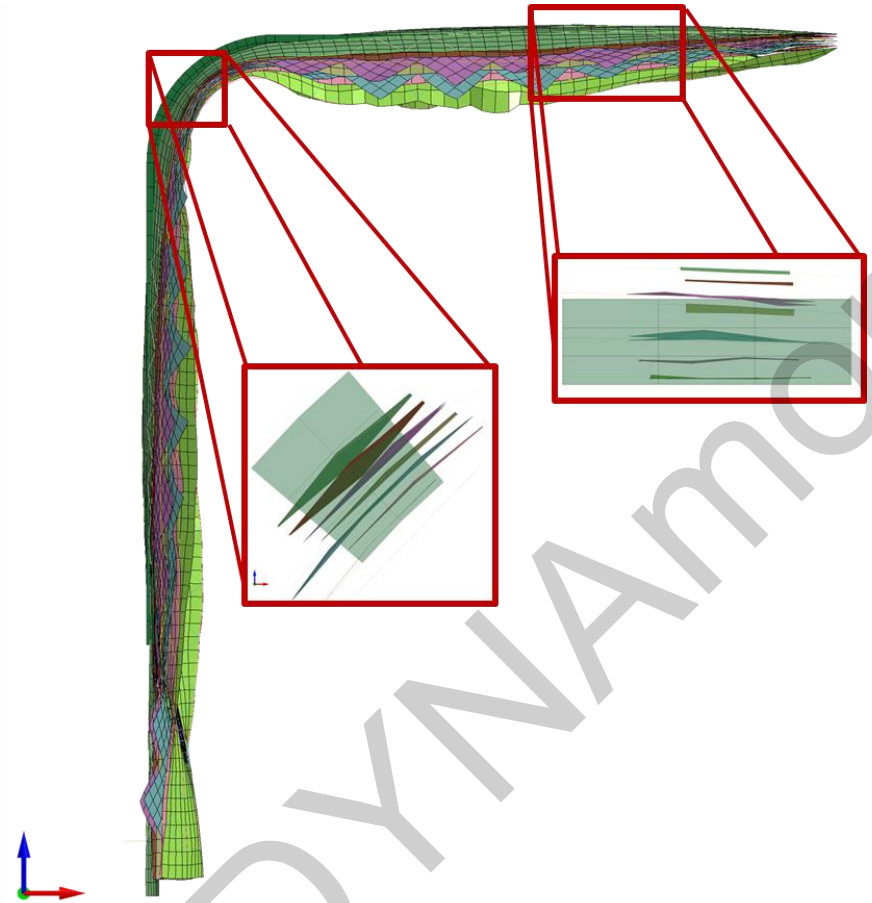


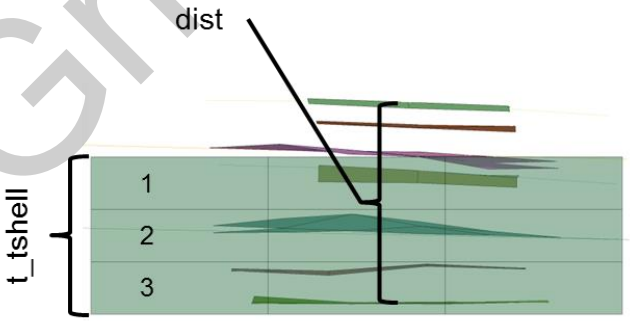
Orientations IP#5:

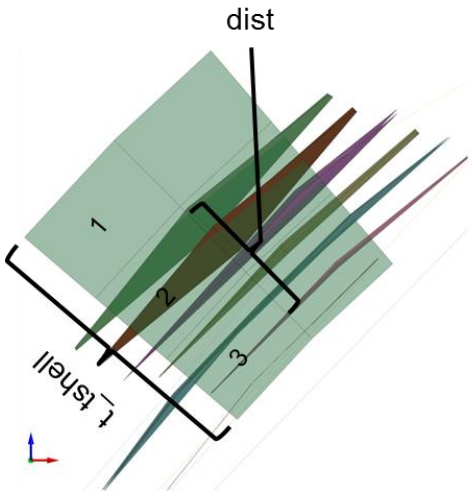


Mapping Capabilities

- STACKED_SHELL -> STACKED_THICK_SHELL



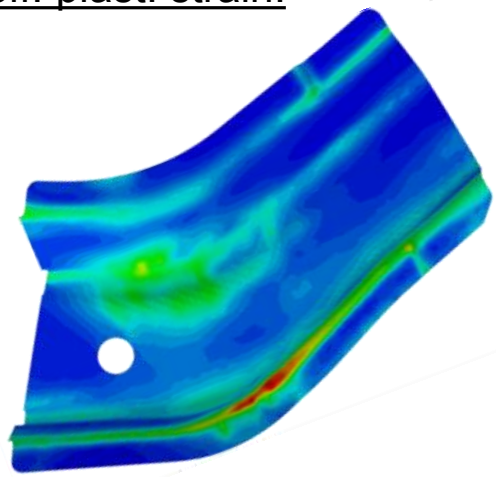




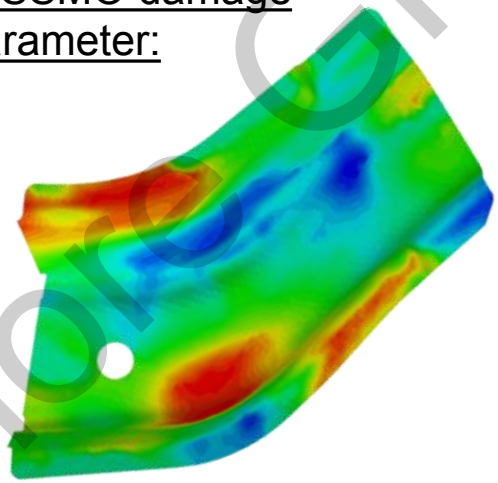
Mapping Capabilities

- SHELL -> SHELL

eff. plast. strain:



GISSMO damage parameter:



