

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

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DYNA
MORE

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 enhancements led to the consideration of fiber orientations gained from draping simulations with *MAT_249 (*MAT_REINFORCED_THERMOPLASTIC) 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 independent **C++** program.

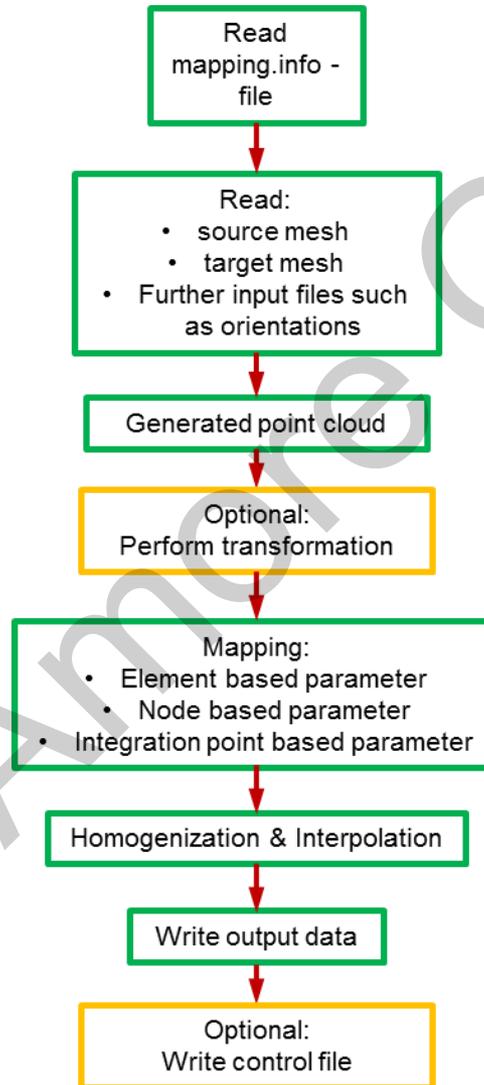
„Historical“ Overview

- 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 been 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 has 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

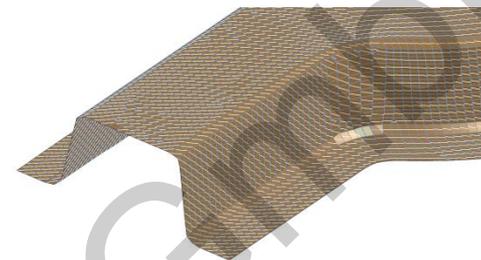
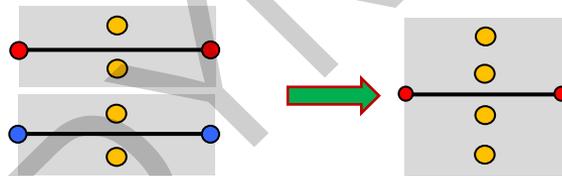
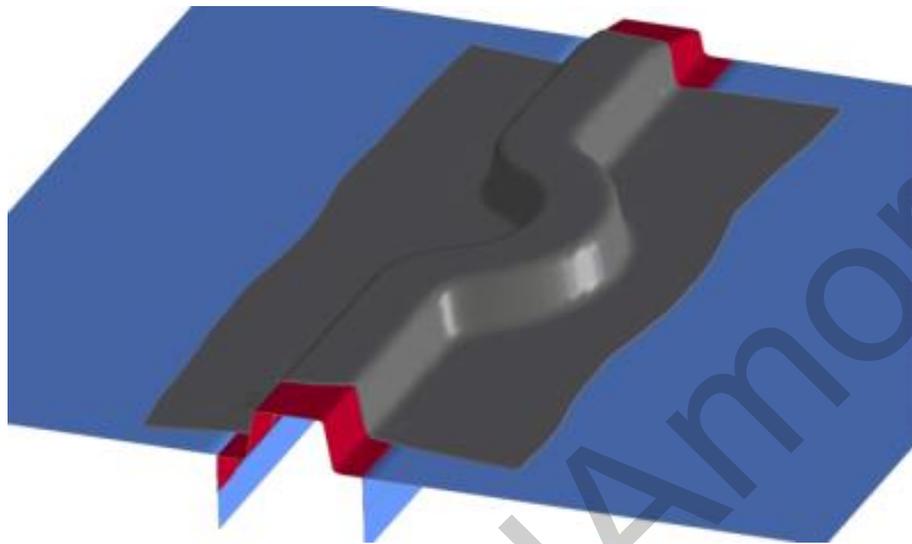


Mapping Capabilities

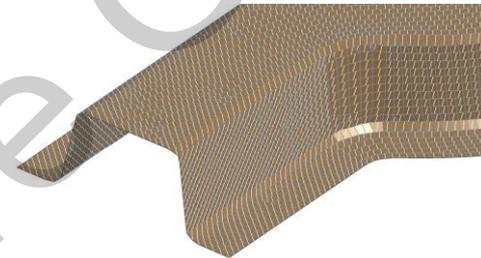
- ORIENTATION -> SHELL
- ORIENTATION -> ALE_MESH
- SHELL -> STACKED_SHELL
- SOLID -> SOLID
- STACKED_SHELL -> SOLID
- BEAM -> ALE_MESH
- SHELL -> SOLID
- SHELL -> THICK_SHELL
- STACKED_SHELL -> STACKED_THICK_SHELL
- SHELL -> SHELL
- SHELL -> SOLID (GENERATION)
- MOLDFLOW -> SHELL
- MOLDFLOW -> SOLID
- 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



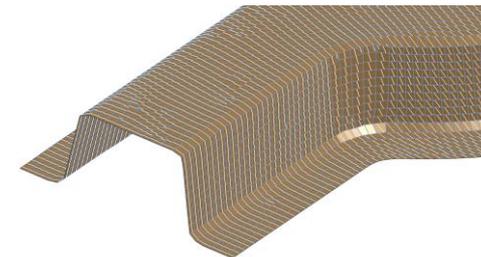
Layer #1:



Layer #2:



Layer #3:



Layer #4:

Mapping Capabilities

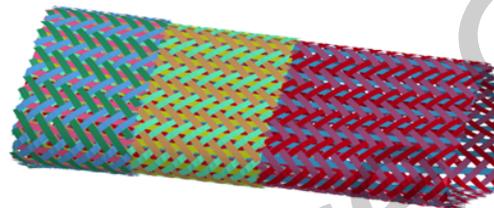
- ORIENTATION -> ALE_MESH



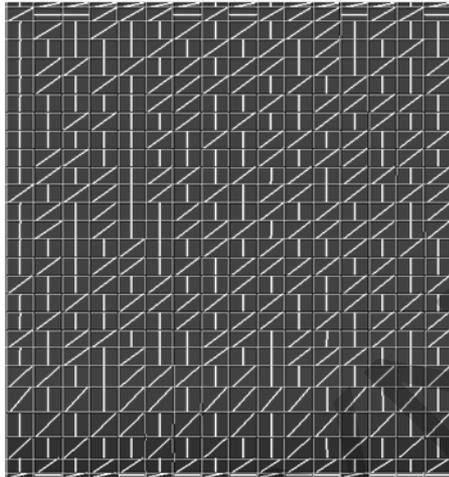
Mapping Capabilities

- SHELL -> STACKED_SHELL

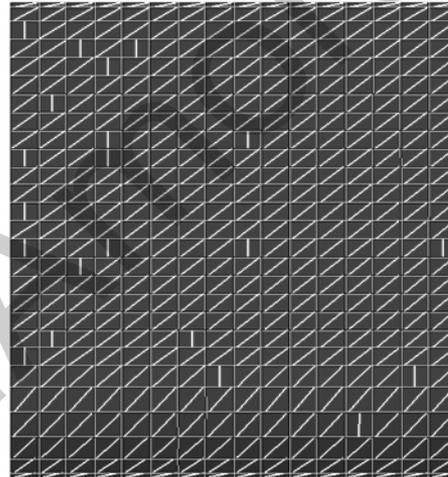
Layer #1:



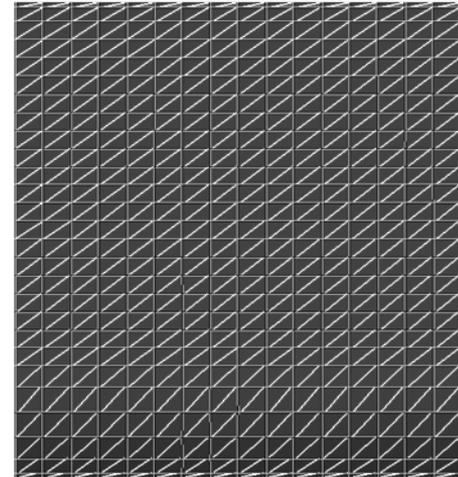
SF = 0.5



SF = 1.0

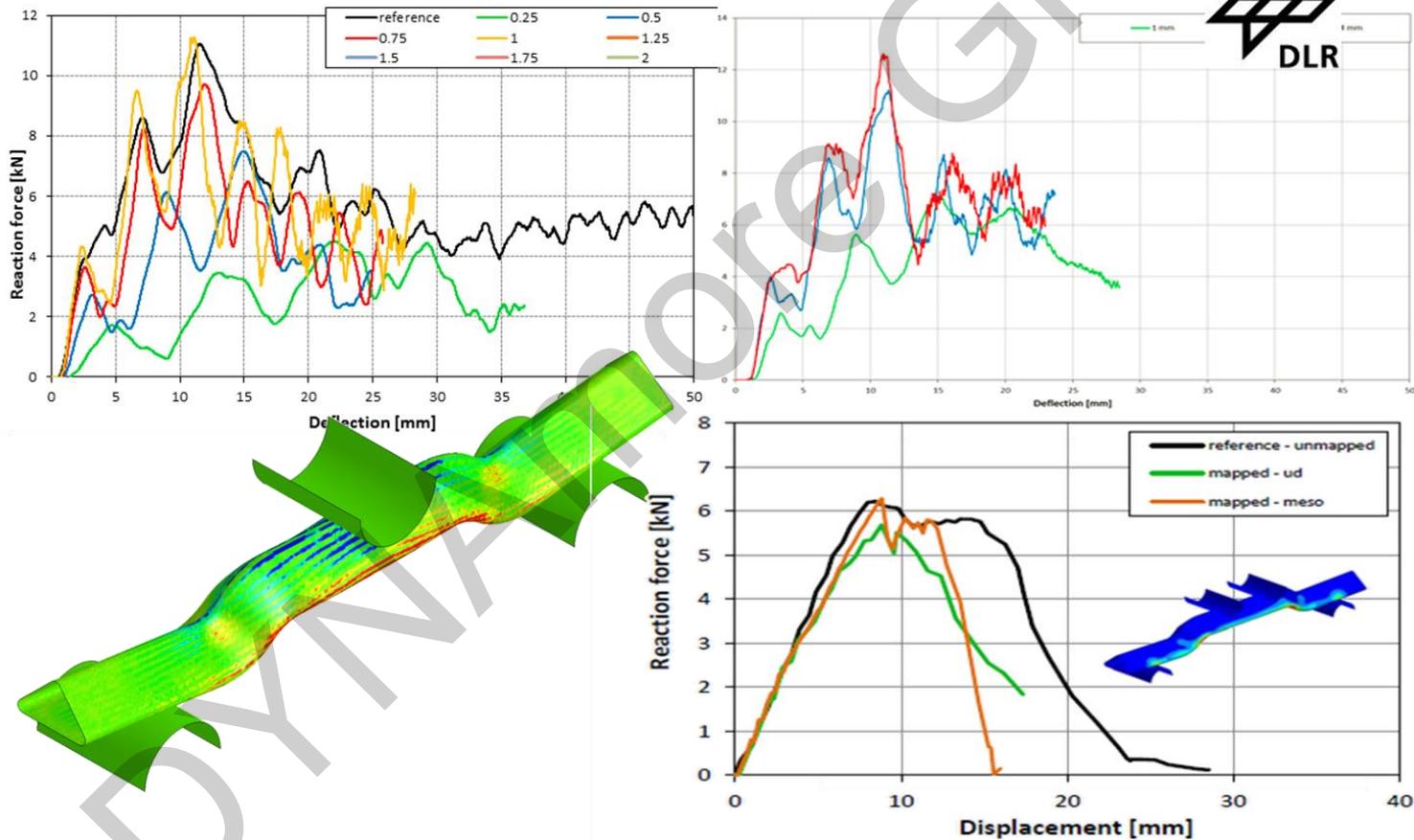


SF = 2.0



Mapping Capabilities

- SHELL -> STACKED_SHELL



Mapping Capabilities

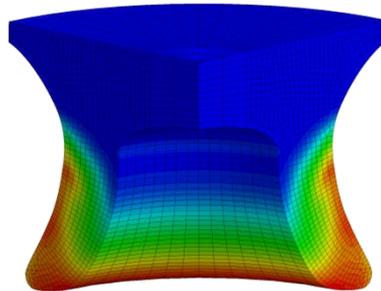
- SOLID -> SOLID

Plast. Strain:

v. Mises stress:

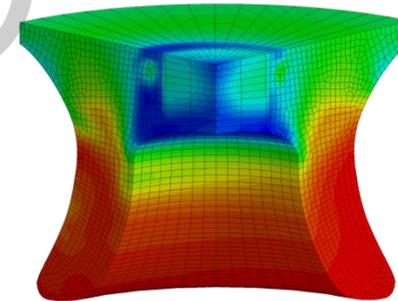
Source:

Contours of plastic strain
min=0, at elem# 8000720
max=0.443386, at elem# 8000709



Fringe Levels
4.434e-01
4.286e-01
4.138e-01
3.990e-01
3.695e-01
3.547e-01
3.399e-01
3.251e-01
3.104e-01
2.956e-01
2.808e-01
2.660e-01
2.513e-01
2.365e-01
2.217e-01
2.069e-01
1.921e-01
1.774e-01
1.626e-01
1.478e-01
1.330e-01
1.182e-01
1.035e-01
8.868e-02
7.390e-02
5.912e-02
4.434e-02
2.956e-02
1.478e-02
0.000e+00

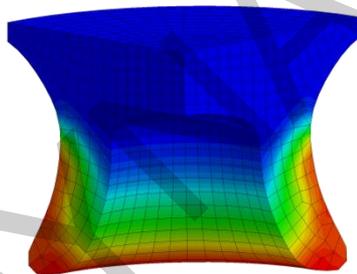
Contours of Von Mises stress
min=0.0433931, at elem# 8011936
max=2.03416, at elem# 8000705



Fringe Levels
2.034e+00
1.968e+00
1.902e+00
1.835e+00
1.769e+00
1.703e+00
1.636e+00
1.570e+00
1.504e+00
1.438e+00
1.371e+00
1.305e+00
1.239e+00
1.172e+00
1.106e+00
1.040e+00
9.735e-01
9.072e-01
8.409e-01
7.746e-01
7.083e-01
6.420e-01
5.757e-01
5.094e-01
4.431e-01
3.769e-01
3.106e-01
2.443e-01
1.780e-01
1.117e-01
4.539e-02

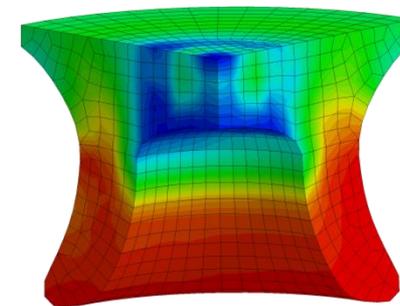
Target:

LS-DYNA keyword deck by LS-PrePost
Contours of plastic strain
min=0, at elem# 281
max=0.417729, at elem# 144



Fringe Levels
4.177e-01
4.038e-01
3.899e-01
3.760e-01
3.620e-01
3.481e-01
3.342e-01
3.203e-01
3.063e-01
2.924e-01
2.785e-01
2.646e-01
2.506e-01
2.367e-01
2.228e-01
2.089e-01
1.949e-01
1.810e-01
1.671e-01
1.532e-01
1.392e-01
1.253e-01
1.114e-01
9.747e-02
8.355e-02
6.962e-02
5.570e-02
4.177e-02
2.785e-02
1.392e-02
0.000e+00

LS-DYNA keyword deck by LS-PrePost
Contours of Von Mises stress
min=0.0474004, at elem# 1579
max=2.02445, at elem# 141



Fringe Levels
2.024e+00
1.959e+00
1.893e+00
1.827e+00
1.761e+00
1.695e+00
1.629e+00
1.563e+00
1.497e+00
1.431e+00
1.365e+00
1.300e+00
1.234e+00
1.168e+00
1.102e+00
1.036e+00
9.700e-01
9.041e-01
8.382e-01
7.723e-01
7.064e-01
6.405e-01
5.746e-01
5.087e-01
4.428e-01
3.769e-01
3.110e-01
2.451e-01
1.792e-01
1.133e-01
4.740e-02

Mapping Capabilities

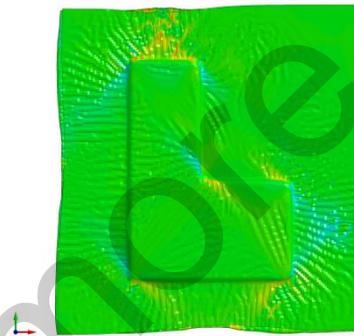
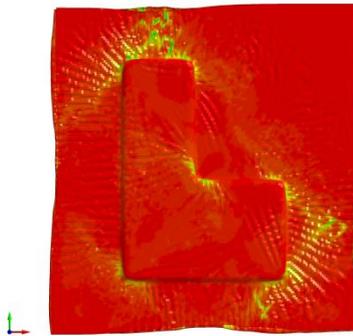
- STACKED_SHELL -> SOLID

Mean strain:

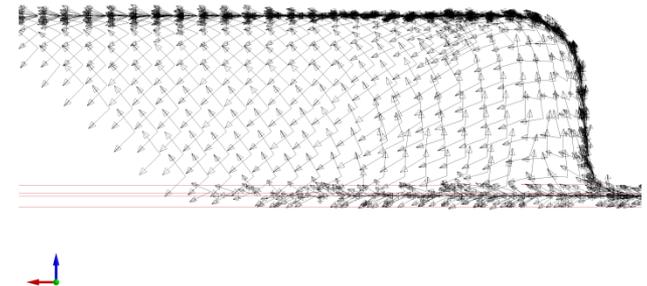
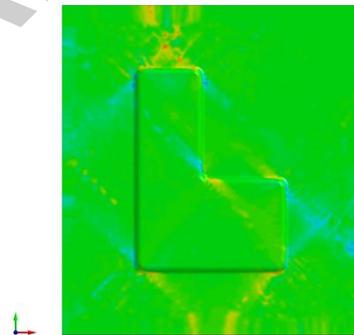
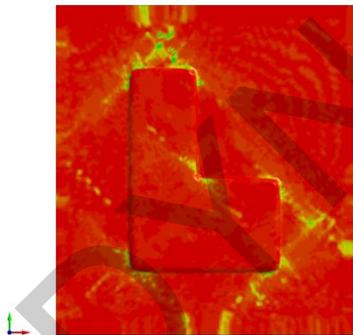
HISV #1:

Fiber orientation output:

original:



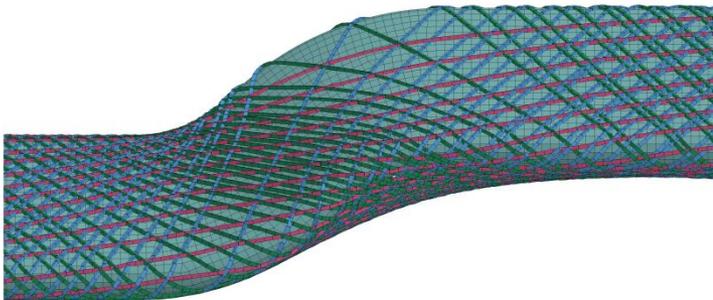
target:



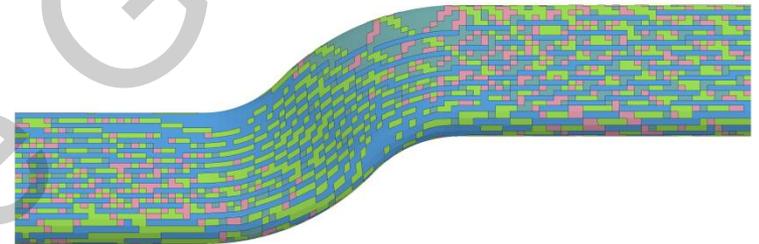
Mapping Capabilities

- BEAM -> SHELL

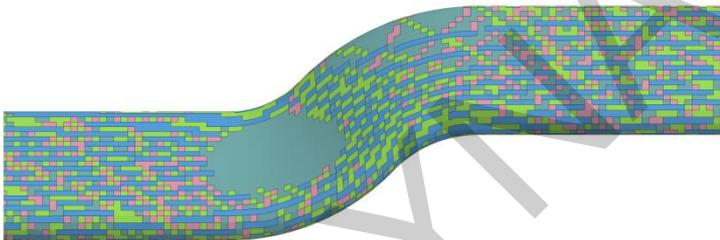
Source – Mesh:



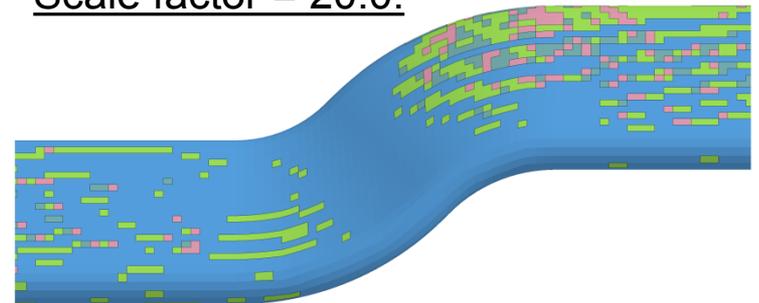
Scale factor = 5.0:



Scale factor = 1.0:



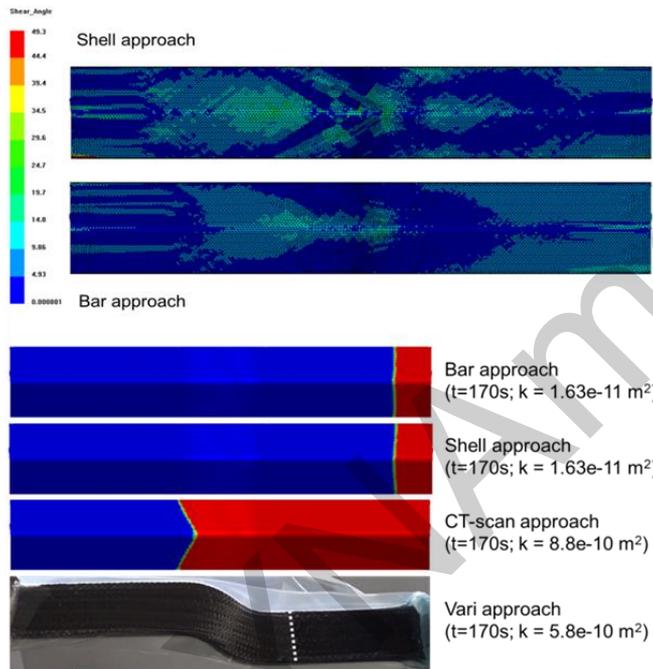
Scale factor = 20.0:



Mapping Capabilities

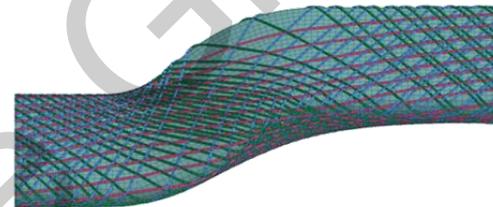
- BEAM -> SHELL

Infiltration Simulation

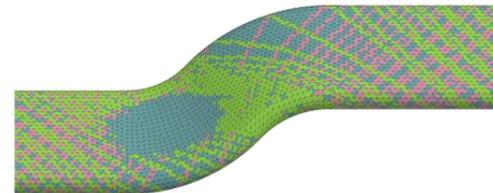


IFB

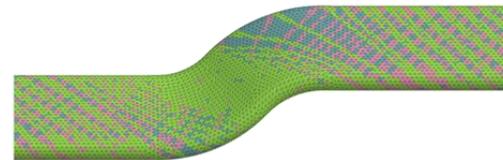
Source – Mesh:



Scale factor = 1.0:

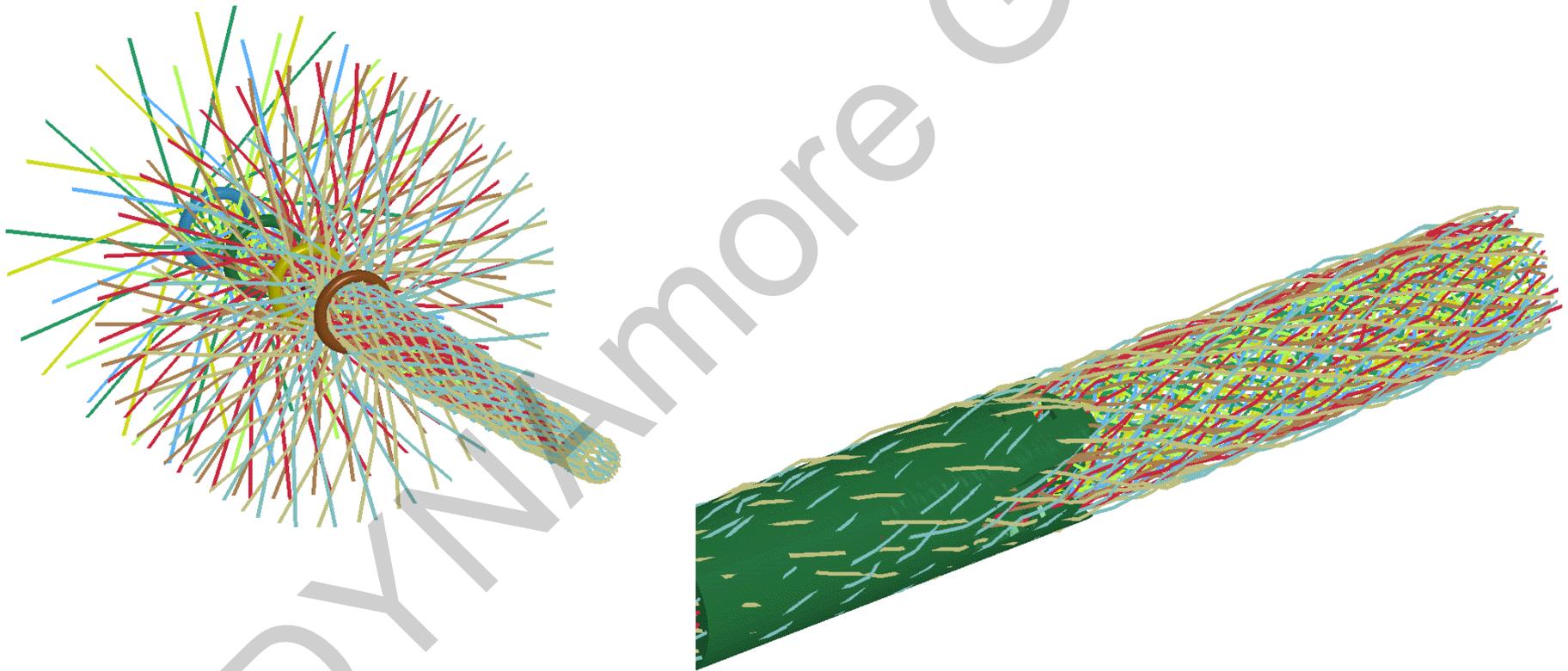


Scale factor = 5.0:



Mapping Capabilities

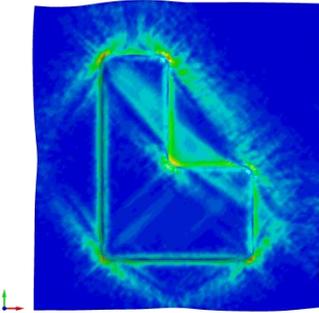
- BEAM -> ALE_MESH



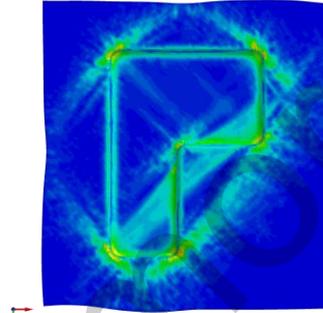
Mapping Capabilities

- SHELL -> SOLID

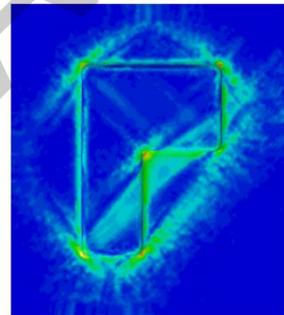
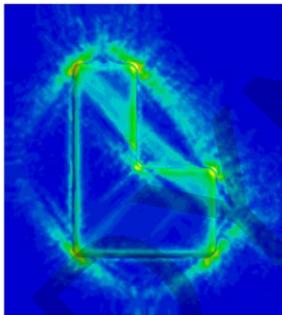
vMises IP1:
(top view)



vMises IP4:
(bottom view)

