VMAP - *Virtual material modelling in manufacturing*

Considering manufacturing induced inhomogeneity in structural material models

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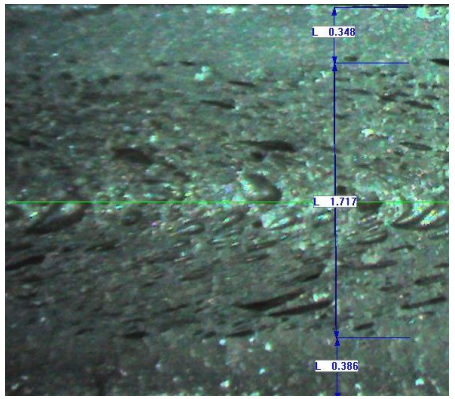
12th European LS-DYNA® USERS CONFERENCE 2019

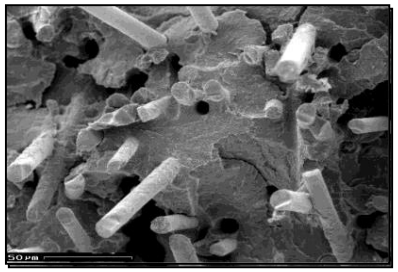
14-16th May 2019, Koblenz

Outline

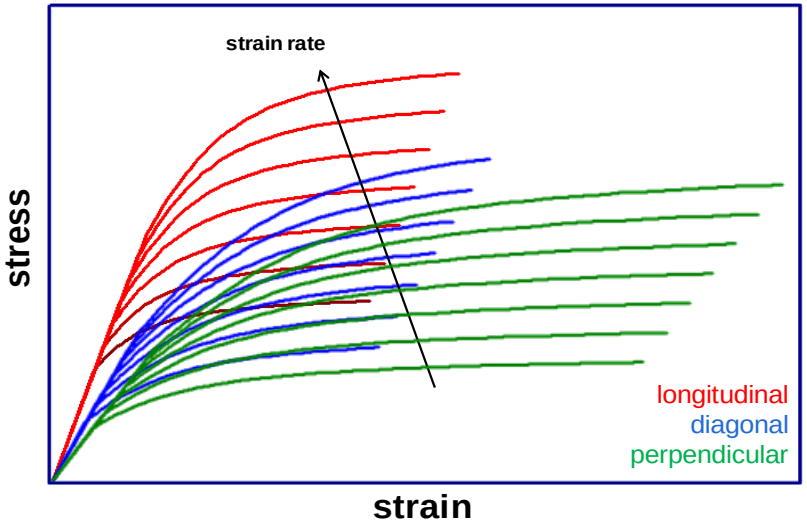
- motivation
- VMAP
- moulding – example
  simulation process chain
- structural foaming
  - CELL MOULD® introduction
  - USE CASE - physical foaming
- outlook & summary

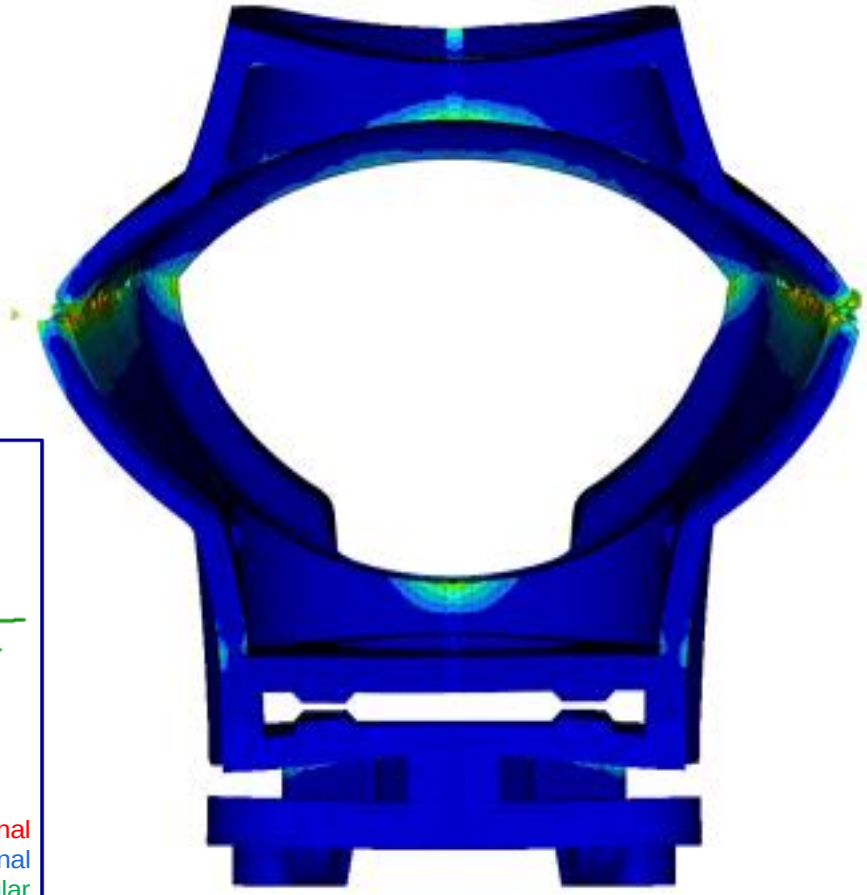


Motivation – current standard



*MAT_024





See more:

S. Seichter et al (Hirtenberger) – Influential parameters on the behavior of short fibre reinforced polyamides with focus on humidity and integrative simulations. German LS DYNA Forum 2018

Motivation - a general problem in many industries

Process 1 – Vendor A

Process 1 – Vendor B

Process 1 – Vendor C

??

File format definitions
notation for discretisation
(Shell) element definitions
results
distributed material props
manufacturing history
….

Process 2 – Vendor B

Process 2 – Vendor C

Process 2 – Vendor D

??

Process 3 – Vendor A

Process 3 – Vendor D

Source: Gino Duffett, Klaus Wolf; A new Interface Standard for Integrated Virtual Material Modelling in Manufacturing Industry
more: http://vmap.eu.com/

New standard

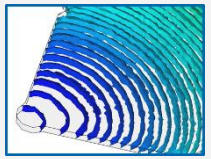
VMAP

- ITEA 3 – standardizing project
- working on a new CAE industry standard
- 29 partners
  - CAE end users
  - application end users
  - R&D engineers
  - software vendors
- use cases in the field
  - metal forming
  - composites manufacturing
  - injection moulding of plastics
  - 3D printing

Simulation process chain – software solutions

process simulation

injection molding



CADMOULD 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

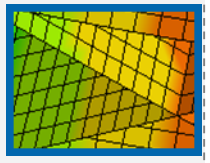
SOLIDWORKS PLASTICS

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

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

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
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binary – own format

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

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

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IntegrationId
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Tauyy
Tauxy
Tauxz
Tauyz
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ASCII – own format

Tensor 2nd order

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

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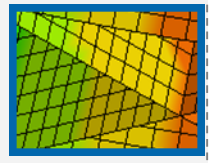
XML - ASCII

Structural simulation – considering anisotropy

- 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



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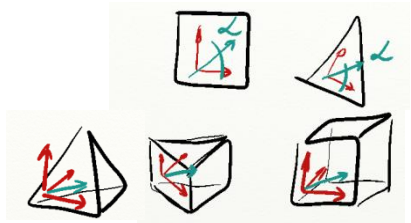
Virtual Performance Solution

Structural simulation – considering anisotropy

- *material model*
  - *anisotropic elasticity*
  - *orthotropic visco plasticity*
  - *micro mechanic model*
- *property*
  - *shell or solid*
  - *composite build up*
- *element formulation*
  - *shell*
  - *solid*
  - *composite*



standard in solver

→ linear

→ non linear

→ new / upcoming

direction

→ MID (material)

→ MID & t_{layer} & α

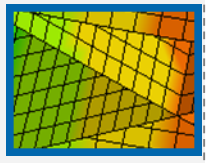
→ vector or α

→ vector

→ MID & t_{layer} & α

structural simulation

stiffness → crash



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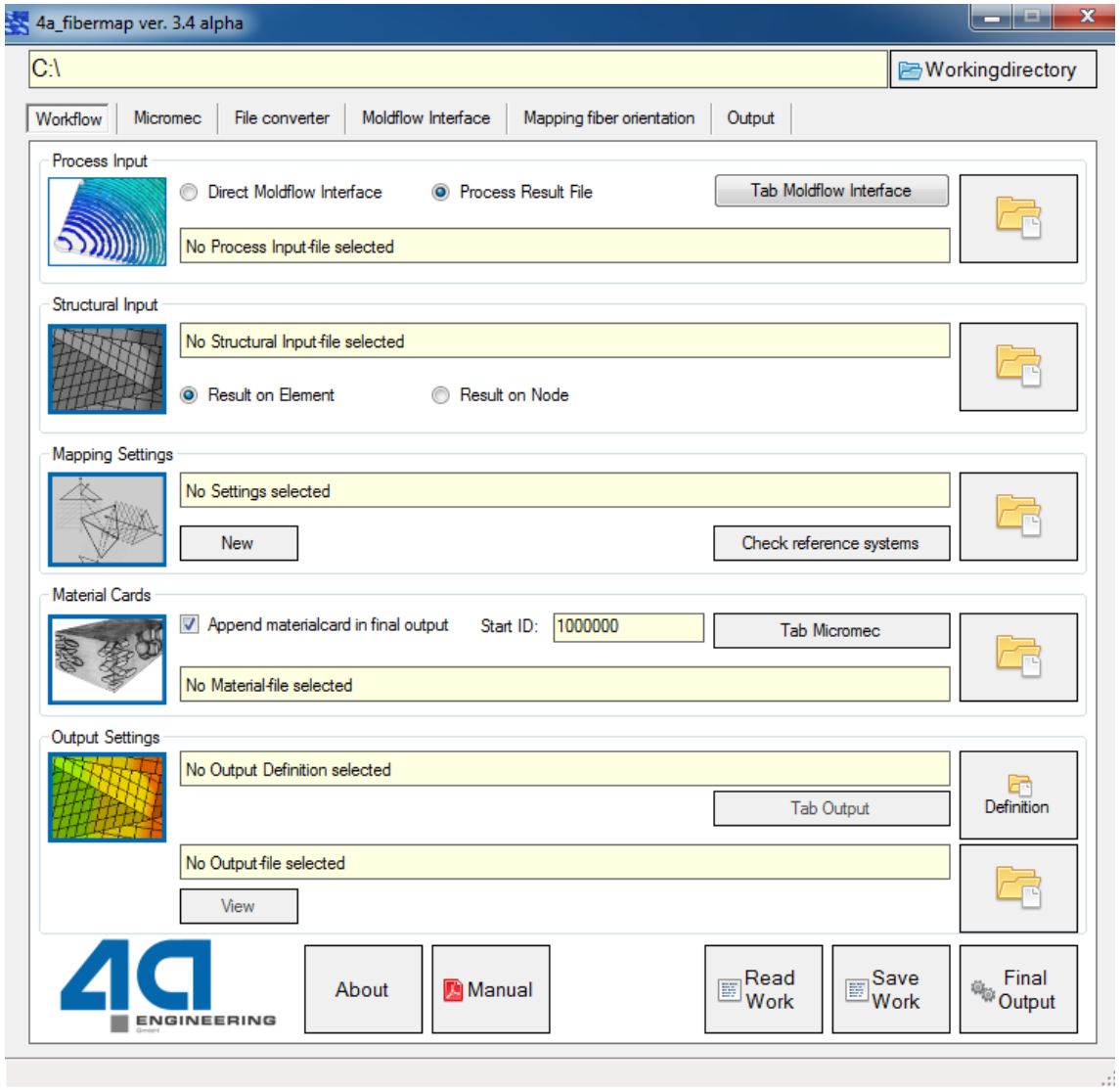
Virtual Performance Solution