Damage estimation

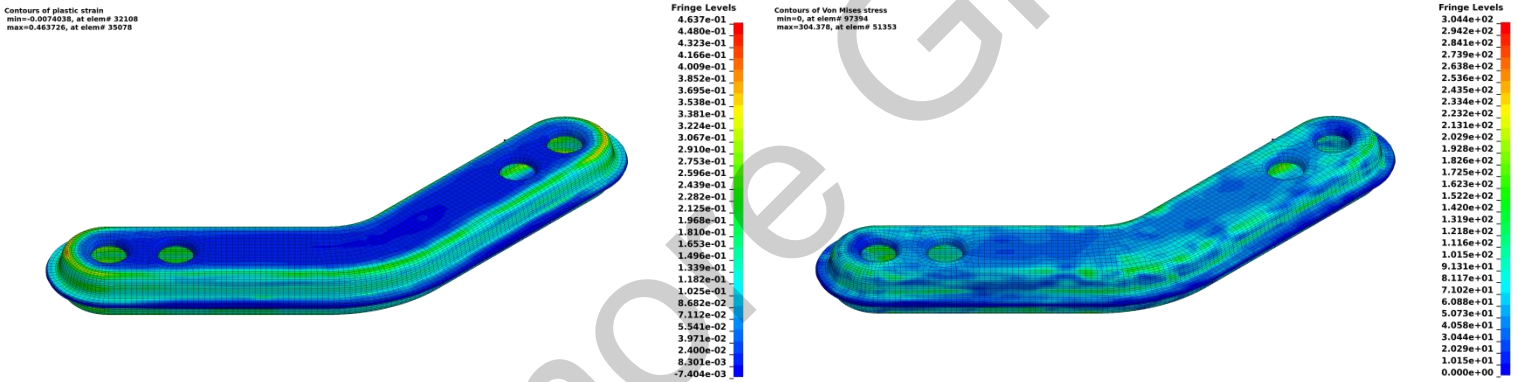
Mapping Capabilities

- SOLID -> SHELL

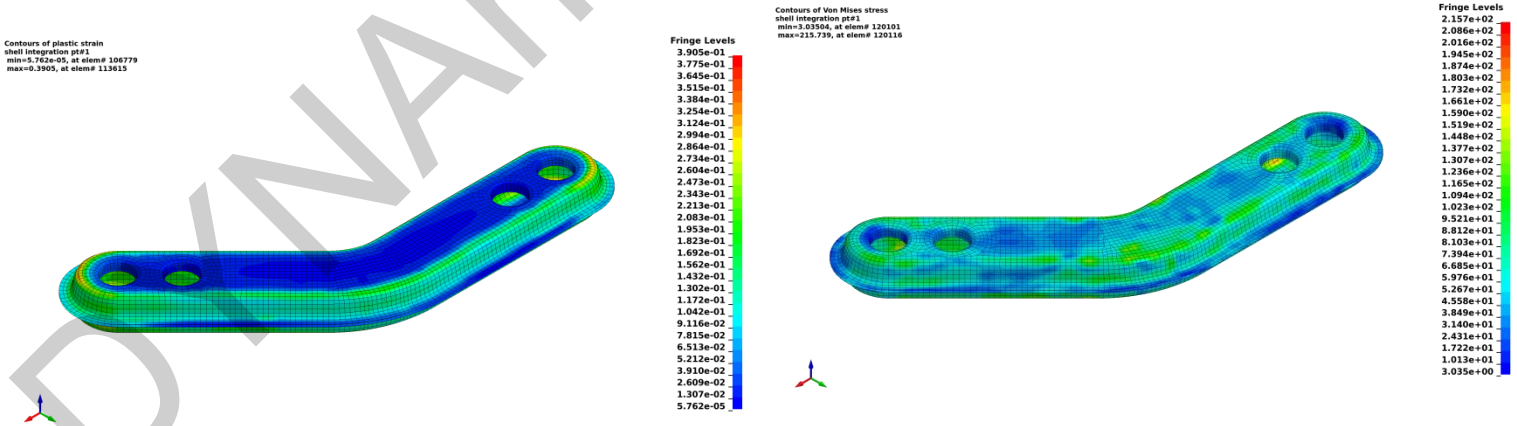
Plast. Strain:

v. Mises stress:

Source:

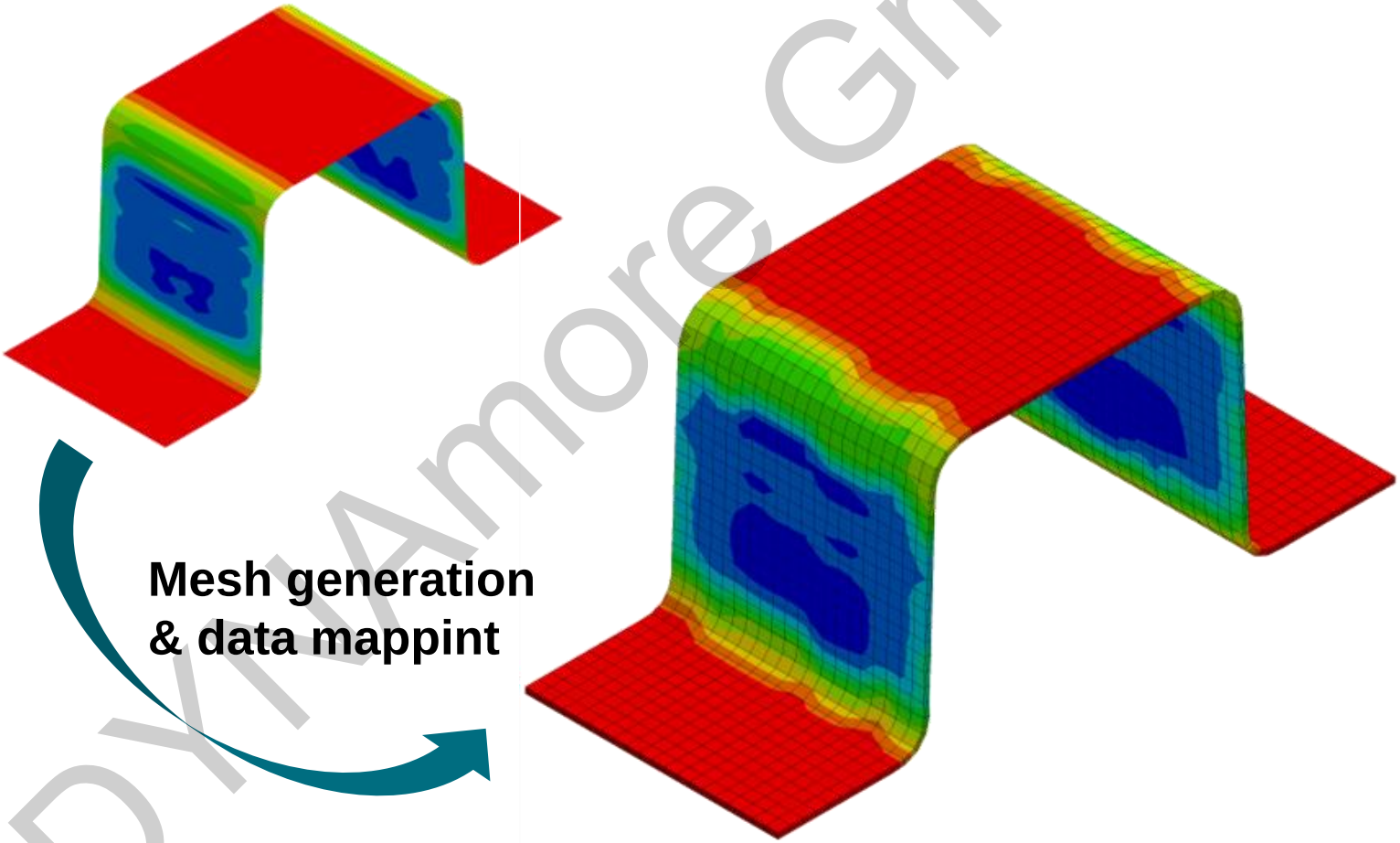


Target:



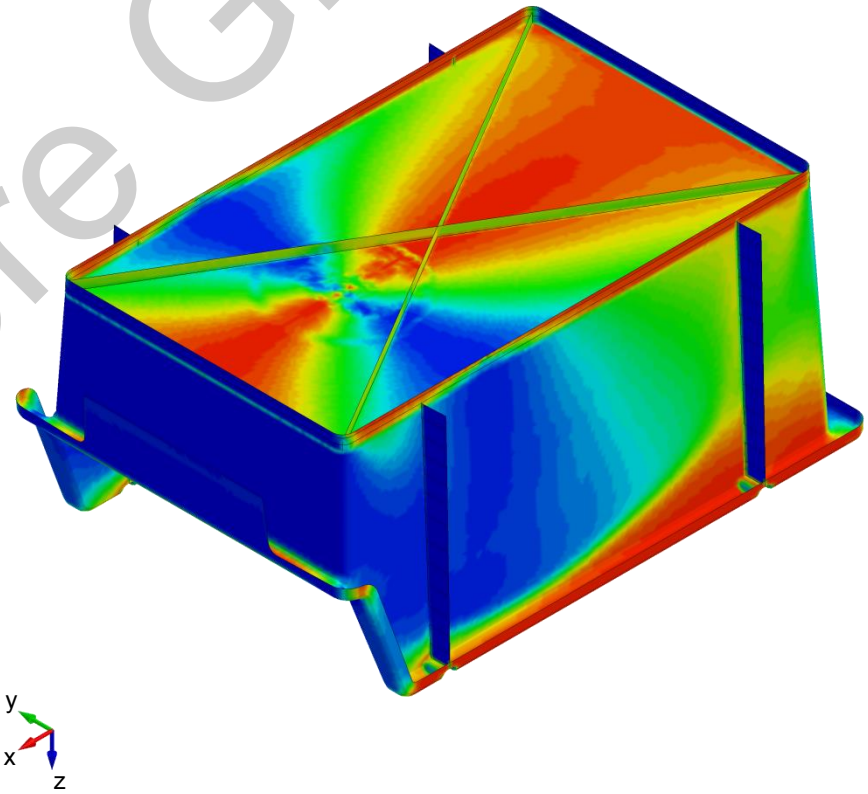
Mapping Capabilities

- SHELL -> SOLID (GENERATION)



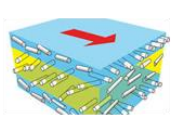
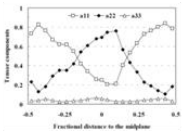
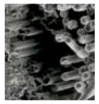
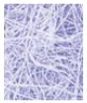
Mapping Capabilities

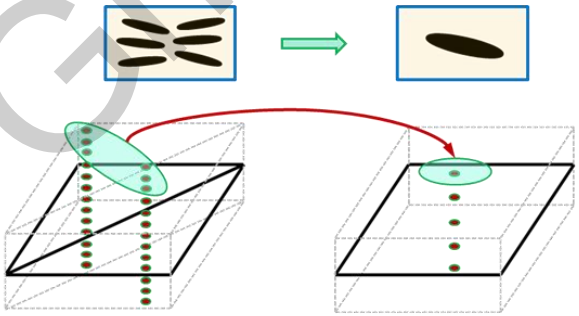
- MOLDFLOW -> SHELL



Mapping Capabilities

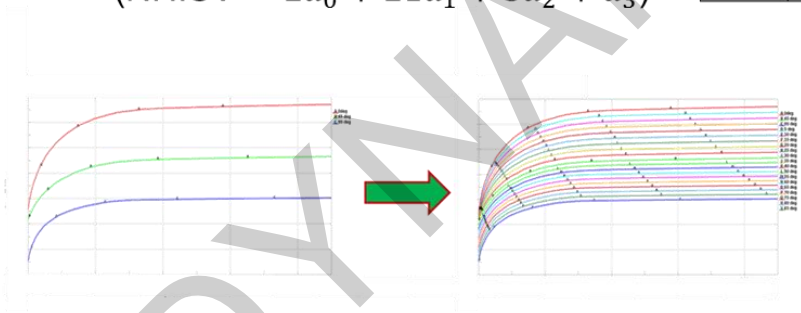
- MOLDFLOW -> SHELL (with plasticity curve interpolation)
  - Mapping (Moldflow/Moldex -> Shell) and homogenization for SFRP – components

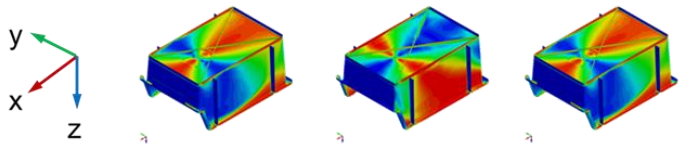


  - Usage of elastic-viscoplastic material model *MAT_157 + *Initial_Stress_Shell
    (NHISV = $2a_0 + 21a_1 + 3a_2 + a_3$)

CARD 1	eid	nplane	nthick	nhisv	ntensor	large	nthint	nthhsv
CARD 2	t	sigxx	sigyy	sigzz	sigxy	sigyz	sigzx	eps
CARD 3	hisv1=q_1	hisv2=q_2	#3=C_{11}	#4=C_{12}	#5=C_{13}	#6=C_{14}	#7=C_{15}	#8=C_{16}
CARD 4	#9=C_{22}	#10=C_{23}	#11=C_{24}	#12=C_{25}	#13=C_{26}	#14=C_{33}	#15=C_{34}	#16=C_{35}
CARD 5	#17=C_{36}	#18=C_{44}	#19=C_{45}	#20=C_{46}	#21=C_{55}	#22=C_{56}	#23=C_{66}	



Flag	Description	Variables	#
a_0	Material directions	q_1, q_2	2
a_1	Anisotropic stiffness	Cij	21
a_2	Anisotropic constants	r_{00}, r_{45}, r_{90}	3
a_3	Stress-strain Curve	LCSS	1

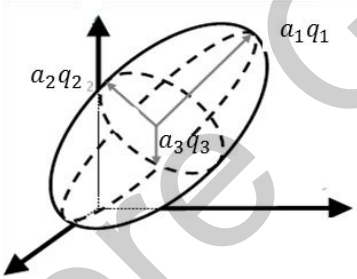


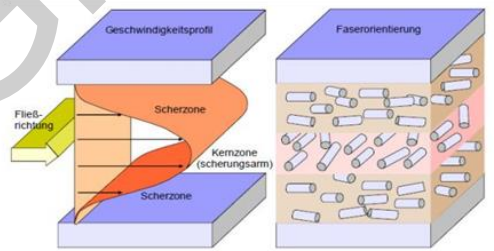
Mapping Capabilities

- MOLDFLOW -> SHELL (with plasticity curve interpolation)

