# VMAP - *Virtual Material Modelling in Manufacturing*

# use cases injection moulding

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**16. 4a Technologietag – Leichtbau & Composites,**
**Schladming 26-27.2.2019**


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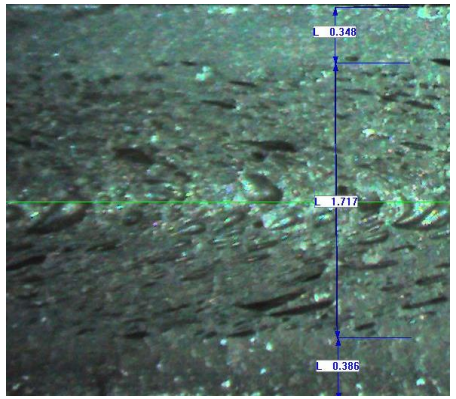
# Outline

- Motivation
- Simulation process chain
- VMAP
- Structural foaming
  - CELL MOULD® introduction
  - USE CASE - physical foaming
- Outlook & Summary





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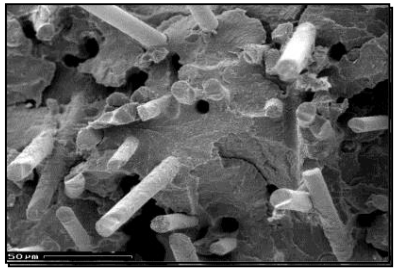
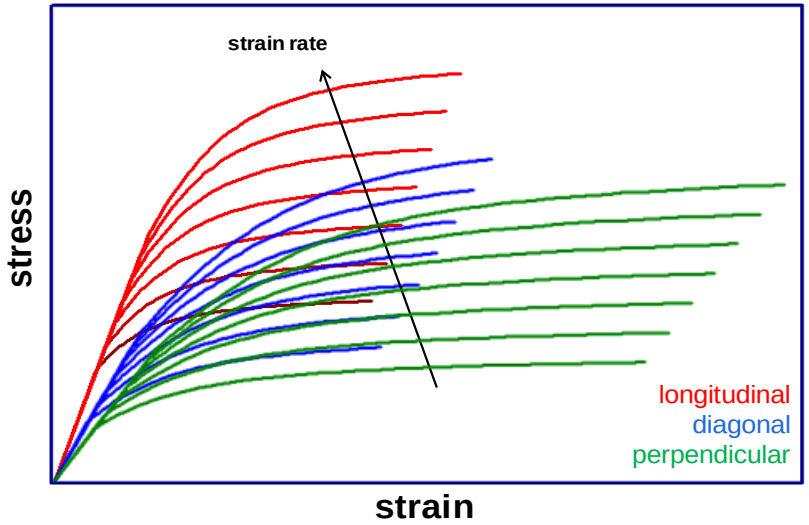
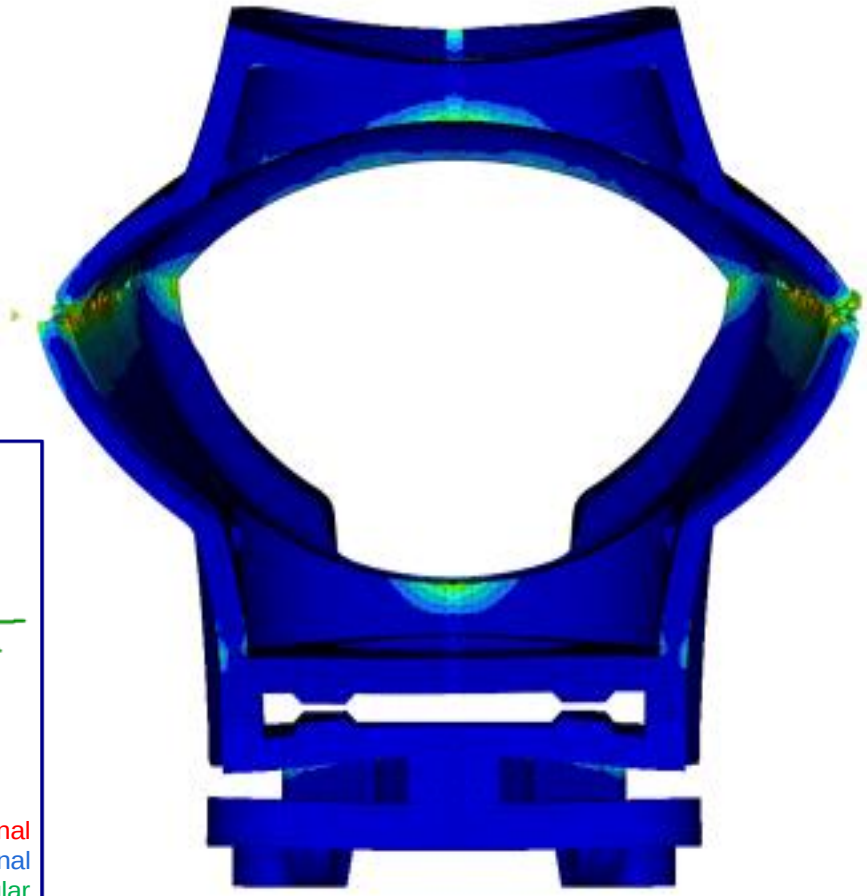
# Motivation – current standard



***MAT_024**



**See more:**

***S. Seichter et al (Hirtenberger) –*** Influence Parameters on the Behaviour of Short Fibre Reinforced Polyamide with Focus on Humidity and Integrative Simulation. German LS DYNA Forum 2018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# 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/


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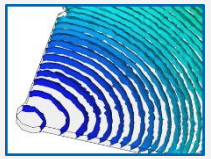
# Simulation process chain – Software solutions

Process simulation

Injection molding



CADMOULD 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

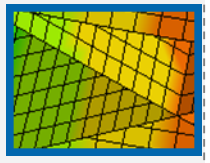
SOLIDWORKS PLASTICS

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



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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


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# 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

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

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

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\\Ac-server\ac-daten\Transfer\Cristoph\4a\MDXProject20150811_Fiber_3\Proc
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IntegrationId
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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



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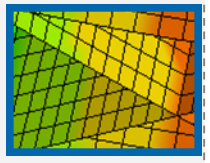
# Structural simulation – considering anisotropy

- 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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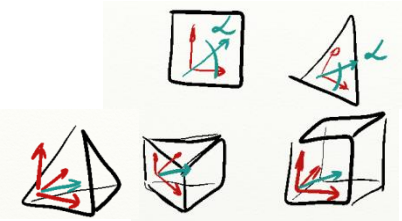
# Structural simulation – considering anisotropy

- *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 & $t_{layer}$ & $\alpha$

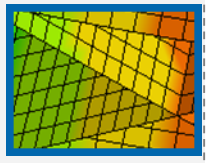
→ vector or $\alpha$

→ vector

→ MID & $t_{layer}$ & $\alpha$

Structural simulation

Stiffness → Crash



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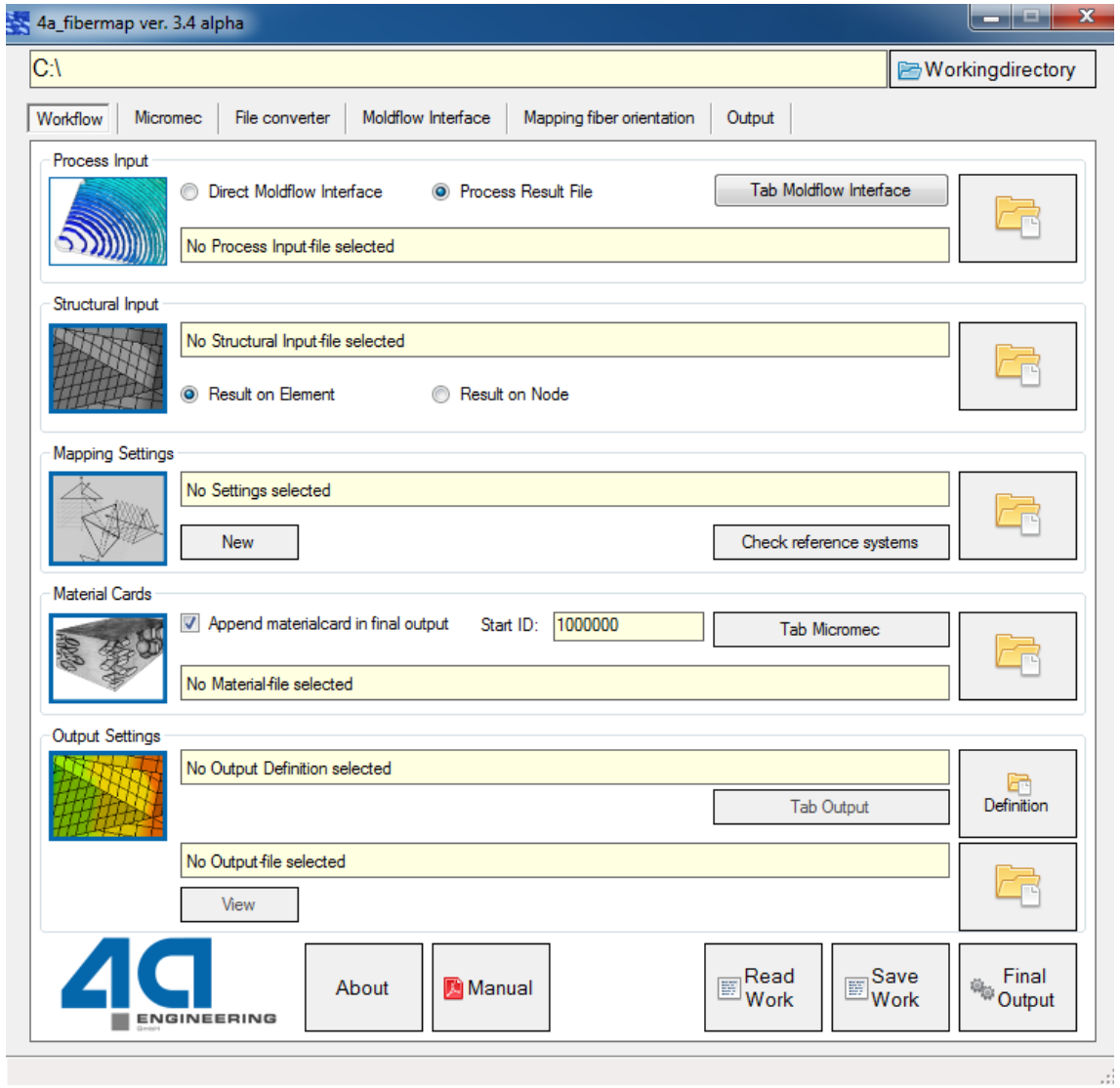
# <<Template>> based mapping workflow