<<Template>> based mapping workflow

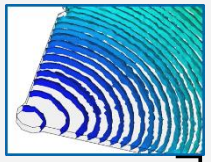
FIBERMAP



Material model - actual approaches

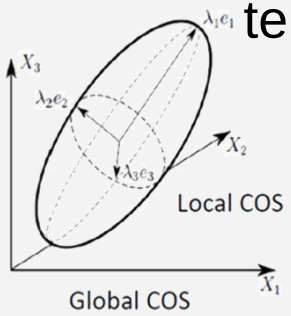
process simulation

filling



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

tensor 2nd order



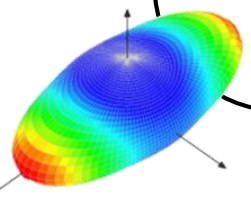
CADMOULD 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

FIBERMAP

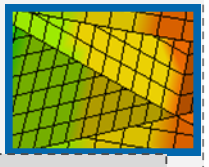
$$C^{-1} = \begin{bmatrix} \frac{1}{E_1} & -\frac{\nu_{21}}{E_2} & -\frac{\nu_{31}}{E_3} & 0 & 0 & 0 \\ -\frac{\nu_{12}}{E_1} & \frac{1}{E_2} & -\frac{\nu_{32}}{E_3} & 0 & 0 & 0 \\ -\frac{\nu_{13}}{E_1} & -\frac{\nu_{23}}{E_2} & \frac{1}{E_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{G_{23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G_{31}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G_{21}} \end{bmatrix}$$



MICROMEC

structural simulation

drop test



homogenization (Micro Scale)

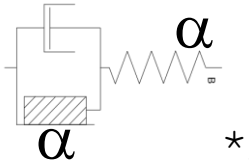
Mean Field Theory

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

*MAT_215

composite (Macro Scale)

Hill Plasticity



*MAT_157

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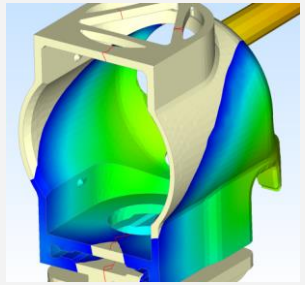
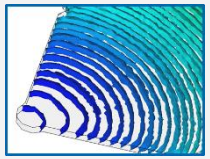
USE CASE – drop test sleeve