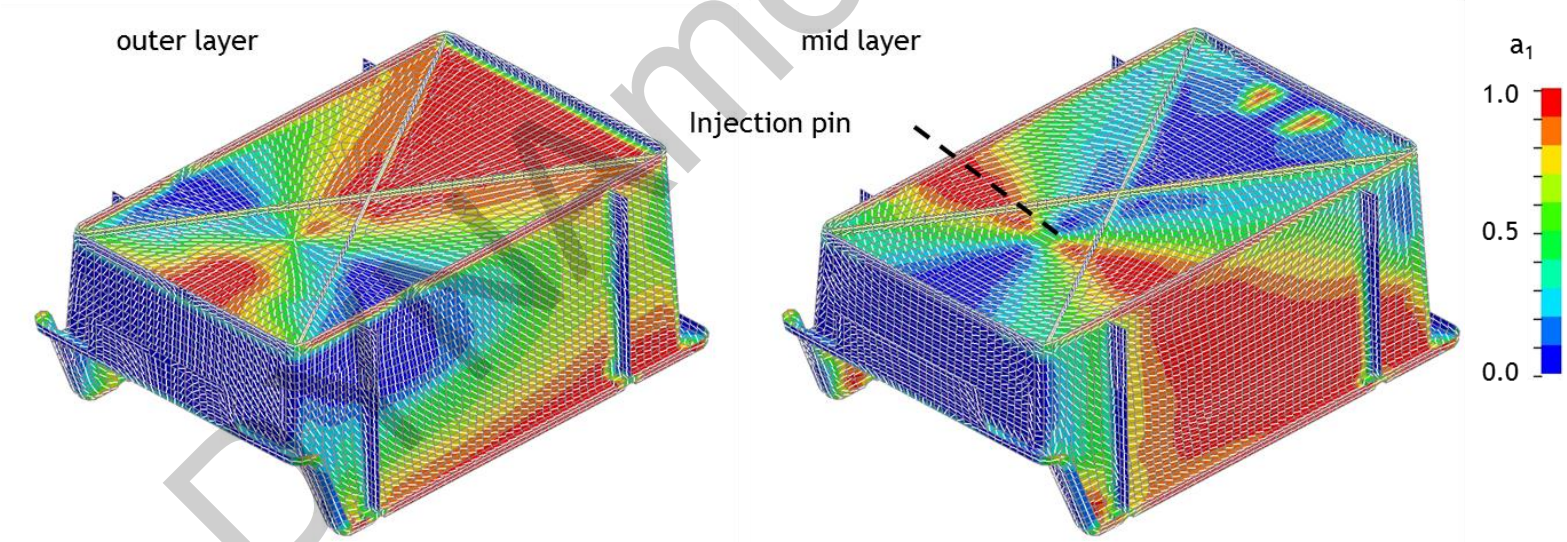
Orientation tensor 2nd order a: Mapped from process simulation as

- eigenvectors q_i (main fiber directions)
- eigenvalues a_i (orientation probability)