FIBERMAP





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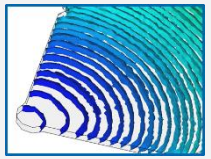
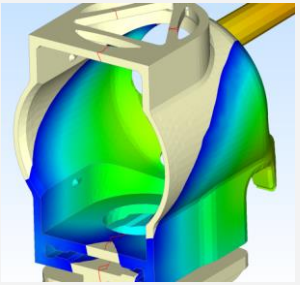
# Use Case – drop test sleeve

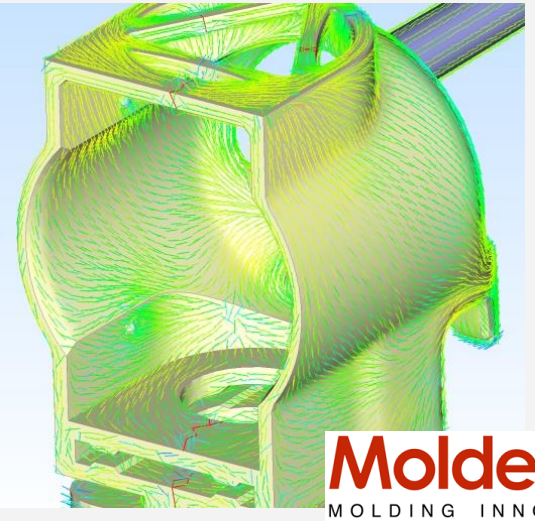
Process simulation

Filling

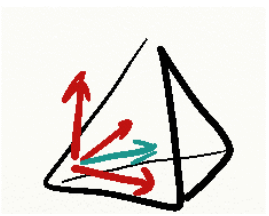




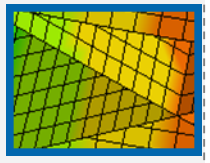
**Fiber orientation**




FIBERMAP



Structural simulation



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**Element orientation**

***ELEMENT_SOLID_ORTHO**


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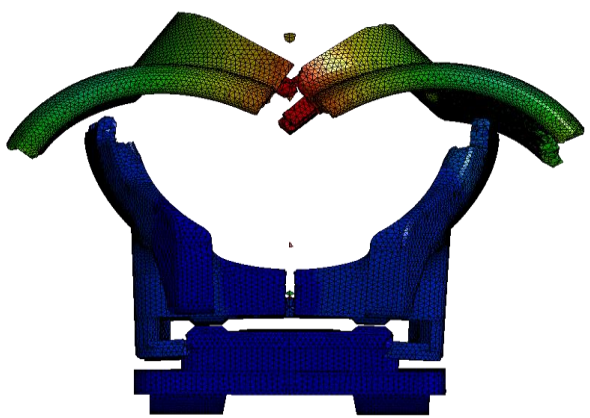
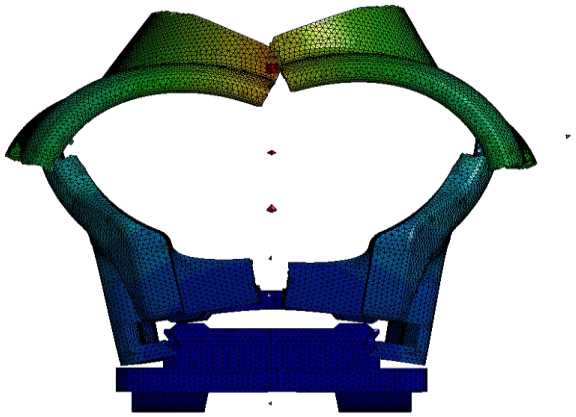
# Use Case – drop test sleeve



*MAT_024
transversal



*MAT_024
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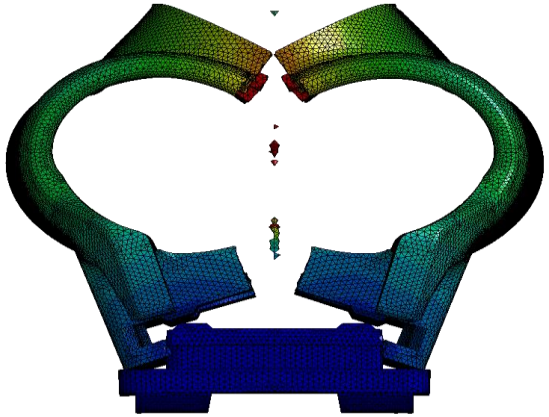
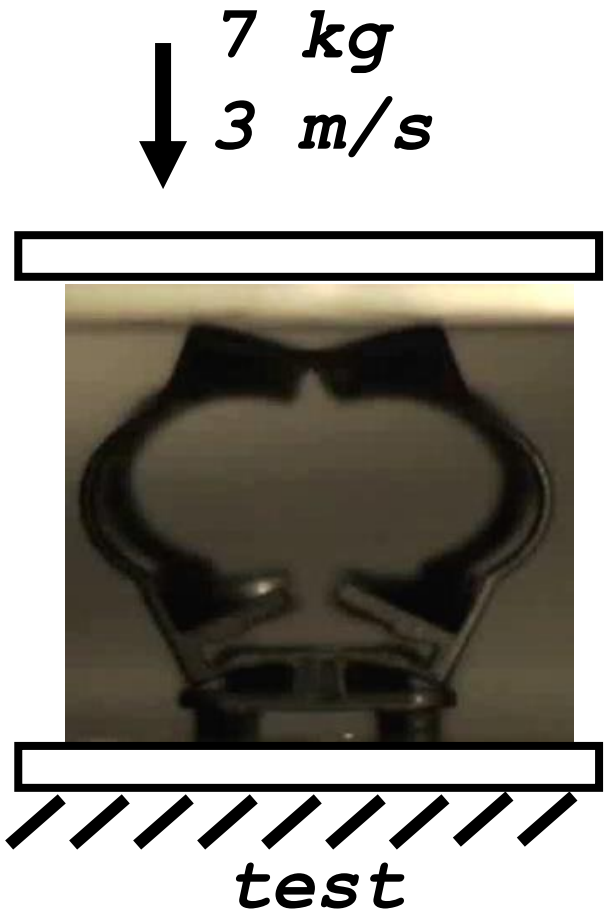


*MAT_157/215
local anisotropy




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


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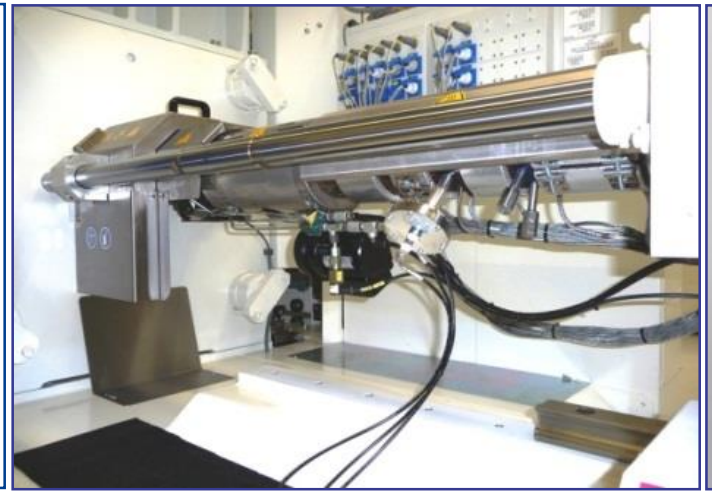
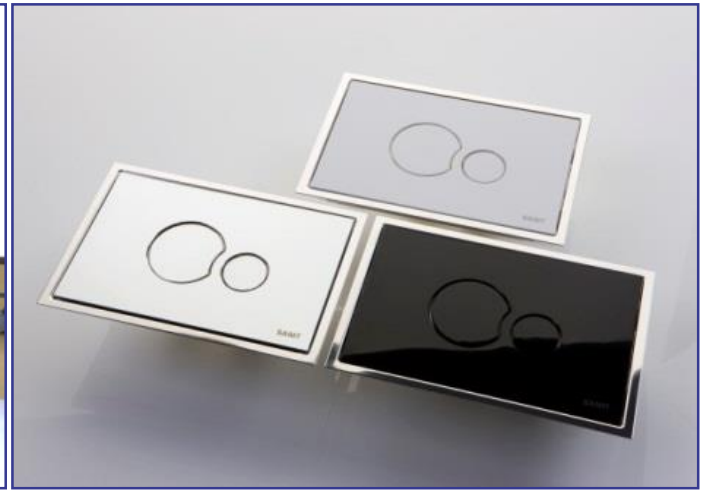
# USE CASE - structural foaming