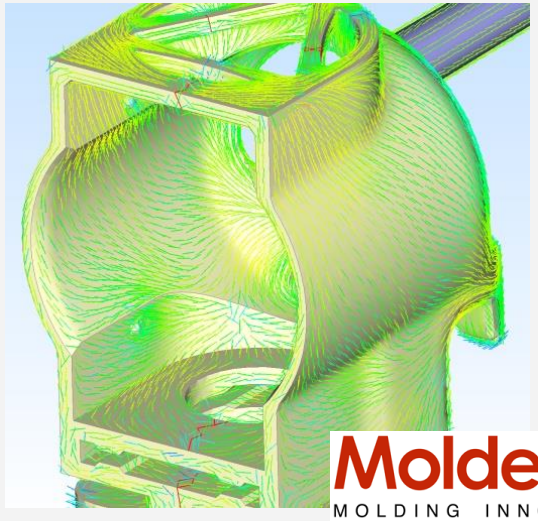
process simulation

filling

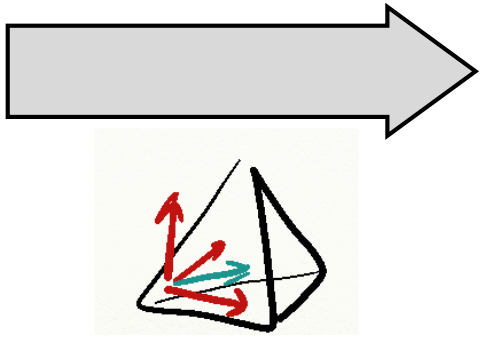




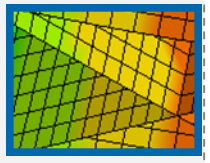
fiber orientation

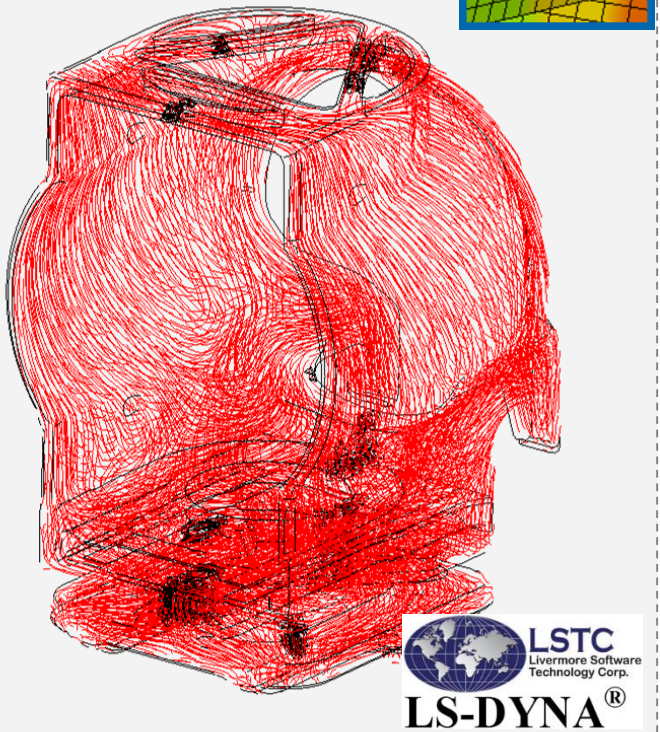


FIBERMAP



structural simulation

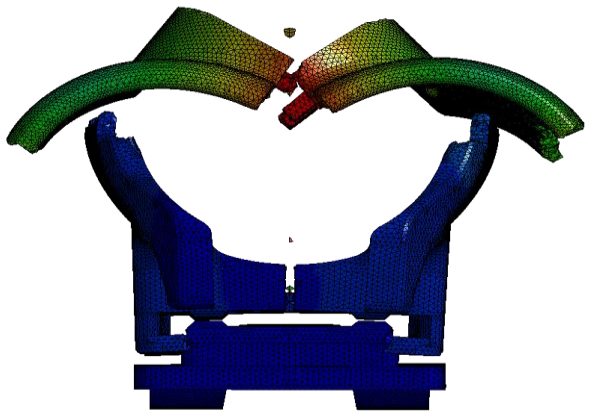




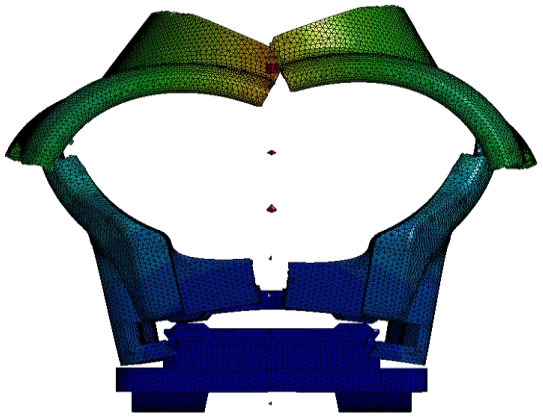
Element orientation

***ELEMENT_SOLID_ORTHO**

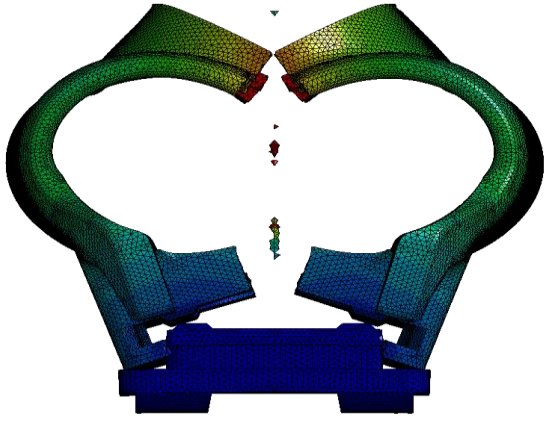
USE CASE – drop test sleeve



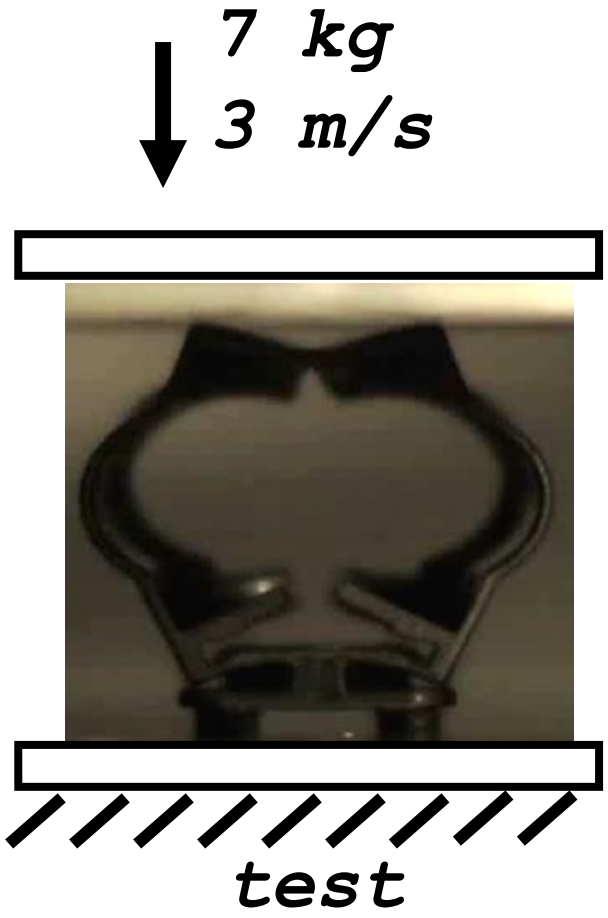
*MAT_024
transversal



*MAT_024
longitudinal



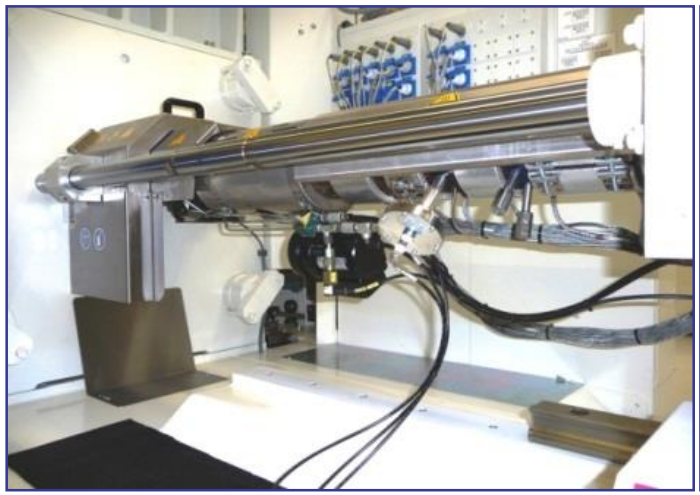
*MAT_157/215
local anisotropy

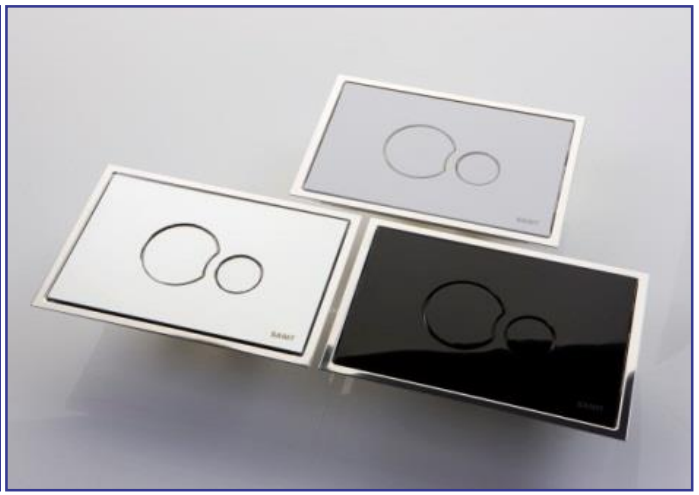


See more details:*MAT_4A_MICROMEC – Generating Material Card and Considering Fiber Orientation; 15th German LS-DYNA Conf.

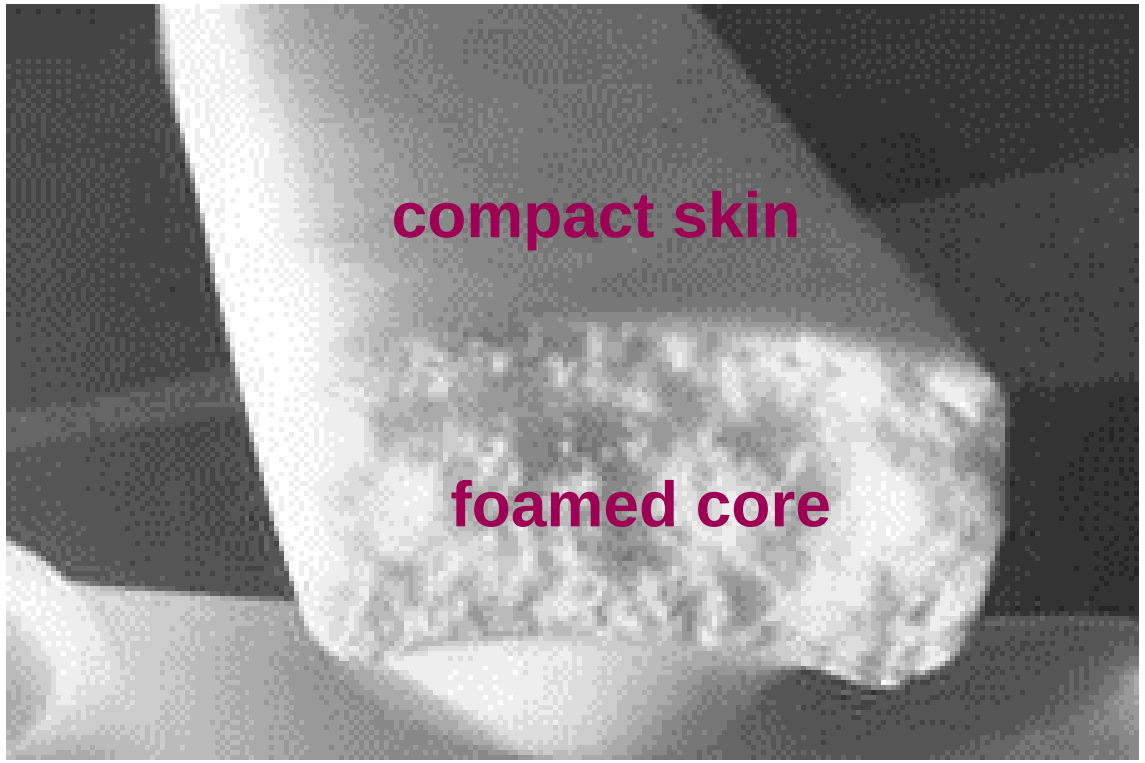
USE CASE - structural foaming

CELLMOULD® – lightweight technology





Source: F. Pühringer (Wittmann Battenfeld) – Schaumspritzgießen 2.0; 4a Technologietag 2016



- chemical blowing agents
- physical blowing agents

The gas in the “melt” takes over the function of the holding pressure.

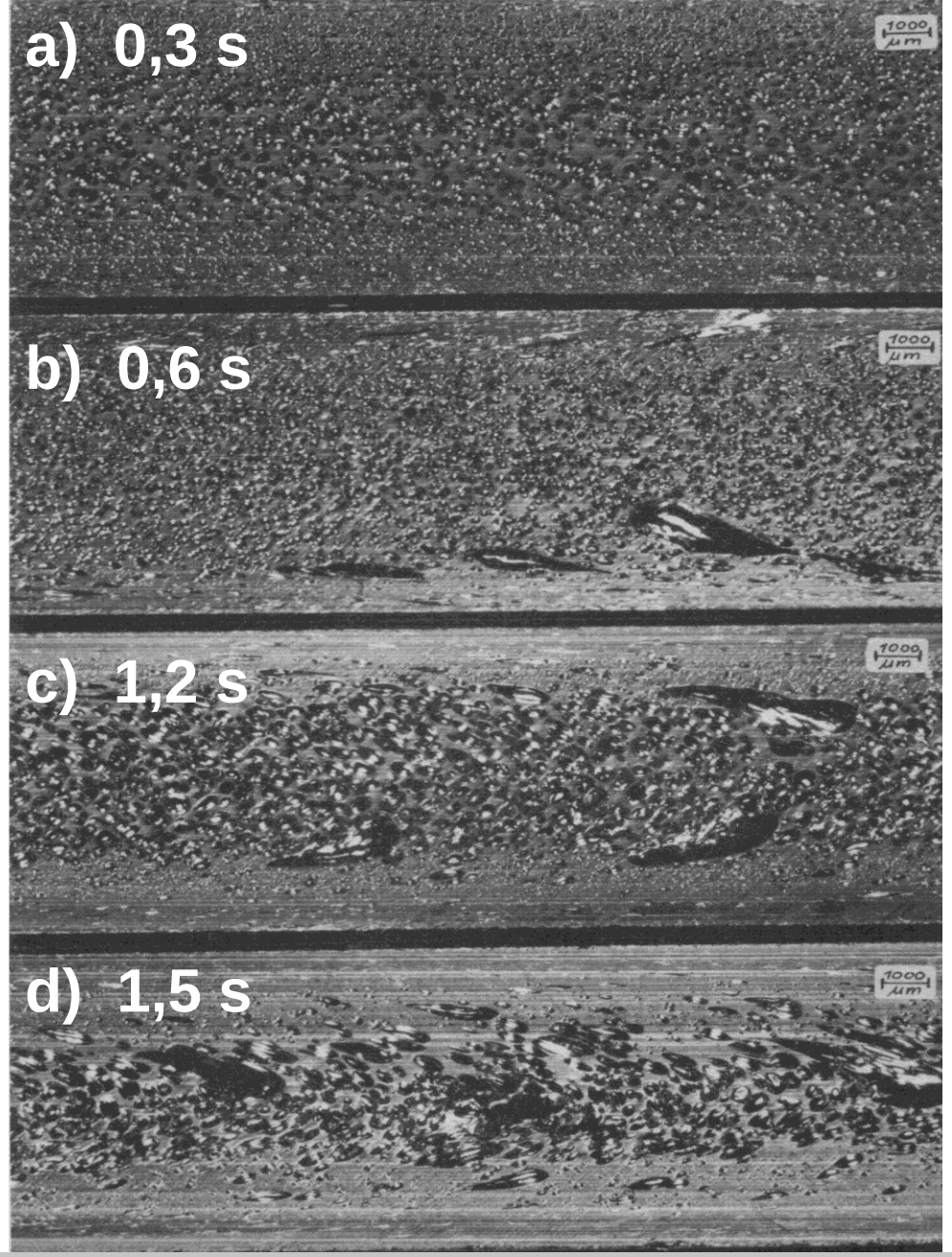
USE CASE - structural foaming

Why structural foam?

advantages of structural foam:

- elimination/reduction of sink marks
- reduction of internal stresses
- elimination/reduction of warpage
- lower injection pressure
- lower cavity pressure
- reduced clamping force
- reduced cycle times
- **reduced weight**

