Considering the local anisotropy simulation process chain for short and long fiber reinforced thermoplastics

P. Reithofer, B. Jilka, A. Fertschej
4a engineering GmbH, Traboch, Austria

automotive CAE GRAND CHALLENGE 2017

5. – 6. April 2017, Hanau

4a engineering GmbH
Industriepark 1
A-8772 Traboch
reithofer@4a.co.at
++43 (0) 664 80106 601

Content

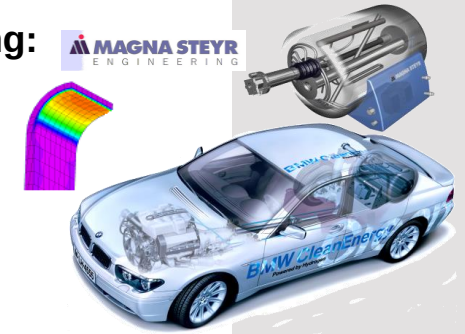
- Introduction 4a engineering & 4a impetus
- Overview short & long fiber reinforced thermoplastics
- Simulation process chain
- 4a fibermap - <<Template>> based mapping
- Case study
- Missing links
- Summary & outlook
- Appendix – short tutorial

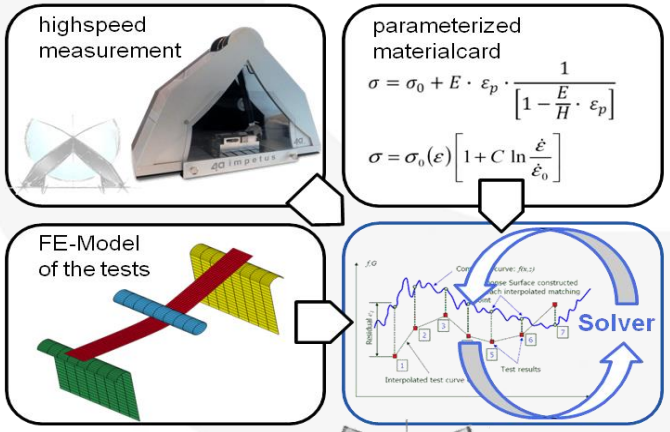
4a engineering GmbH

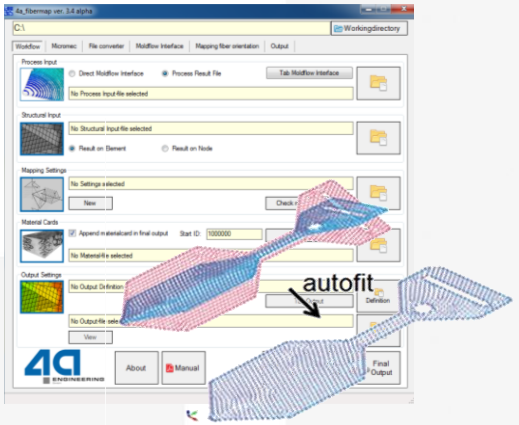
- polymer and materials science
- numerical simulation methods
- fiber reinforced plastics and composites
- method and software development
- material characterization
- product development

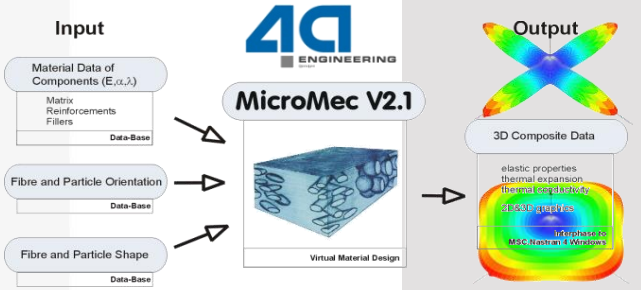
strut bar:

LH_2 – tank mounting:



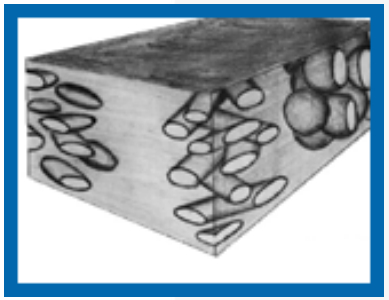






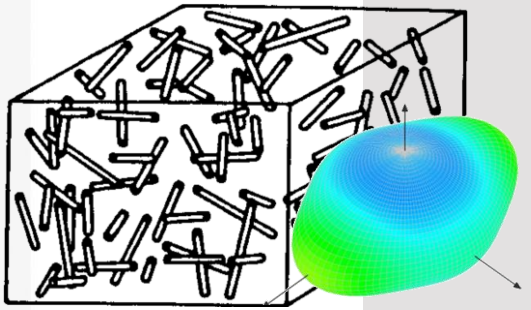
IMPETUS FIBERMAP MICROMEC

Overview SFRT / LFRT

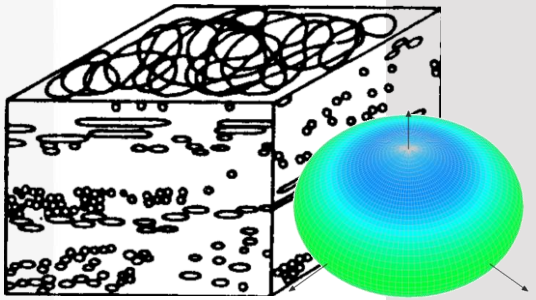


Overview composites
Polymer composites

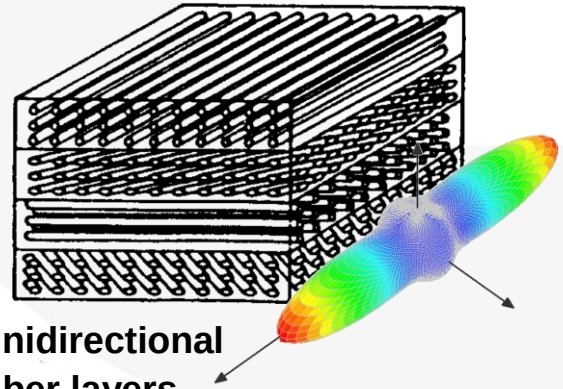
- Unreinforced
- Particle reinforced (l/d<1)
- Short fiber reinforced **(l/d 20-40, d~10µm)**
- Long fiber reinforced **(l/d 100-200, d~20µm)**
- Endless fiber reinforced (l/d >> 1000)



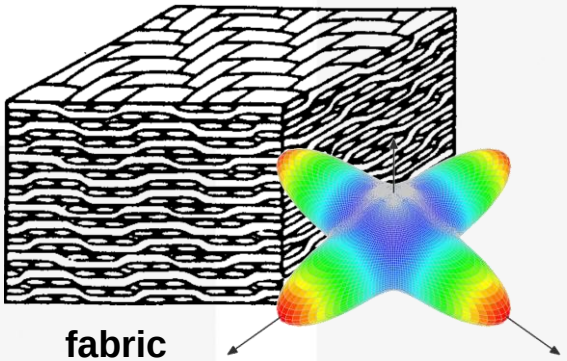
Short resp. long fiber



fiber mat



unidirectional fiber layers

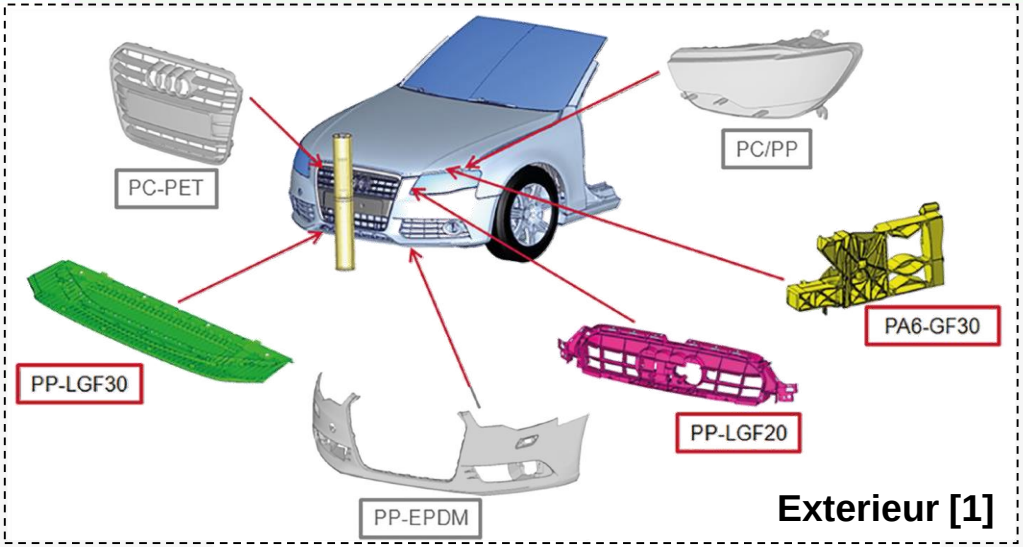


fabric

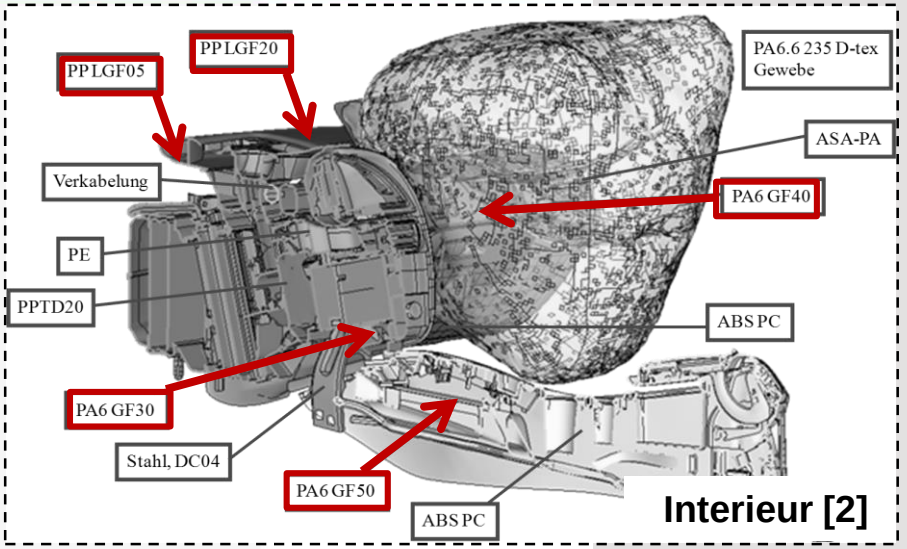
Source: Physik und Werkstoffkunde der Kunststoffe VO02/03, Montanuniversität Leoben

Overview SFRT / LFRT

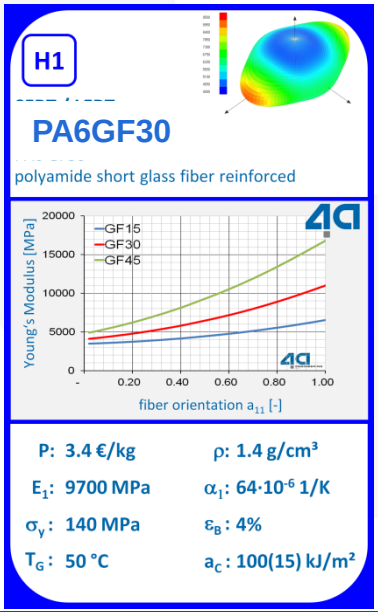
Typical applications and materials

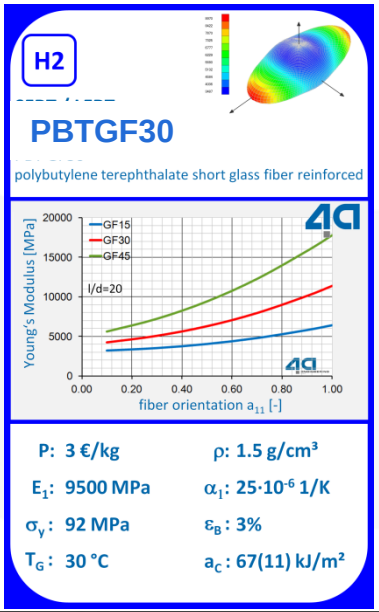


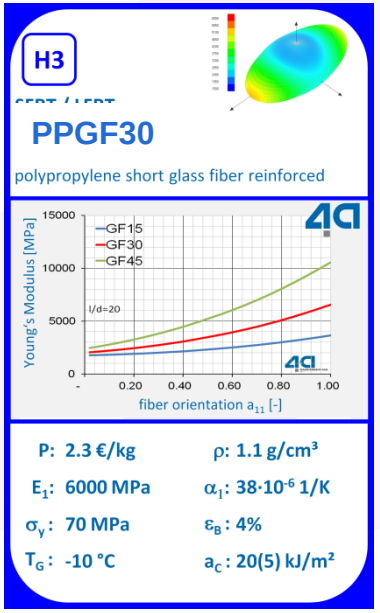
Exterieur [1]

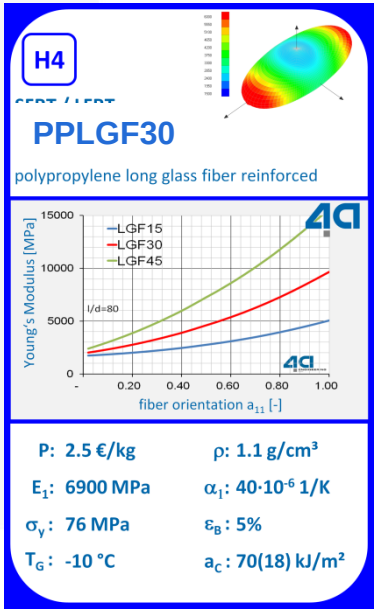


Interieur [2]





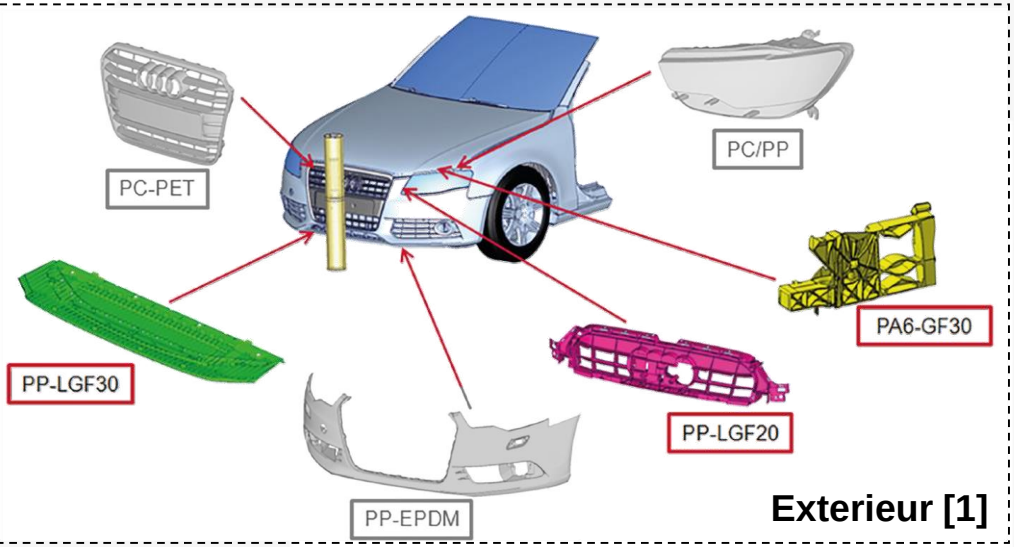




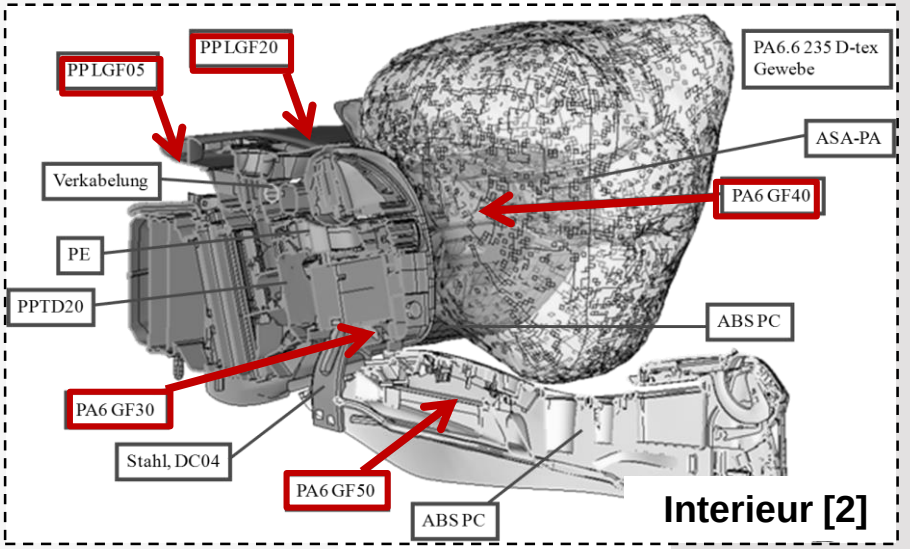
[1] A. Koukal, Audi AG - *Crash- und Bruchverhalten von Kunststoffen im Fußgängerschutz von Fahrzeugen*, TU München, 2014