## CELLMOULD® – Lightweight Technology





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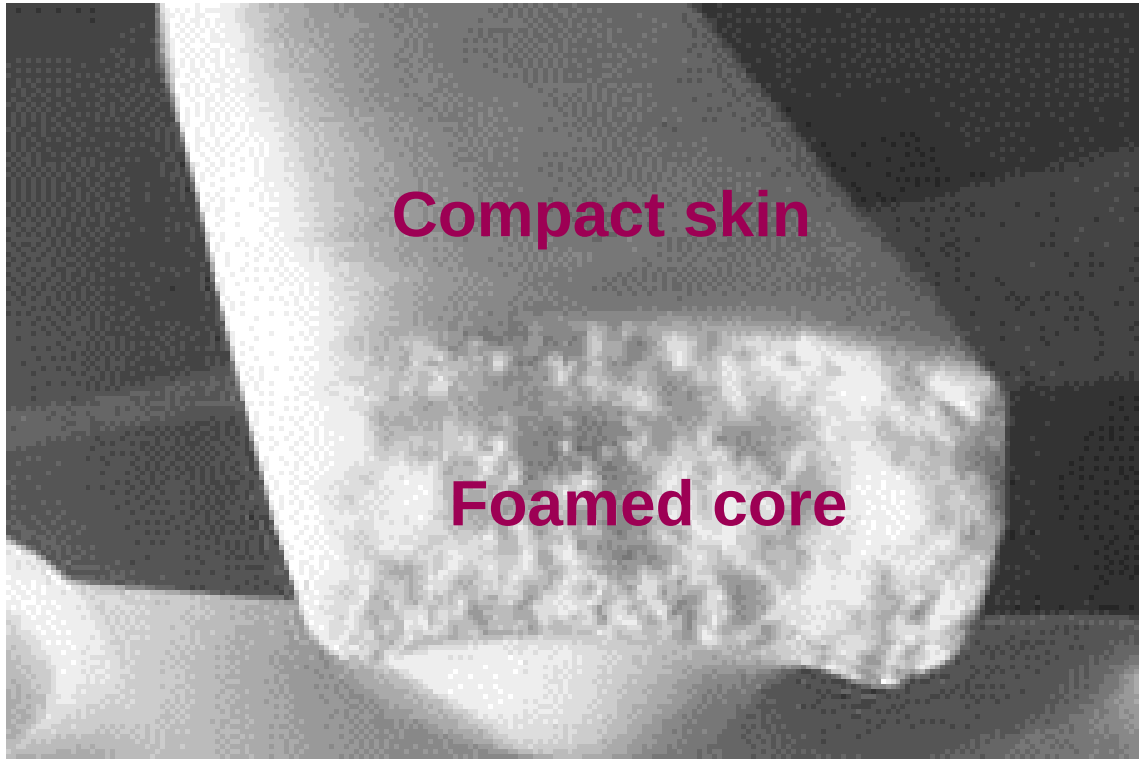


- Chemical Blowing Agents
- Physical Blowing Agents

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

# 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


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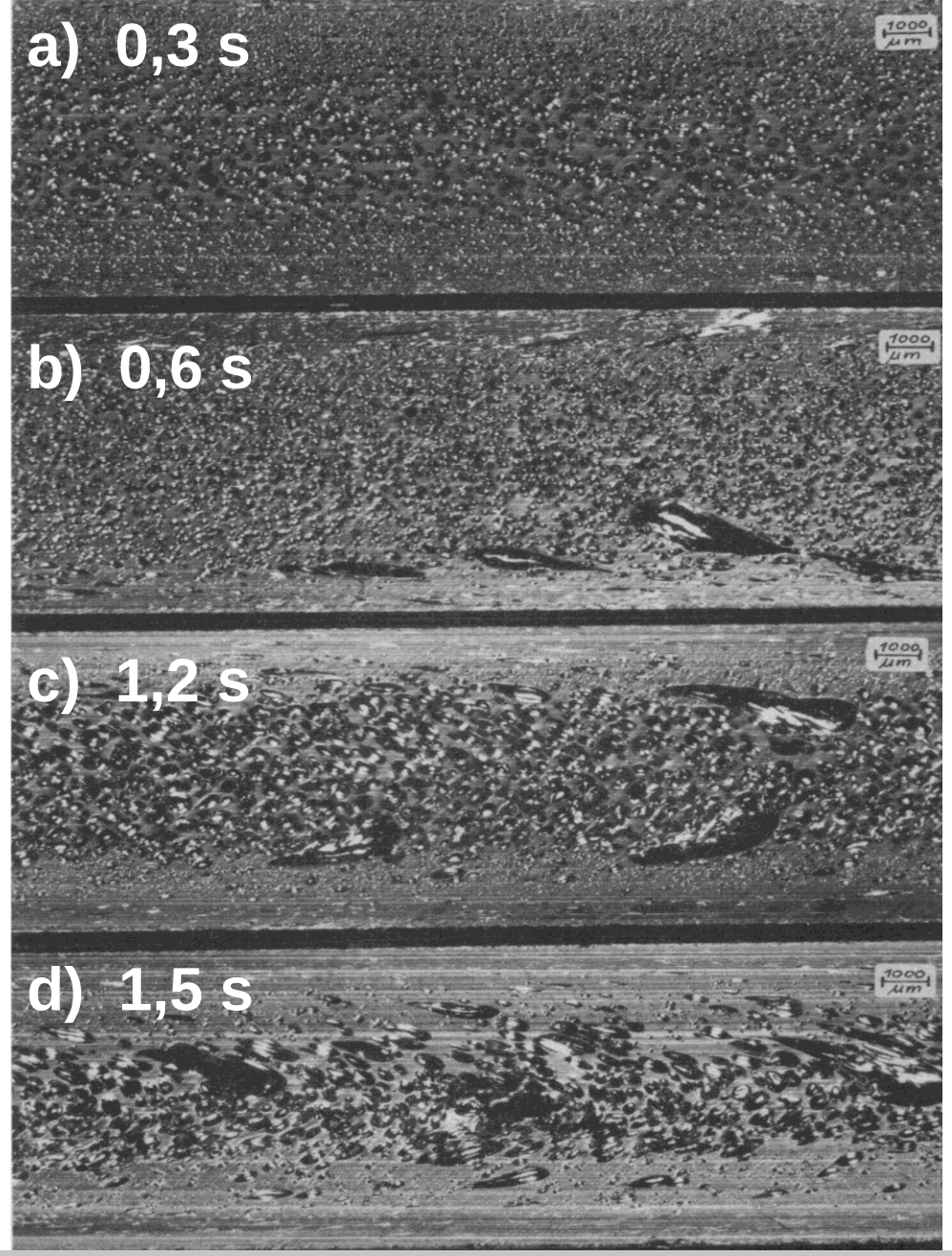
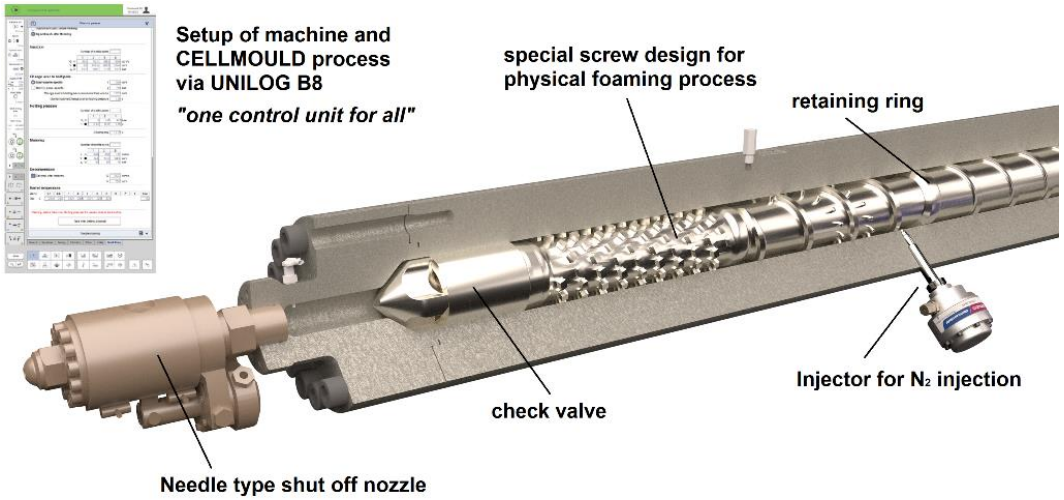