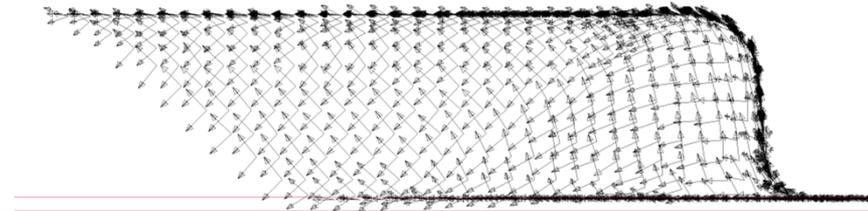


original:



target:

Fiber orientation output:



Mapping Capabilities

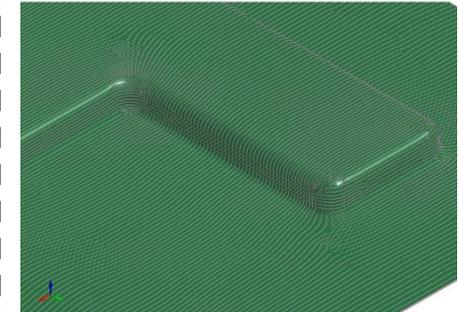
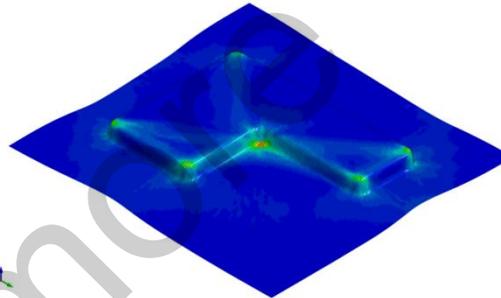
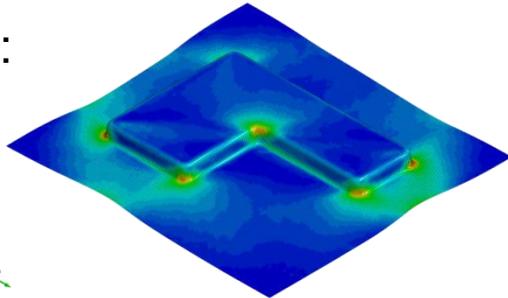
- SHELL -> THICK_SHELL

eff Strain:

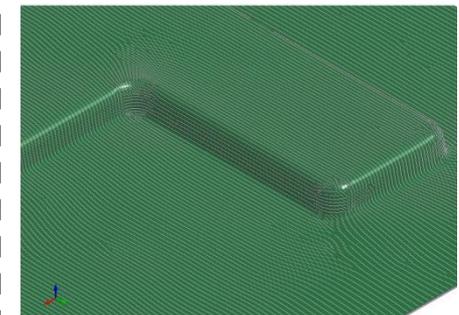
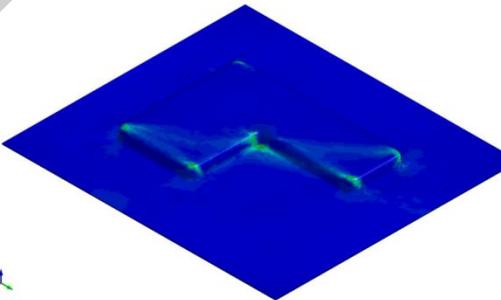
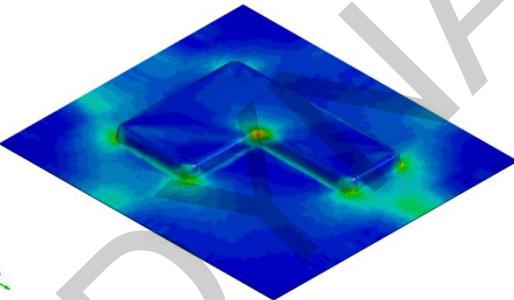
v Mises stress:

Orientations:

Source:



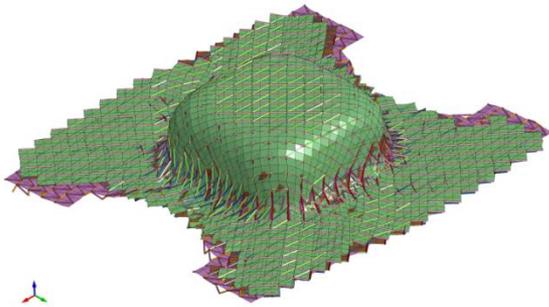
Target:



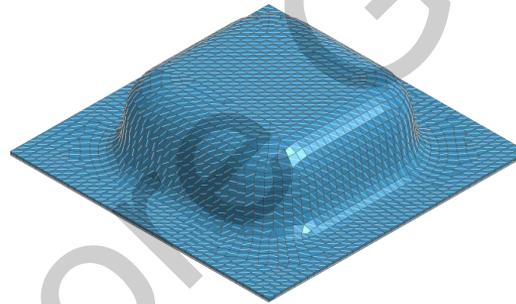
Mapping Capabilities

- STACKED_SHELL -> STACKED_THICK_SHELL

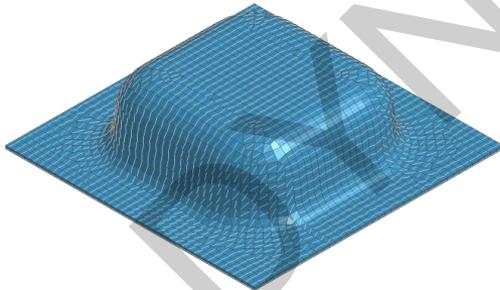
Source – Mesh -Stacked
Shells (5 Layers):



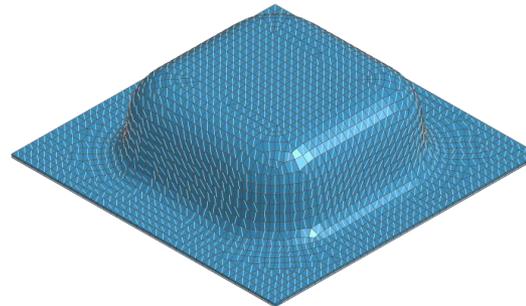
Orientations IP#3:



Orientations IP#1:

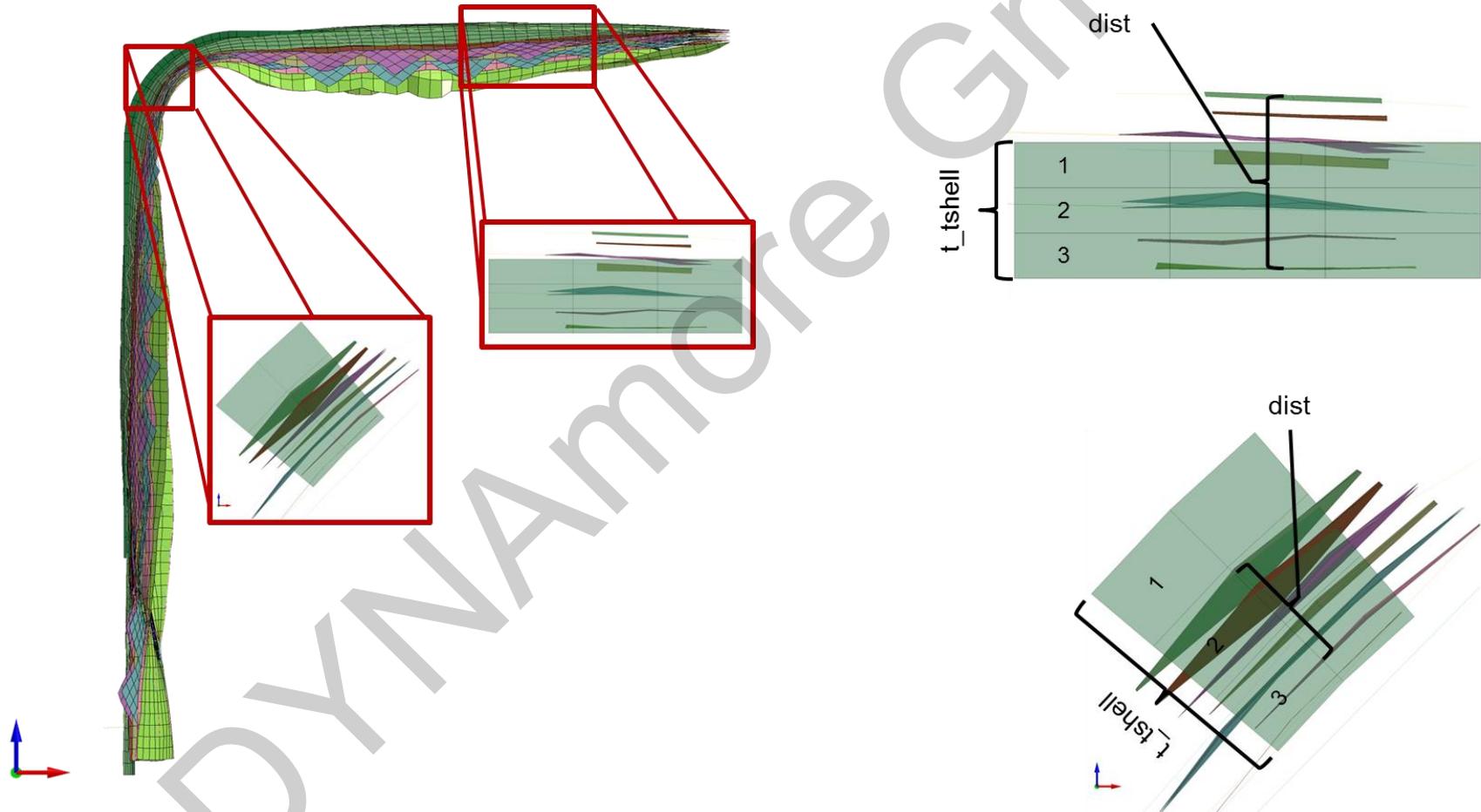


Orientations IP#5:



Mapping Capabilities

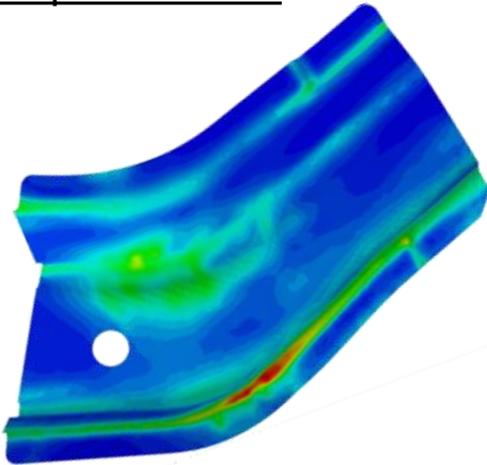
- STACKED_SHELL -> STACKED_THICK_SHELL



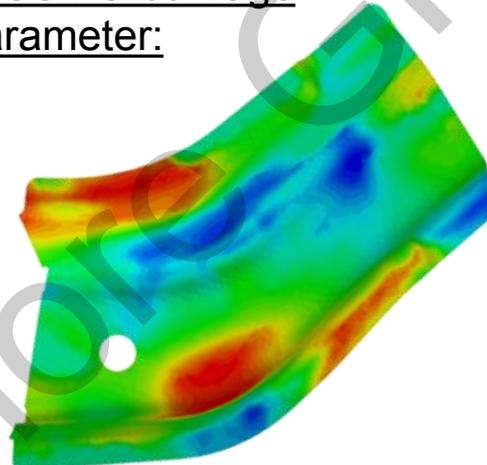
Mapping Capabilities

- SHELL -> SHELL

eff. plast. strain:



GISSMO damage parameter:



Damage estimation

Mapping Capabilities

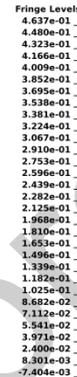
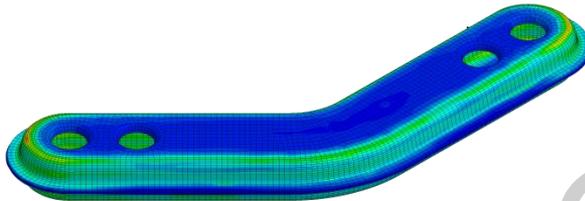
- SOLID -> SHELL

Plast. Strain:

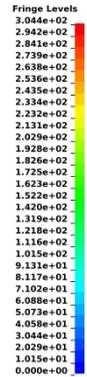
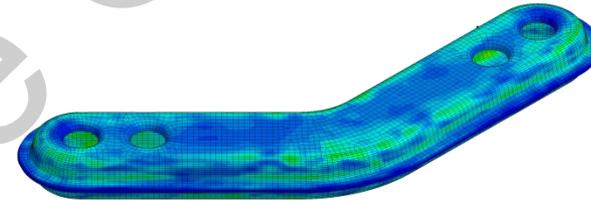
v. Mises stress:

Source:

Contours of plastic strain
min=0.0016261, at elem# 32108
max=0.463726, at elem# 33078

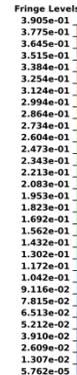
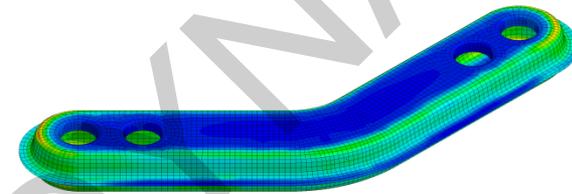


Contours of Von Mises stress
min=0, at elem# 97394
max=304.378, at elem# 51353

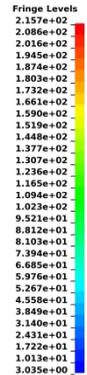
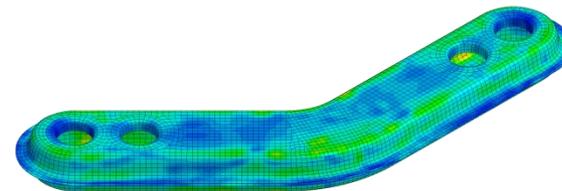


Target:

Contours of plastic strain
shell integration pt#1
min=5.762e-05, at elem# 106779
max=0.3905, at elem# 113615

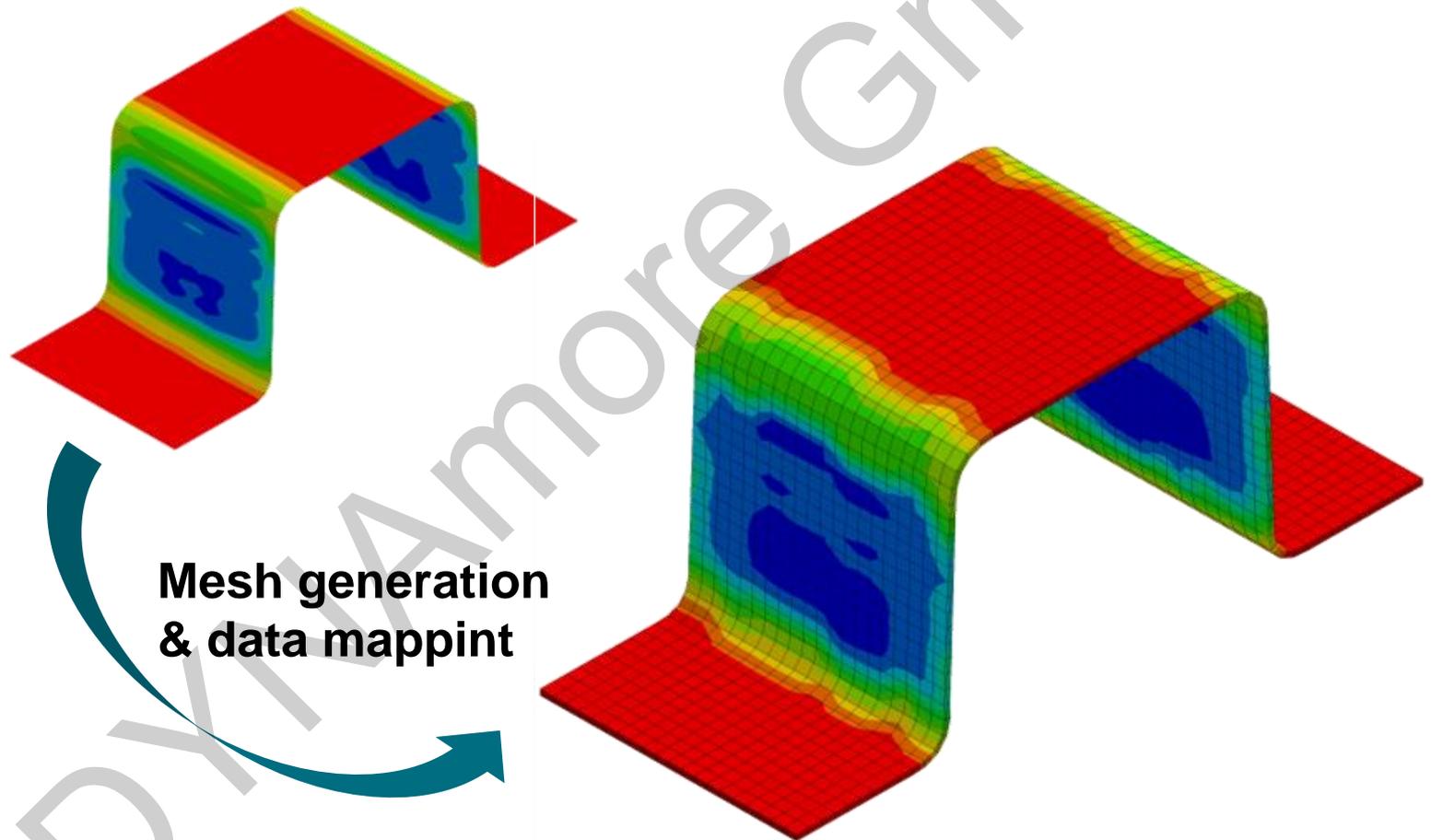


Contours of Von Mises stress
shell integration pt#1
min=3.03504, at elem# 120101
max=215.739, at elem# 120101



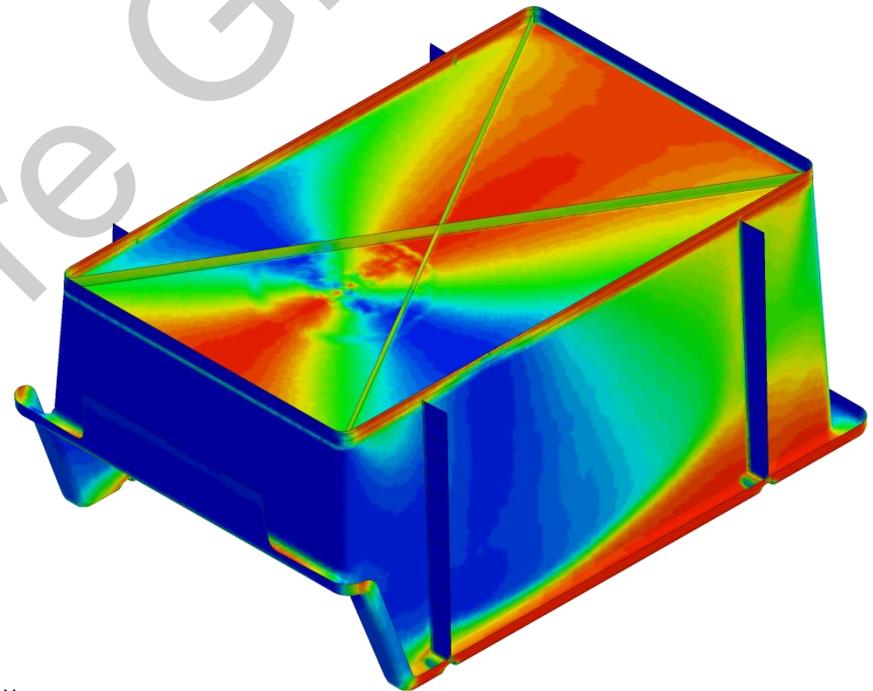
Mapping Capabilities

- SHELL -> SOLID (GENERATION)