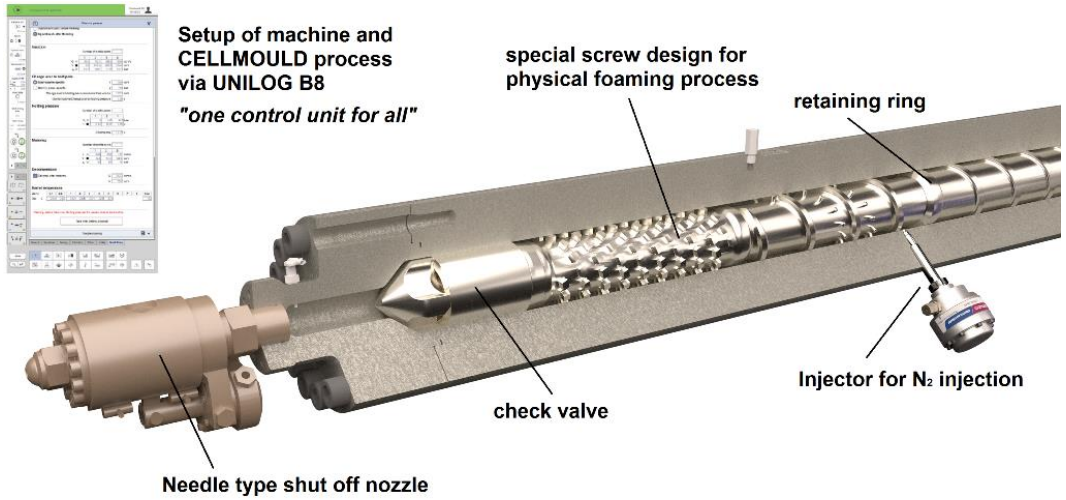
Source: F. Pühringer (Wittmann Battenfeld) – Schaumspritzgießen 2.0; 4a Technologietag 2016



USE CASE - structural foaming

Influences - physical foaming

- design (wall thickness)
- process parameter **(e.g. fill times)**



Source: F. Pühringer (Wittmann Battenfeld) – Schaumspritzgießen 2.0; 4a Technologietag 2016

USE CASE - structural foaming

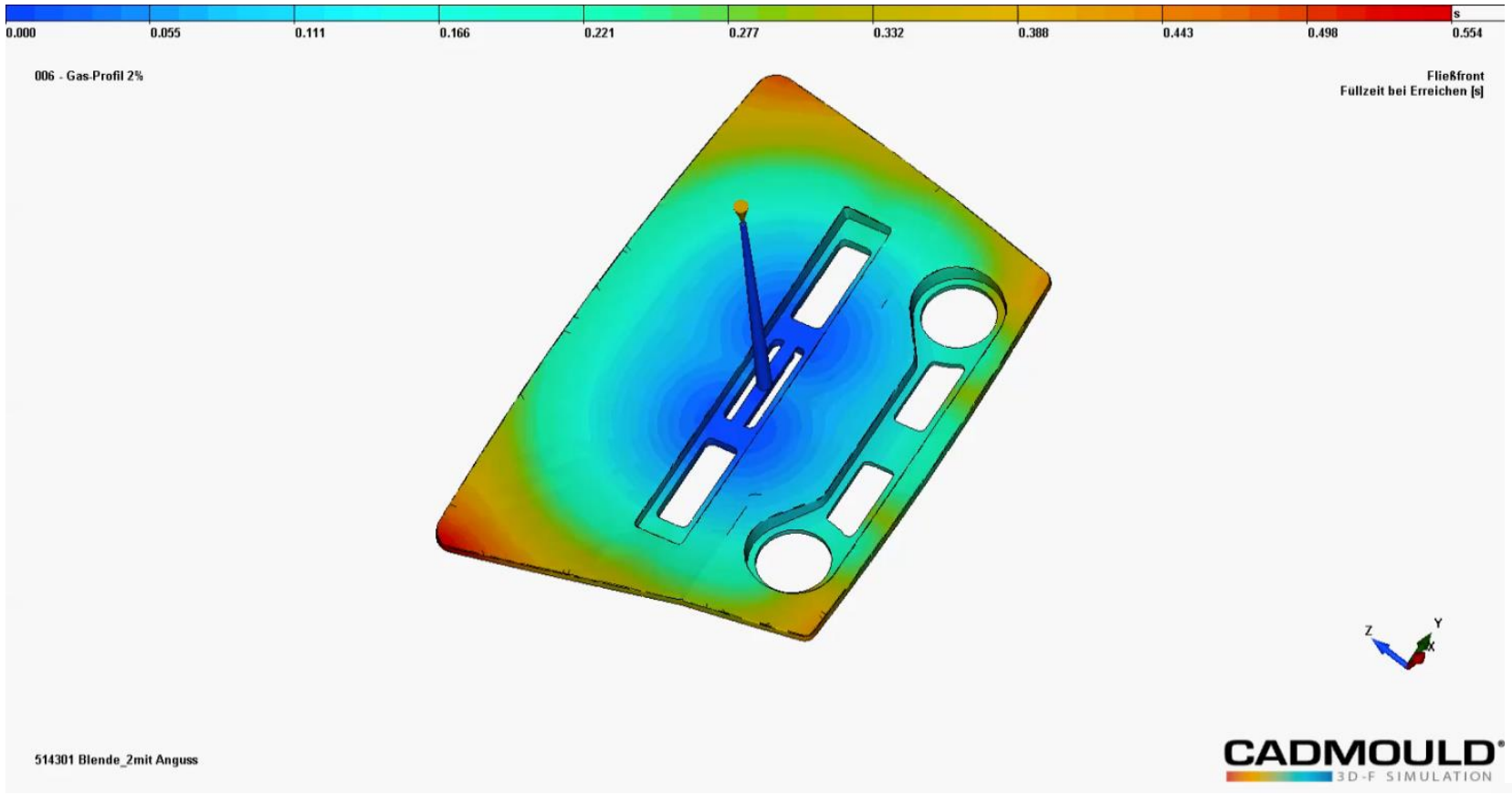
demonstrator „radio mask“

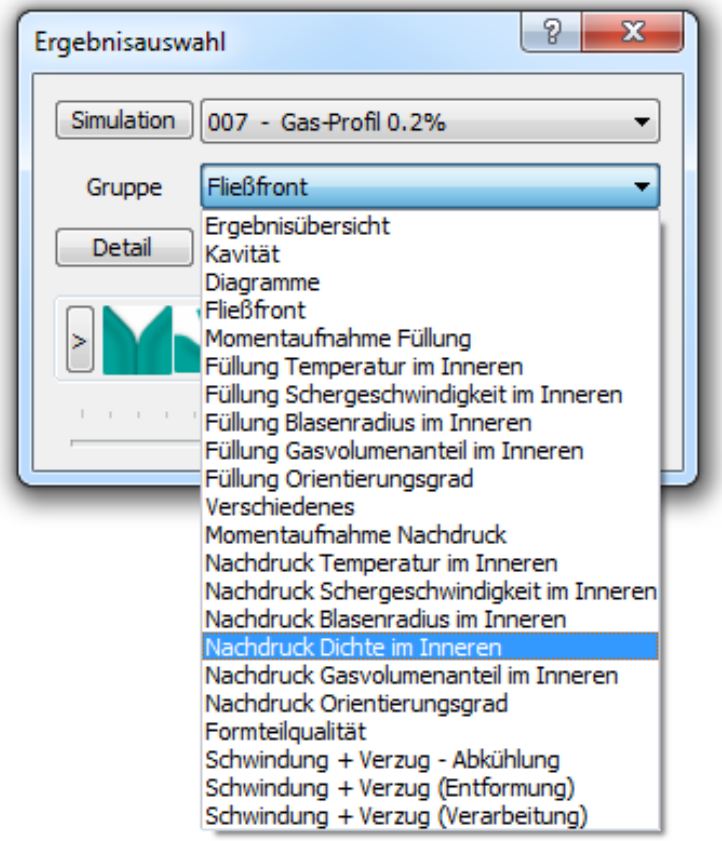
- **investigations**
  - different processing ***compact & foamed***
  - foam distribution
  - mechanical behavior
- **correlation simulation**
  - virtual material modeling
  - foam prediction
  - structural prediction
- **testing of new VMAP interface**

project schedule: 2018-2020

USE CASE - structural foaming

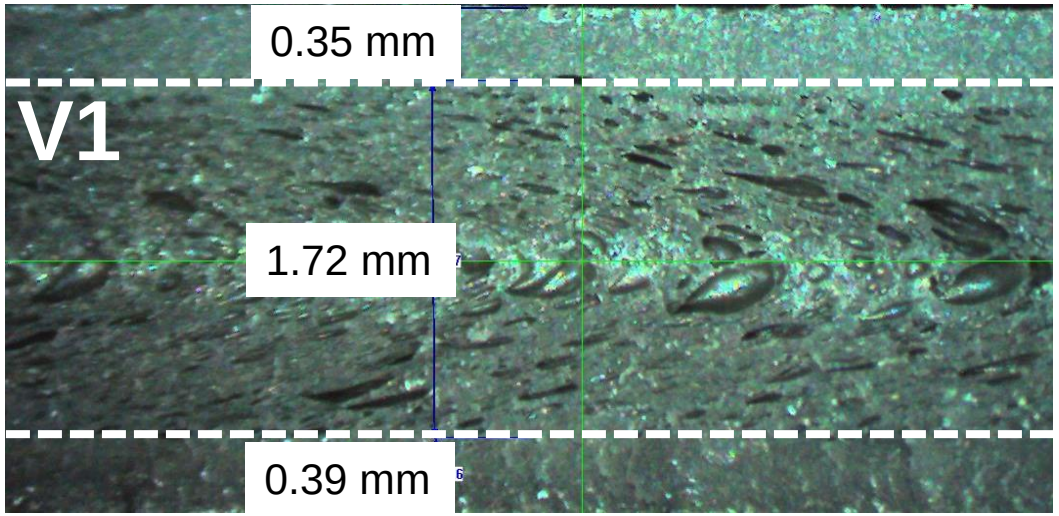
- rheological simulation of foamed part – work in progress