# Influences - physical foaming

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




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

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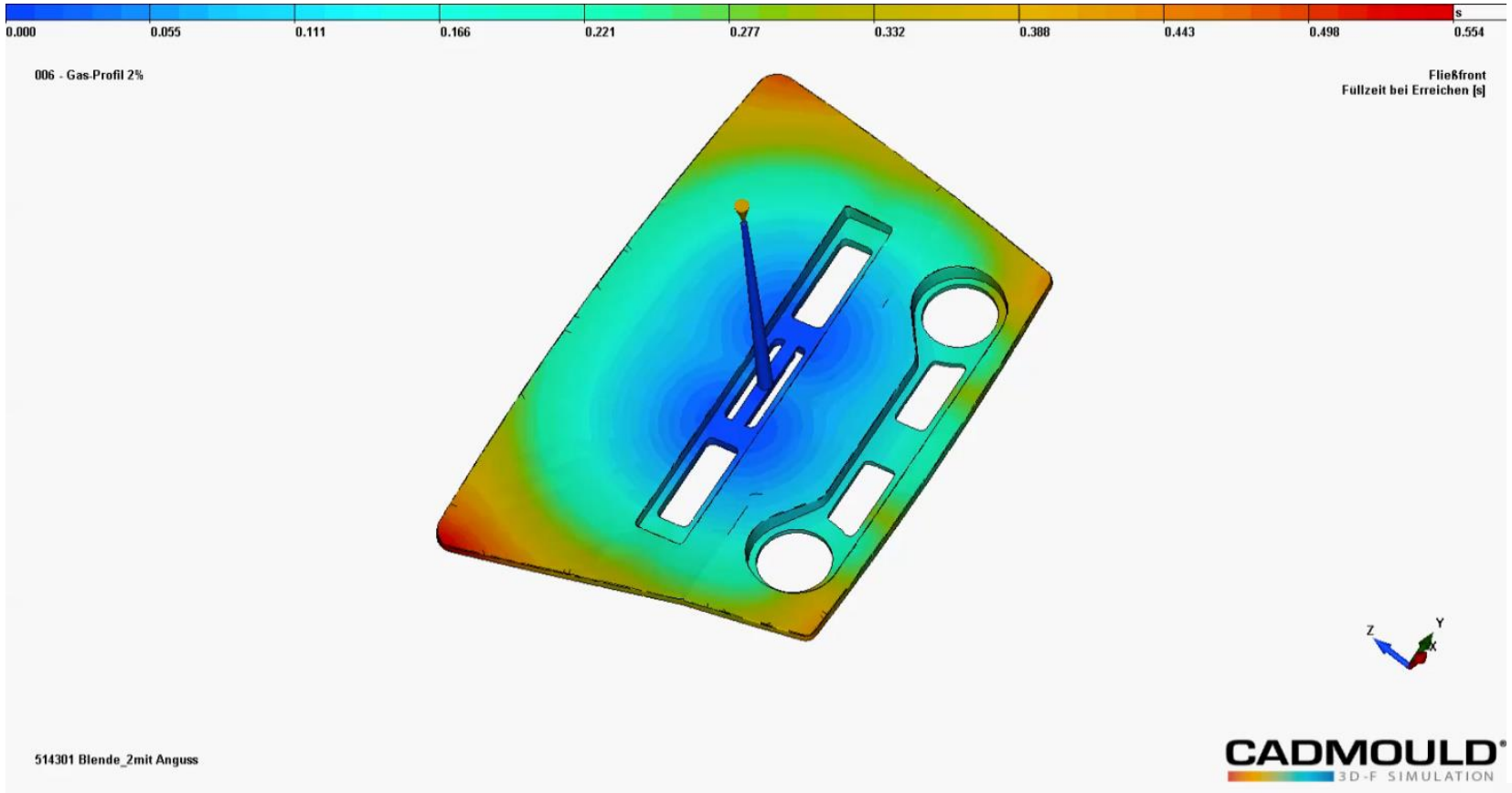
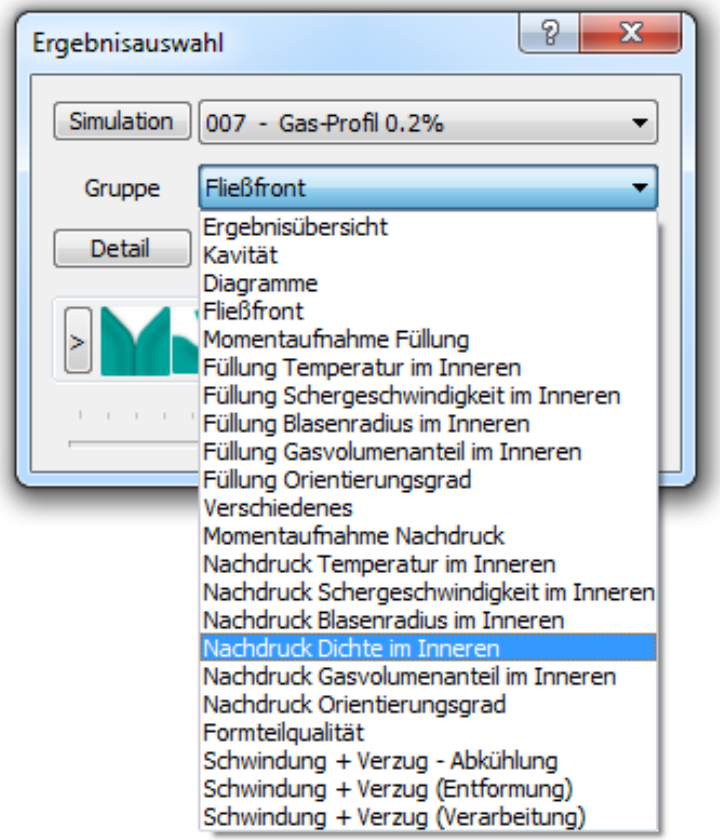
# USE CASE - structural foaming

- rheological simulation of foamed part – work in progress





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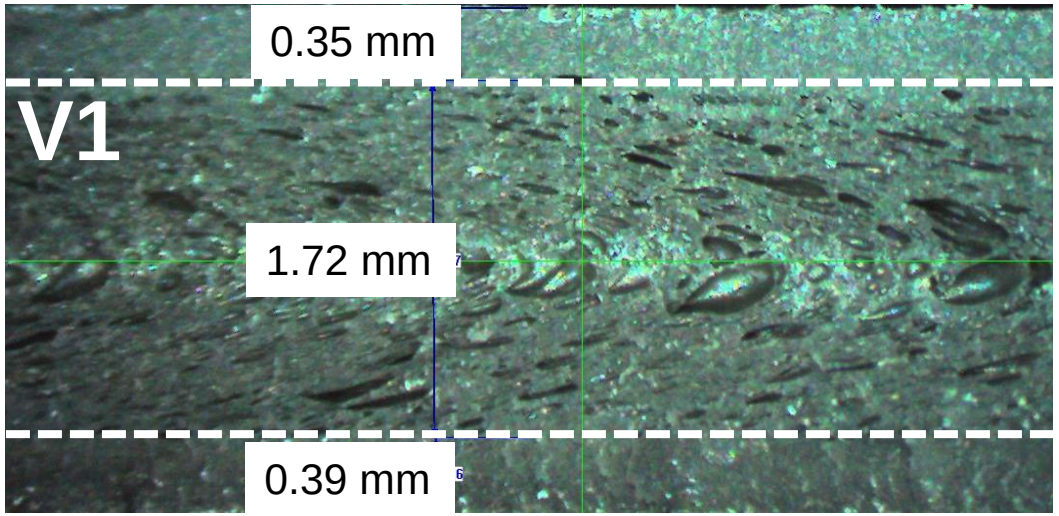
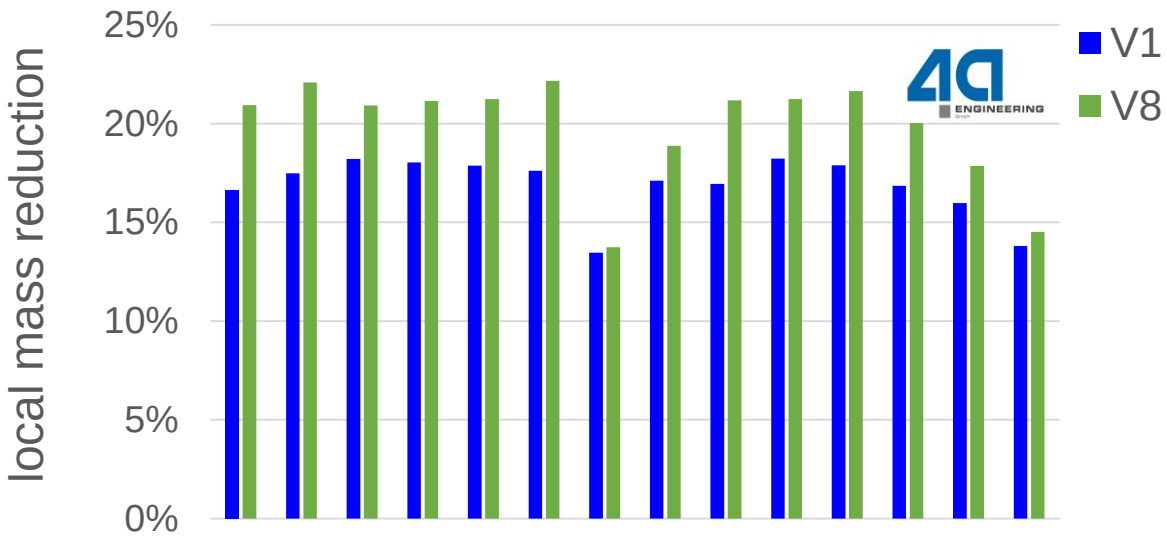
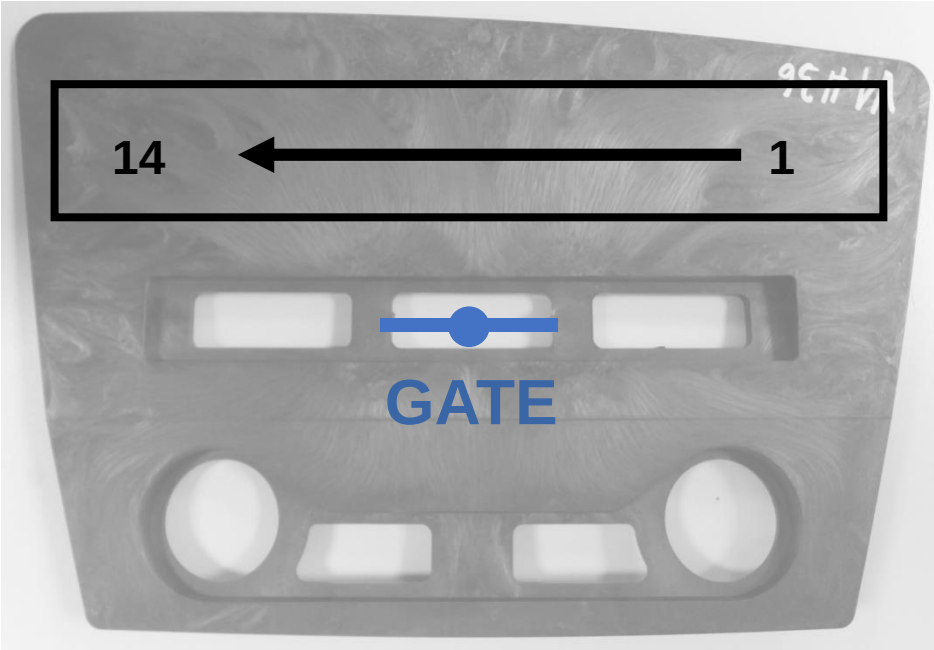
# USE CASE - structural foaming