[2] R. Luijkx, Audi AG - *Kunststoffmaterialien in der Interieur Funktionsauslegung bei Audi AG,* 4a Technologietag 2010

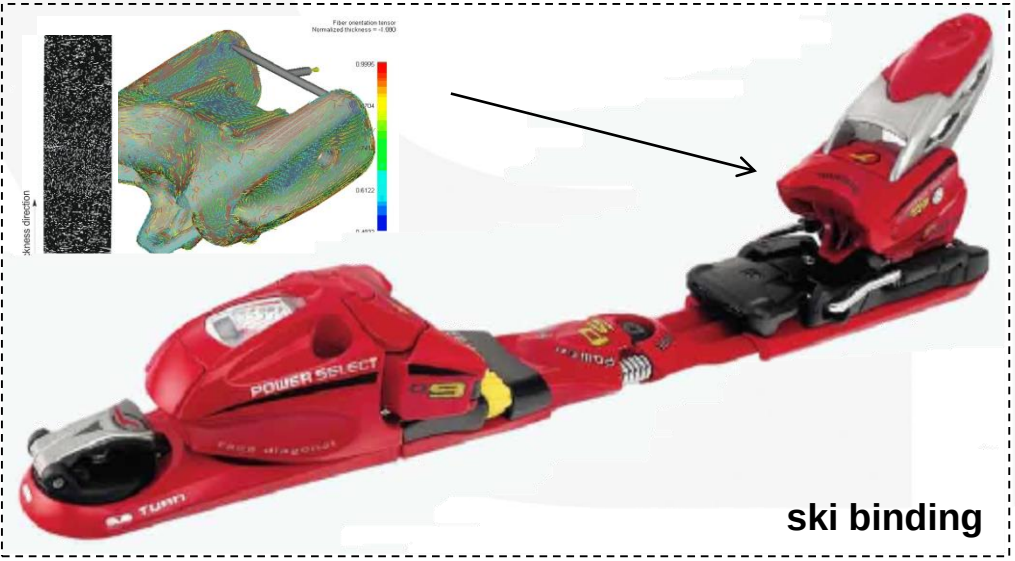
Short and long fiber reinforced thermoplastics
Typical applications



Exterieur [1]



Interieur [2]

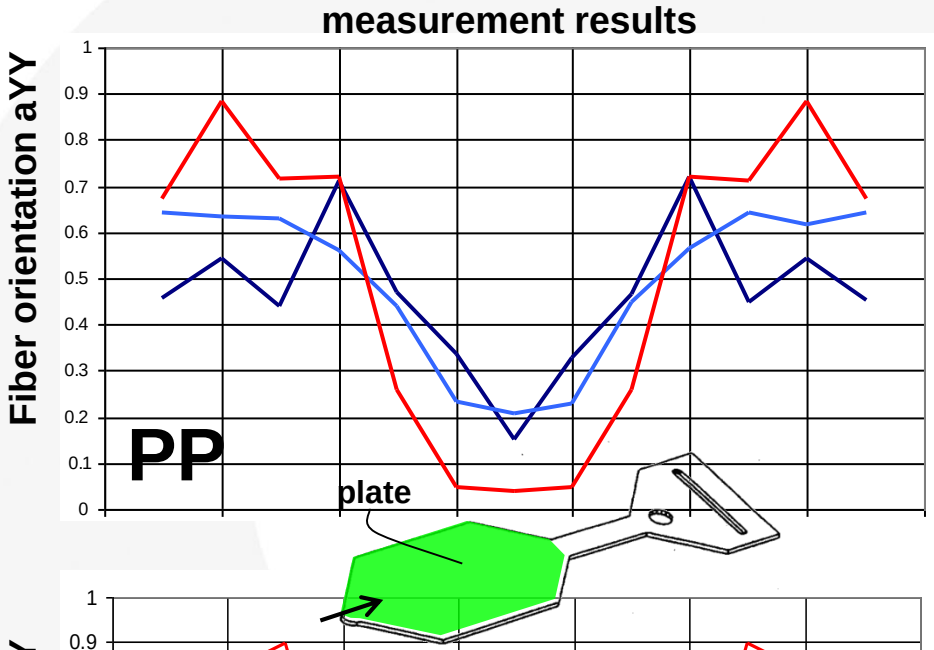


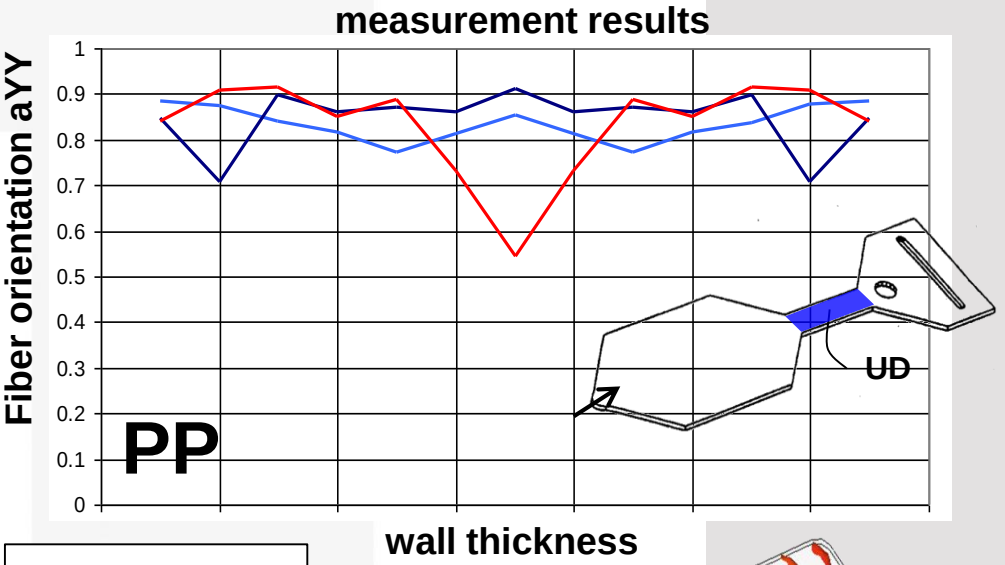
ski binding

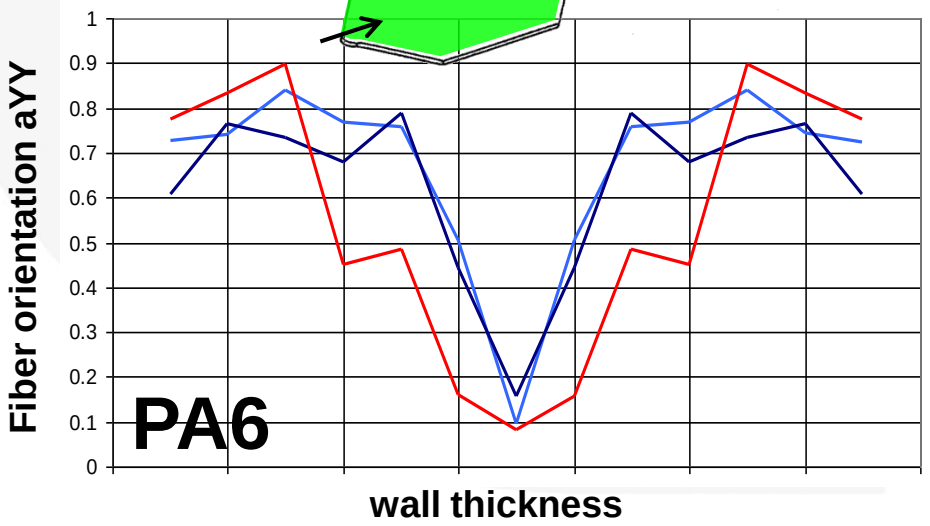
- Consumer goods
- Power Tools
- ....

Overview SFRT / LFRT

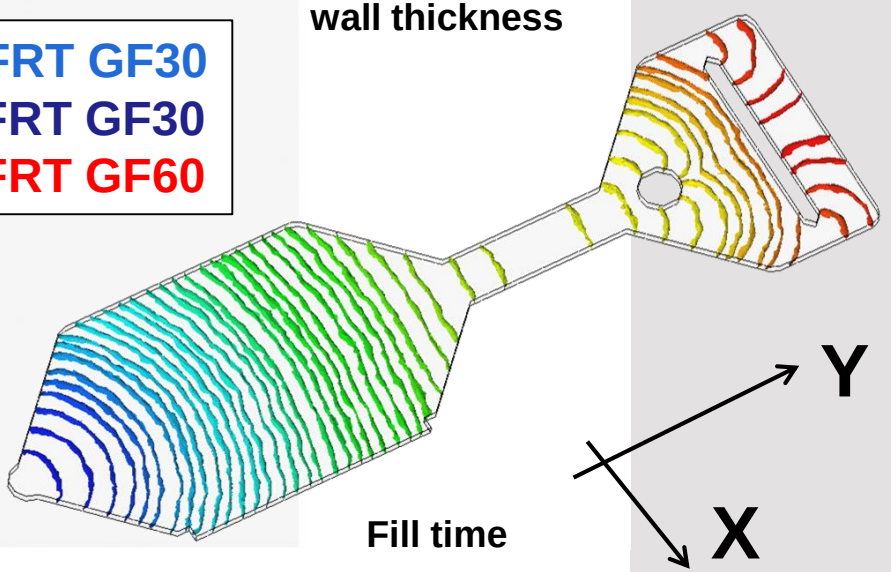
Fiber orientation





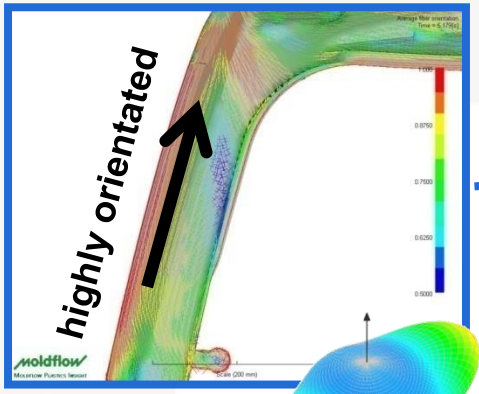


SFRT GF30
LFRT GF30
LFRT GF60

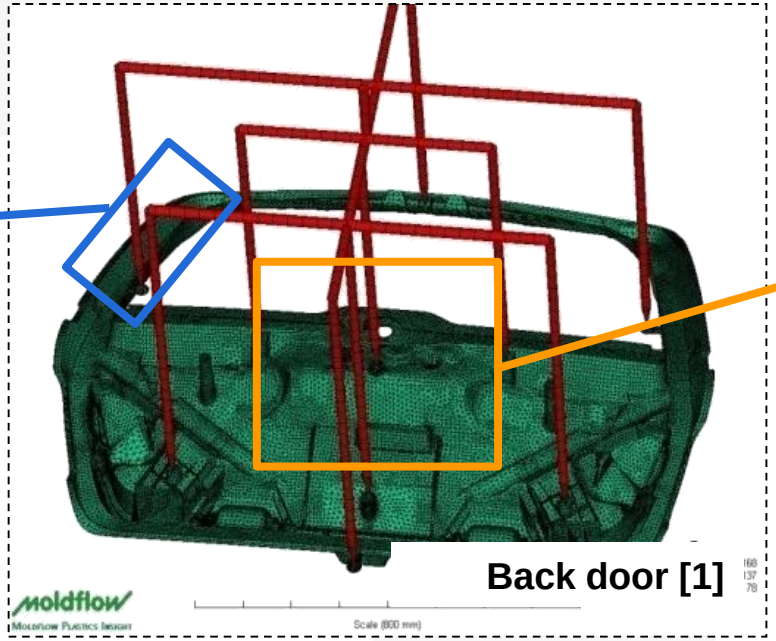


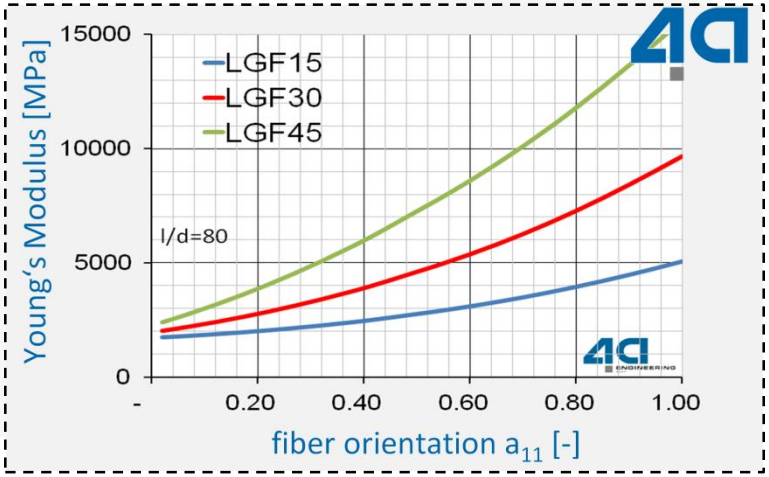
Overview SFRT / LFRT

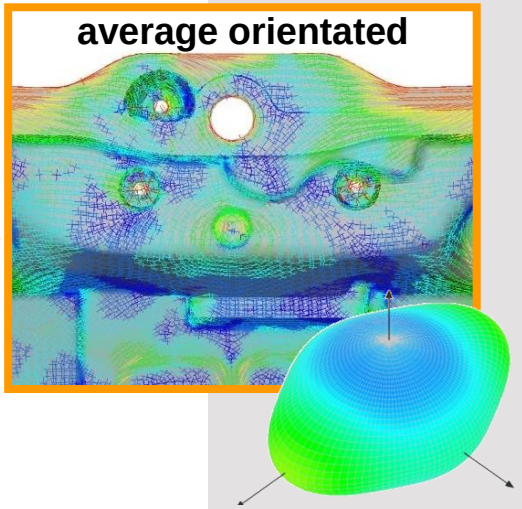
Fiber orientation



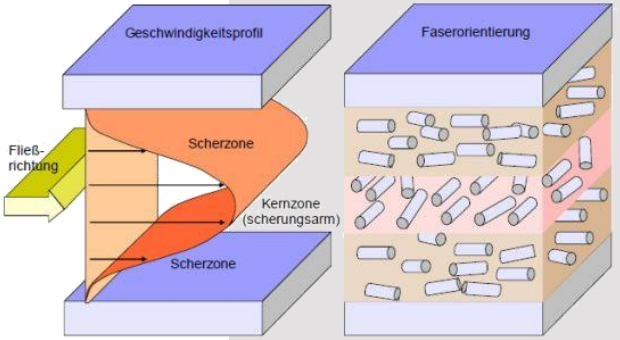
$$a_{ij} = \begin{bmatrix} 0{,}87 & 0 & 0 \\ 0 & 0{,}11 & 0 \\ 0 & 0 & 0{,}02 \end{bmatrix}$$







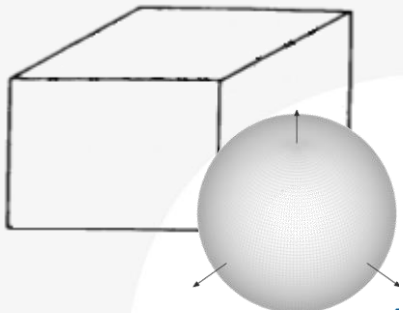
$$a_{ij} = \begin{bmatrix} 0{,}66 & 0 & 0 \\ 0 & 0{,}32 & 0 \\ 0 & 0 & 0{,}02 \end{bmatrix}$$