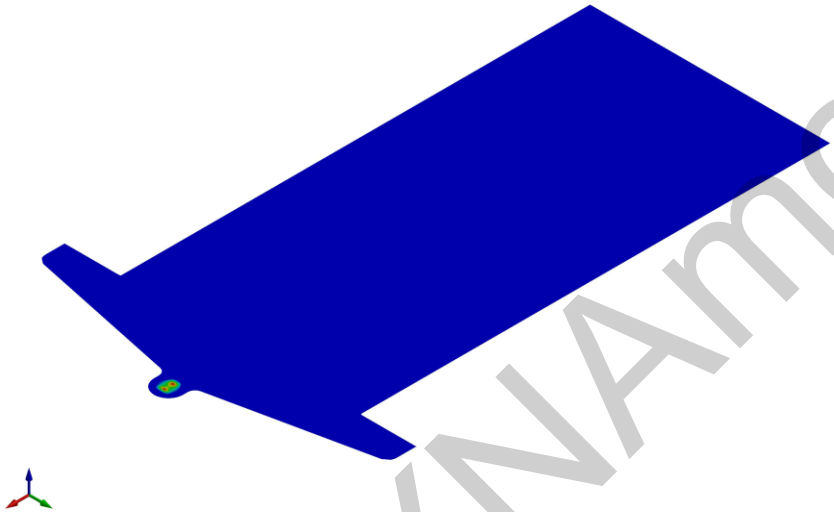


Example: "Nutini-box" eigenvalue a_1 and eigenvector q_1

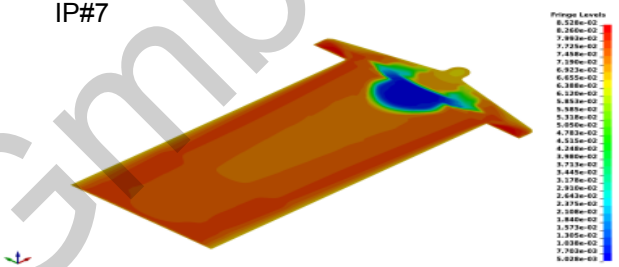


Mapping Capabilities

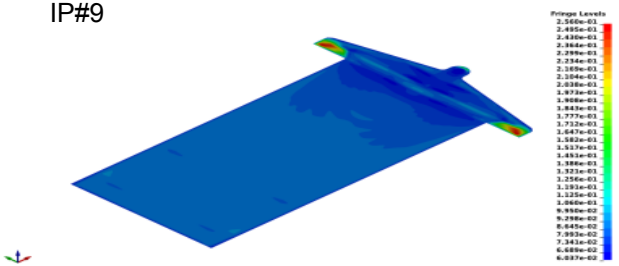
- Moldflow visualization



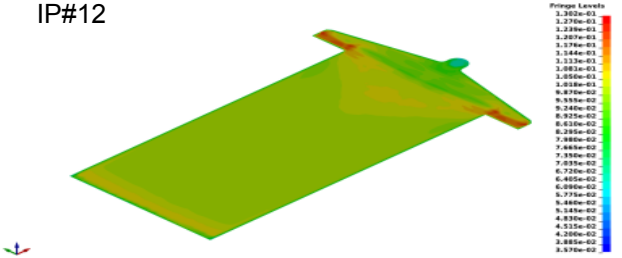
IP#7



IP#9

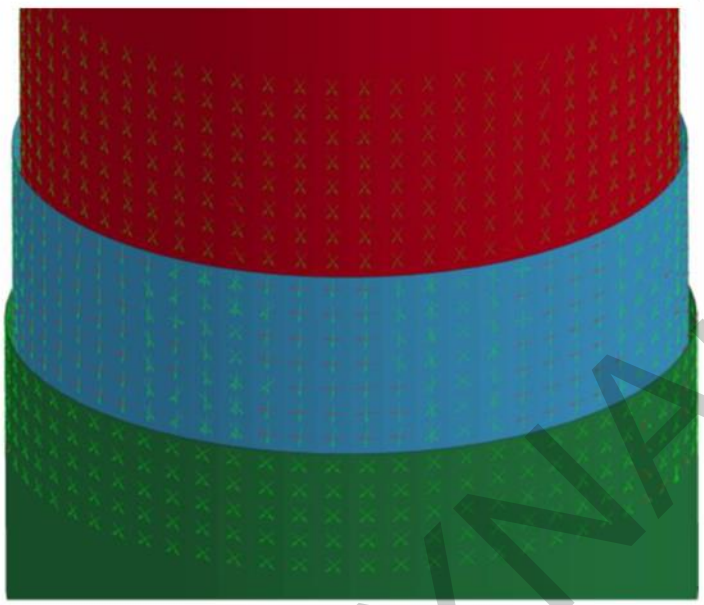


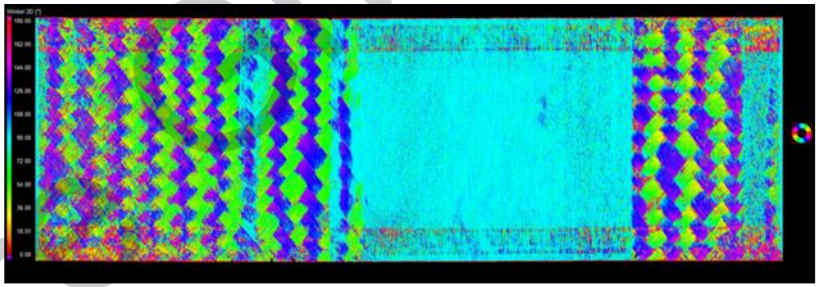
IP#12

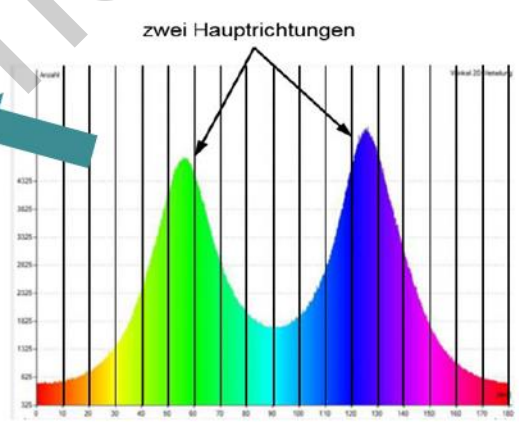


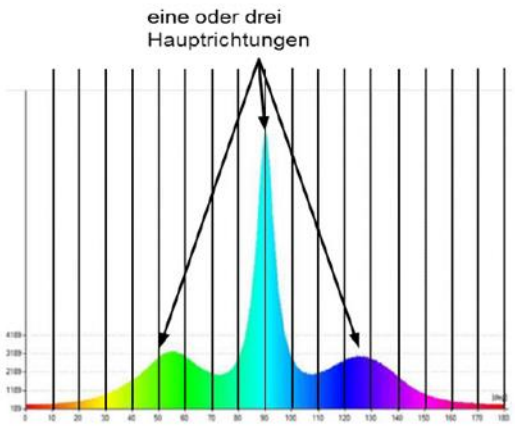
Mapping Capabilities

- CT-Scan -> SHELL



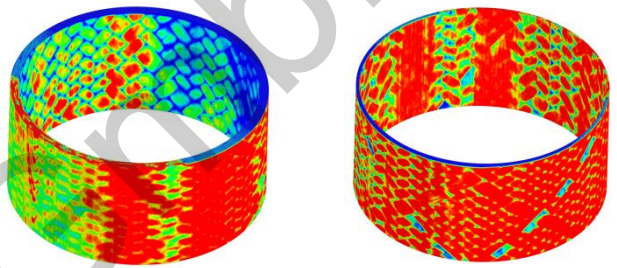






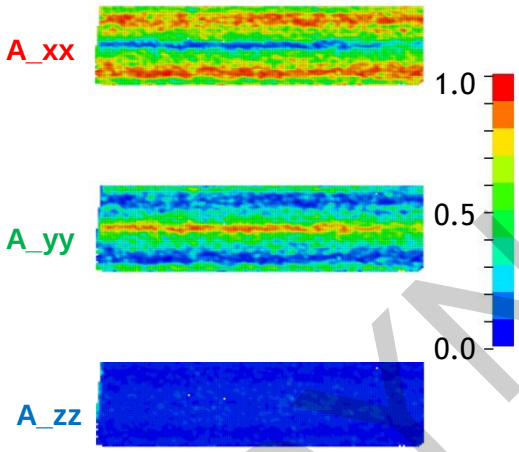
Mapping Capabilities