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





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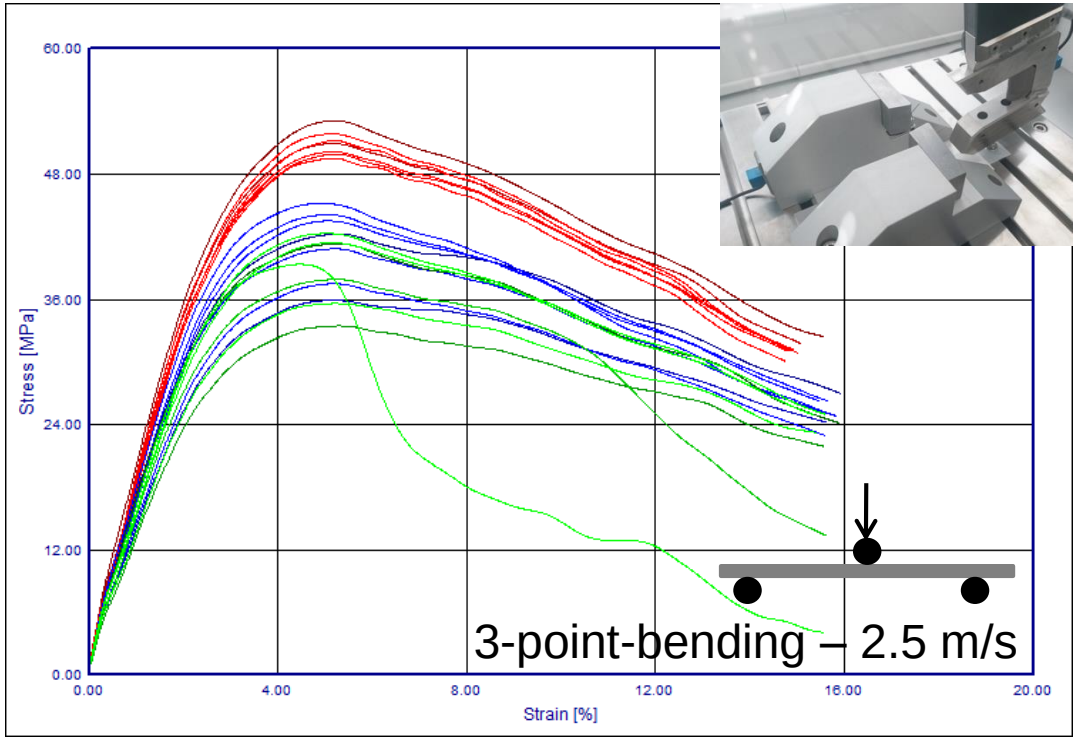
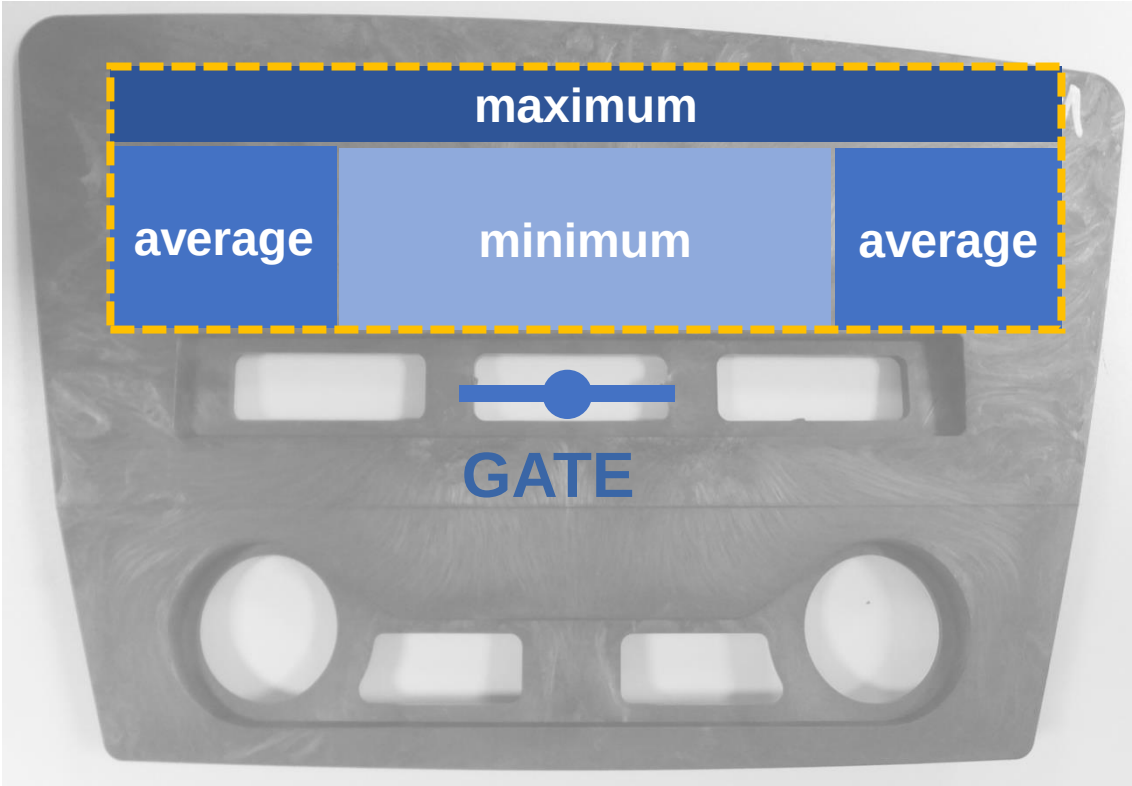
# USE CASE - structural foaming