Mapping Capabilities

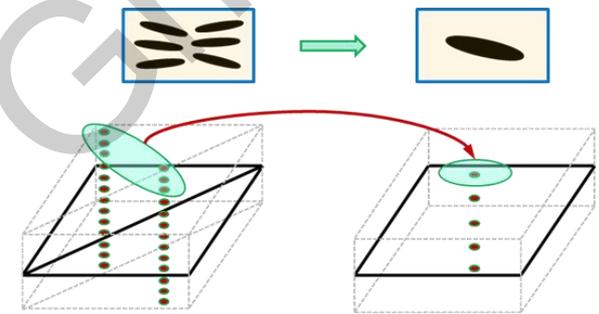
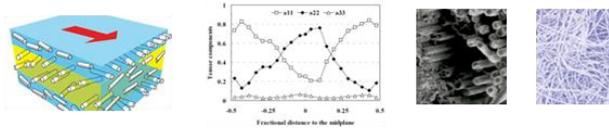
- MOLDFLOW -> SHELL



Mapping Capabilities

- MOLDFLOW -> SHELL (with plasticity curve interpolation)

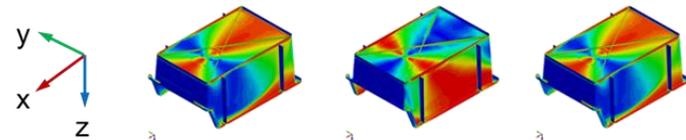
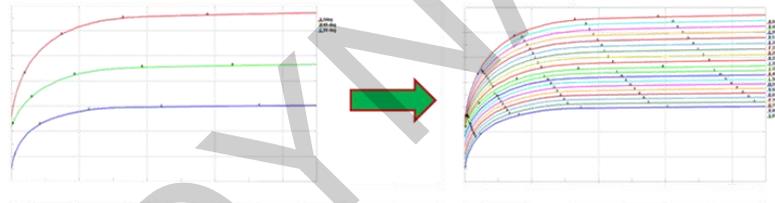
- Mapping (Moldflow/Moldex -> Shell) and homogenization for **SFRP** – components



- 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	nthsv
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	C _{ij}	21
a ₂	Anisotropic constants	r ₀₀ , r ₄₅ , r ₉₀	3
a ₃	Stress-strain Curve	LCSS	1

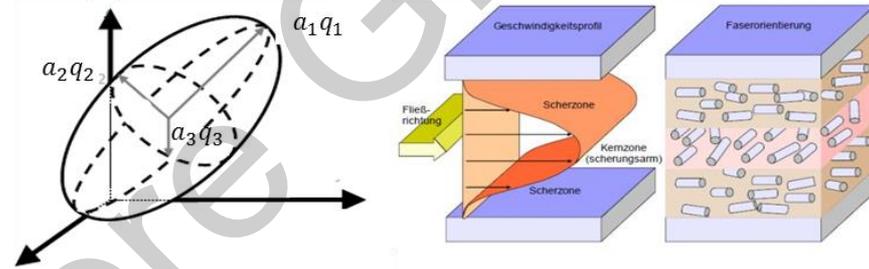


Mapping Capabilities

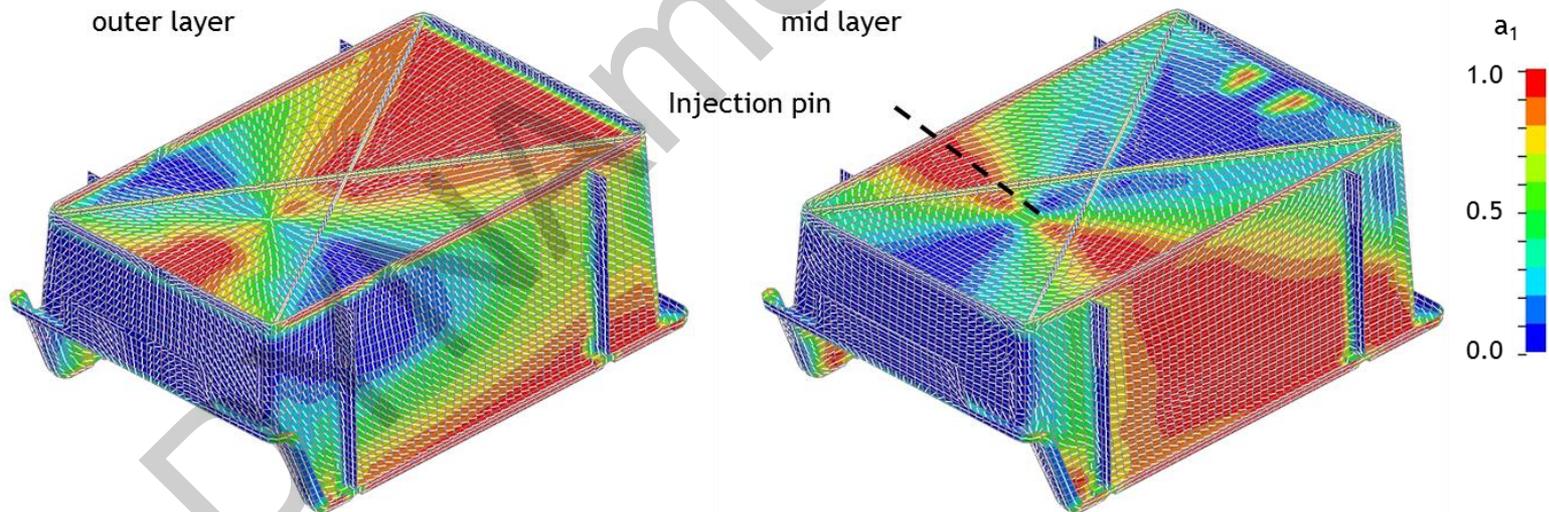
- MOLDFLOW -> SHELL (with plasticity curve interpolation)