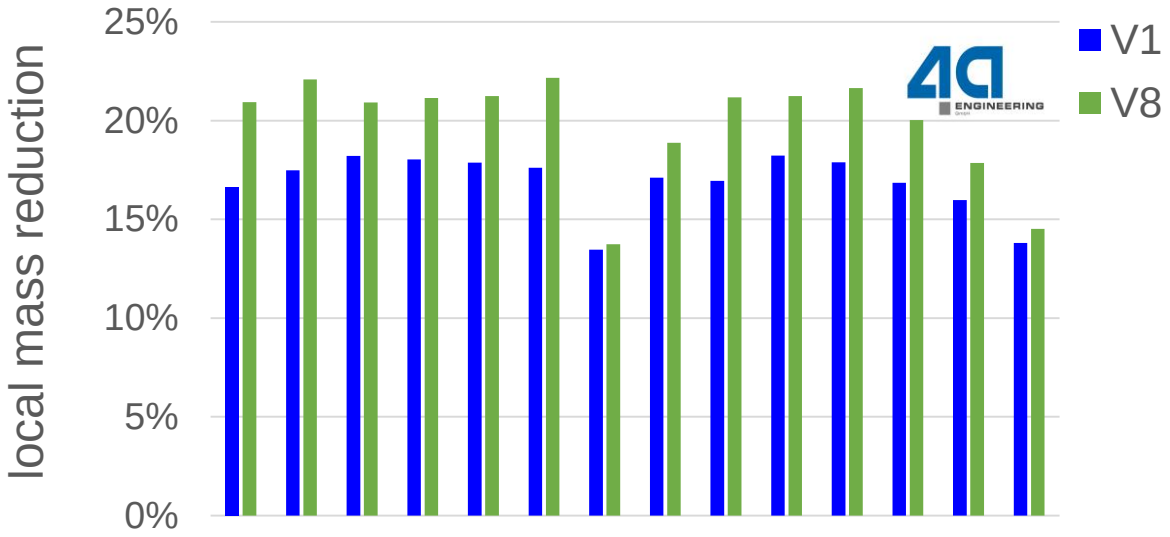


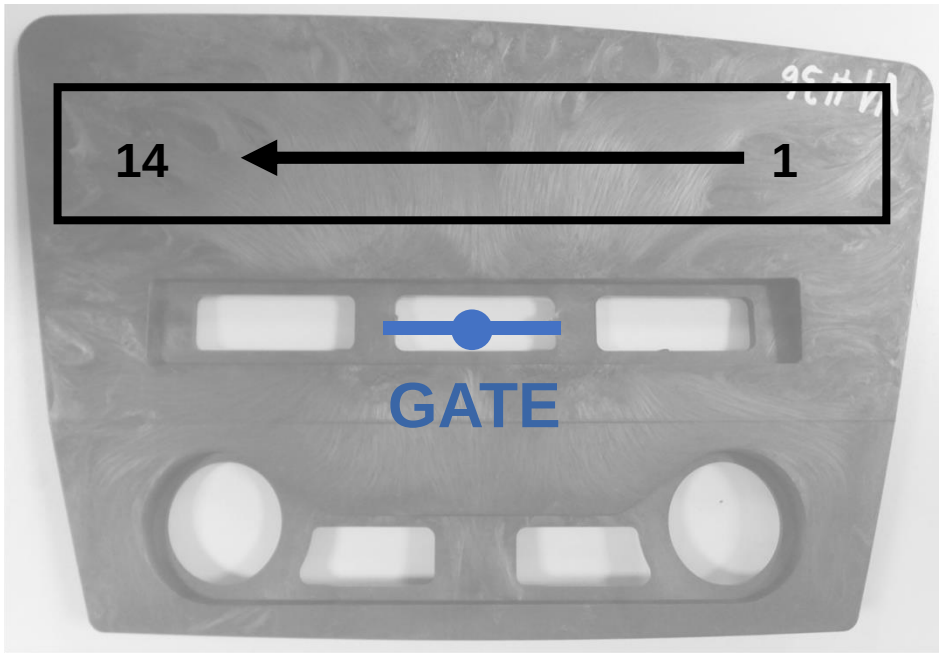


USE CASE - structural foaming

- **investigations**
  - different processing
    - ***compact***
    - ***foamed*** ***V1: -12% mass***
    - ***foamed*** ***V8: -14% mass***
  - foam distribution

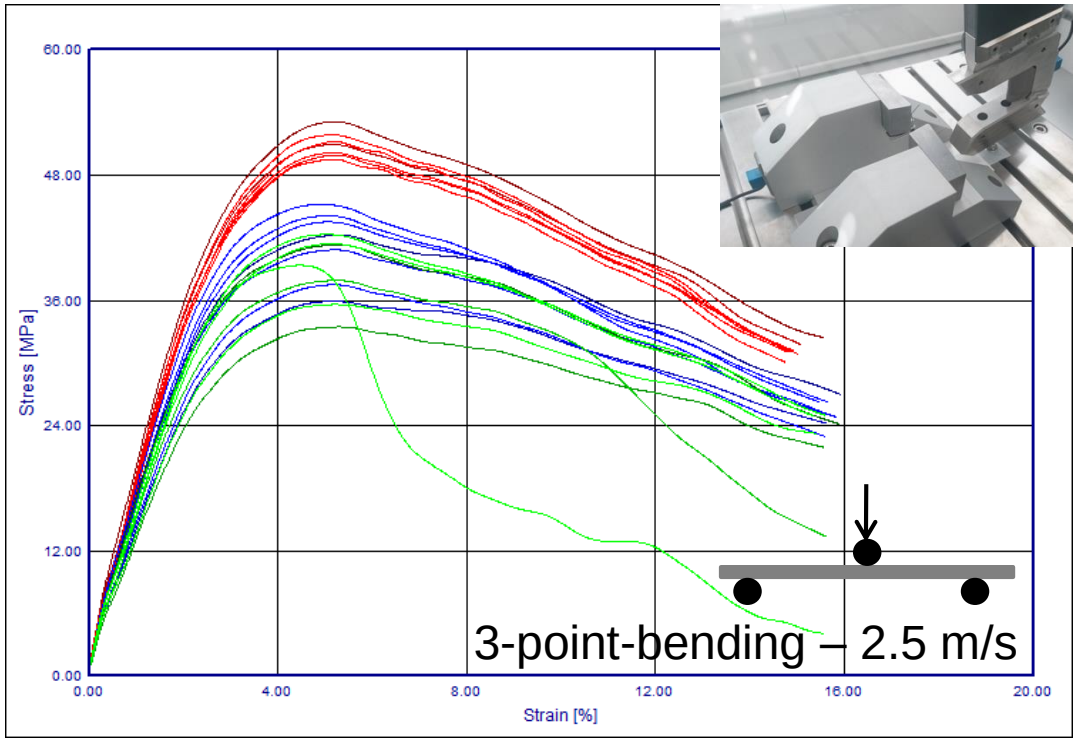


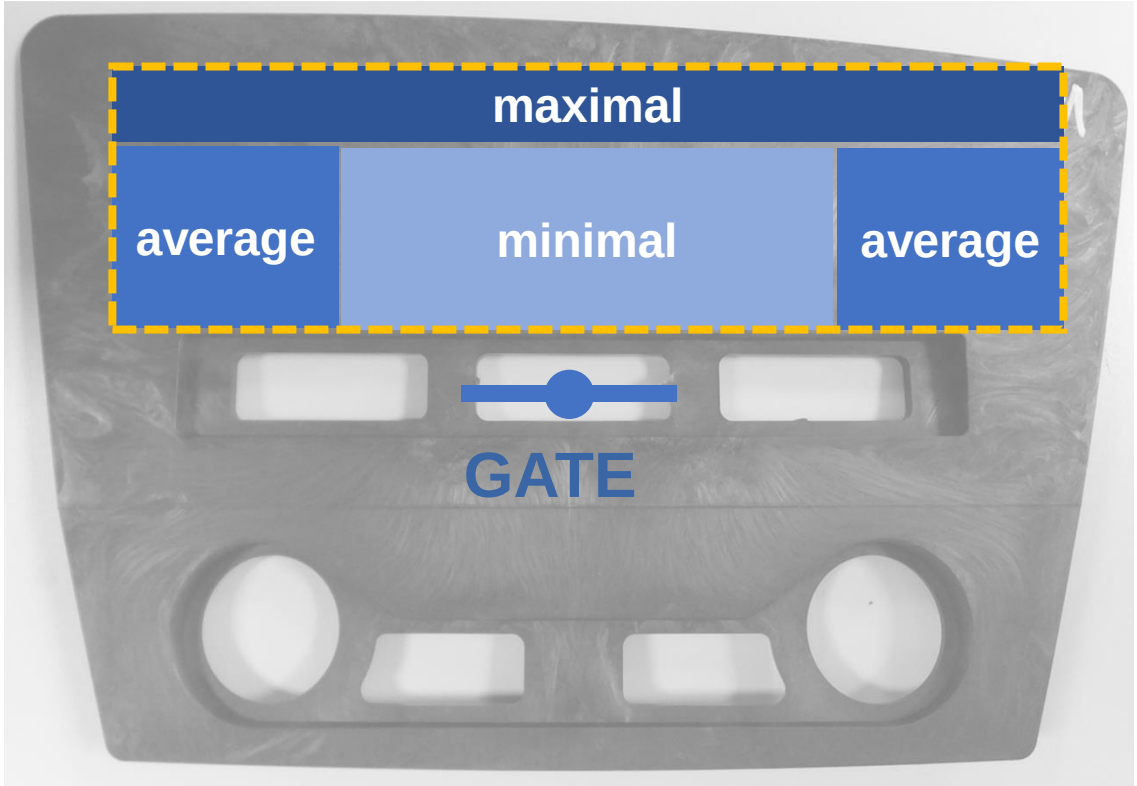




USE CASE - structural foaming

- investigations **mechanical behavior**
  - static tensile tests
  - static & **dynamic bending tests**
  - **dynamic puncture tests**