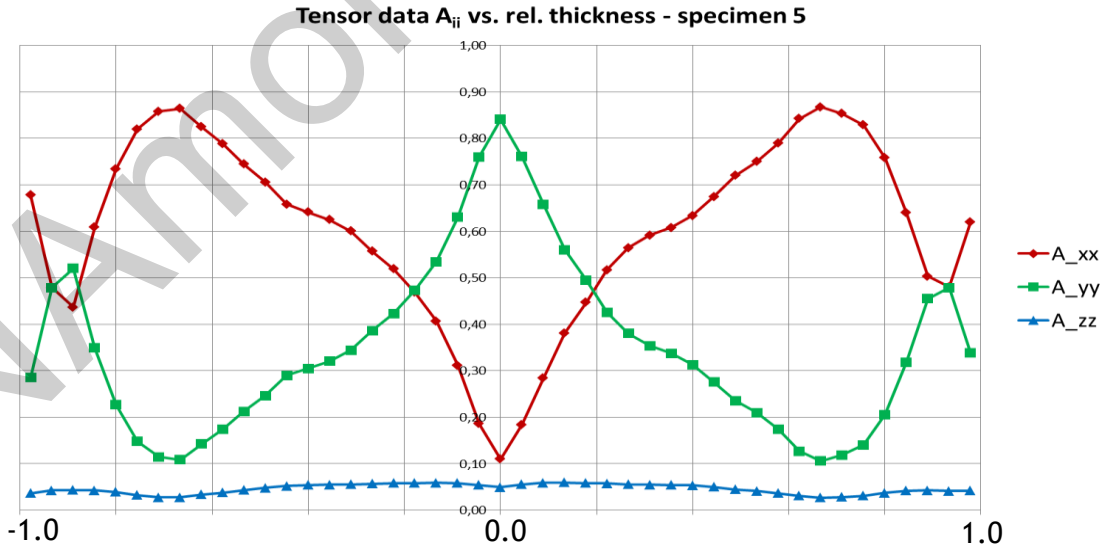
- CT-Scan Visualization



- CT-Scan -> Through Thickness Curves

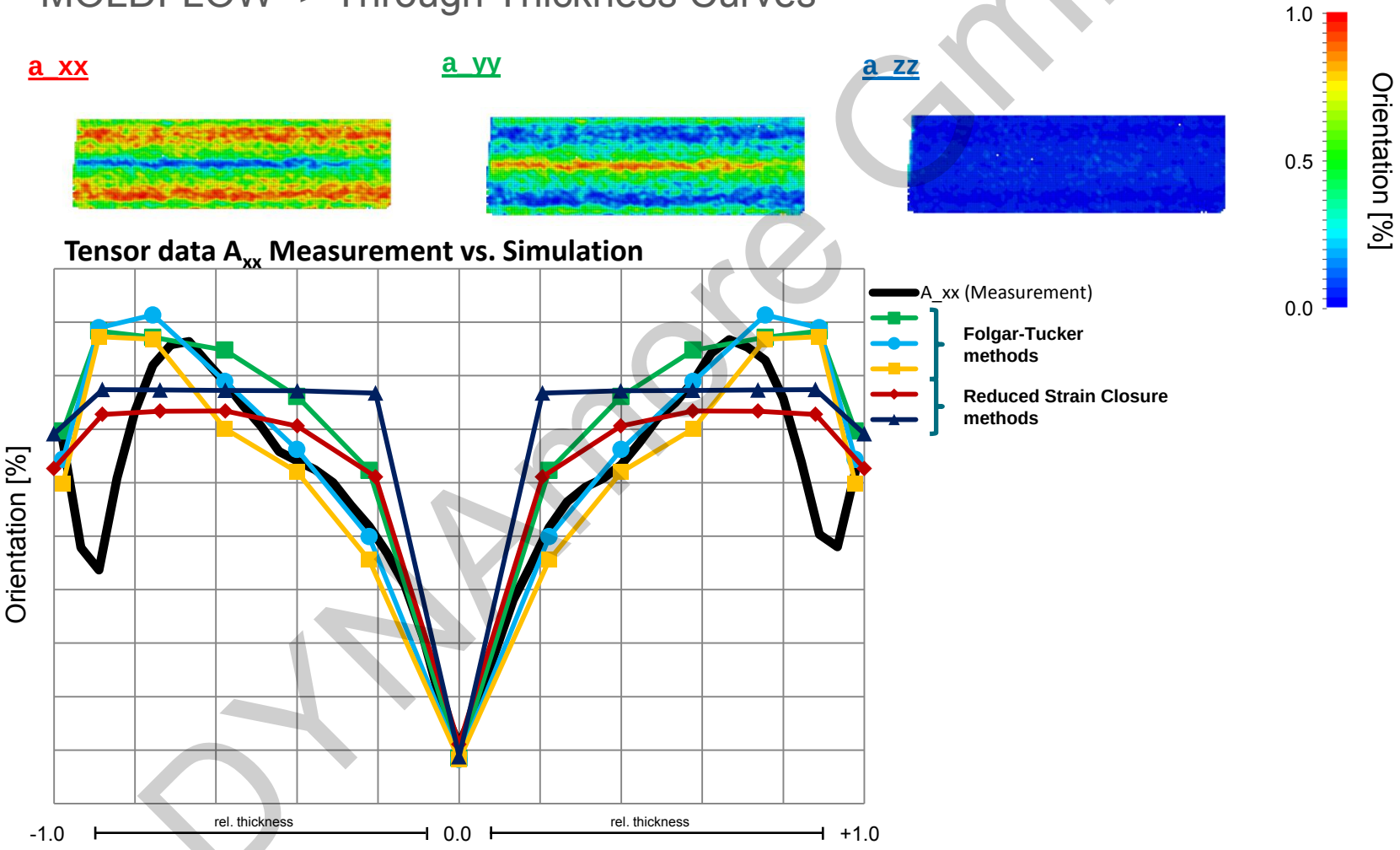
- **Fiber orientation of 0°- specimen over thickness:**





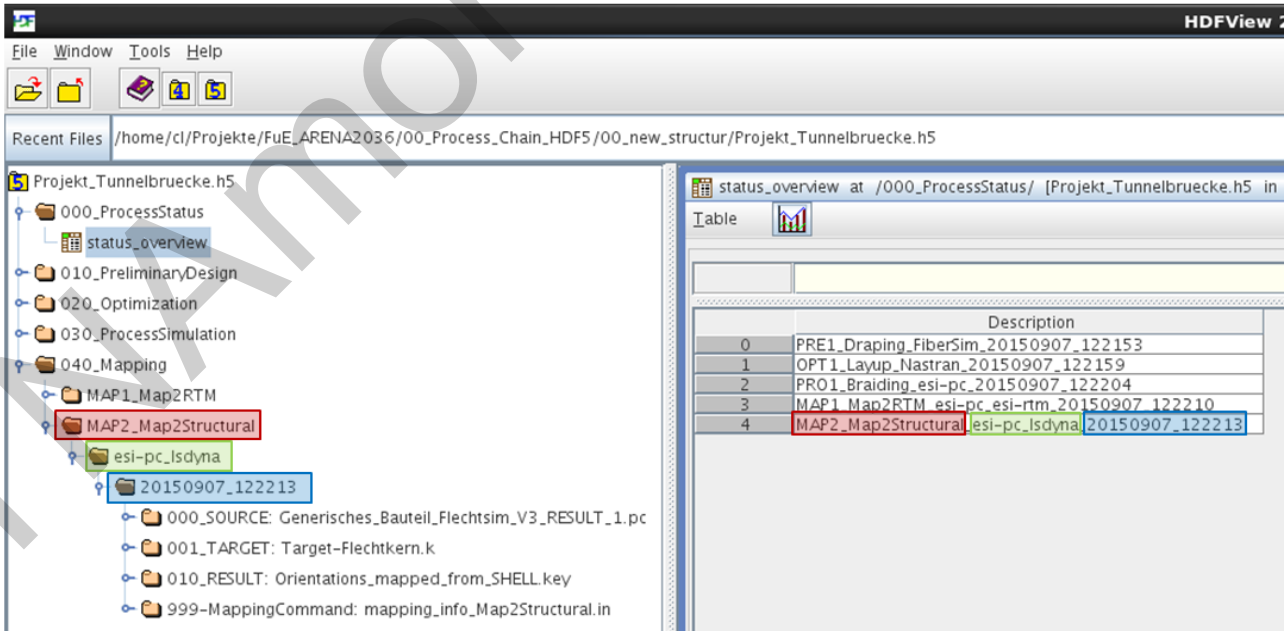
Mapping Capabilities

- MOLDFLOW -> Through Thickness Curves



Mapping Capabilities

- HDF5-Input
  - A platform independent, HDF5 data storage container is defined within the ARENA2036 project, allowing to access and track simulation results from other partners within a defined project.
  - This is available for different FE solvers an will be extended as needed