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




***compact***
***V1: -12% mass***
***V8: -14% mass***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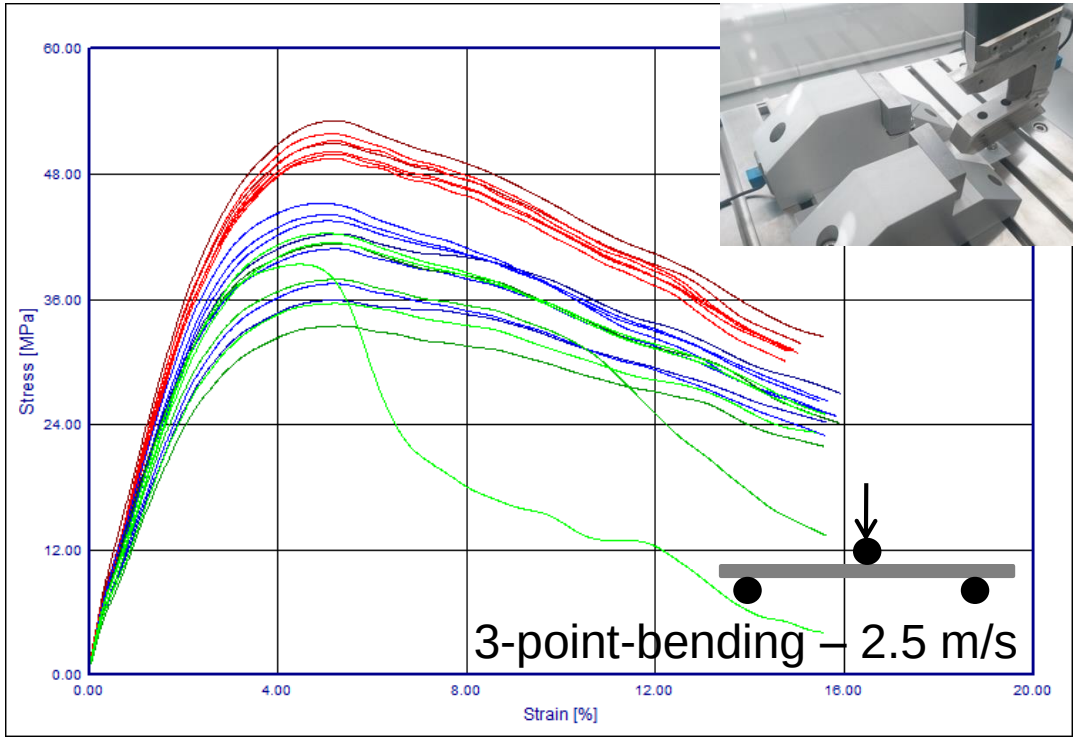
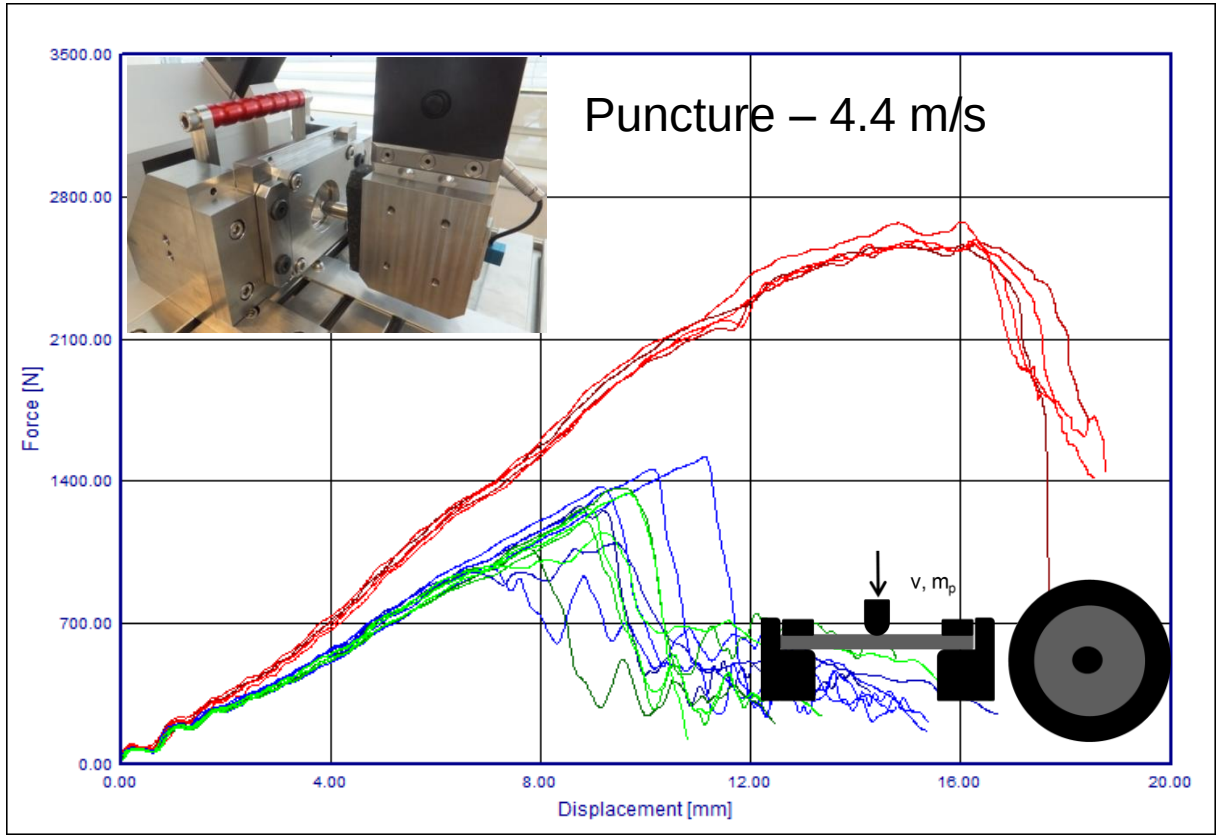
# USE CASE - structural foaming

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




***compact***
***V1: -12% mass***
***V8: -14% mass***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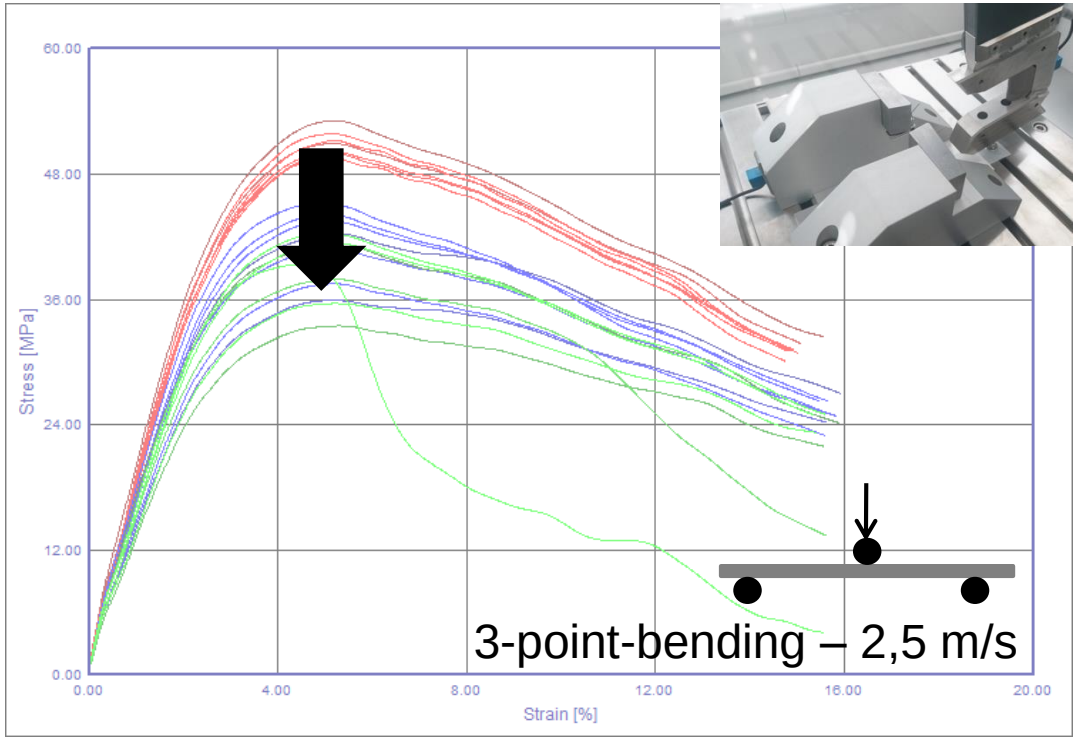
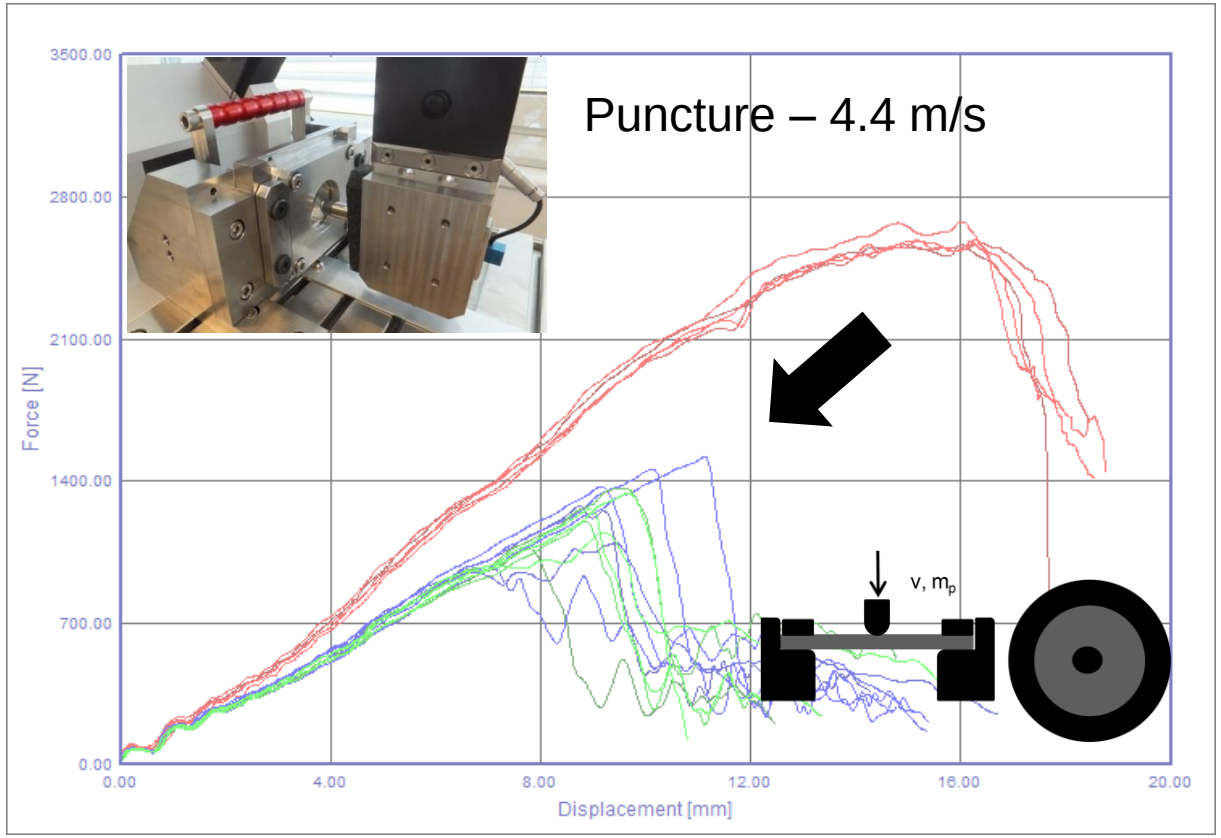
# USE CASE - structural foaming

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




***compact***
***V1: -12% mass***
***V8: -14% mass***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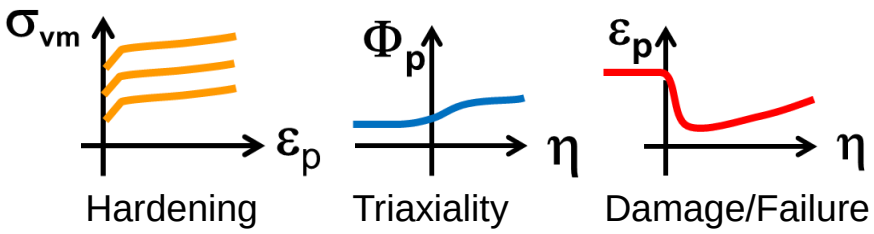
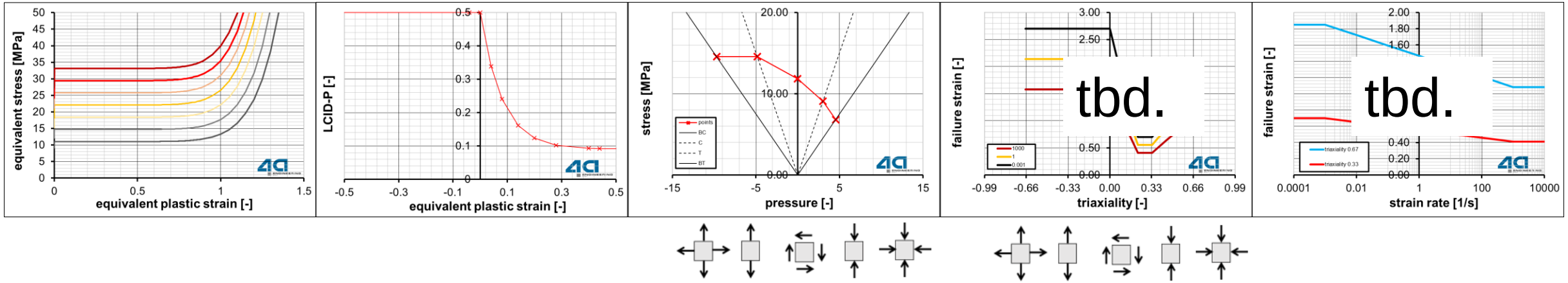
# USE CASE - structural foaming

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





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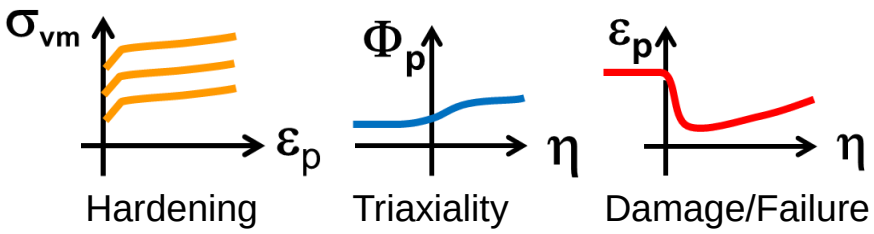
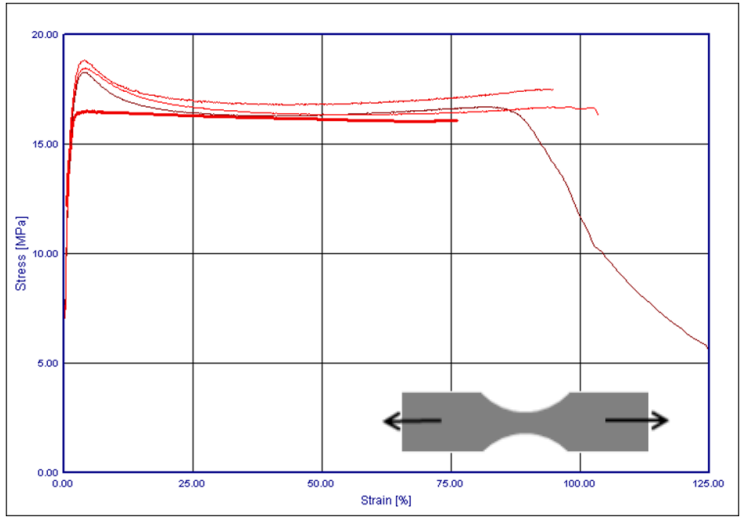
# USE CASE - structural foaming

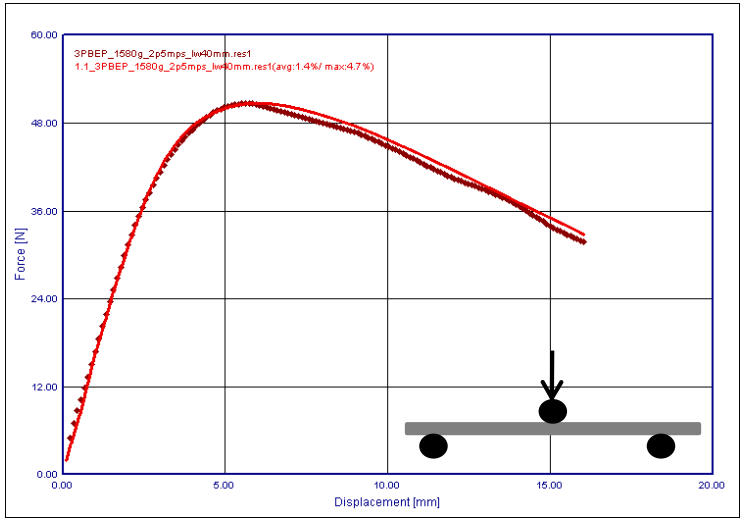
- **virtual material modeling**
  1. compact material – PP T10 determine ***MAT_SAMP-1** by reverse engineering



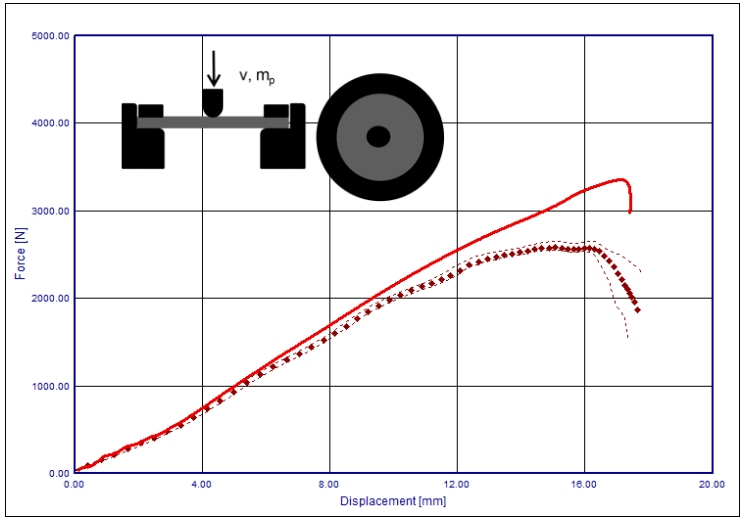

static tensile




dynamic bending




dynamic puncture test





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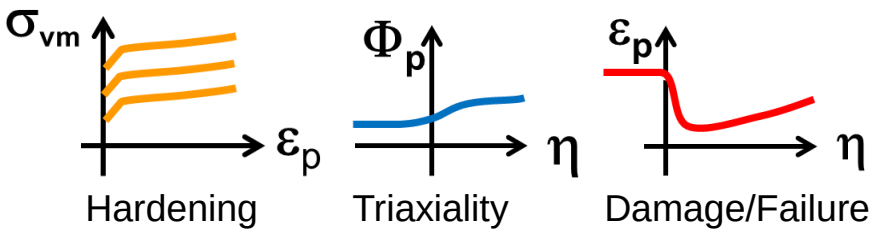
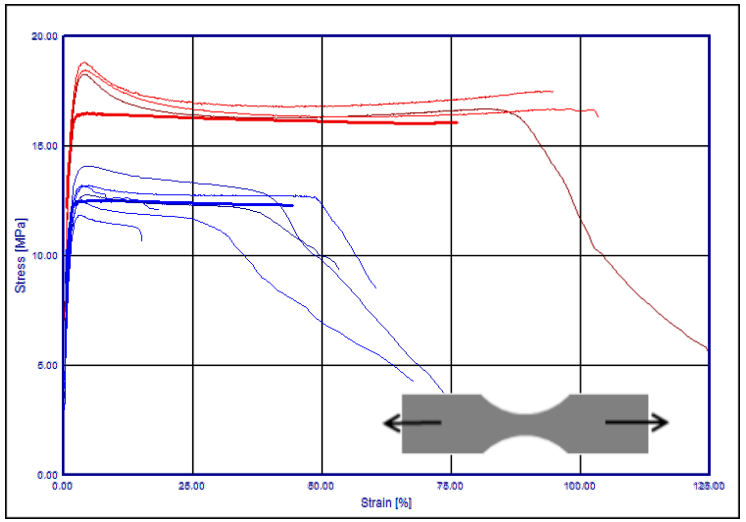
# USE CASE - structural foaming

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

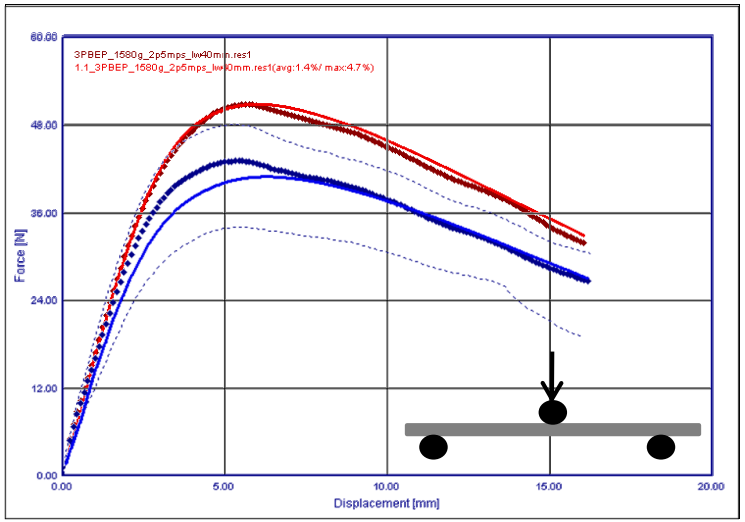



compact
foamed V1

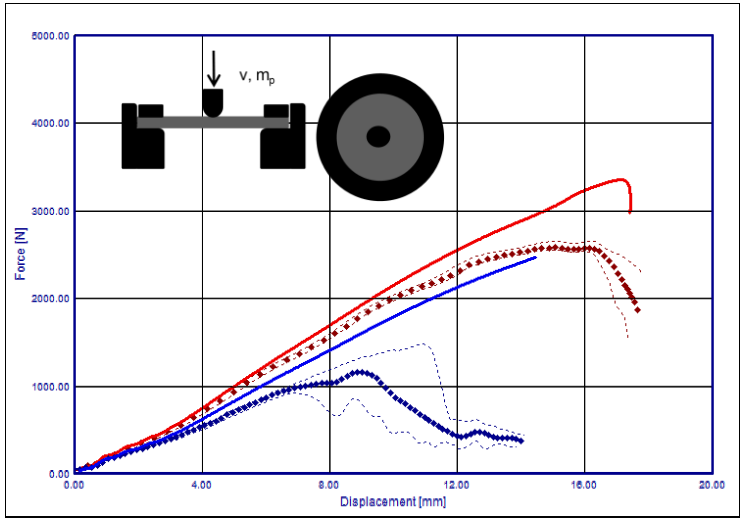
static tensile




dynamic bending




dynamic puncture test





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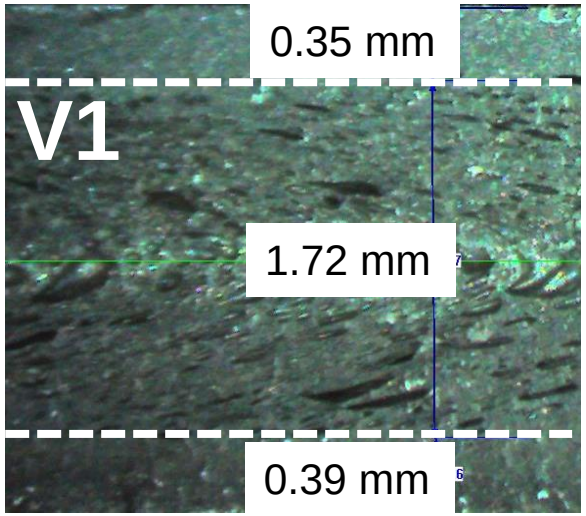
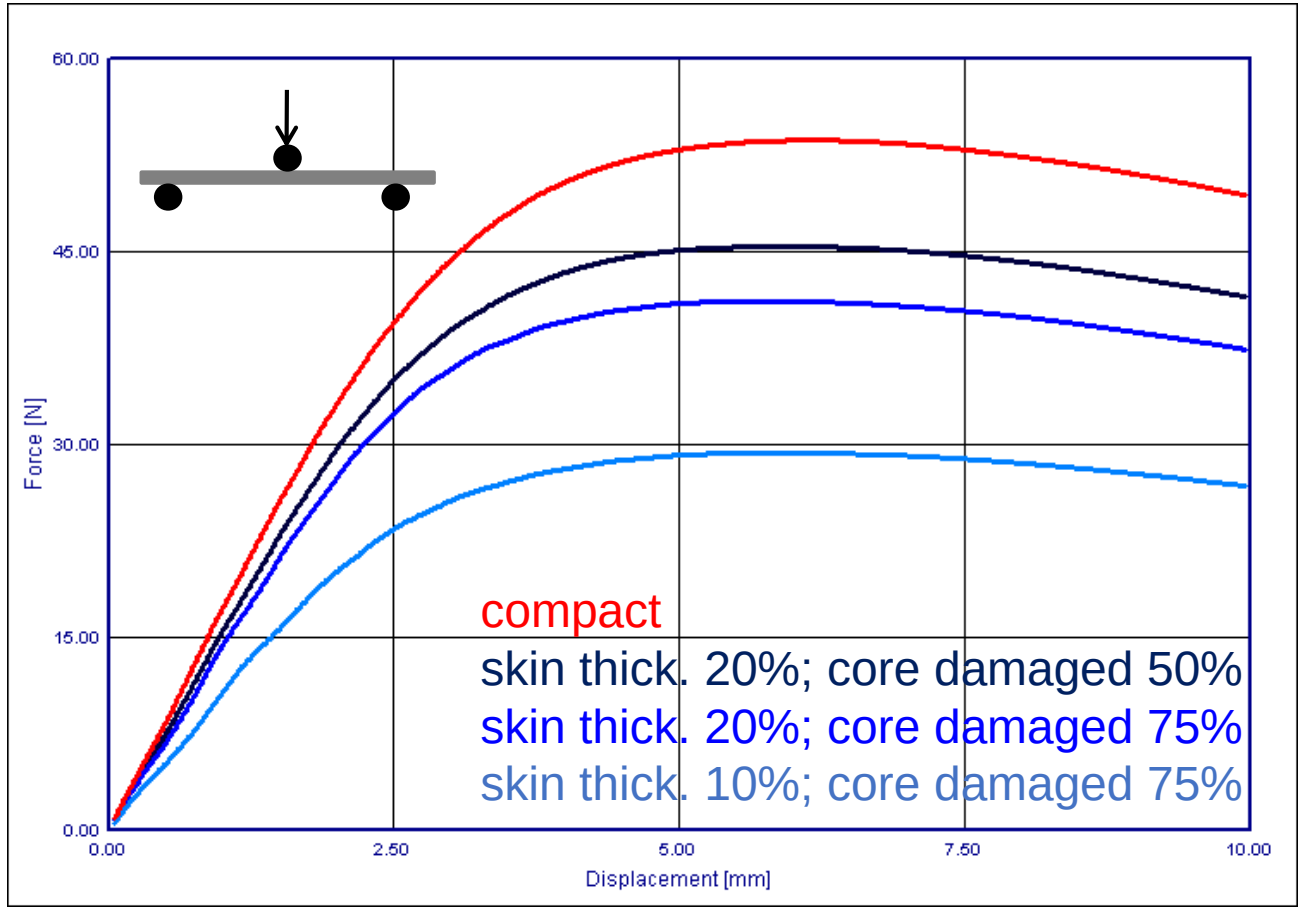
# USE CASE - structural foaming

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




## SIMULATION with SKIN-CORE-SKIN





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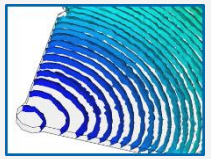
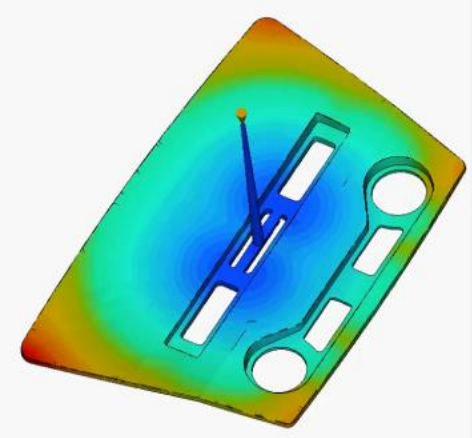
# Outlook

Process simulation

Filling



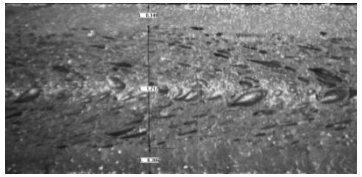


**foam distribution**
**cell volume**

CADMOULD® 3D-F SIMULATION

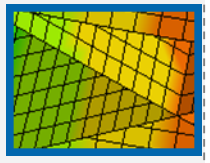
FIBERMAP

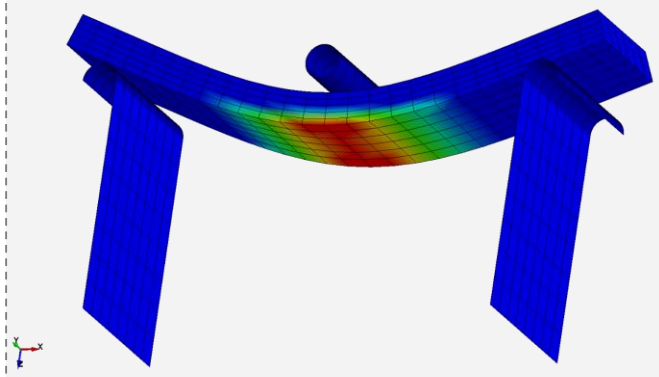
VMAP



Structural simulation

coupon level





**damaged material**

SIMULIA

LSTC Livermore Software Technology Corp. LS-DYNA®

Virtual Performance Solution



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# 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


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# Thanks
# for your attention

Österreichische
Forschungsförderungsgesellschaft

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


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