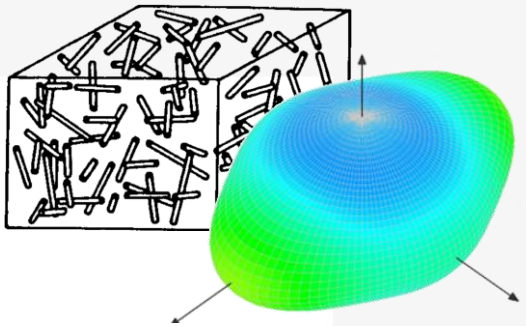


Source: wiki.polymerservice-merseburg.de

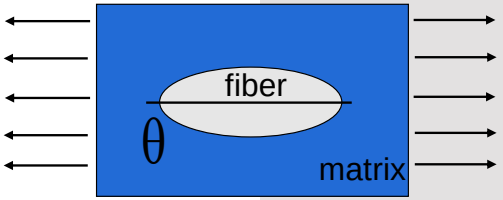
Source: P. Reithofer - *Integrative Simulation – Berücksichtigung der prozessbedingten Anisotropie,* 4a Technologietag 2011

Overview SFRT / LFRT
Actual approaches





$$\bar{\sigma}^{C} = \varphi\bar{\sigma}^{F} + (1-\varphi)\bar{\sigma}^{M}$$



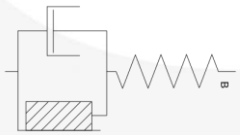
Eshelby Tensor

macro scale
(const. law → composite)

micro scale
(homogenization)

Mises plasticity

- quick & dirty



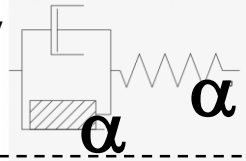
- critical loading transversal to fiber orientation

elastic

- orthotropic
- anisotropic

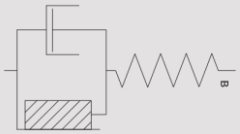
elastic viscoplastic

- Hill plasticity



M… matrix

- isotropic elastic viscoplastic

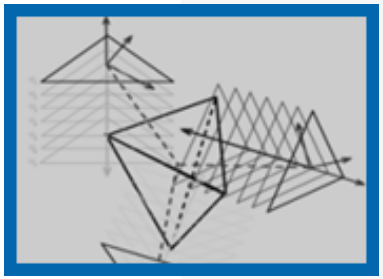


F… fiber

- isotropic elastic

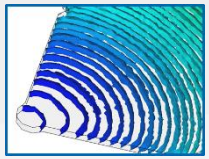
α – orientation dependent

Simulation process chain

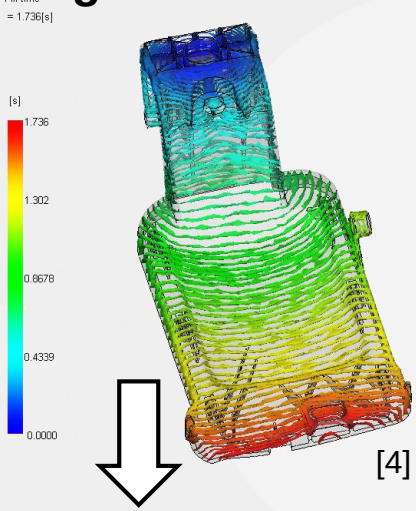


Simulation process chain
Simulation tasks

Process simulation

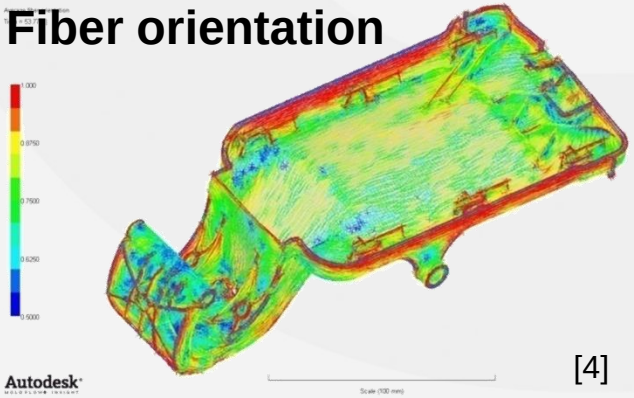


Filling



[4]

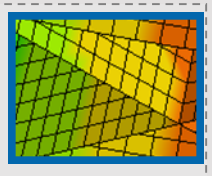
Fiber orientation



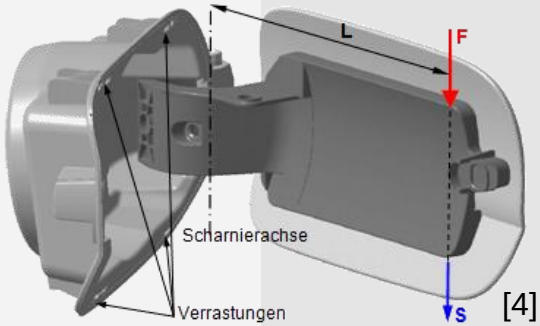
[4]

mapping

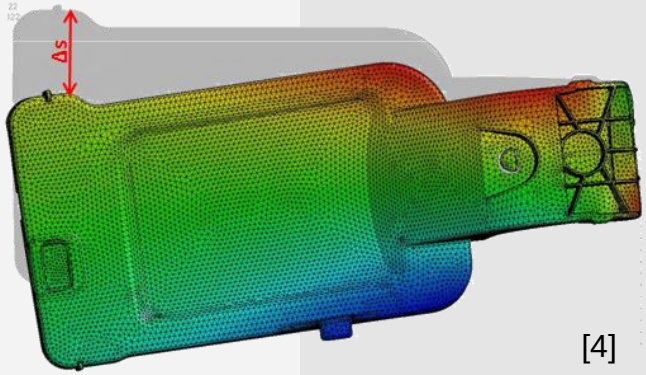
Structural simulation



Stiffness bending



[4]



[4]

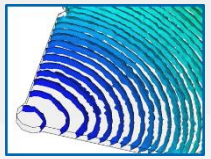
Source: M. Gramling, Audi AG - *Integrative Simulation von kurzfaserverstärkten Thermoplasten am Beispiel einer Tank-klappe,* 4a Technologietag 2012

Simulation process chain

Simulation software tools

Process simulation

Injection molding



CADMOULD® 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

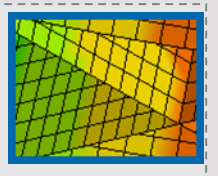
SOLIDWORKS PLASTICS

SIGMASOFT®

mapping

Structural simulation

Stiffness → Crash



ANSYS®

MSC Nastran

NX NASTRAN

AUTODESK NASTRAN

SIMULIA

LSTC Livermore Software Technology Corp.

LS-DYNA®

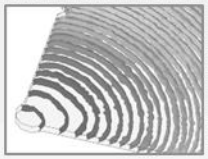
Virtual Performance Solution

Simulation process chain

Exemplary output fiber orientation

Process simulation

Injection molding



CADMOULD® 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

SOLIDWORKS PLASTICS

SIGMASOFT®

result types ***(nodal, elemental, on integration point)***

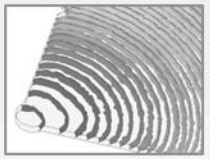
- ***scalar field***
  - fill time, bulk temperature, pressure, shear rate, …
  - melt & weldlines
- ***vector field***
  - velocity
  - warpage
  - …
- ***tensor field***
  - residual stress, wall shear stress, …
  - fiber orientation

Simulation process chain

Exemplary output fiber orientation

Process simulation

Injection molding



CADMOULD® 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

SOLIDWORKS PLASTICS

SIGMASOFT®

```
1000 0000 0011 1100 0011 1011 1000
1000 0000 0011 1100 0011 1011 1000
1101 1111 0111 1100 1111 1011 1110
1101 1111 0111 1100 1111 1011 1110

0011 1110 1110 0000 0111 0001 1100
0011 1110 1110 0000 0111 0001 1100
1011 1110 1111 1001 1111 0111 1101
1011 1110 1111 1001 1111 0111 1101
```

Binary – own format

Source: https://www.geocaching.com/geocache/GC54VQ7_alles-binar-oder-was?guid=65cfbc06-71cb-4bc5-a7b6-ba6ebeacd20d

$$a_{ij} = \begin{bmatrix} 0.5+a & b & 0 \\ & 0.5-a & 0 \\ & & 0 \end{bmatrix}$$

```
[HEADER]
1004
\\Ac-server\ac-daten\Transfer\Cristoph\4a\MDXProject20150811_Fiber_3\Mesh
\\Ac-server\ac-daten\Transfer\Cristoph\4a\MDXProject20150811_Fiber_3\Mate
\\Ac-server\ac-daten\Transfer\Cristoph\4a\MDXProject20150811_Fiber_3\Proc
473452
7
09/24/15  09:52:51
[VARBLE INFO]
ElementId
IntegrationId
Tauxx
Tauyy
Tauxy
Tauxz
Tauyz
[RESULTS EOF]
54895  1 3.3254e-001 3.2991e-001 -5.8438e-004 -2.8732e-003 2.1898e-003
54896  1 3.3370e-001 3.3002e-001 6.7502e-004 2.9449e-003 2.0597e-003
54897  1 3.3525e-001 3.2637e-001 3.1483e-004 -7.3823e-003 1.0411e-003
55094  1 2.8750e-001 3.2273e-001 -6.7643e-004 1.8706e-003 -7.2378e-002
```

ASCII – own format

Tensor 2nd order

$$a_{ij} = \begin{bmatrix} a_{xx} & a_{xy} & a_{xz} \\ & a_{yy} & a_{yz} \\ & & a_{zz} \end{bmatrix}$$

```
<HEADER>
  <NAME>  Moldflow Simulation Results XML Writer</NAME>
  <Version>  1.00</Version>
</HEADER>
<Dataset Name="Fiber orientation tensor" ID="4021">
  <DataType>  NDDT(Node data)</DataType>
  <DeptVar Name="Fiber orientation tensor on nodes (3D)" Unit=""/>
  <NumberOfComponents>  6</NumberOfComponents>
  <NumberOfIndpVariables>  0</NumberOfIndpVariables>
  <Blocks>
    <NumberOfBlocks>  1</NumberOfBlocks>
    <Block Index="1">
      <NumberOfDependentVariables>  179843</NumberOfDependentVariables>
      <Data>
        <NodeData ID="16846">
          <DeptValues>  2.6154e-001  2.0777e-001  5.3069e-001  0.0000e+000  0.0000e+000  0.0000e+000</DeptValues>
        </NodeData>
        <NodeData ID="268618">
          <DeptValues>  4.3461e-001  2.4906e-001  3.1633e-001  1.0760e-003  1.3450e-003  1.4949e-001</DeptValues>
        </NodeData>
        <NodeData ID="14502">
          <DeptValues>  6.2213e-002  5.6278e-001  3.7501e-001  3.0401e-002  3.8002e-002  -4.1725e-001</DeptValues>
```

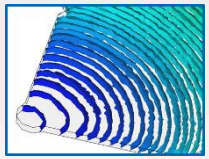
XML - ASCII

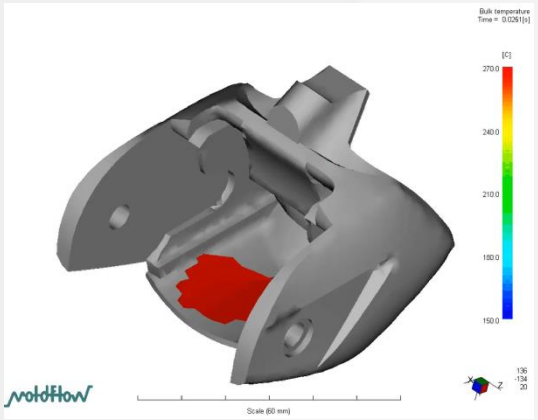
Simulation process chain

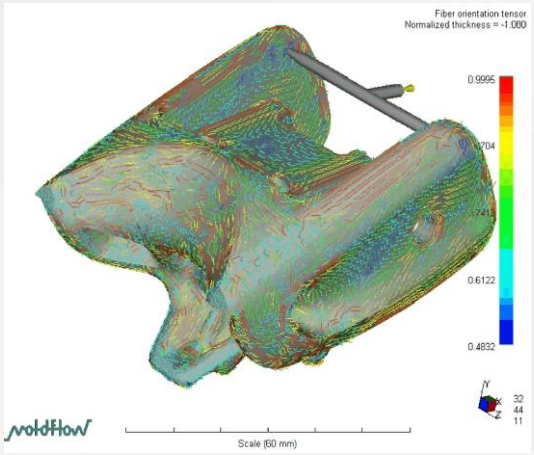
4a micromec - first implementation in 2002

Process simulation

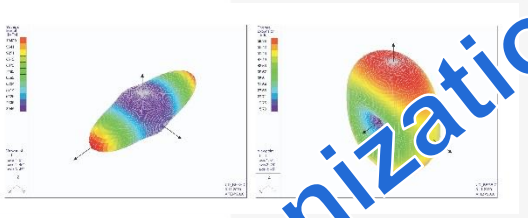
Injection molding







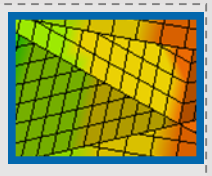
direct interface
mainly anisotropic
thermo-elastic
material properties

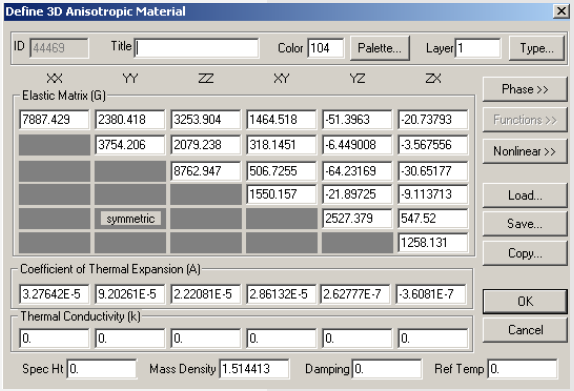


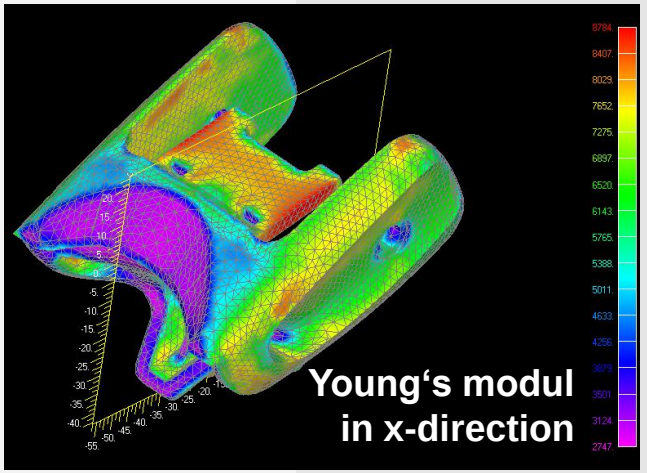
homogenization

Structural simulation

Stiffness → Warpage







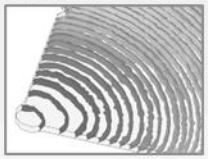
Source: P. Reithofer, ape GmbH – MSC Tagung, München 2004

Simulation process chain

Export interfaces process simulation tools

Process simulation

Injection molding



CADMOULD® 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

SOLIDWORKS PLASTICS

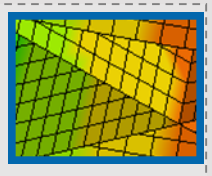
SIGMASOFT®

direct interface
mainly anisotropic
thermo-elastic
material properties

State of the art

Structural simulation

Stiffness → Crash



ANSYS®

MSC Nastran

NX NASTRAN

AUTODESK NASTRAN

SIMULIA

LSTC Livermore Software Technology Corp.
LS-DYNA®

Virtual Performance Solution

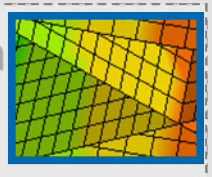
Simulation process chain
Structural simulation – considering anisotropy

Idealization

- ***Material model***
  - anisotropic elasticity
  - orthotropic visco plasticity
  - micro mechanic model
- ***Property***
  - shell or solid
  - composite build up
- ***Element formulation***
  - shell
  - solid
  - composite

Structural simulation

Stiffness → Crash



ANSYS®

MSC Nastran

NX NASTRAN

AUTODESK NASTRAN

SIMULIA

LSTC Livermore Software Technology Corp.