Mapping Capabilities

- Springback Analysis

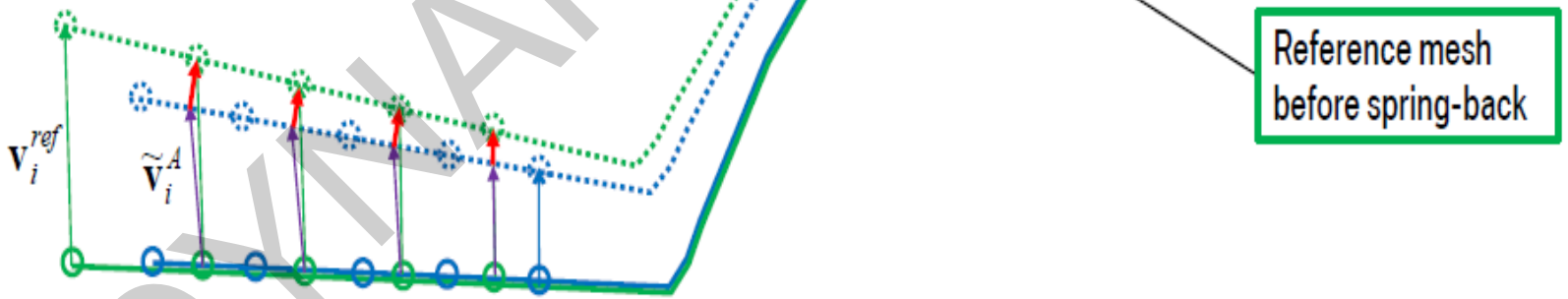
$$\mathbf{V}^{*} = \underbrace{\left[\mathbf{v}_1^{*} \quad \cdots \quad \mathbf{v}_{N^{ref}}^{*}\right]^T}_{(N^{*}\times 7)}$$

$$\mathbf{v}_i^{*} = \left[NID \quad x_{start} \quad y_{start} \quad z_{start} \quad x_{end} \quad y_{end} \quad z_{end}\right]$$

$$\mathbf{V}^{ref} = \underbrace{\left[\mathbf{v}_1^{ref} \quad \cdots \quad \mathbf{v}_{N^{ref}}^{ref}\right]^T}_{(N^{ref}\times 7)}$$

$$\tilde{\mathbf{V}}^{A} = \underbrace{\left[\tilde{\mathbf{v}}_1^{A} \quad \cdots \quad \tilde{\mathbf{v}}_{N^{ref}}^{A}\right]^T}_{(N^{ref}\times 7)}$$

$$\underbrace{\mathbf{D}}_{(N^{ref}\times 7)} = \underbrace{\mathbf{V}^{ref}}_{(N^{ref}\times 7)} - \underbrace{\tilde{\mathbf{V}}^{A}}_{(N^{ref}\times 7)}$$



Example

```
$#--------------------------
$# Main mapping definition
$#--------------------------
FIBERMAP=MOLDFLOW-SHELL(PLASTICITY_CURVE-GEN)
$#--------------------------
$# Activate transformation
$#--------------------------
TRANSFORMATION=NO
SourceUnitSystem=kg-m-s
TargetUnitSystem=kg-mm-ms
$#--------------------------
$# In- and output meshes
$#--------------------------
SourceFile=MOLDFLOW_SOURCE.key
TargetFile=TARGET_LS-DYNA.key
MappingResult=FILE_FOR_STRUCTURAL_ANALYSIS.key
OrientationFile=MOLDFLOW-ORIENTATIONS.xml
SectionFile=SECTION_CARDS.key
```

Example

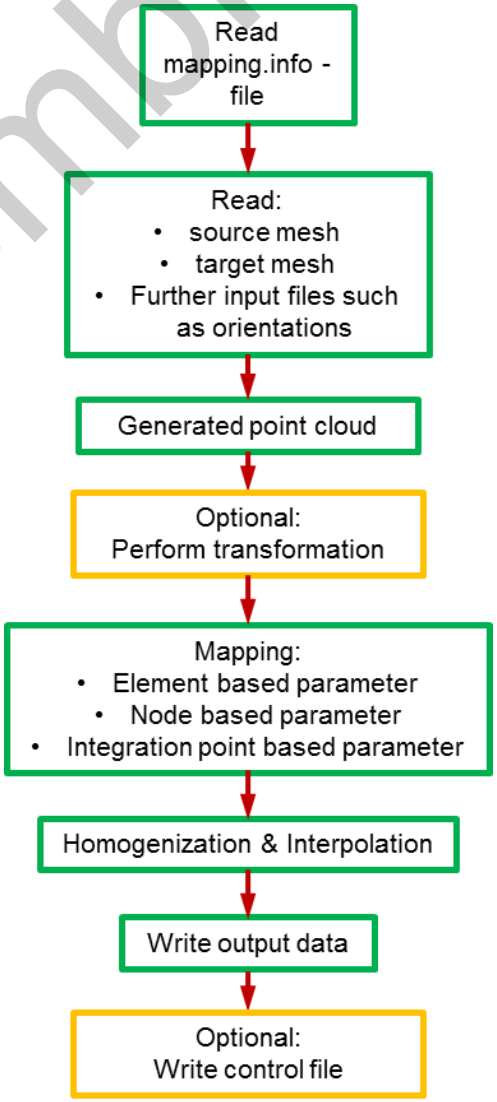
```
$#--------------------------
Target – Properties
$#--------------------------
NumberOfTARLayers=5
NumberOfTARInPlaneIPs=4
MapStress=YES
TargetThickness=2.5
MapMainDir=NO
$#--------------------------
$# Mapping-Options
$#--------------------------
ALGORITHM=ClosestPoint
SORT=BUCKET
TargetMaterialModel=157
HomogenizationMethod=Mori-Tanaka
ClosureApproximation=hybrid
E11F=
E22F=
RHOF=
PRBAF=
PRCBF=
G12F=
EM=
RHOM=
PRM=
AspectRatio=
FiberVolumeFraction=
InclusionShape=Spheroidal
```

Example

```
$#--------------------------
$# Define Curve Input
$#--------------------------
NumberOfCurveFiles=3
CurveFileName#1=0deg_curves.inc
…
$#--------------------------
$# Strain Rate Info
$#--------------------------
NumberOfDirections=3
Direction#1=0
…
NumberOfStrainRates=4
StrainRate#1=
…
StrainRate#1Direction#1=995
...
StrainRate#1Direction#2=45995
...
StrainRate#1Direction#3=90995
…
StrainRate#4Direction#3=90998
$#--------------------------
$# END-OF-FILE
$#--------------------------
```