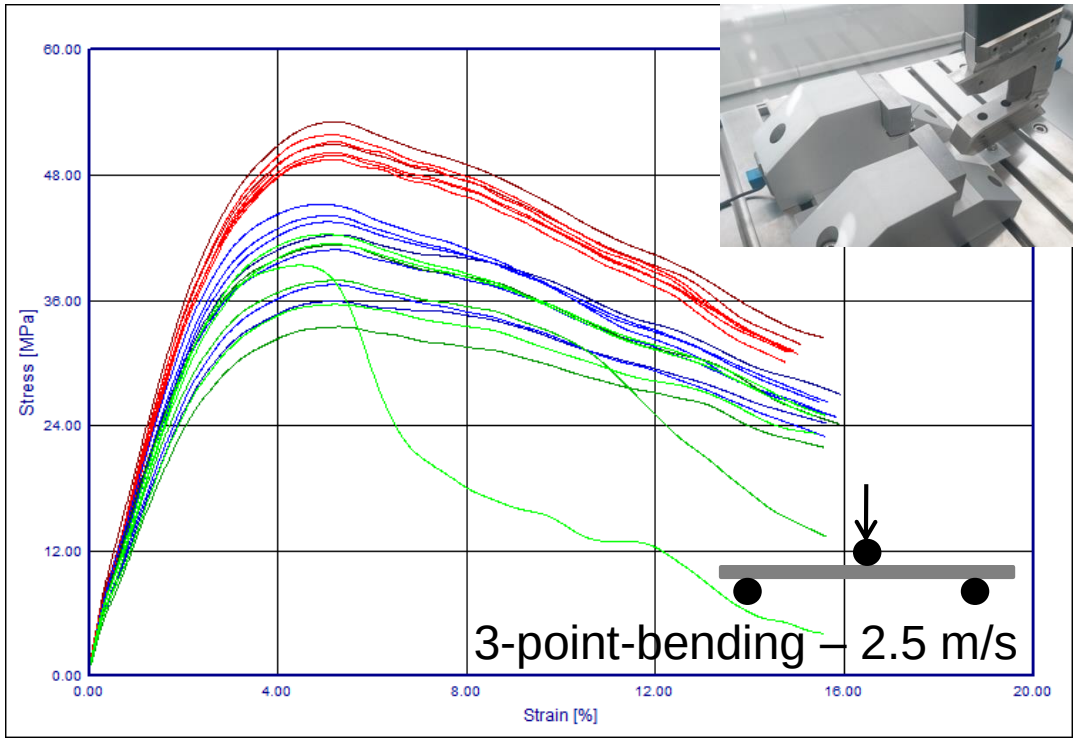


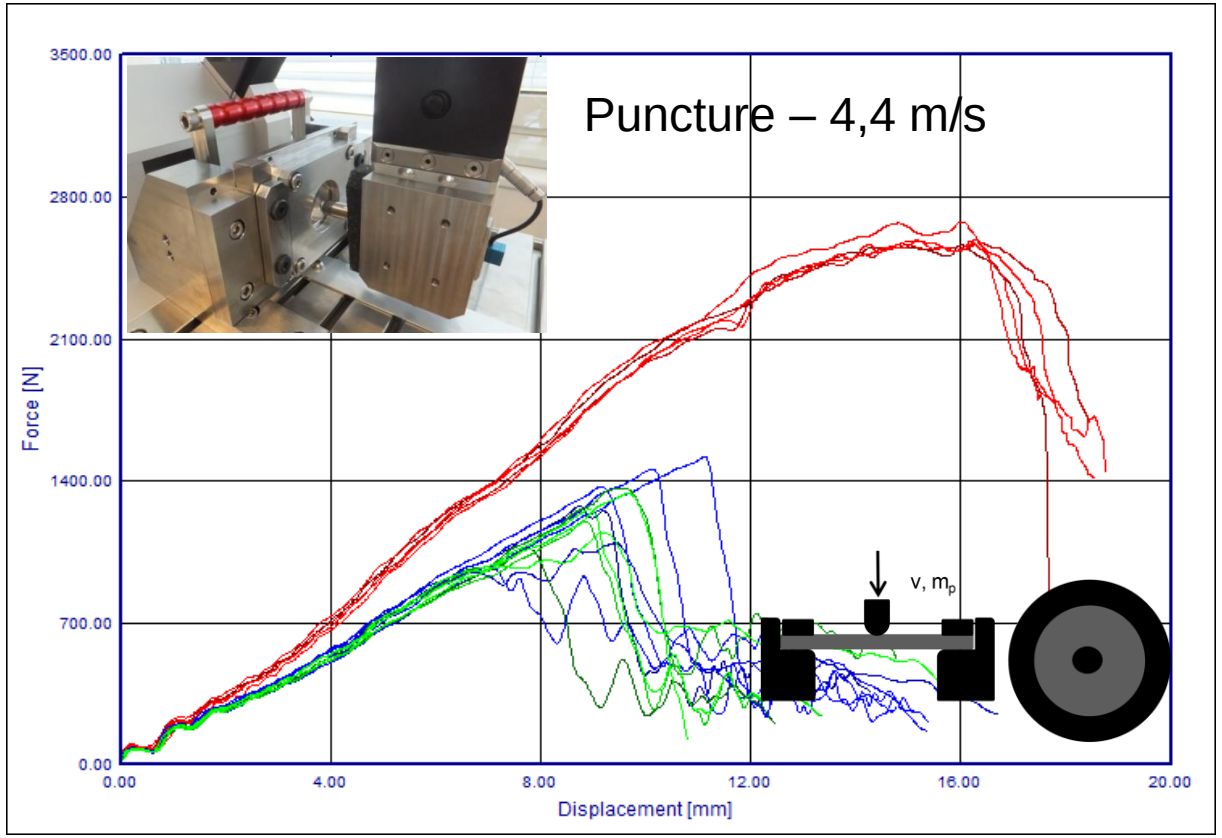


compact
V1: -12% mass
V8: -14% mass

USE CASE - structural foaming

- investigations **mechanical behavior**
  - static tensile tests
  - static & **dynamic bending tests**
  - **dynamic puncture tests**

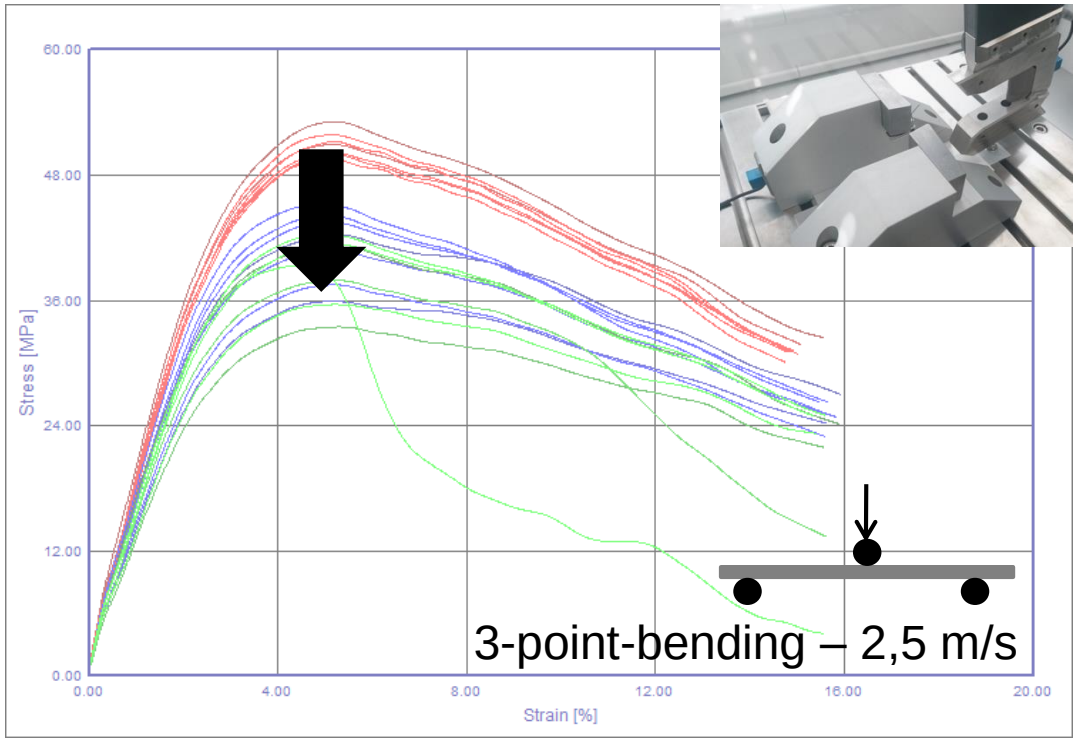


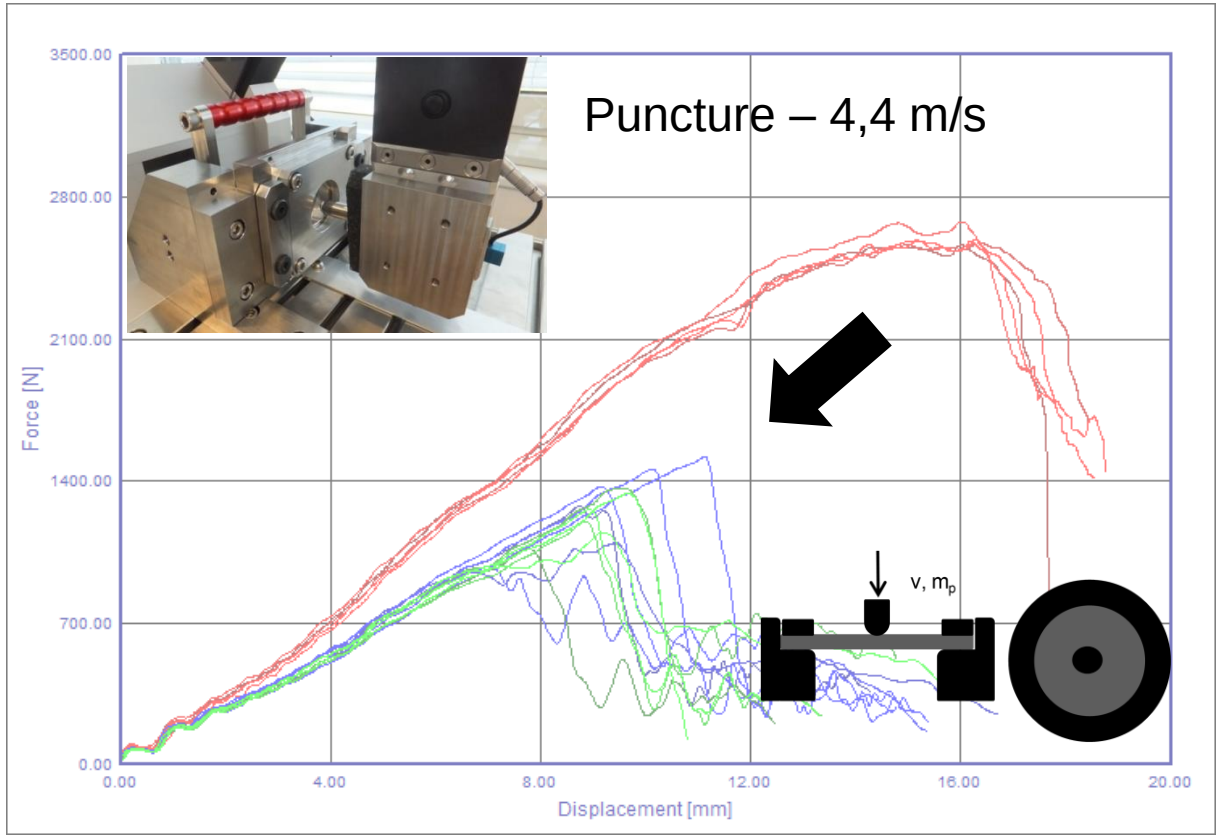


compact
V1: -12% mass
V8: -14% mass

USE CASE - structural foaming

- investigations **mechanical behavior**
  - static tensile tests
  - static & **dynamic bending tests**
  - **dynamic puncture tests**