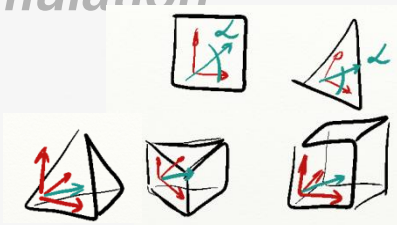
LS-DYNA®

Virtual Performance Solution

Simulation process chain
Structural simulation – considering anisotropy

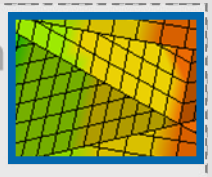
Idealization

- ***Material model*** — Standard in solver
  - anisotropic elasticity → linear
  - orthotropic visco plasticty → non linear
  - micro mechanic model → new / upcoming
- ***Property*** — ***Direction***
  - shell or soild → MID (material)
  - composite build up → MID & t_{layer} & α
- ***Element formulation***
  - shell → vector or α
  - solid → vector
  - composite → MID & t_{layer} & α



Structural simulation

Stiffness → Crash



ANSYS®

MSC Nastran

NX NASTRAN

AUTODESK NASTRAN

SIMULIA

LSTC Livermore Software Technology Corp.

LS-DYNA®

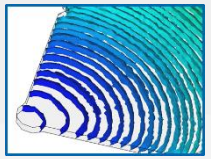
Virtual Performance Solution

Simulation process chain

Simulation software tools

Process simulation

Injection molding



CADMOULD® 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

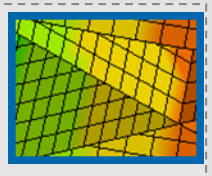
SOLIDWORKS PLASTICS

SIGMASOFT®

mapping
m:n
possibilities

Structural simulation

Stiffness → Crash



ANSYS®

MSC Nastran

NX NASTRAN

AUTODESK NASTRAN

SIMULIA

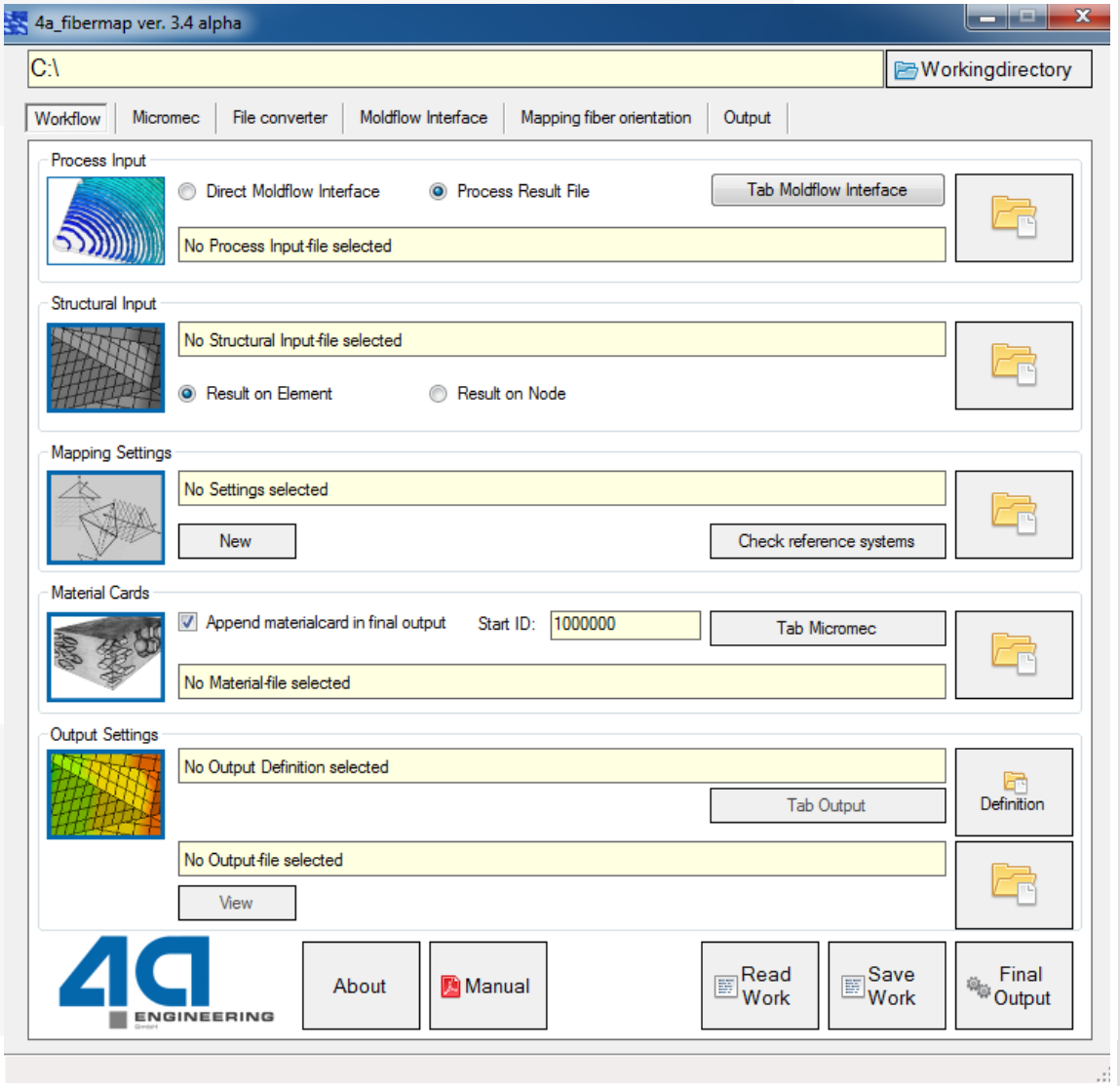
LSTC Livermore Software Technology Corp.
LS-DYNA®

Virtual Performance Solution

<<Template>> based mapping

<<Template>> based mapping

4a fibermap - workflow

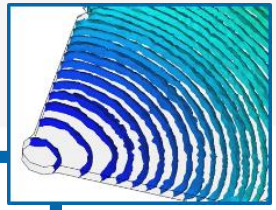


FIBERMAP

<<Template>> based mapping

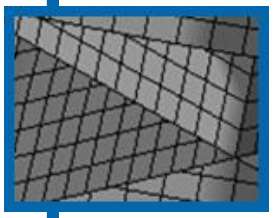
4a fibermap - workflow

process simulation result



CADMOULD 3D-F SIMULATION | Moldex3D MOLDING INNOVATION | MOLDFLOW

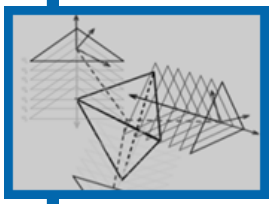
structural mesh

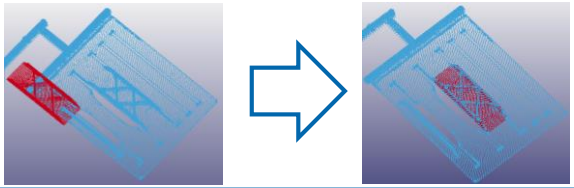


LSTC Livermore Software Technology Corp. LS-DYNA® | SIMULIA

shell
solid

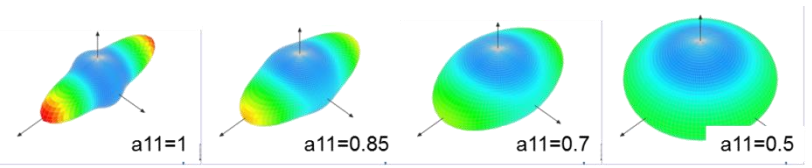
mapping settings





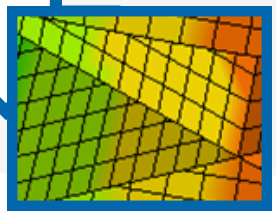
Transformation mapping (KD-Tree)

material card definition



orthotropic
elastic
visco plastic

structural output



LSTC Livermore Software Technology Corp. LS-DYNA® | SIMULIA | ANSYS | Virtual Performance Solution | MSC Nastran

Template based
ASCII output

<<Template>> based mapping

4a fibermap - workflow

process simulation result

structural mesh

mapping settings

material card definition

structural output

SIMULIA

Direction

Example given:

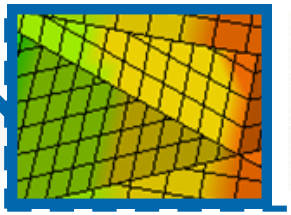
```
*ORIENTATION, NAME=MatOrient
Distr1
3,0
*DISTRIBUTION TABLE, Name=Table1
COORD3D, COORD3D
*DISTRIBUTION,Name=Distr1, LOCATION=element, TABLE=Table1
 ,1,0,0,0,1,0
1000001,-0.730574,-0.6825756,0.01876505,-0.6706954,0.7224748,0.1679222
1000002,-0.8933346,-0.448588,0.02687123,-0.4458205,0.8921726,0.07260921
1000003,-0.9445068,-0.3230198,0.05970896,-0.3186696,0.9451182,0.07212023
1000004,-0.4956961,-0.8674375,-0.04286759,-0.8076552,0.4422604,0.3899984
```

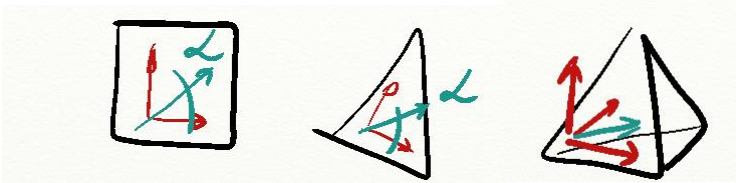
Template based

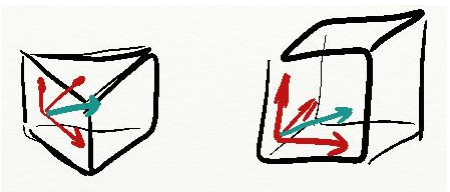
ASCII output

<<Template>>

<<EID>>,<<V1X>>,<<V1Y>>,<<V1Z>>,<<V2X>>,<<V2Y>>,<<V2Z>>







<<Template>> based mapping

4a fibermap - workflow

process simulation result

structural mesh

mapping settings

material card definition

structural output

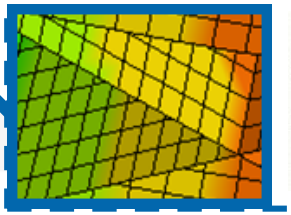
LSTC Livermore Software Technology Corp.
LS-DYNA®

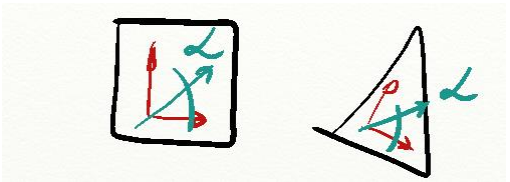
*ELEMENT_SHELL_BETA

Card 1	1	2	3	4	5	6	7	8	9	10
Variable	EID	PID	N1	N2	N3	N4	N5	N6	N7	N8
Type	I	I	I	I	I	I	I	I	I	I
Default	none	none	none	none	none	none	0	0	0	0
Remarks			3	3	3	3				

Thickness Card. Additional card for THICKNESS, BETA, and MCID keyword options.

Card 2	1	2	3	4	5	6	7	8	9	10
Variable	THIC1		THIC2		THIC3		THIC4		BETA or MCID	
Type	F		F		F		F		F	
Default	0.		0.		0.		0.		0.	
Remarks	1								2	





Template based ASCII output

<<Template>> based mapping

4a fibermap - workflow

process simulation result

structural mesh

mapping settings

material card definition

structural output

LSTC Livermore Software Technology Corp.

LS-DYNA®

Direction (angle)

Example given:

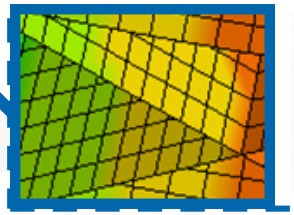
Template based

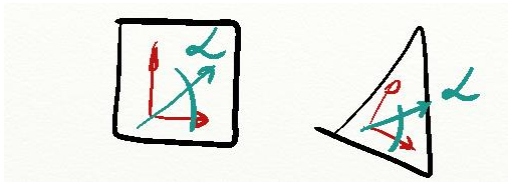
ASCII output

```
*ELEMENT_SHELL_BETA
 1000001       1 1001164 1000927 1001159 1001159
                                                -2.72155
 1000002       1 1001820 1000231 1000232 1001824
                                                133.7043
 1000003       1 1001824 1000232 1000233 1001828
                                                132.0292
 1000004       1 1001828 1000233 1000235 1000767
                                                133.6325
 1000005       1 1000236 1000438 1001801 1001801
                                                 106.386
 1000006       1 1000230 1001322 1000418 1000418
                                                90.98151
```

<<Template>>

<<EL_ID;0D8S>><<PartID;0D8S>><<N1;0D8S>><<N2;0D8S>>…..
<<Orient_theta;5D16S>>





<<Template>> based mapping

4a fibermap - workflow

process simulation result

structural mesh

mapping settings

material card definition

structural output

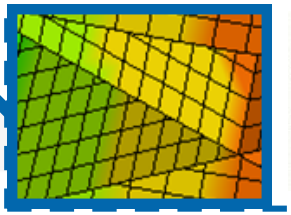
Template based
ASCII output

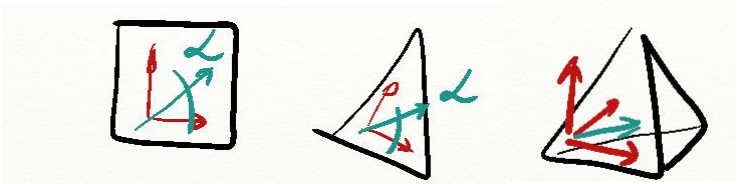
<<Templates>>
for common simulation tasks
are provided with the software
and can be easily extended