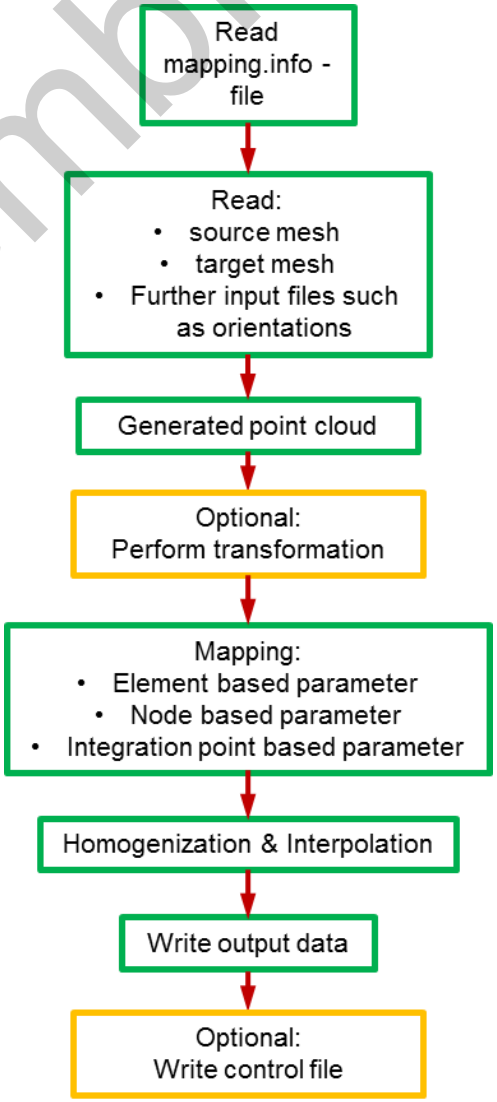
Future Plans

- GUI implementation
- A return mapping has to be performed in order to quantify and „postprocess“ the loss of information during the mapping process (by now, only visual quality check).
- Possible evaluation criteria:
  - Overlap of mapped areas
  - Average offset btw. meshes
  - Comparison btw. element normals
  - „jumps“ within the mapped parameter
  - Difference btw. transfered energies
  - Offsets btw. corresponding elements
- Output can be local (element or nodewise) or global
- …



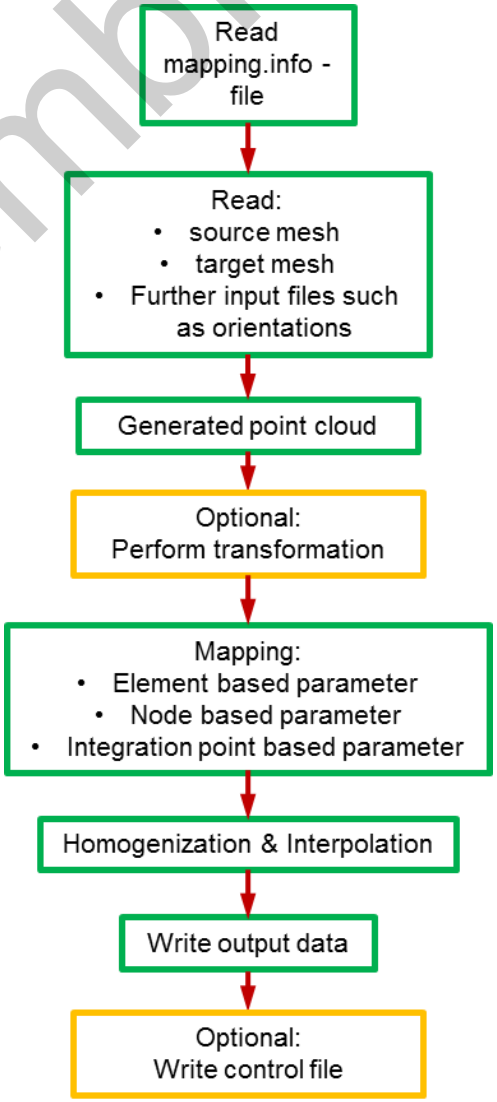
Future Plans

- **Tensor interpolation methods:**
  - Several approaches exist:
    - Euclidean interpolation
    - Riemannian interpolation
    - Log-Euclidean method
    - Geodesic-loxodrome approach
    - Approaches using partial differential equations
  - Target: properly transfer shape and orientation
  - Tensor characteristics are described by eigenvalues, eigenvectors
  - The usage of tensor invariants is proposed for tensor interpolation



Future Plans

- **Scalar value interpolation methods:**
  - Several approaches exist:
    - Inverse distance weighted methods (Shepard's method)
    - Rectangle based blending methods
    - Triangle based blending methods
    - Finite element based methods
    - Foley's methods
    - Global basis function type methods
    - Modified maud methods



Future Plans

- Envyo® will be available on **Windows** and **Linux** platforms
- first test versions will be available by the end of this year
- after a successful testing period it is thought to distribute Envyo® commercially. Details will follow in due time.

Remark:

- the quality and the capability of the program are highly dependent on its usage. Feedback is very appreciated.

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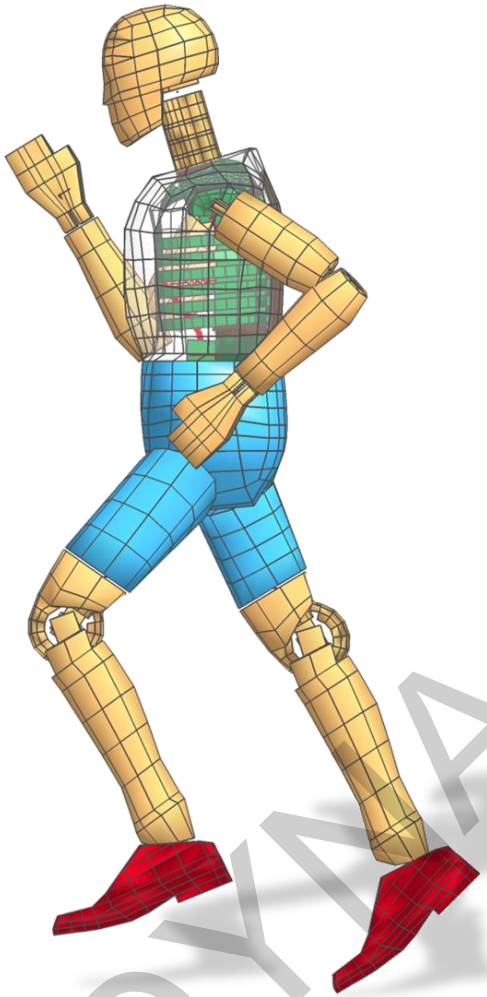
Questions & Answers



FIN

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