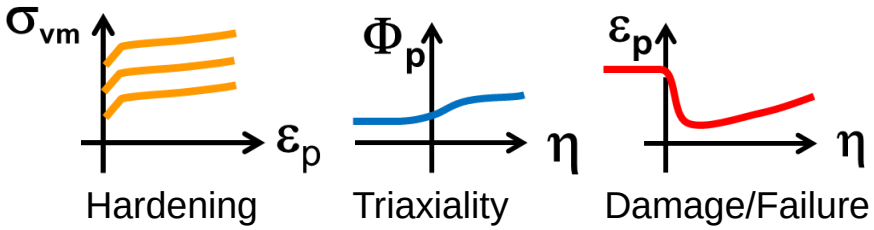


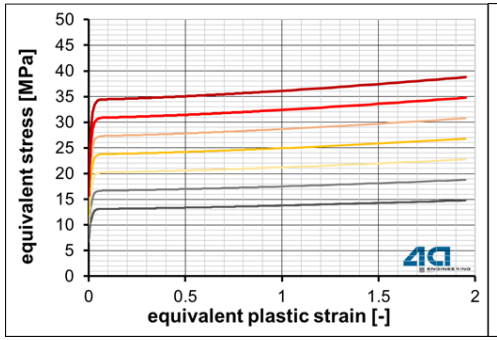
compact
V1: -12% mass
V8: -14% mass

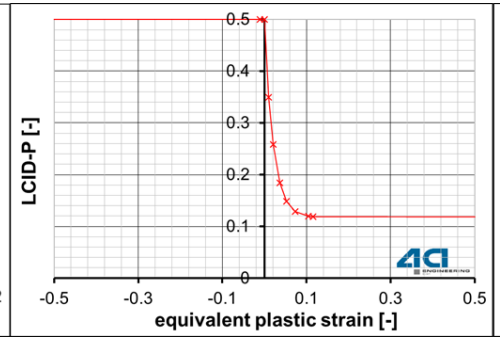
USE CASE - structural foaming

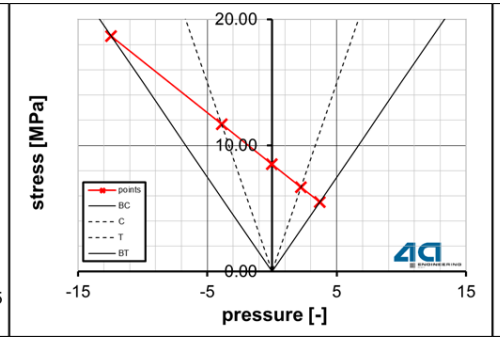
VALIMAT

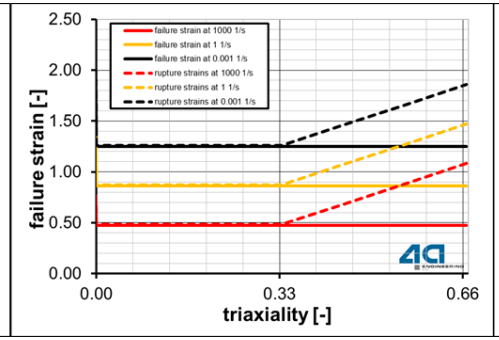
- **virtual material modeling**
  1. compact material – PP T10
     determine ****MAT_SAMP-1***
     by reverse engineering

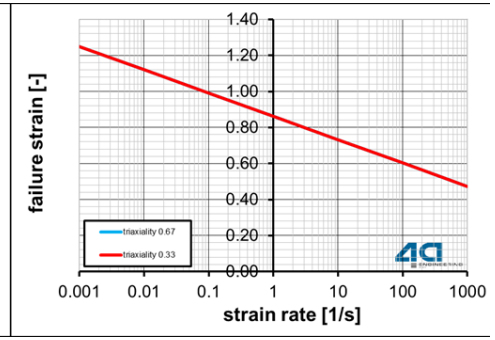


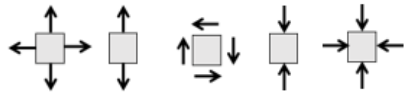


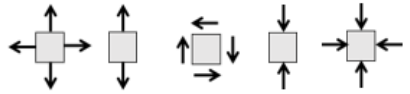






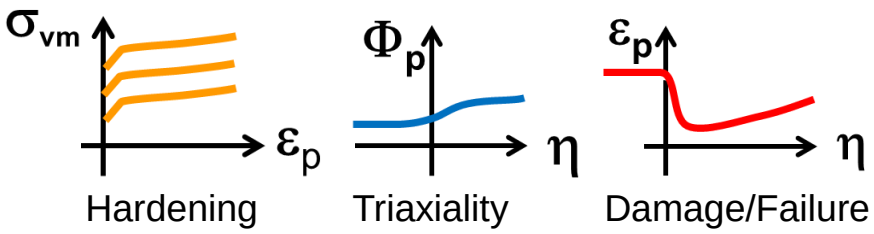




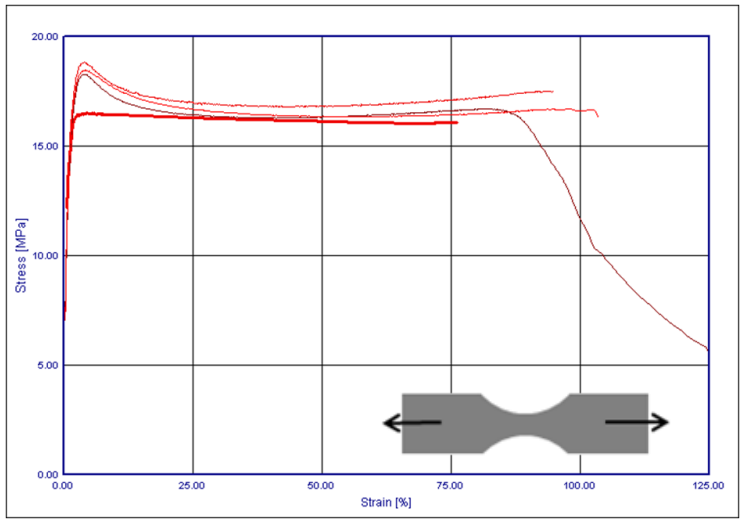


USE CASE - structural foaming

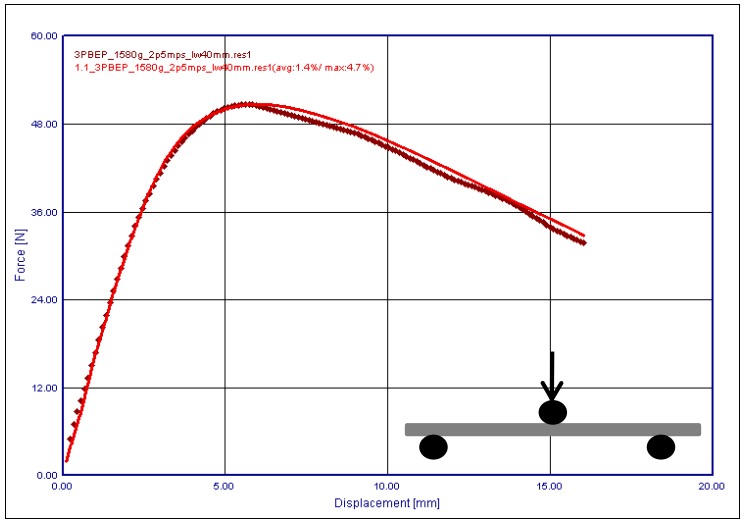
- **virtual material modeling**
  1. compact material – PP T10
     determine ****MAT_SAMP-1***
     by reverse engineering



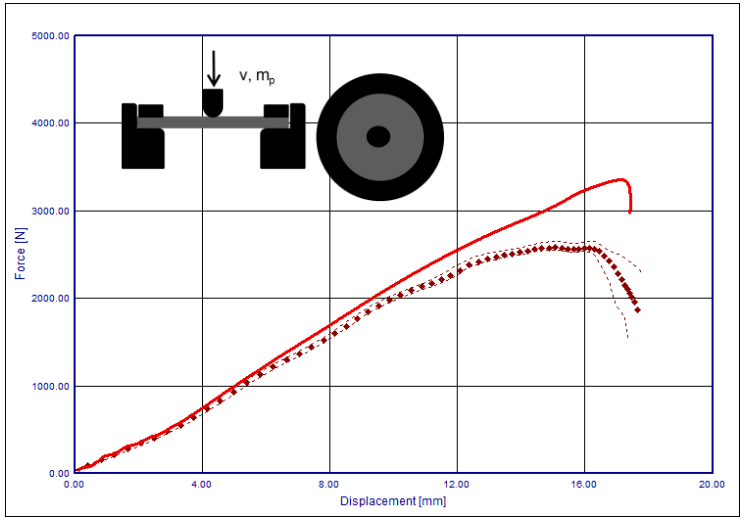
static tensile



dynamic bending



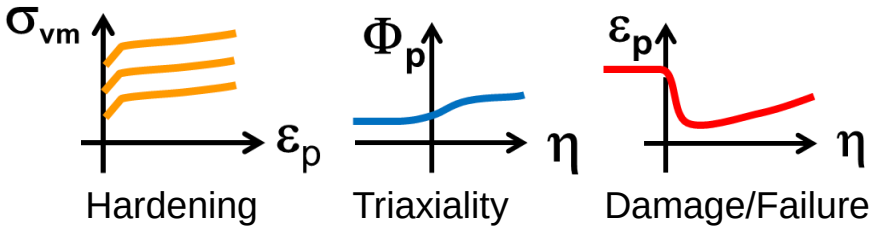
dynamic puncture test



USE CASE - structural foaming

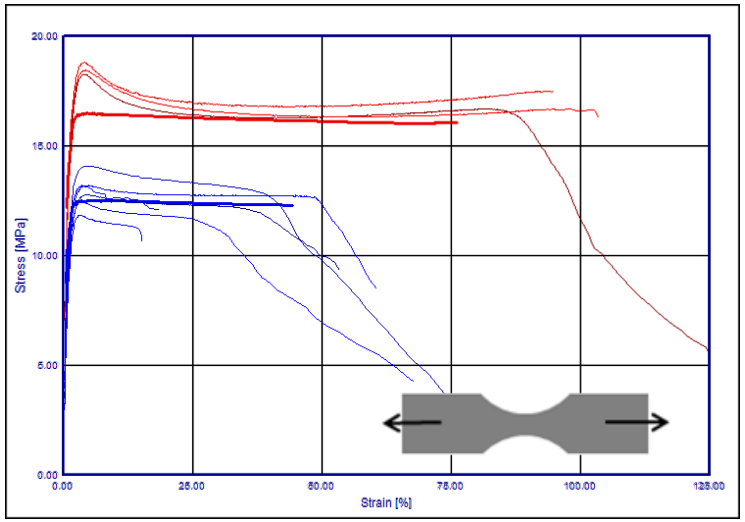
VALIMAT

- **virtual material modeling**
  1. compact material – PP T10
     determine ***MAT_SAMP-1***
     by reverse engineering
  2. **foamed material scaled by 0.8**