LSTC Livermore Software Technology Corp. LS-DYNA®

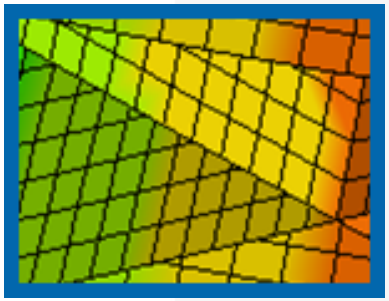
SIMULIA

Virtual Performance Solution



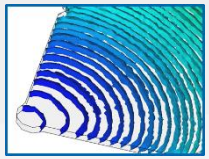


Case studies

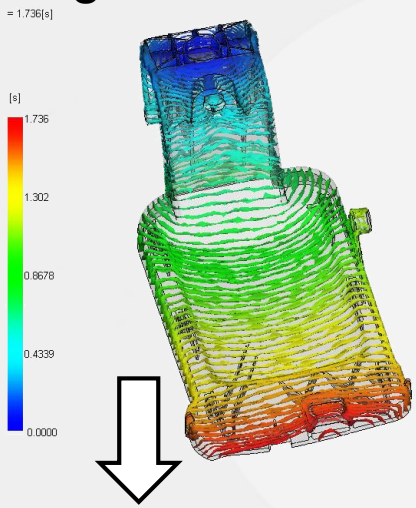


Case study Stiffness
Fuel door

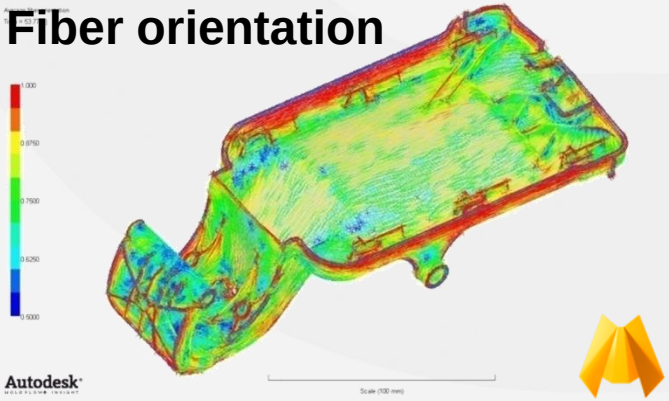
Process simulation



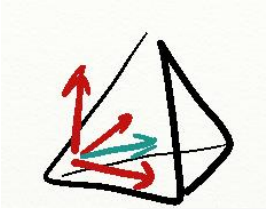
Filling

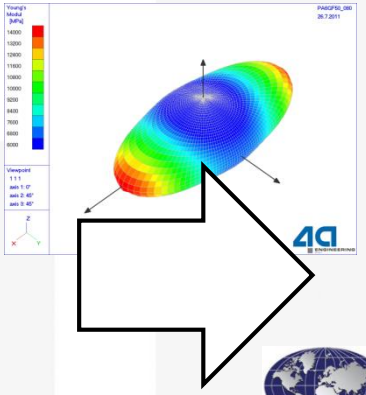


Fiber orientation



FIBERMAP



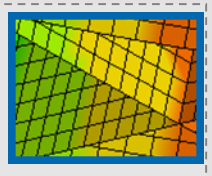


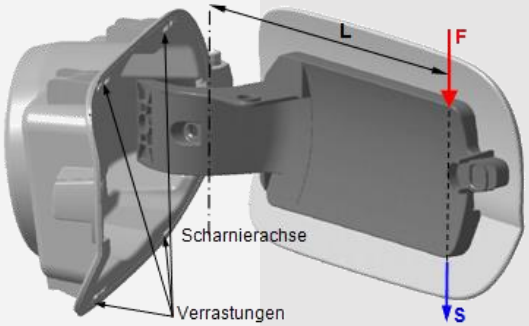
MOLDFLOW

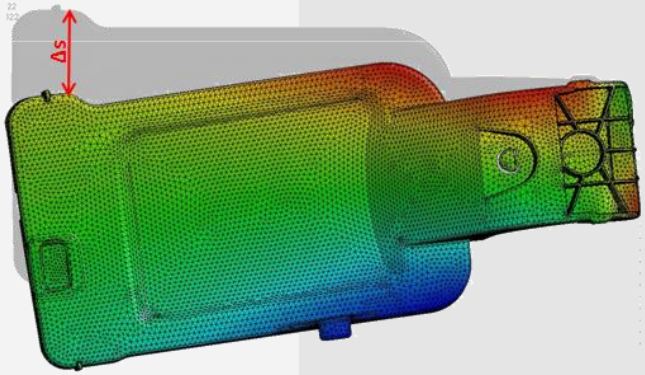
LSTC Livermore Software Technology Corp.
LS-DYNA®

Structural simulation

Stiffness bending



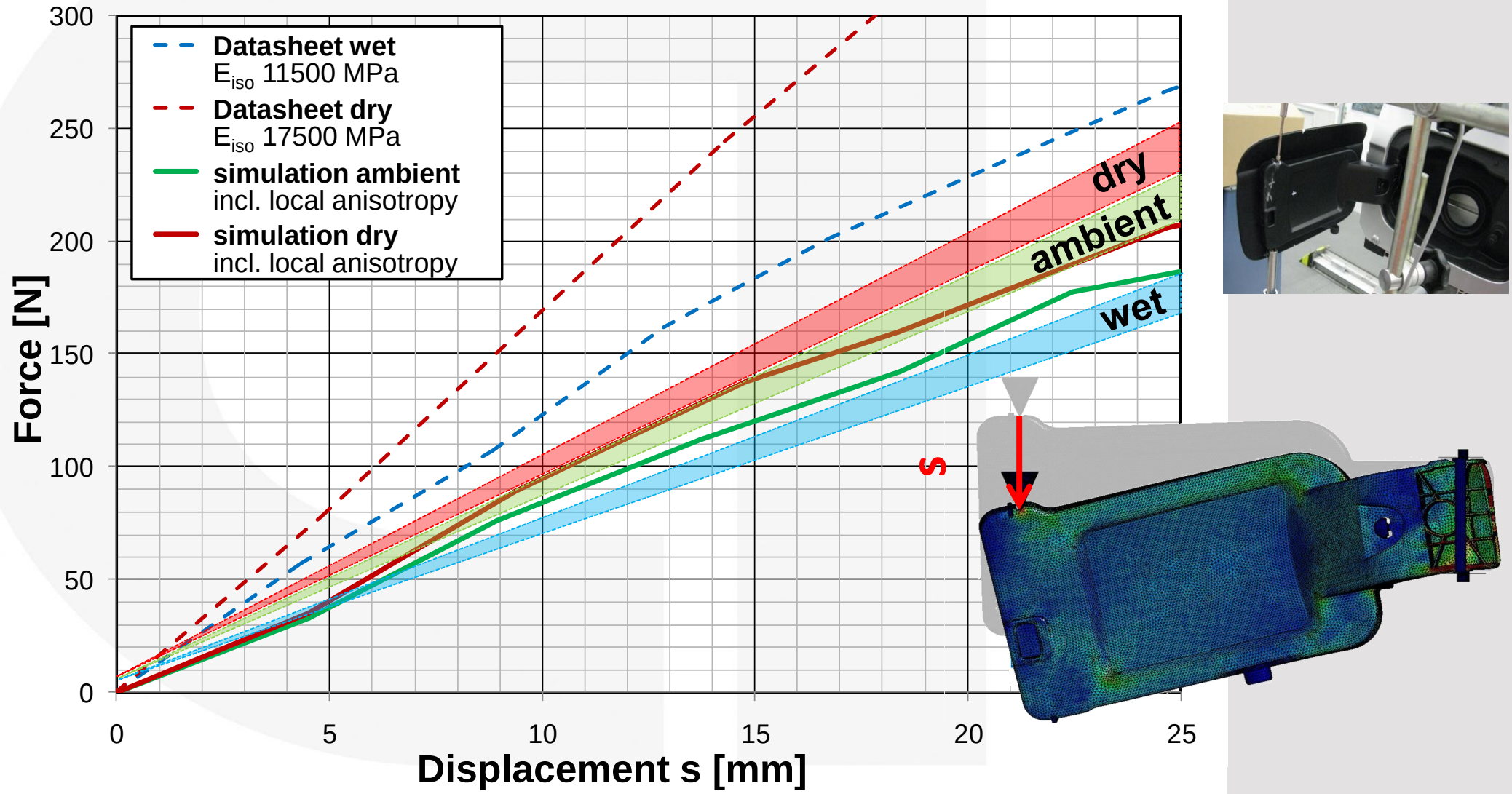




Source: M. Gramling, Audi AG - *Integrative Simulation von kurzfaserverstärkten Thermoplasten am Beispiel einer Tankklappe*, 4a Technologietag 2012

Case study Stiffness

Fuel door – good correlation



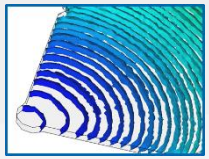
Source: M. Gramling, Audi AG - *Integrative Simulation von kurzfaserverstärkten Thermoplasten am Beispiel einer Tankklappe*, 4a Technologietag 2012

Case study Stiffness

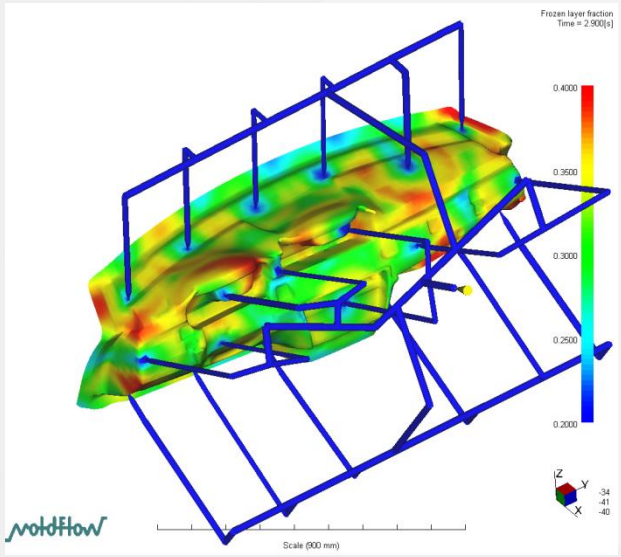
Instrument panel - foaming

Process simulation

Filling

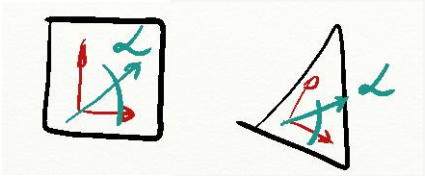


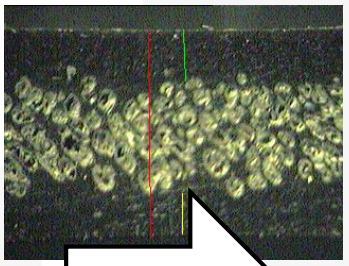
FIBERMAP



Fiber orientation

Frozen layer fraction



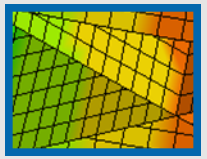


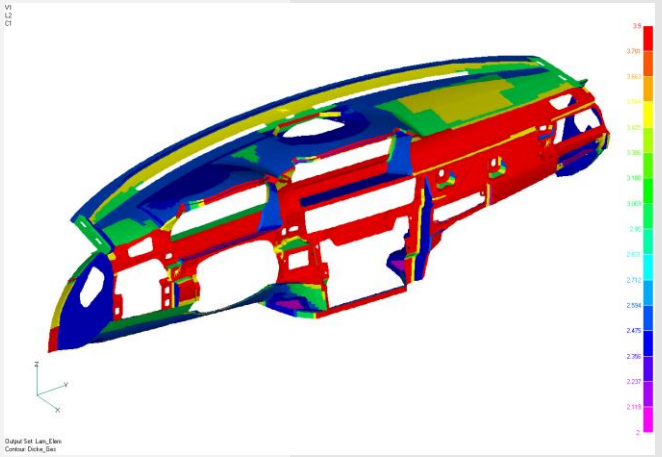
PCOMP

MOLDFLOW MSC Nastran

Structural simulation

Stiffness



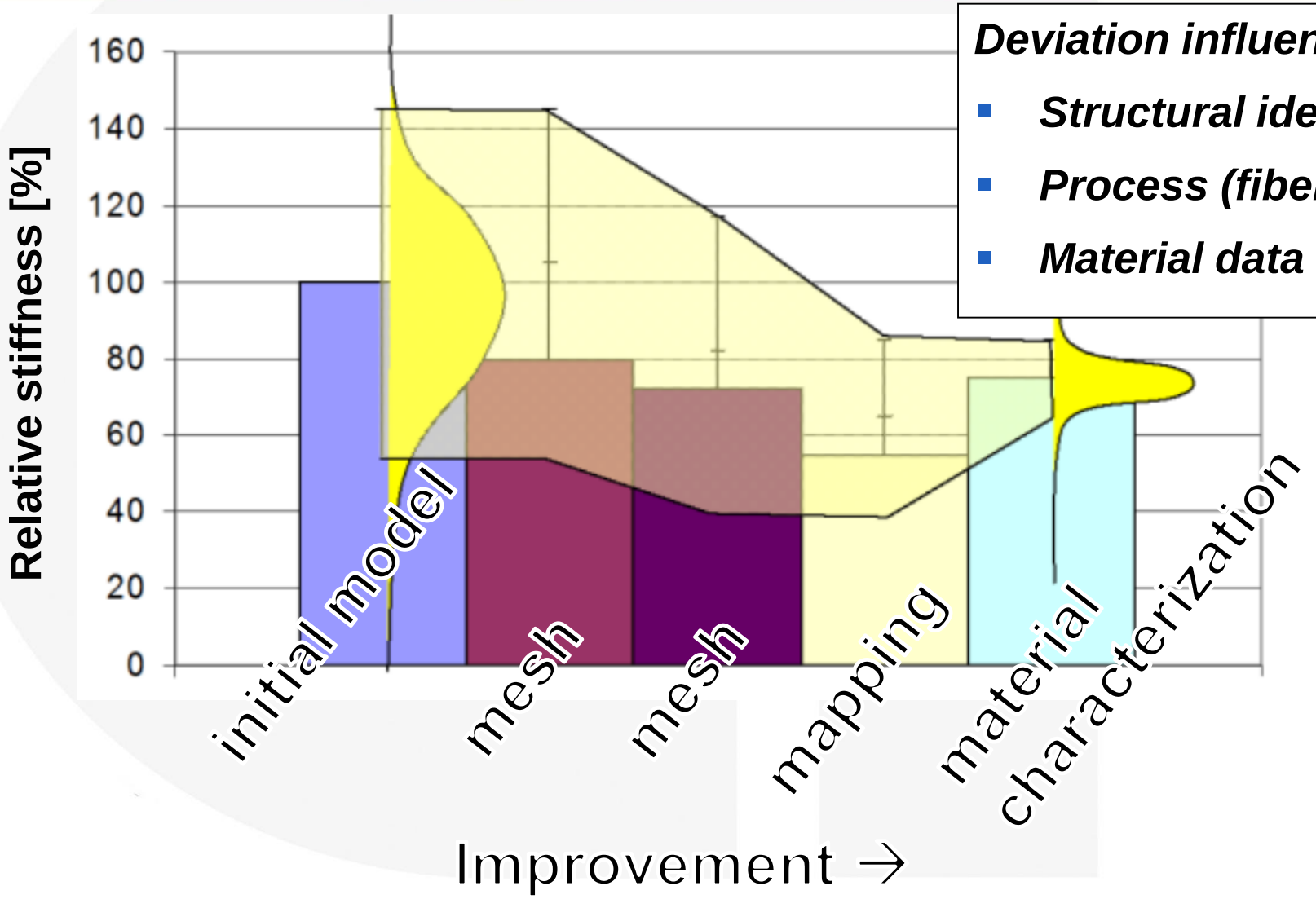


Composite layup **(PCOMP)**

fiber orientation
thickness of foam core

Source: T. Wimmer, P. Reithofer, 4a engineering GmbH - *Abbildung von Sonderverfahren,* 4a Technologietag 2010

Case study Stiffness
Instrument panel - foaming



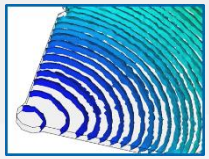
Deviation influenced by

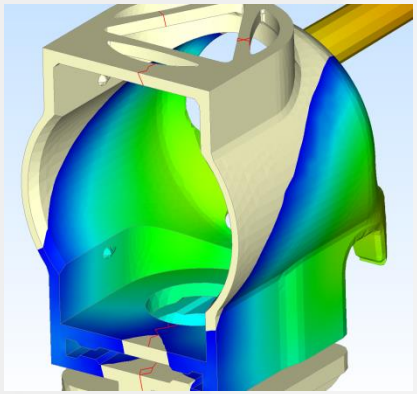
- ***Structural idealization***
- ***Process (fiber, foam)***
- ***Material data***

Source: T. Wimmer, P. Reithofer, 4a engineering GmbH - *Abbildung von Sonderverfahren,* 4a Technologietag 2010