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

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

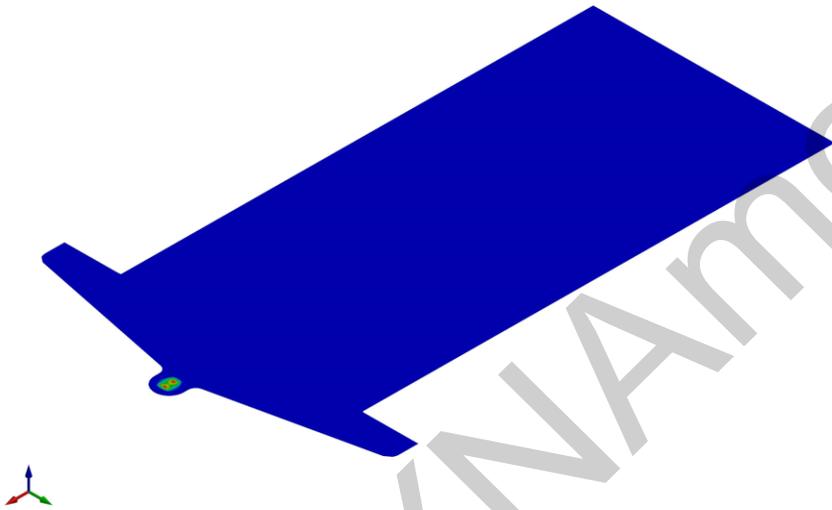


Example: “Nutini-box” eigenvalue a_1 and eigenvector q_1

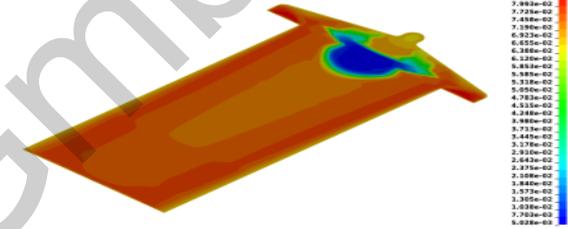


Mapping Capabilities

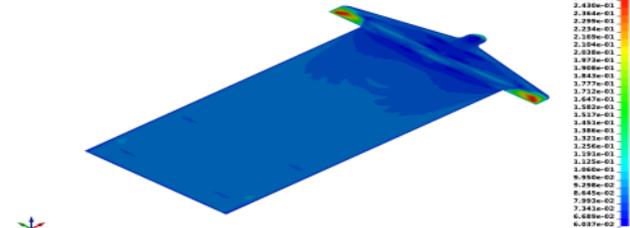
- Moldflow visualization



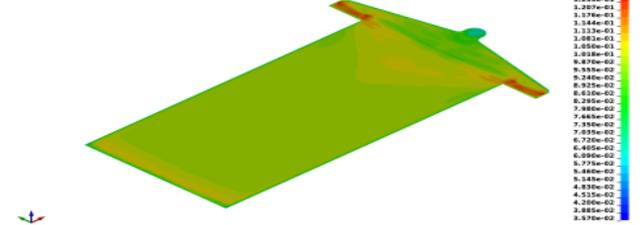
IP#7



IP#9

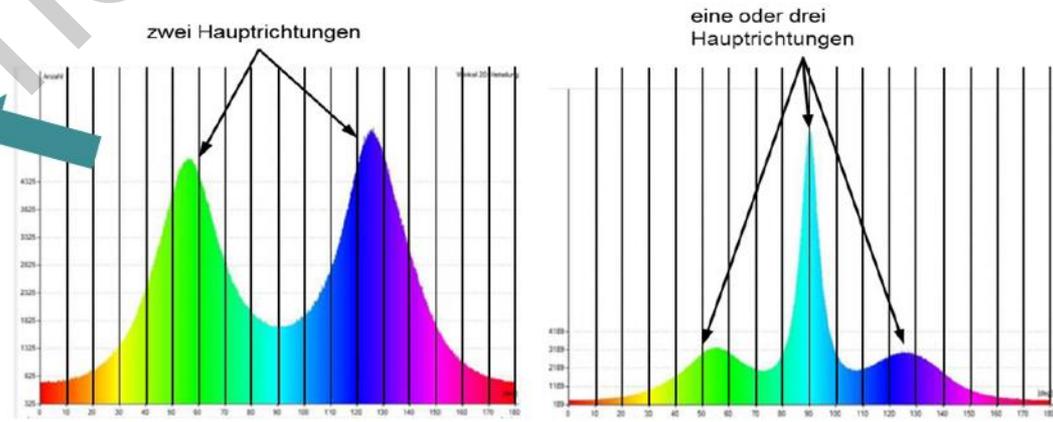
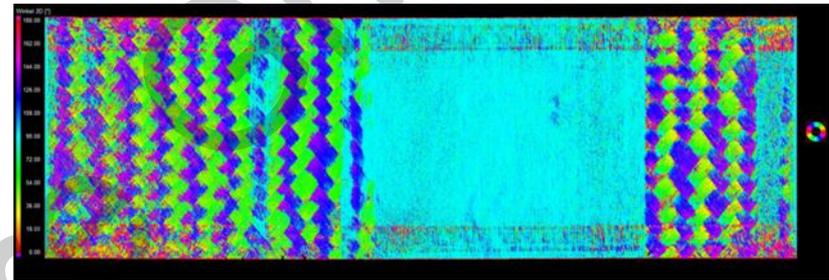
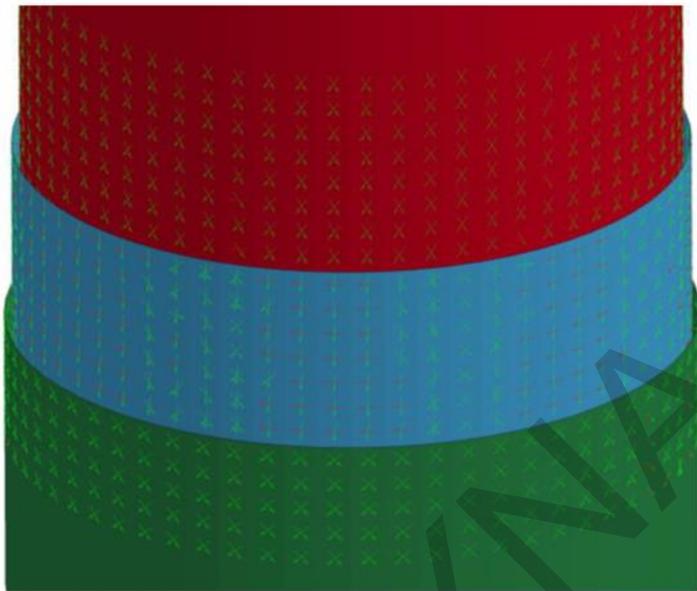


IP#12



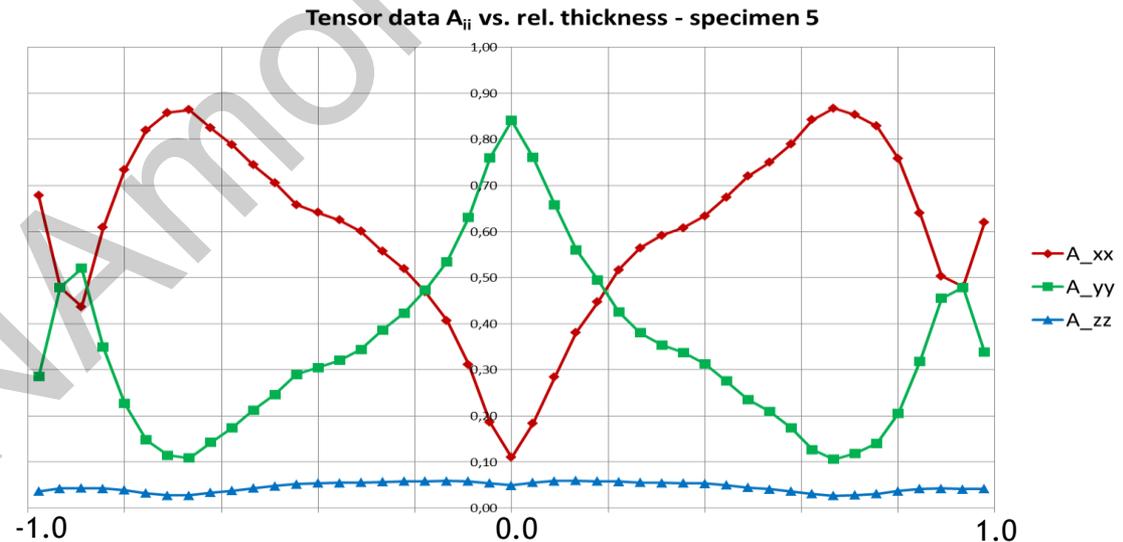
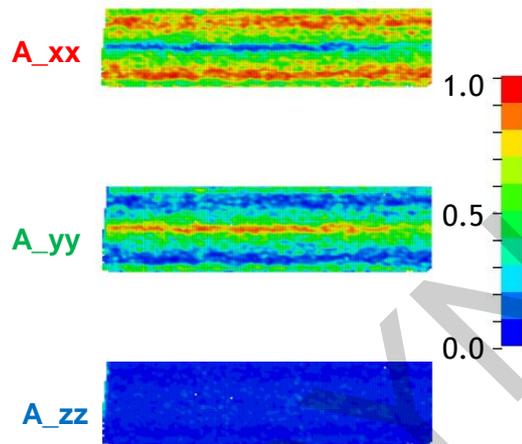
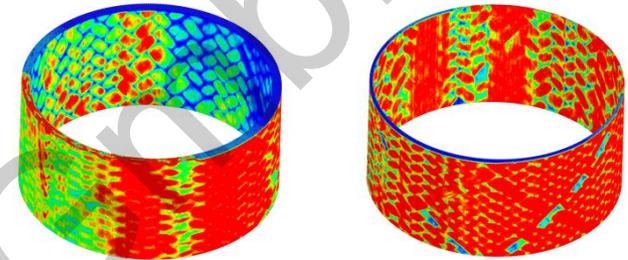
Mapping Capabilities

- CT-Scan -> SHELL



Mapping Capabilities

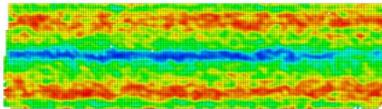
- CT-Scan Visualization
- CT-Scan -> Through Thickness Curves
- Fiber orientation of 0°- specimen over thickness:



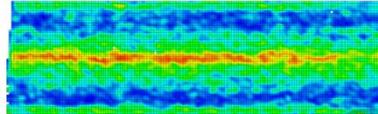
Mapping Capabilities

- MOLDFLOW -> Through Thickness Curves

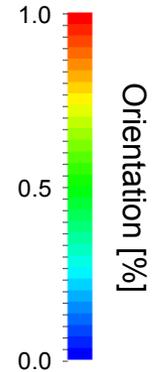
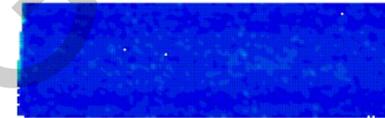
a_{xx}



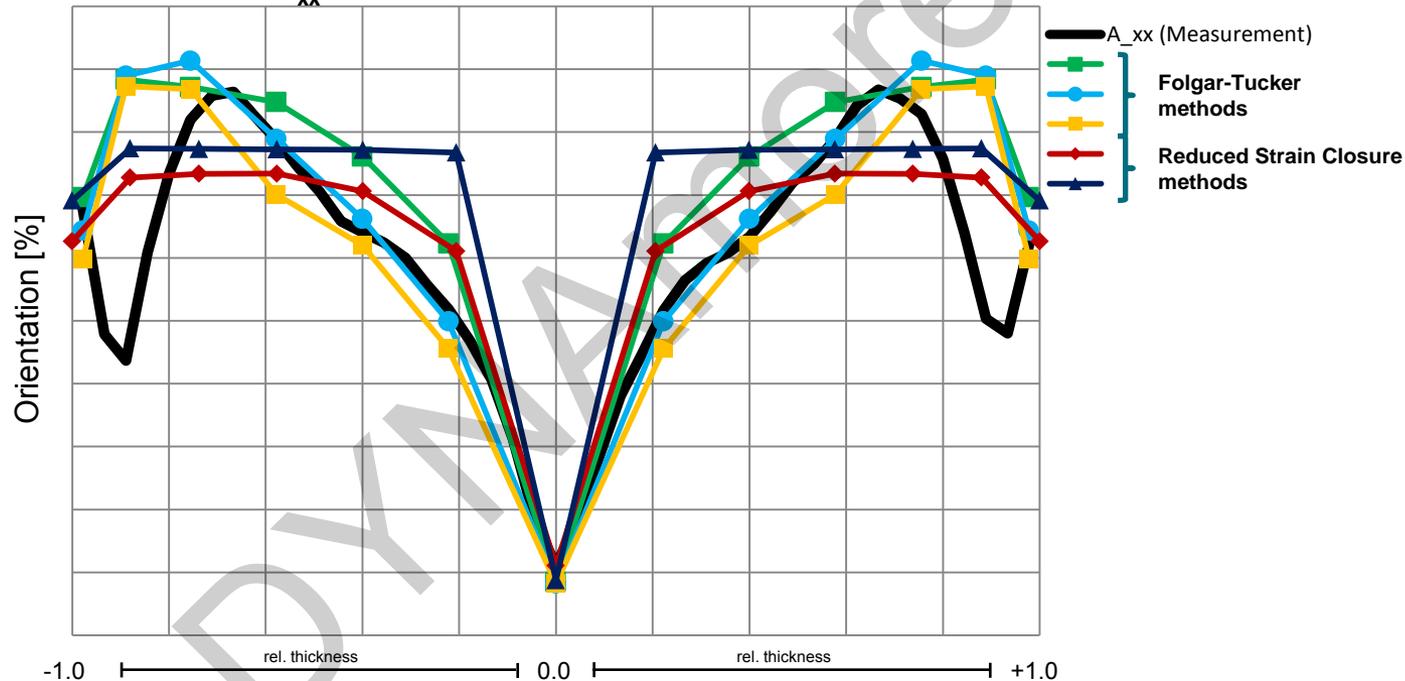
a_{yy}



a_{zz}



Tensor data A_{xx} Measurement vs. Simulation



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 and will be extended as needed