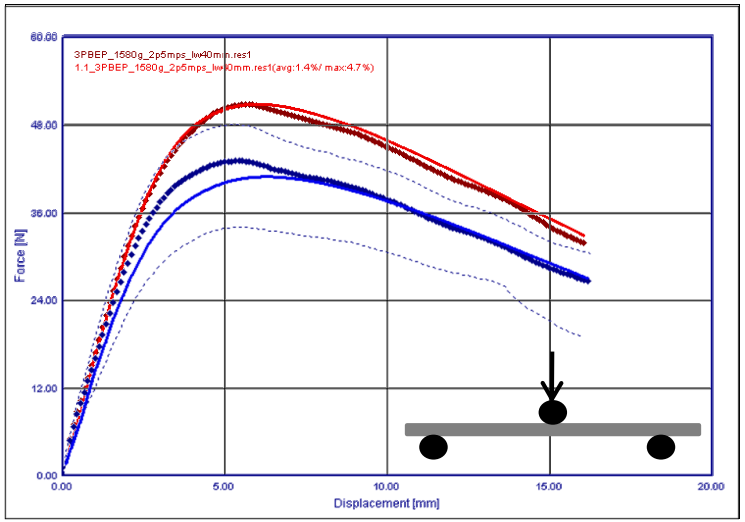


compact
foamed V1

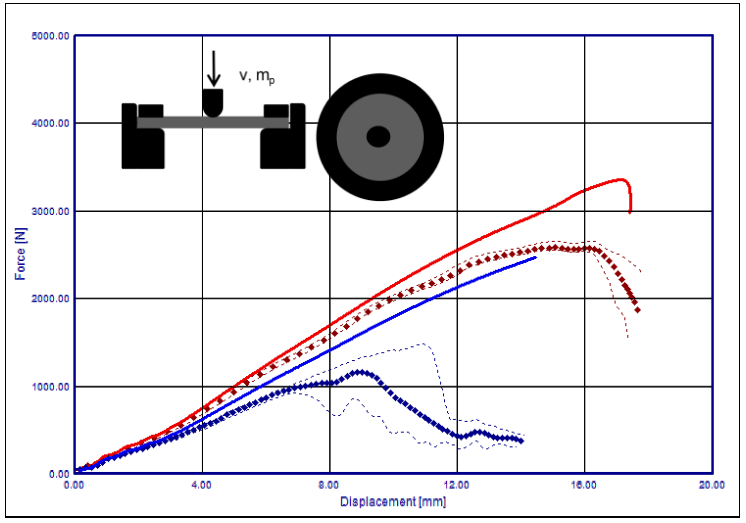
static tensile



dynamic bending



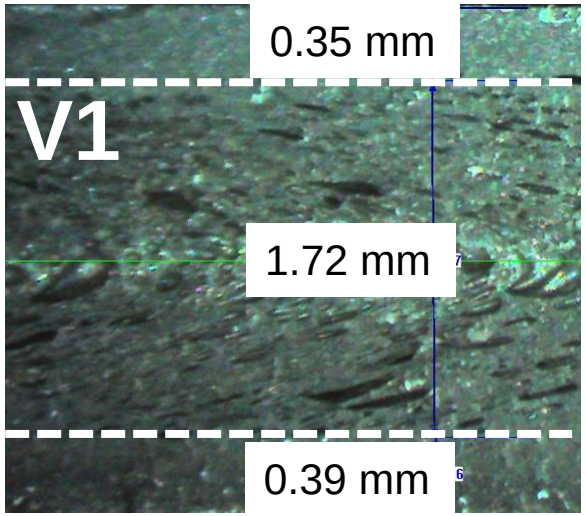
dynamic puncture test



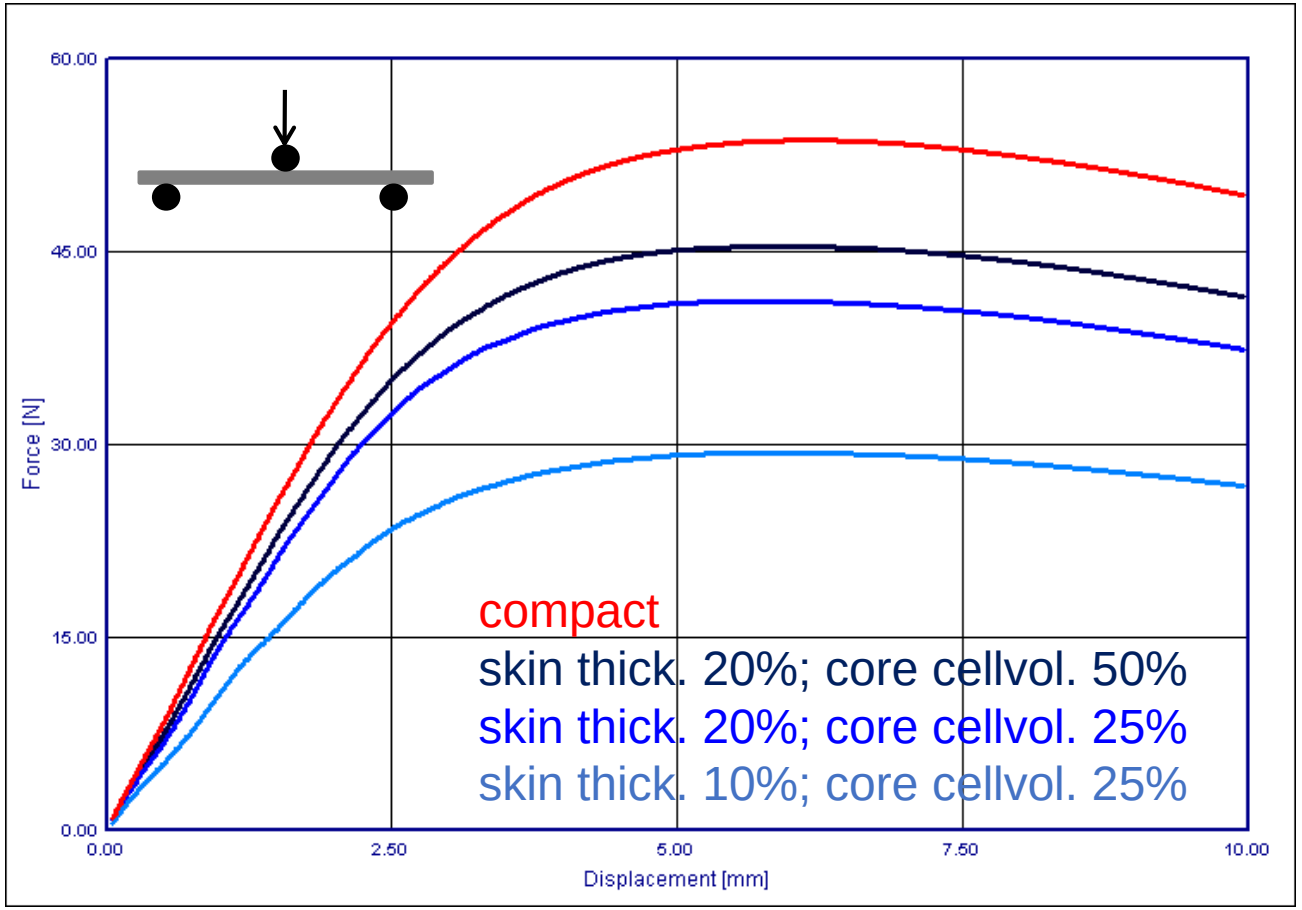
USE CASE - structural foaming

VALIMAT

- correlation simulation
  - virtual material modeling
  - structural prediction
    - **variation skin thickness**
    - **variation of cell volume**



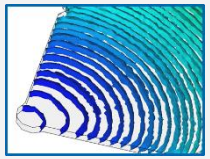
SIMULATION with SKIN-CORE-SKIN

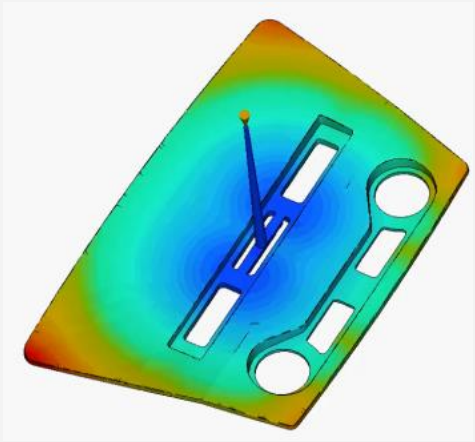


Outlook

process simulation

filling



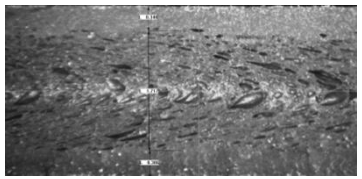


foam distribution
cell volume

CADMOULD® 3D-F SIMULATION

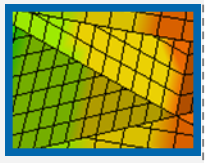
FIBERMAP

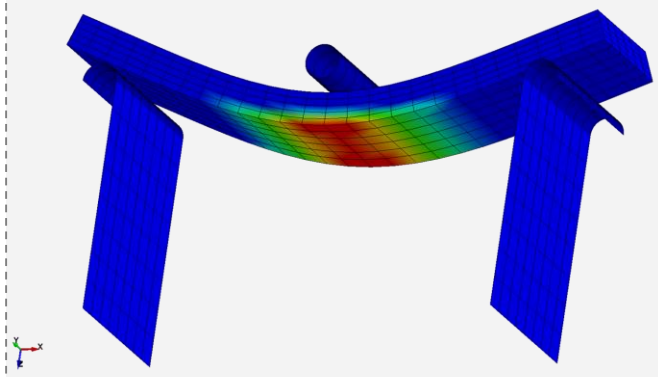
VMAP



structural simulation

coupon level





damaged material

SIMULIA

LSTC Livermore Software Technology Corp. LS-DYNA®

Virtual Performance Solution

Summary

structural foaming

- simple scale rough estimation
- local distribution → local strength and failure strain

challenges for future

- machine ↔ process sim. ↔ virt. material ↔ structural sim.
- material transfer models / material model
- simplification

→ **defining a new CAE standard** VMAP

Thank you
for your attention

ITEA3: Defining Standards for Material Data Transfer in Manufacturing Virtual Simulation