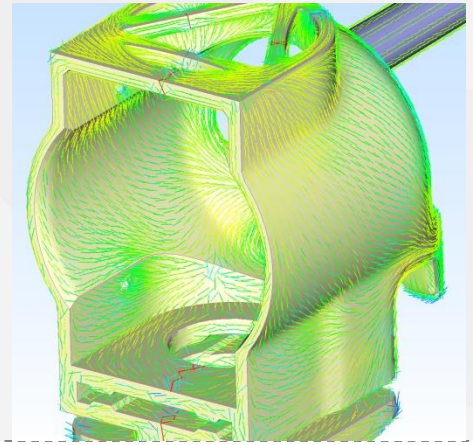
Case study Drop test
Sleeve

Process simulation
Filling

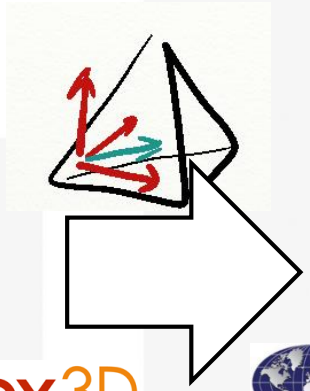




Fiber orientation



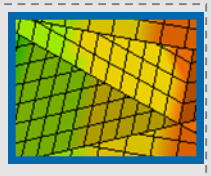
FIBERMAP

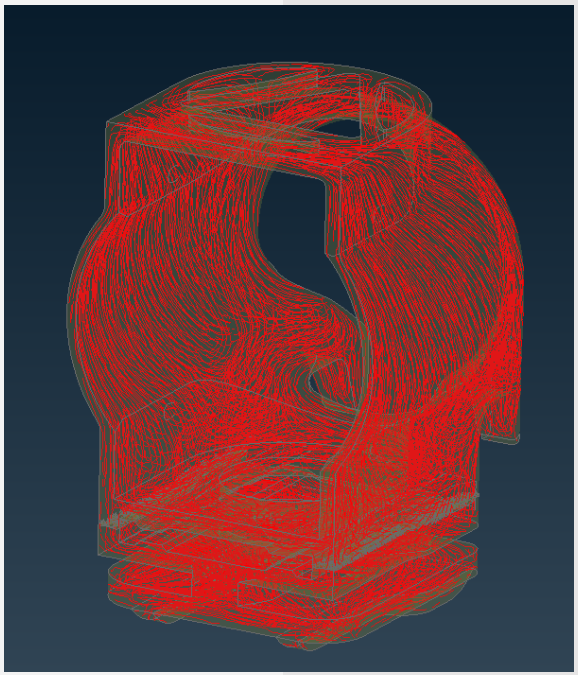


Moldex3D MOLDING INNOVATION

LSTC Livermore Software Technology Corp. LS-DYNA®

Structural simulation
Drop test



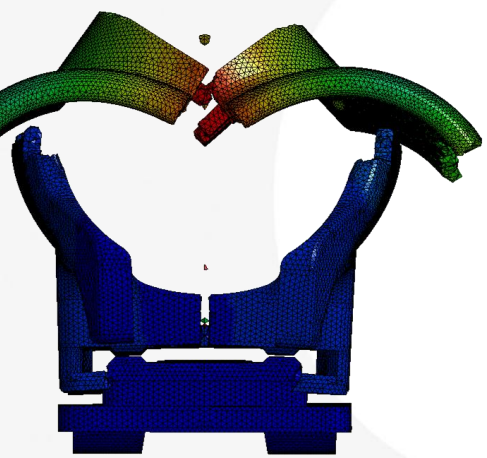


Fiber orientation

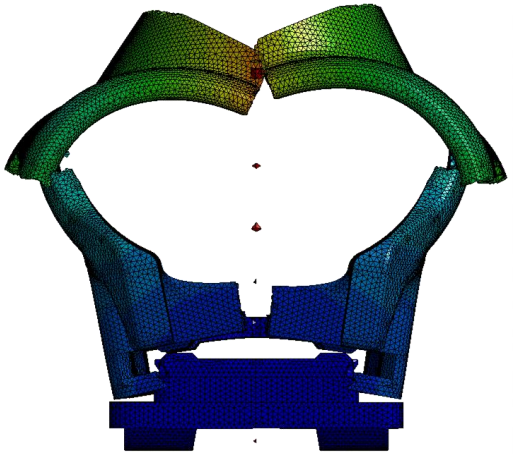
`*ELEMENT_SOLID_ORTHO`

more: R. Steinberger, et.al. Hirtenberger Automotive Group – *Considering the Local Anisotropy of Short Fiber Reinforced Plastics, European Dynaforum 2017*

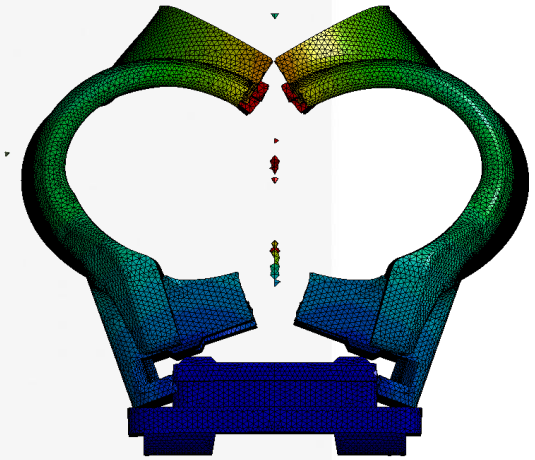
Case study Drop test
Sleeve



*MAT_24
transversal



*MAT_24
longitudinal



*MAT_157
local anisotropy

test

hirtenberger
Automotive Safety

LSTC Livermore Software Technology Corp.
LS-DYNA®

more: R. Steinberger, et.al. Hirtenberger Automotive Group – *Considering the Local Anisotropy of Short Fiber Reinforced Plastics, European Dynaforum 2017*

Summary & outlook

Summary

- Simulation process chain
  - **m:n** possibilities from **process → structural**
    different approaches for each solver/application needed
  - missing process information
    in common CAE developments
  - standardization needed → **easy to use**
- mapping provides benefits
  - considering local anisotropy
  - wall thickness
- 4a fibermap - workflow
  - flexible **<<template>>** based mapping

Outlook
Presentations on European LS-DYNA Conference

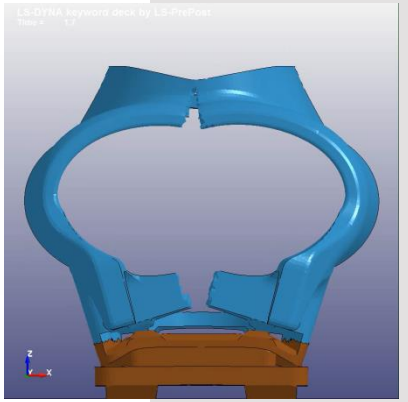
MATERIALS – SHORT FIBER

Compression Molding Analysis of Long Fiber Reinforced Plastics using Coupled Method of Beam and 3D Adaptive EFG in LS-DYNA
S. Hayashi (JSOL); H. Chen, W. Hu (LSTC)

***MAT_4A_MICROMEC – Theory and Application Notes**
P. Reithofer, A. Fertschej, B. Jilka (4a engieering); A. Erhart, S. Hartmann (DYNAmore)

High-Dynamic Drop Test Simulation for Fiber Reinforced Plastics in Automotive Electronic Control Units
T. Zhao, D. Papathanassiou (Bosch Automotive Products)

Considering the Local Anisotropy of Short Fiber Reinforced Plastics: Validation on Specimen and Component
R. Steinberger, T. Gross (Hirtenberger Automotive Group); S. Paul (Simpatec); P. Reithofer (4a engineering)



Hirtenberger Automotive Safety GmbH & Co KG

Bosch Automotive Products (Suzhou) Co., Ltd

and hopefully many of your applications …

Outlook

VMAP Project – European Initiative Standardization

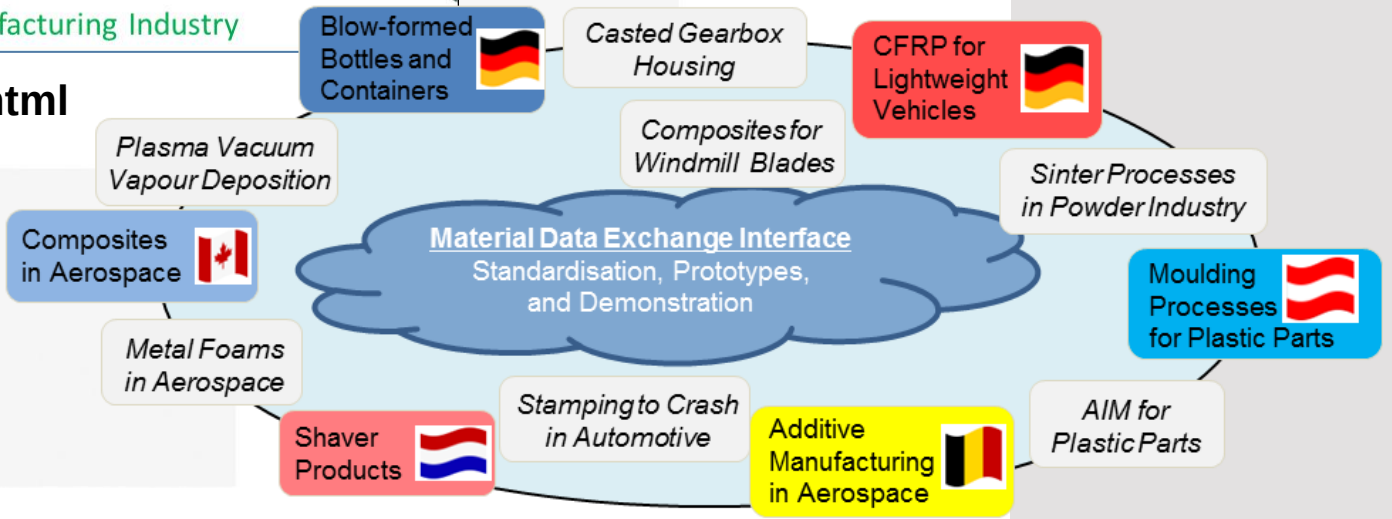
ITEA 3

Project Profile

VMAP

A new Interface Standard for
Integrated Virtual Material Modelling in Manufacturing Industry

https://itea3.org/project/vmap.html



Thank you for your attention!

„in physics we trust”

Appendix
short tutorial

4a fibermap - short tutorial
Task

- Scope of work:
  - A double crossed rib (test specimen) is retrieved out of an injection molded part.
  - The fiber orientation (Autodesk Moldflow®) is mapped to the structural mesh (**`*INITIAL_STRESS_SHELL`**)
  - A dynamic 3-point-bending of the component is simulated in LS-Dyna® taking the local anisotropy into account.
- Material: Stamax 30YM 240 (PP LGF30)
- Necessary data:
  - Injection molding simulation of the part (e.g. Autodesk Moldflow®)
  - FEM model of the structural part / test specimen (shell idealization, element size of 1 mm)
  - Appropriate material model (e.g. **`*MAT_157`** or **`*MAT_215`**)

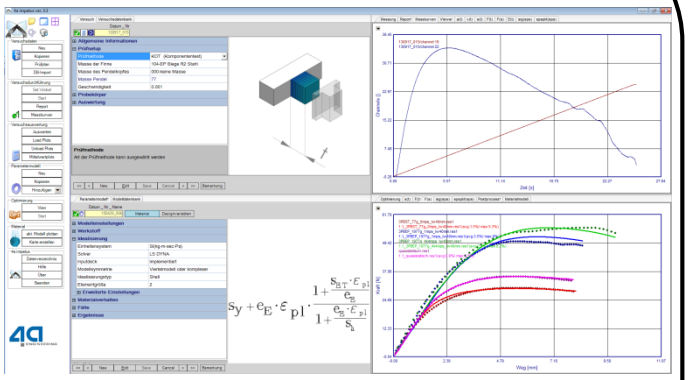
4a fibermap - short tutorial

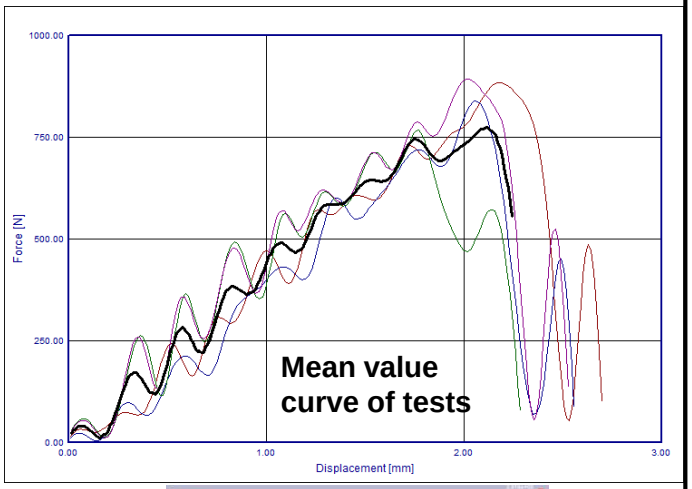
Task

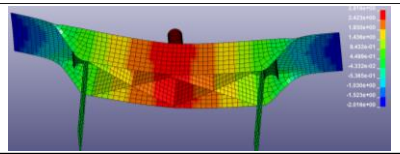
- 3-point-bending of the double crossed rib:

4a impetus hardware

4a impetus software

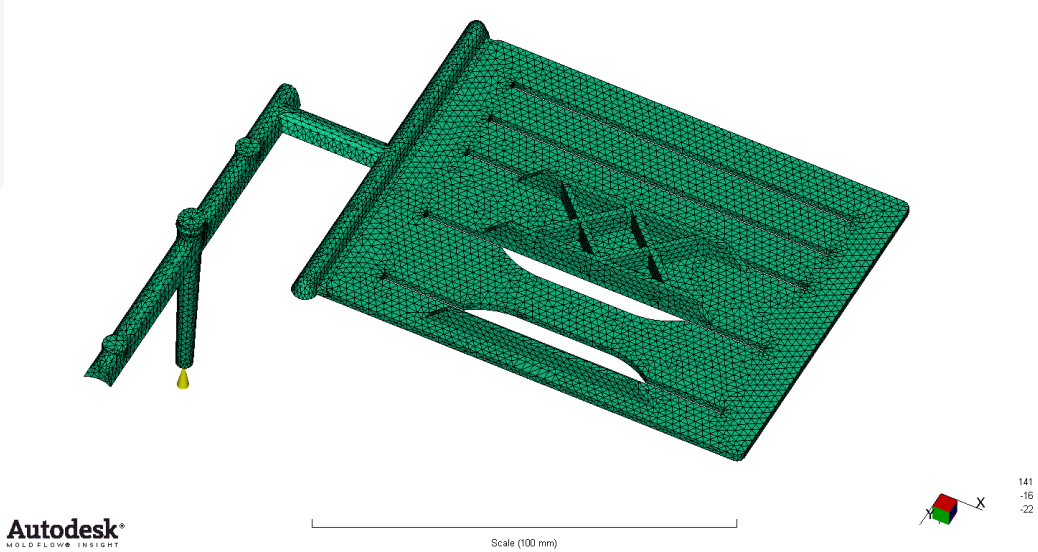




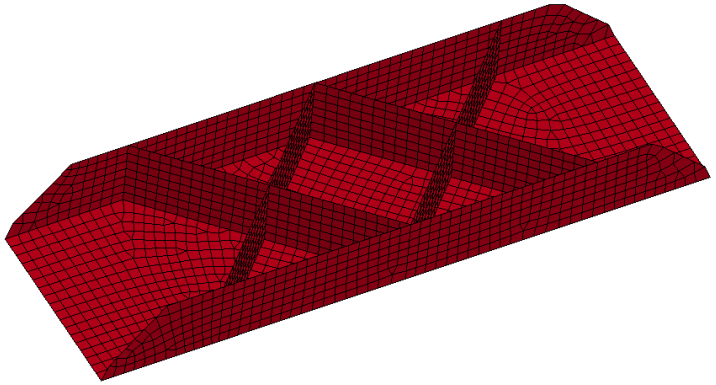


4a fibermap - short tutorial
Task

- Model in Autodesk Moldflow®



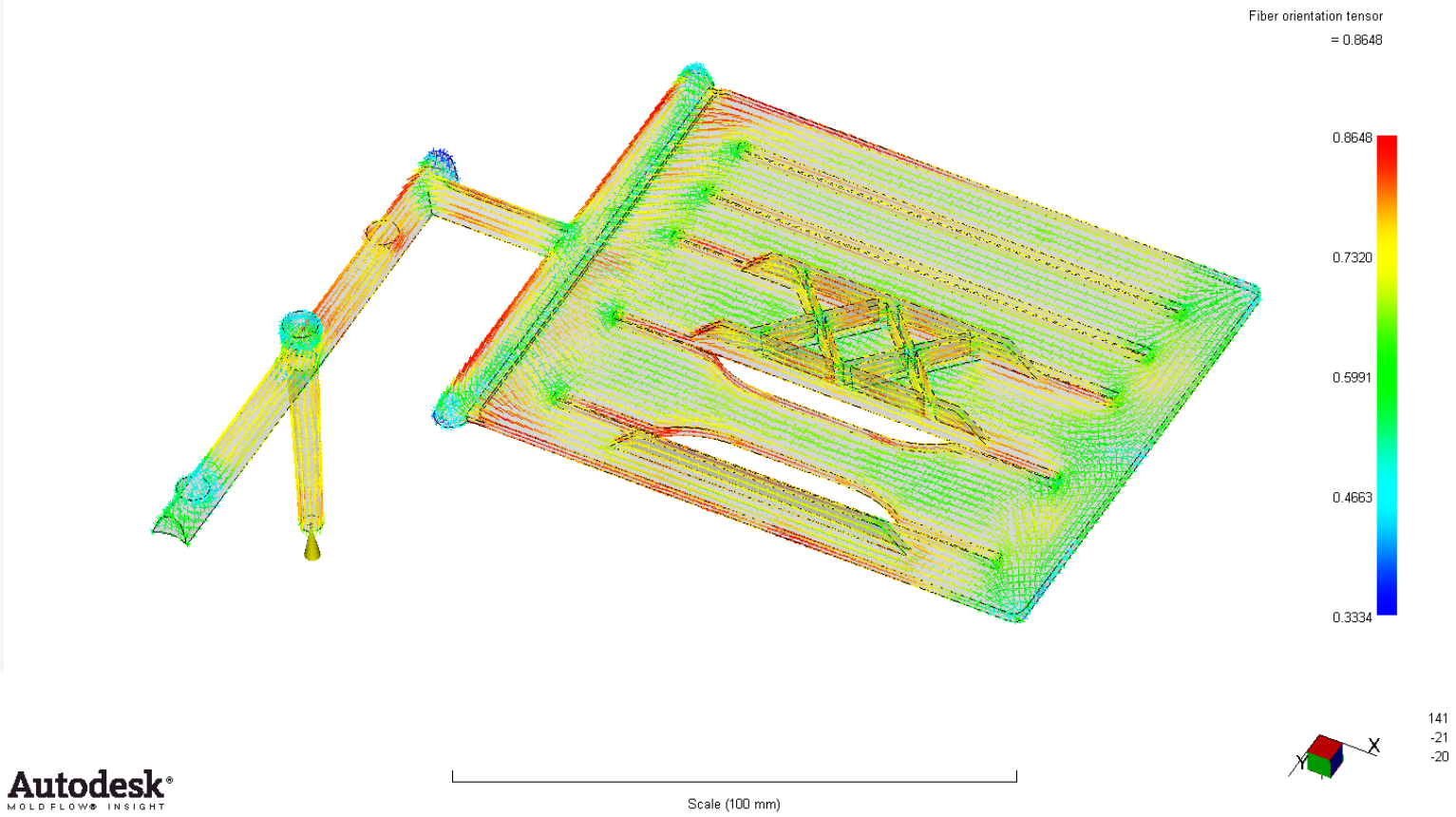
- LS-DYNA® input deck



4a fibermap - short tutorial

Task

- Result of the fiber orientation tensor in Autodesk Moldflow®



4a fibermap - short tutorial
Procedure

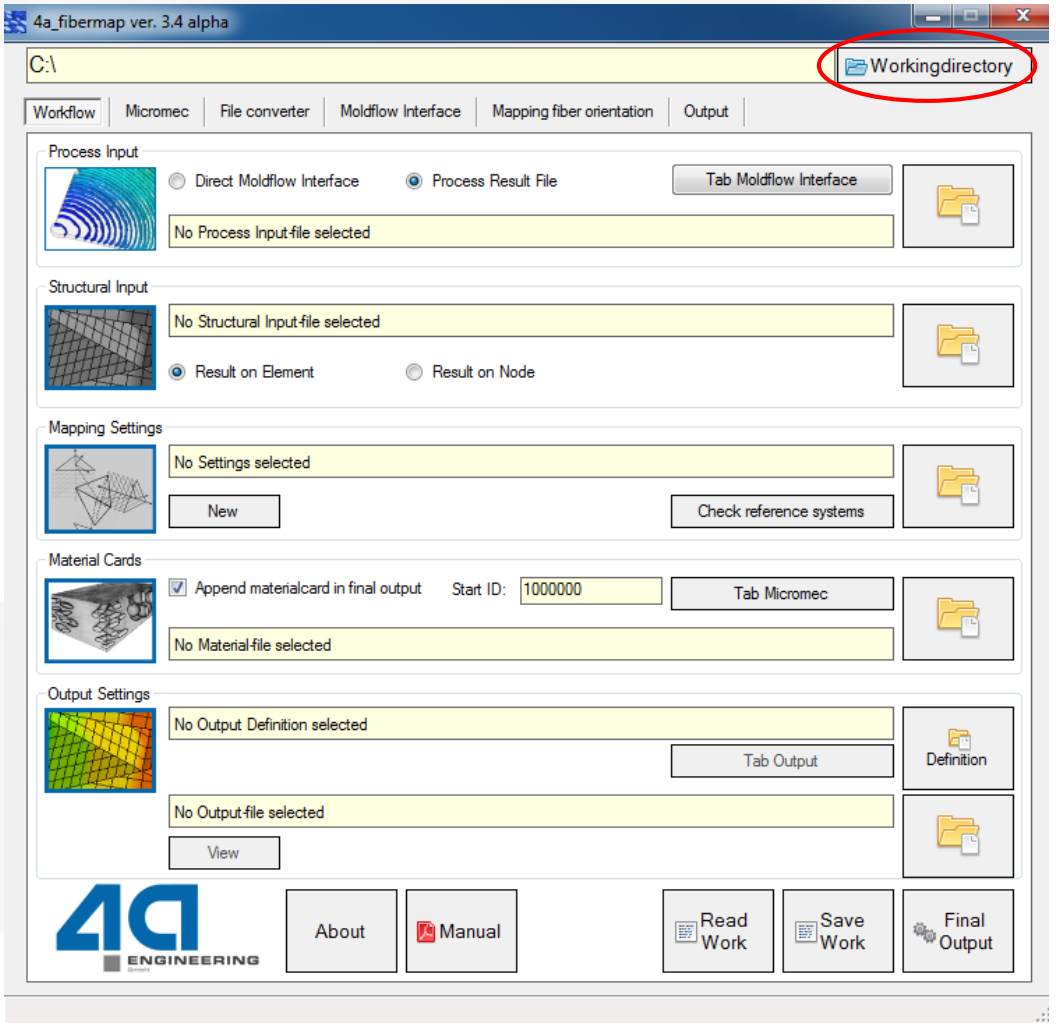
The procedure of mapping is specified as follows:

- 1. Performing an injection molding simulation
  (e.g. Autodesk Moldflow®) and exporting the results (XML, Patran)
- 2. FEM model build up (e.g. using ANSA®)
- 3. Performing the mapping process using 4a fibermap (workflow)
  - 3a. Start 4a fibermap
  - 3b. Import results from injection molding
  - 3c. Perform mapping
  - 3d. Export the mapped properties (template)
- 4. FEM simulation (e.g. using LS-Dyna®)
  regarding the mapping results

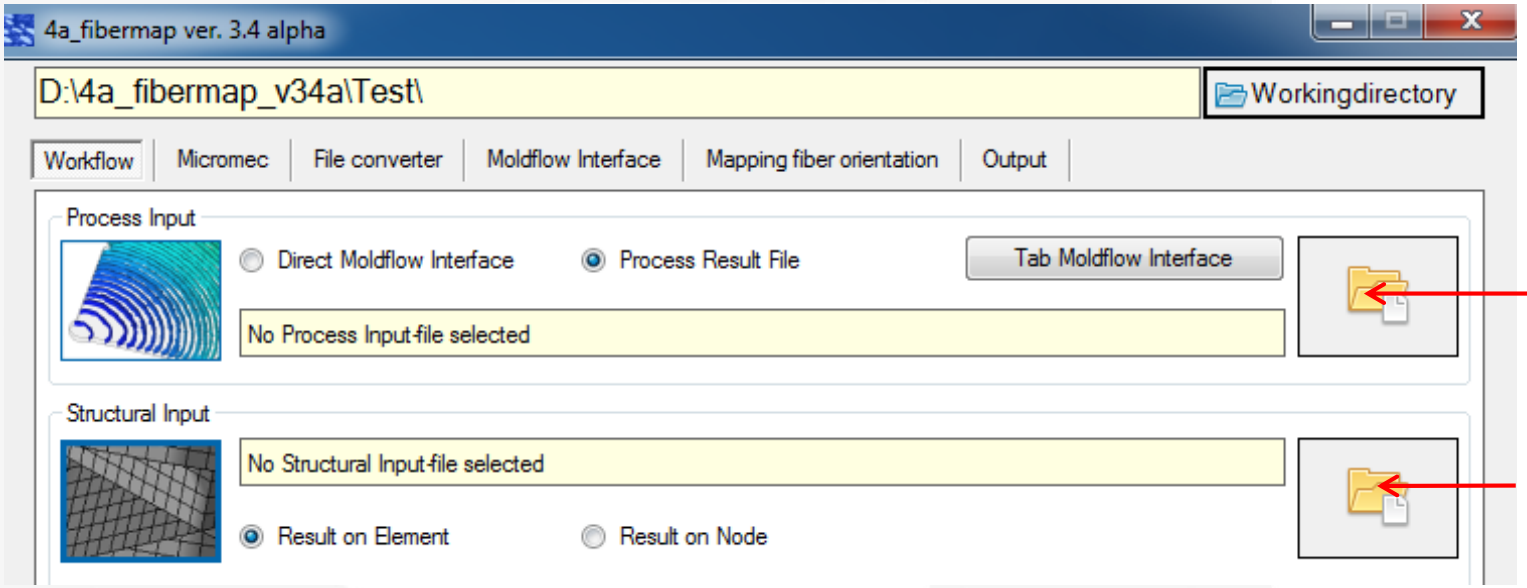
4a fibermap - short tutorial

3. Mapping process using 4a fibermap (workflow)

- First 4a fibermap is started and the working directory is chosen.



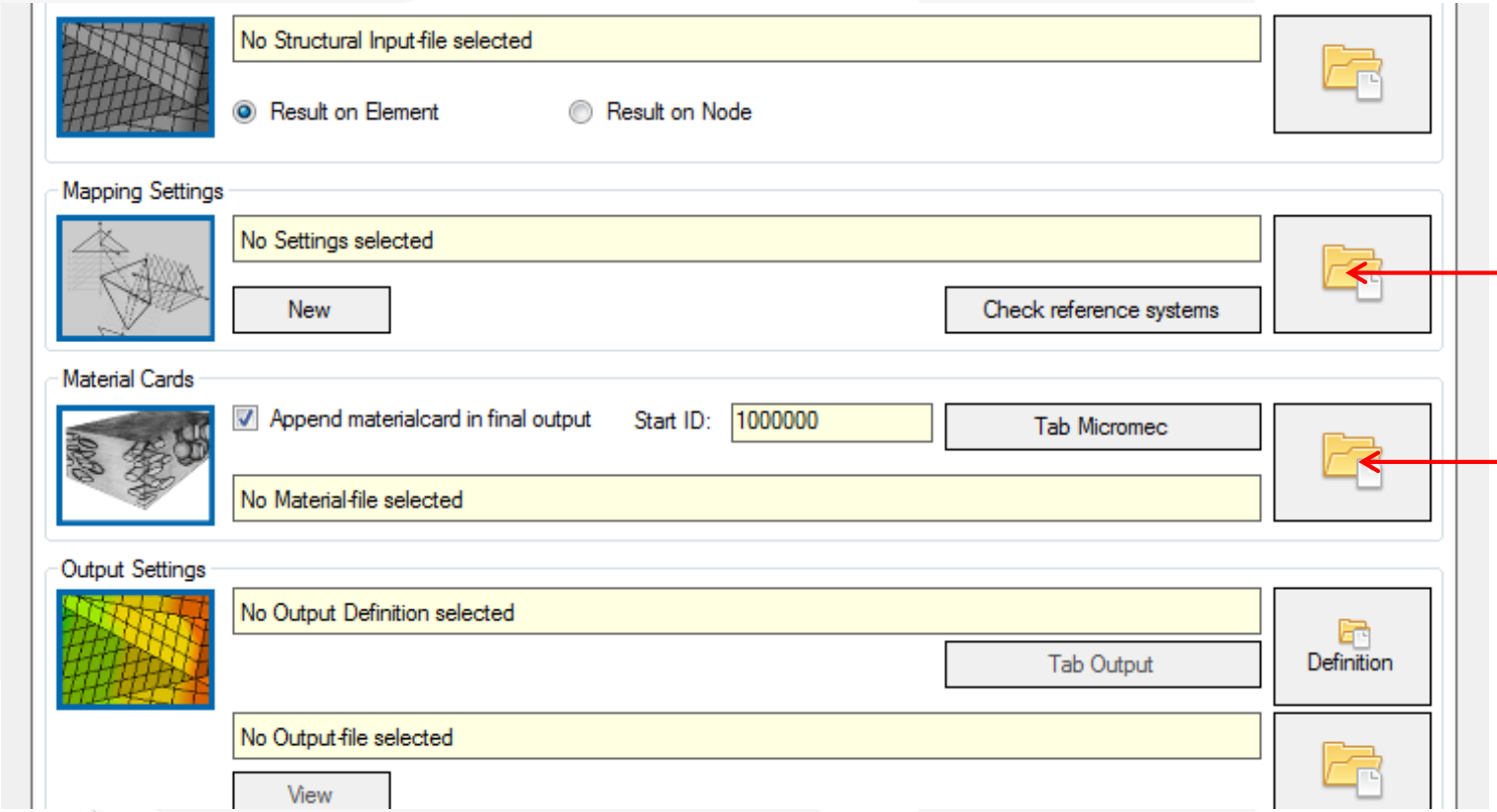
- Then the according files have to be specified:



Moldflow® result (XML)

FEM model (LS-Dyna / Abaqus / …)

- Then the mapping settings have to be specified:



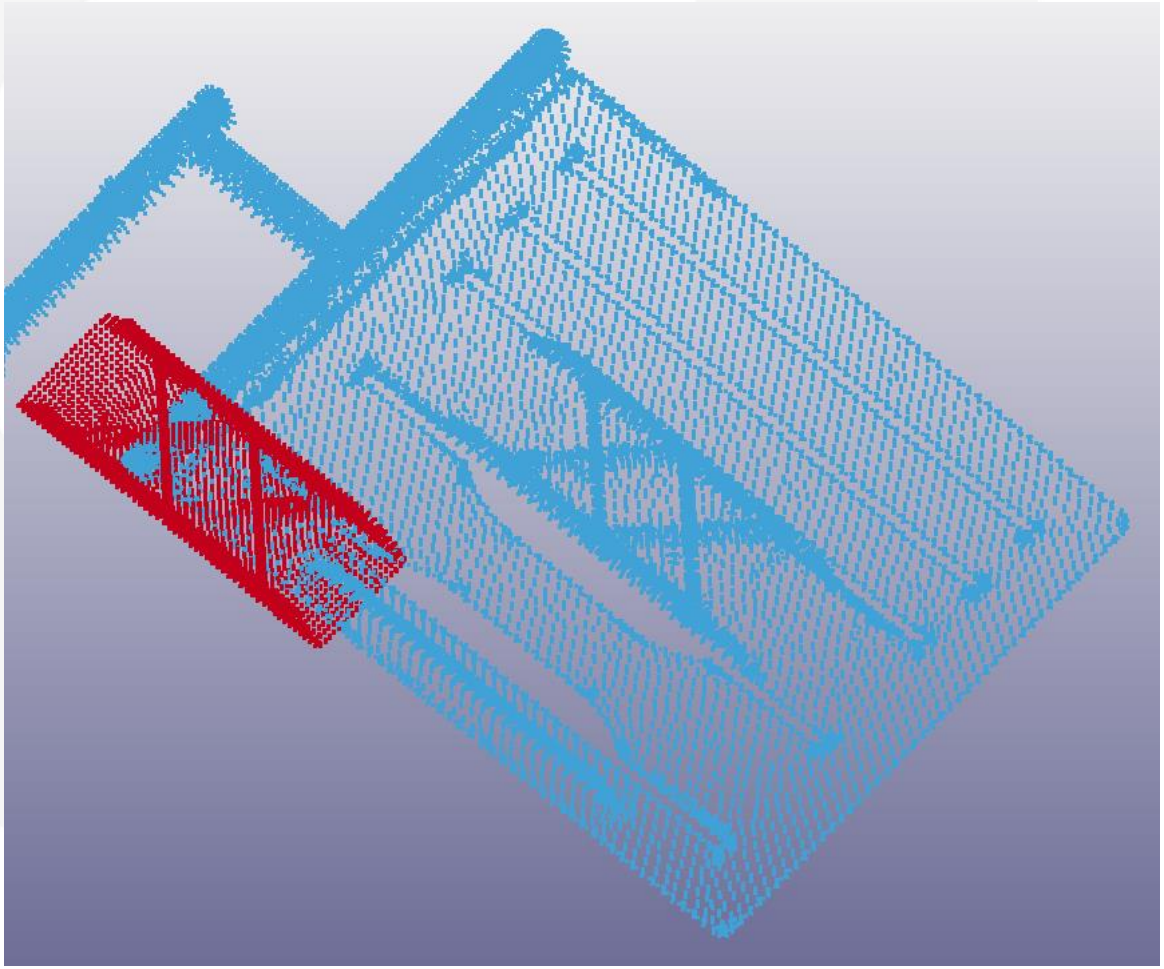
Mapping settings (if available)