The screenshot displays the HDFView 2.0 application window. The main area shows a hierarchical tree structure of the project 'Projekt_Tunnelbruecke.h5'. The tree includes folders for '000_ProcessStatus', '010_PreliminaryDesign', '020_Optimization', '030_ProcessSimulation', '040_Mapping', 'MAP1_Map2RTM', 'MAP2_Map2Structural', 'esi-pc_Isdyna', and '20150907_122213'. The 'MAP2_Map2Structural' folder is highlighted with a red box. The '20150907_122213' folder is highlighted with a blue box. The right pane shows a table view of the selected folder, with the table content as follows:

	Description
0	PRE1_Drapping_FiberSim_20150907_122153
1	OPT1_Layup_Nastran_20150907_122159
2	PRO1_Braiding_esi-pc_20150907_122204
3	MAP1_Map2RTM_esi-pc_esi-rtm_20150907_122210
4	MAP2_Map2Structural_esi-pc_Isdyna_20150907_122213

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

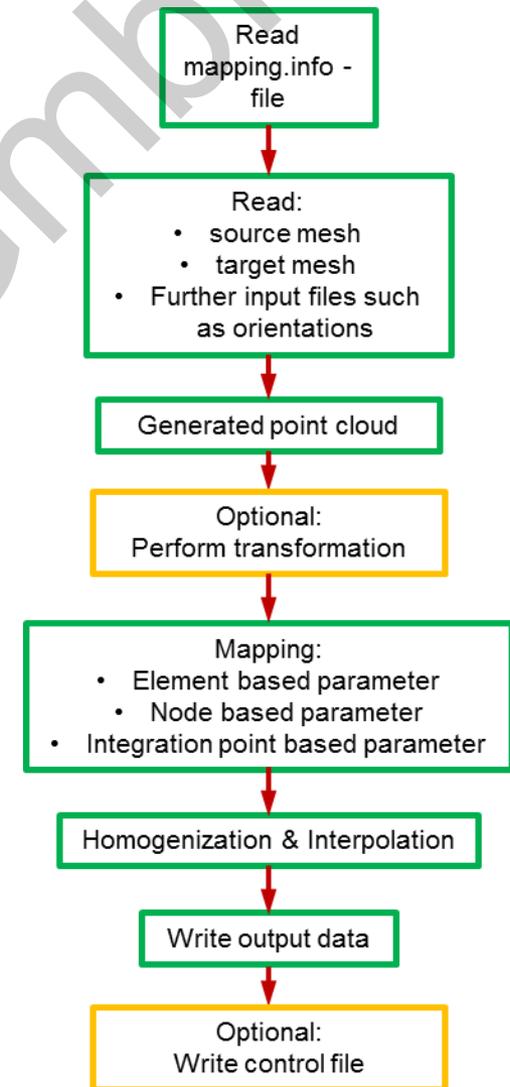
Example

```
$#-----  
$# 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

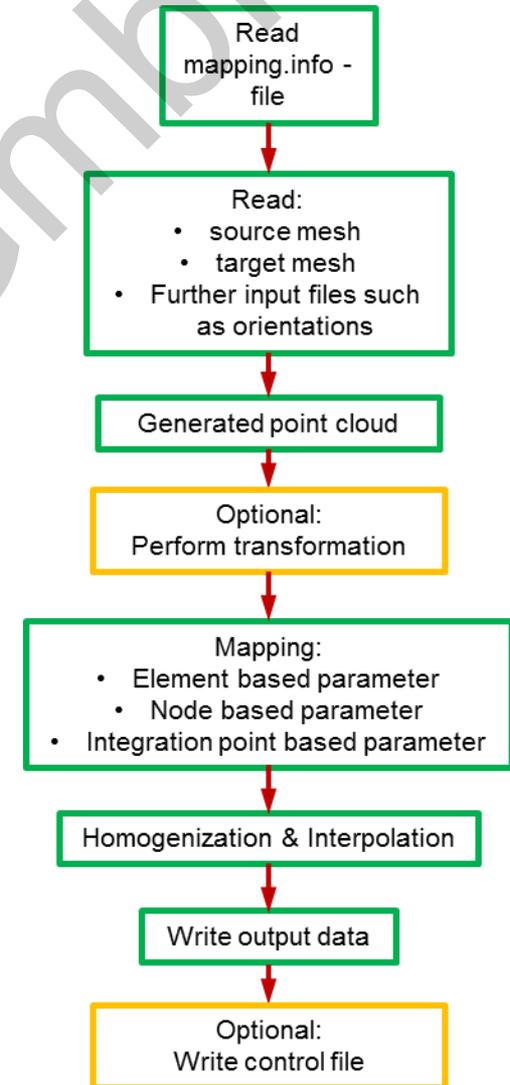
- GUI implementation
- A return mapping has to be performed in order to quantify and „postprocess“ the loss of information during the mapping process (by now, only visual quality check).
- Possible evaluation criteria:
 - Overlap of mapped areas
 - Average offset btw. meshes
 - Comparison btw. element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



Future Plans

■ Tensor interpolation methods:

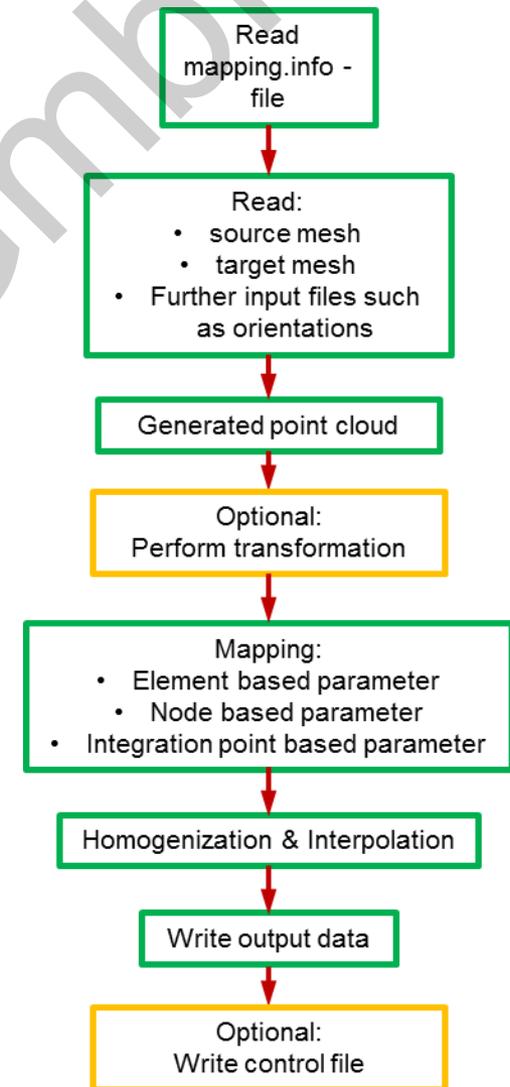
- Several approaches exist:
 - Euclidean interpolation
 - Riemannian interpolation
 - Log-Euclidean method
 - Geodesic-loxodrome approach
 - Approaches using partial differential equations
- Target: properly transfer shape and orientation
- Tensor characteristics are described by eigenvalues, eigenvectors
- 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



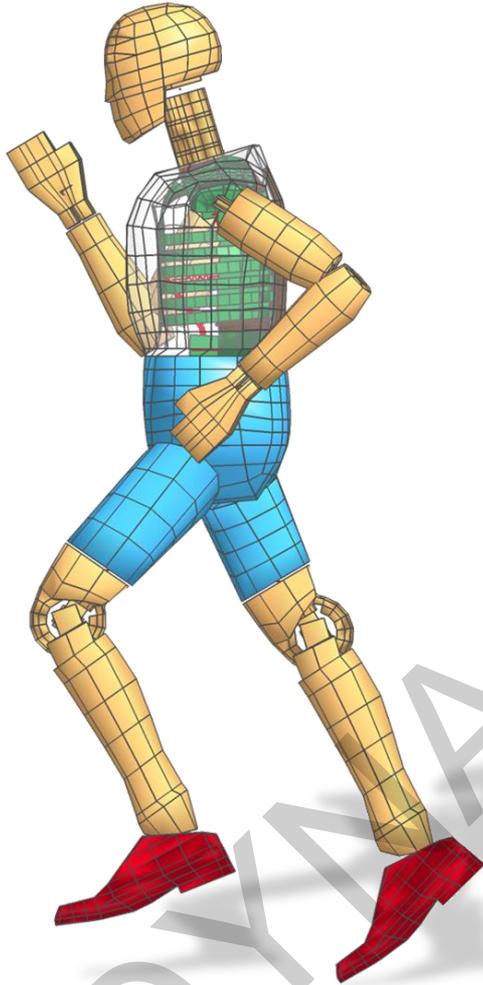
Future Plans

- 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.

Questions & Answers



FIN

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 **DYNA**
MORE