Optional: material card

4a fibermap - short tutorial

3c. Performing the mapping

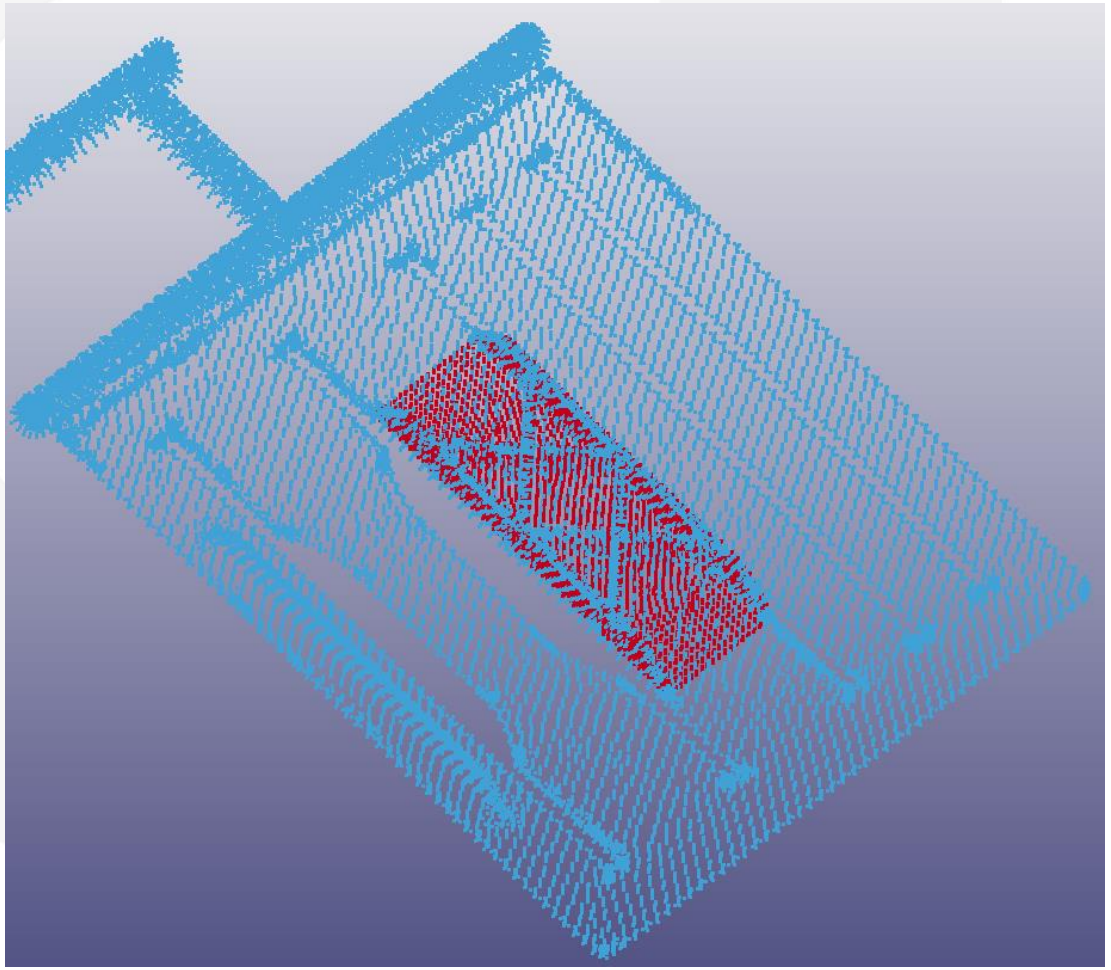
- Transformation of the injection molded part (blue) and the test specimen (structural simulation, red) based on the settings of the reference systems. The test specimen has to be aligned to the mold.



4a fibermap - short tutorial

3c. Performing the mapping

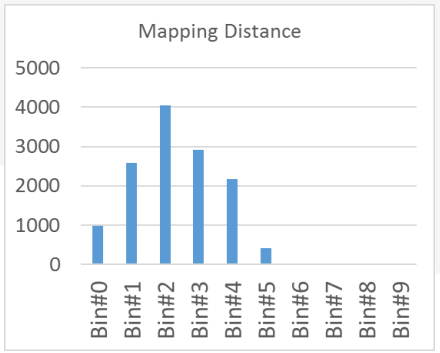
- After adapting the values of the reference system of the test specimen it is now in the correct position so that it matches with the injection molded part.

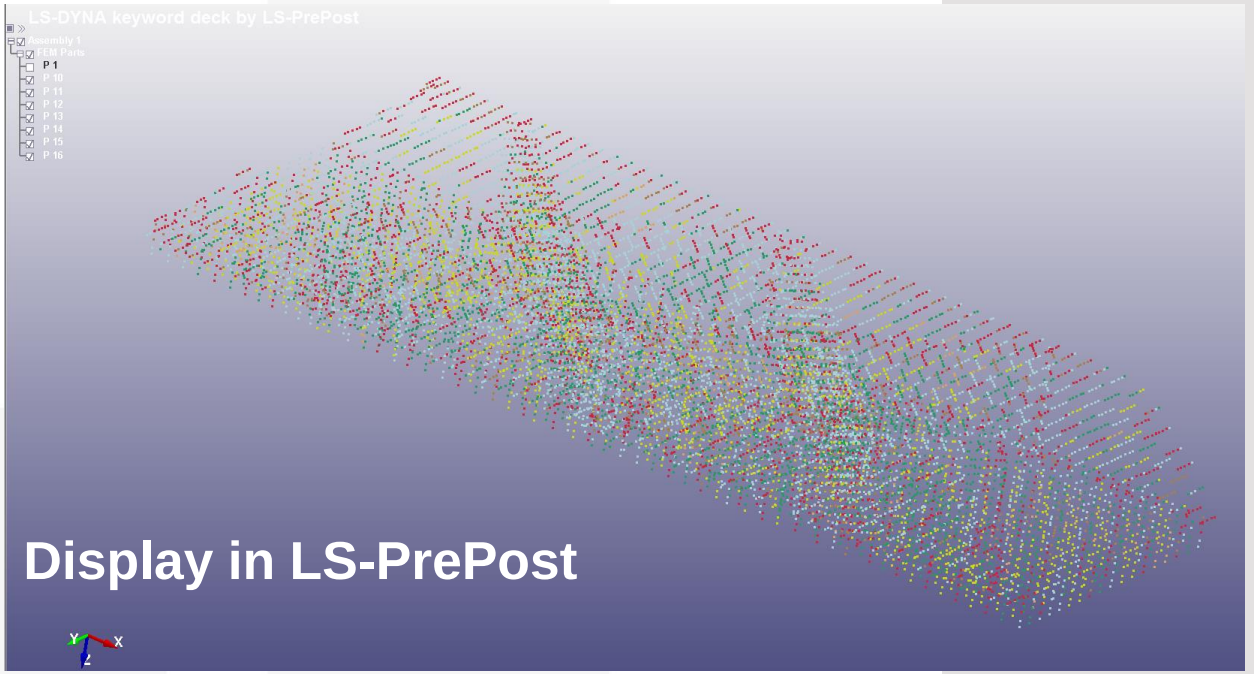


Quality check (after mapping)

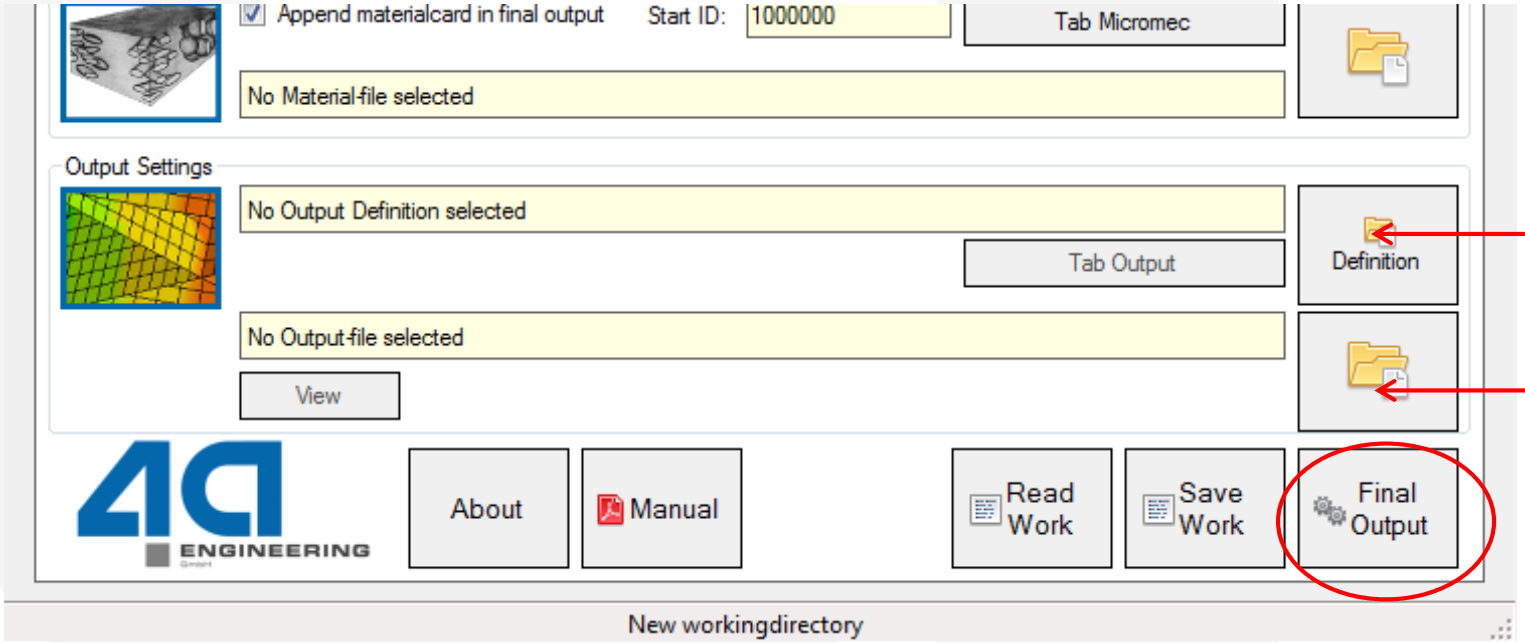
- A statistic is automatically exported as CSV file as well as another LS-Dyna file that shows the mean „mapping distance“.
- This can be used to check the quality of the mapping.

Bin-Name	Lower-limit mm	Upper-limit mm	Count -
Bin#0	0	0.2	982
Bin#1	0.2	0.4	2580
Bin#2	0.4	0.6	4047
Bin#3	0.6	0.8	2911
Bin#4	0.8	1	2162
Bin#5	1	1.2	408
Bin#6	1.2	1.4	5
Bin#7	1.4	1.6	0
Bin#8	1.6	1.8	0
Bin#9	1.8	2	0





- Choose Template for export
- Clicking on „Final Output“ the mapping is performed and the result is written into the output file.



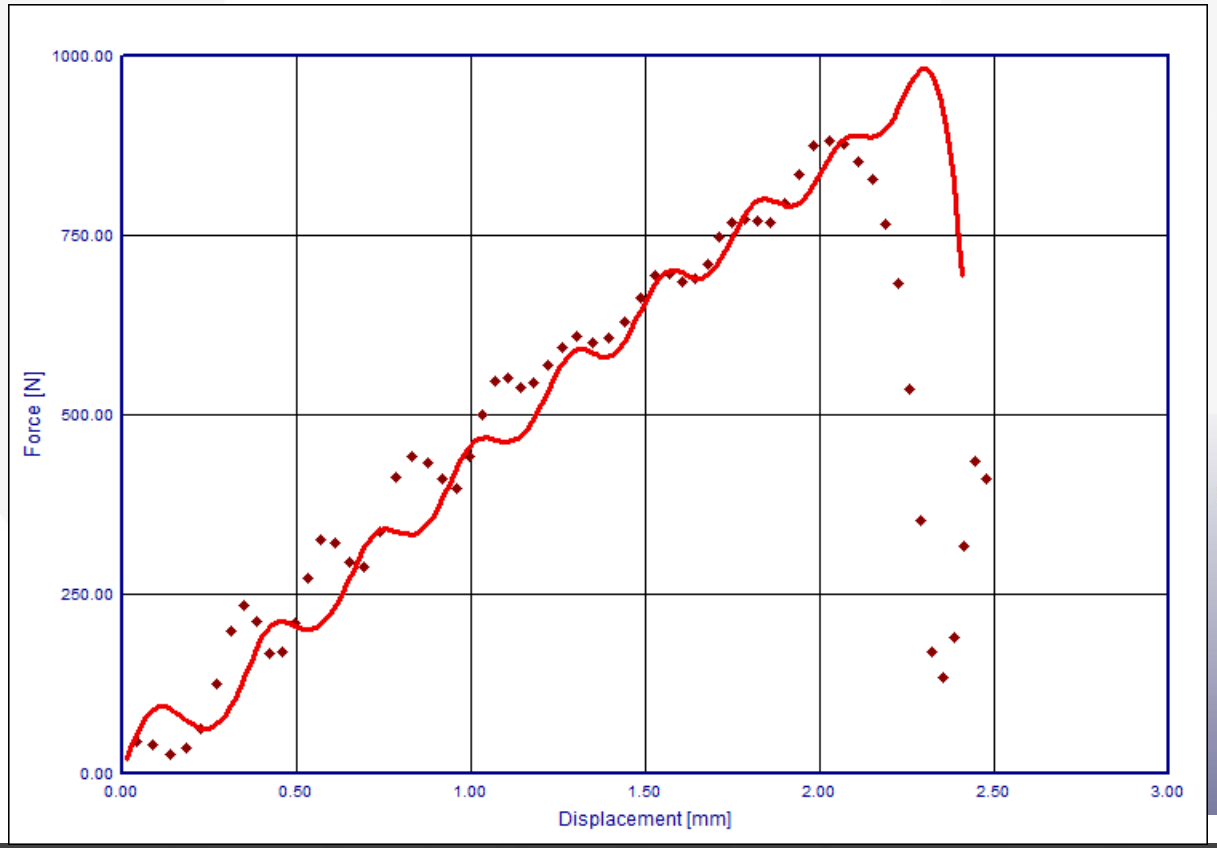
Template for mapping (e.g. for *Element_Shell_Beta)

Output file

4a fibermap - short tutorial

4. FEM calculation - result

- Result: The red solid line shows the force-displacement relation in the simulation for the mapped double crossed rib. The good matching between testing (dashed curve) and simulation is visible.



..... mean value curve of testing
_____result simulation

Displacement in z-direction: