



Using rate dependent material properties in a drop simulation of partly liquid filled and sealed plastic containers

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4a Technologietag, Schladming, 28.02.2018 - 01.03.2018

ALPLA

- Introduction of ALPLA and its simulation tasks
- Drop test
 - Experiment: Drop test / QA
 - Simulation
 - Validation of simulation
- Summary

Turnover 2017: **3.4 Billion Euros**

- ⇒ Employees worldwide **19,300** (16,000 @ 4a TT 2016)
- ⇒ Production sites **176** (160 @ 4a TT 2016)
- ⇒ Countries worldwide **45** (41 @ 4a TT 2016)



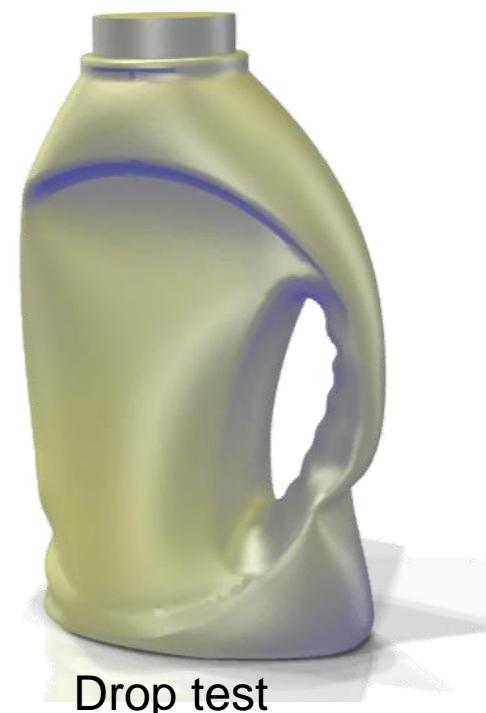
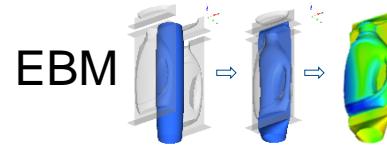
Modelling & Simulation

- Types of simulations

Process simulation

Distributions of:
Thickness, Stiffness, ...

Product simulation



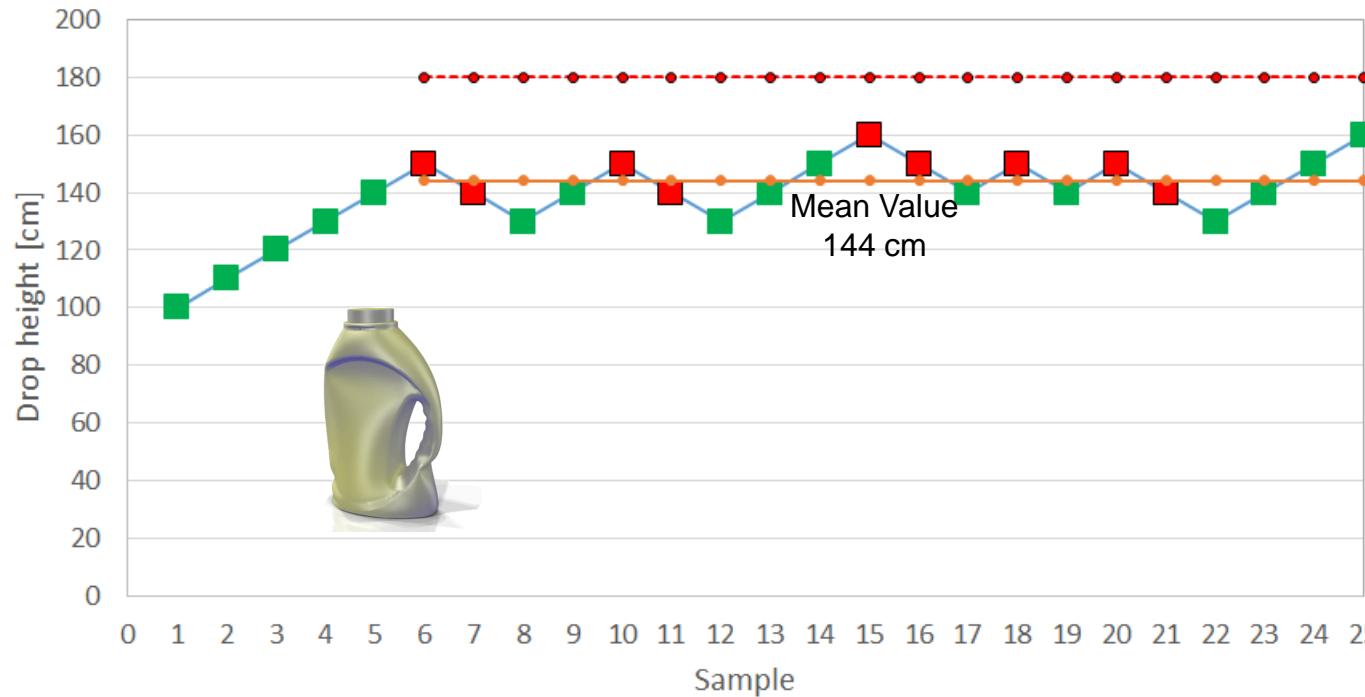
etc...

Drop test

ALPLA

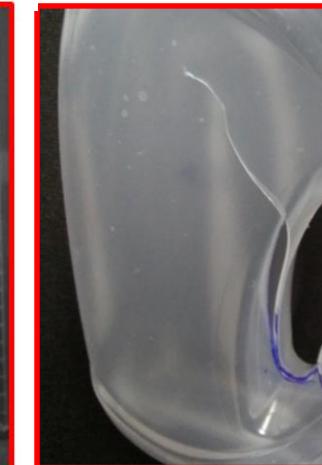
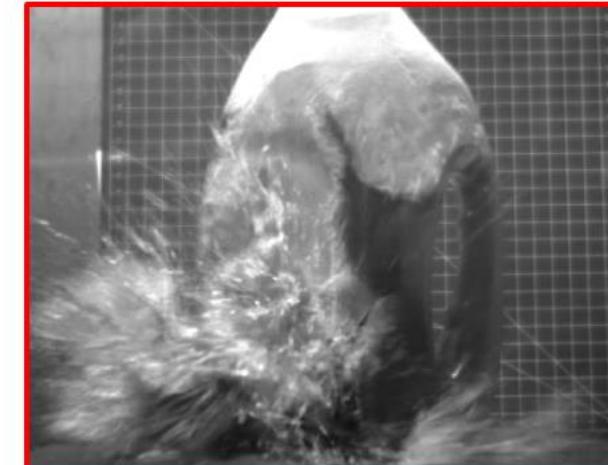
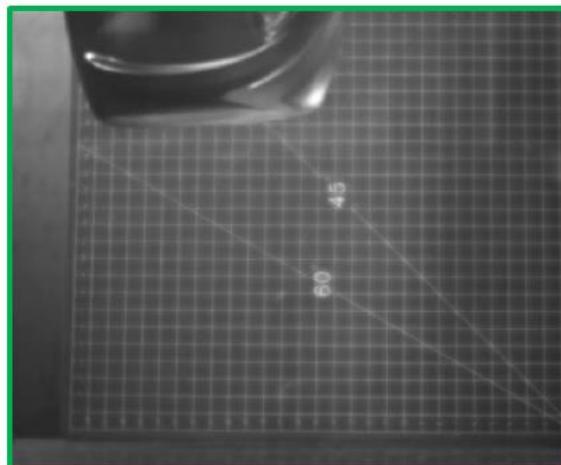
Experiment: Drop test / QA

- Bruceton staircase test



Failure pattern depends on drop height (kinetic energy)

⇒ Rate dependent

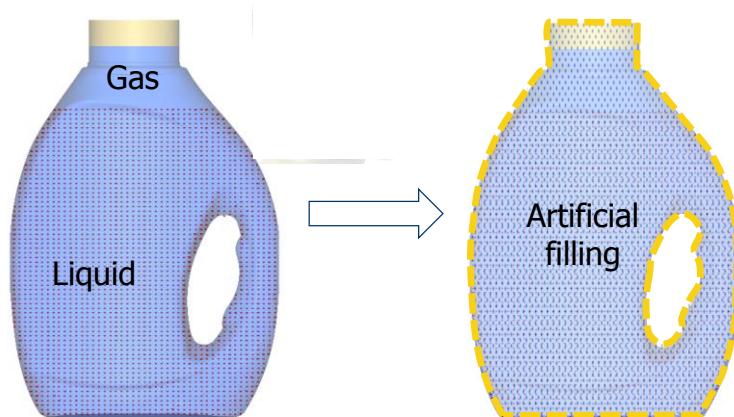


Simulation of drop test

- Compressible head space

— Surface-based fluid cavity:

- DOF 8 = pressure p
- Temperature θ



Hydraulic
fluid

Mixture of ideal gases
(Abaqus/Explicit)

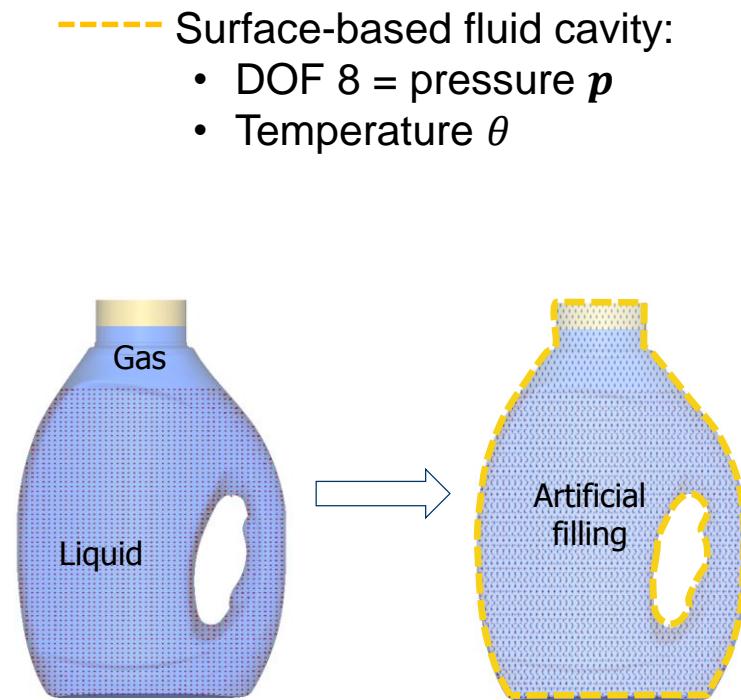
Pneumatic
fluid

User defined constitutive
law (UFLUID)
(Abaqus/Standard)

Drop test

Simulation of drop test

- Compressible head space

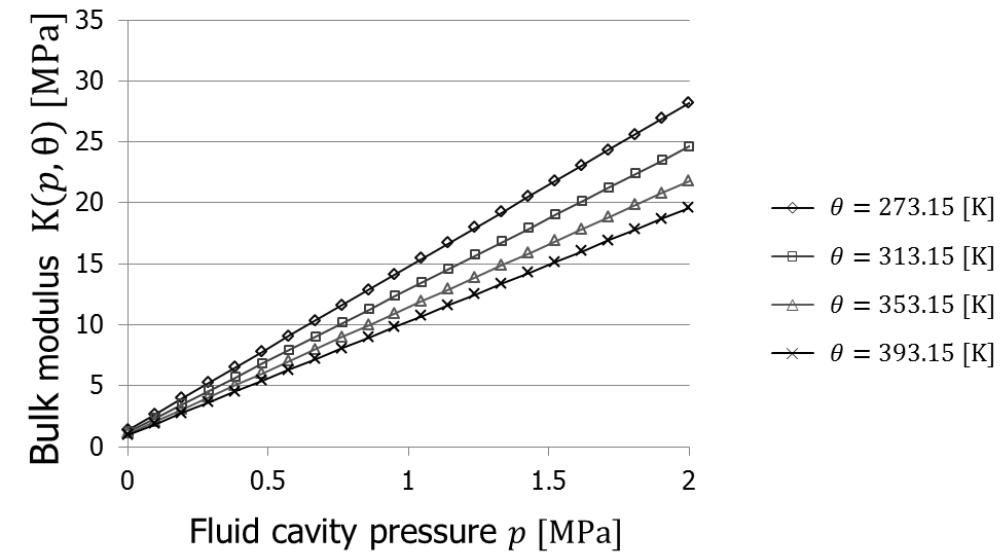


Hydraulic fluid
Bulk modulus $K(p, \theta)$
of artificial filling

$$K(p, \theta) = -p * \left(\frac{V(p = 0, \theta_{ini})}{V(p, \theta) - V(p = 0, \theta)} \right)$$

$$V_{Gas} + V_{Liquid} = V(p, \theta)$$

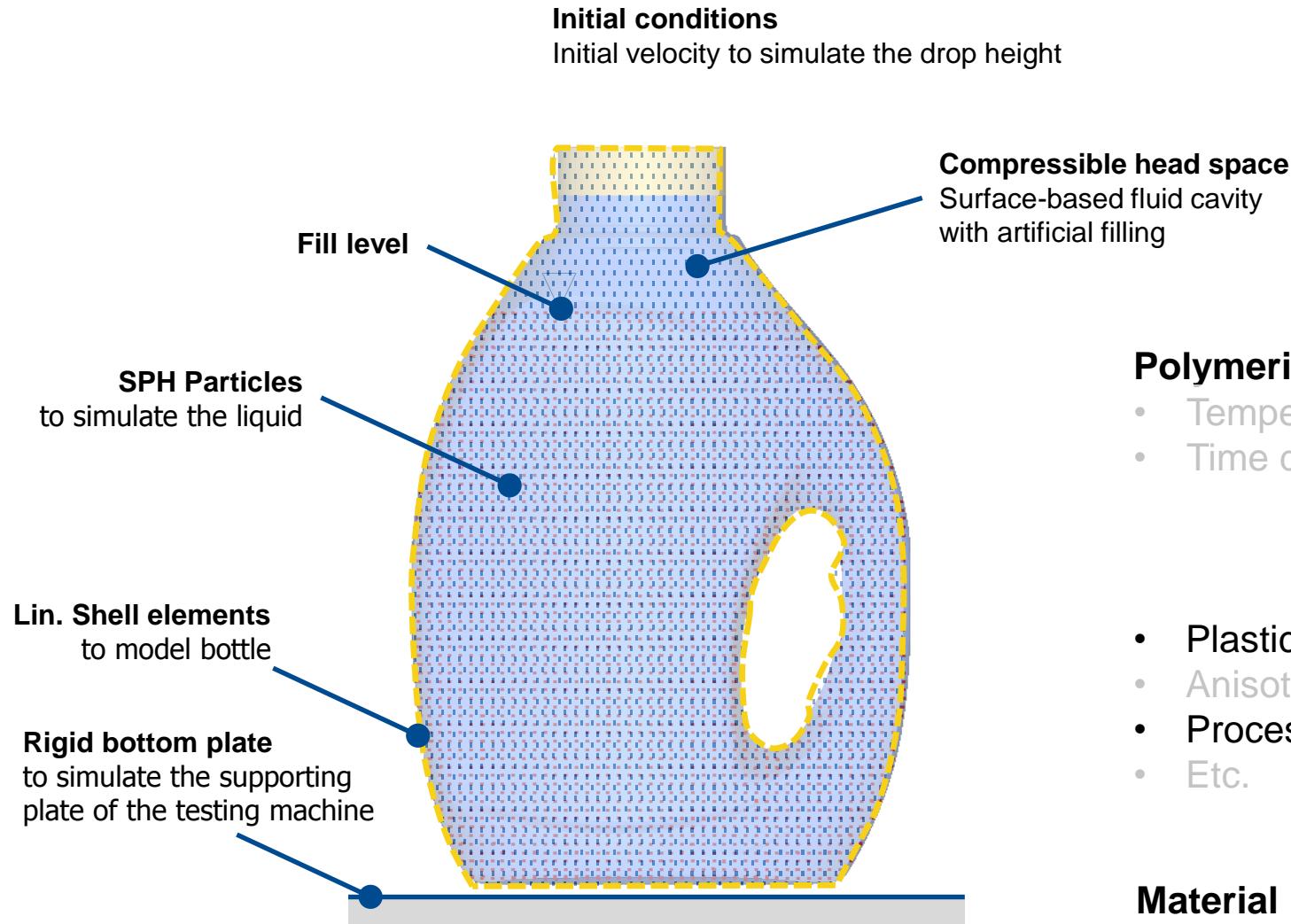
$$V_{Gas} = \frac{(p_{ini} + p_{amb}) * \theta * V_{Gas,ini}}{(p + p_{amb}) * \theta_{ini}} \quad \text{Ideal gas}$$



Drop test

Simulation of drop test

- Simulation procedure



Polymeric materials

- Temperature dependent
- Time dependent
 - ⇒ Creeping, relaxing
 - ⇒ Rate dependent

- Plasticity
- Anisotropy
- Process dependent
- Etc.

Material model

- Piecewise linear elastic plastic
- Rate dependent plasticity
- Hardening
- Damage initiation & evolution

Drop test

Simulation of drop test

- Obtaining material parameters

Material model

- Piecewise linear elastic plastic
- Rate dependent plasticity
- Hardening
- Damage initiation & evolution

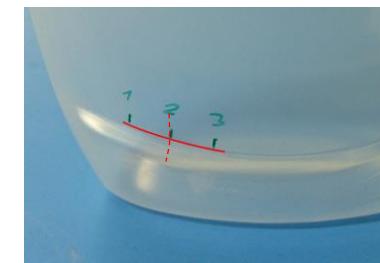
Sample bottles



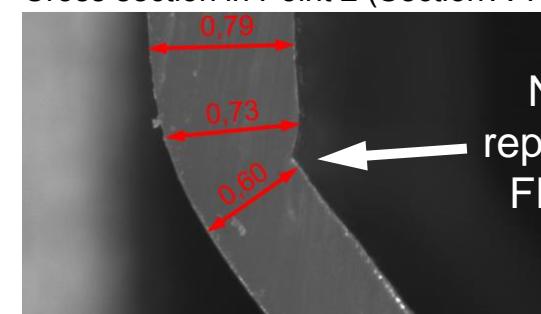
- Homogeneous wall thickness distribution for specimens
- Different process compared to large-scale production

Computer Tomography (CT)
to get best information:

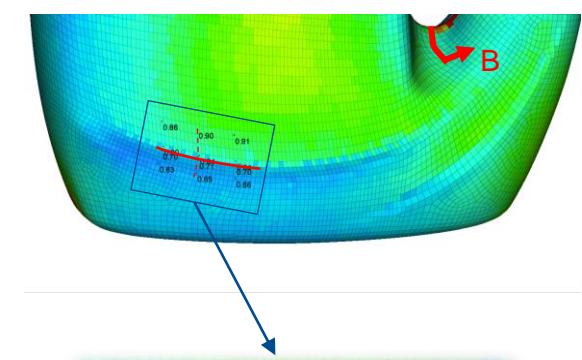
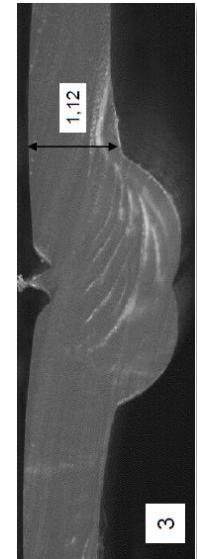
- Wall thickness
- Real bottle shape



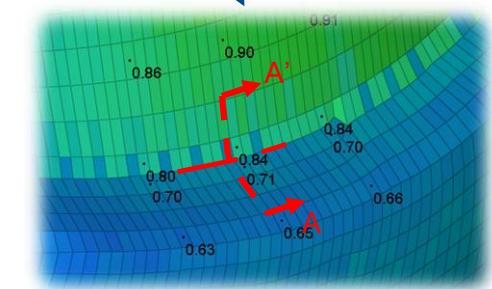
Cross section in Point 2 (Section A'-A)



Notch not represented in FEM-mesh!



Notch not represented in FEM-mesh!



Drop test

Simulation of drop test

- Obtaining material parameters

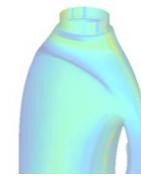
Material model

- Piecewise linear elastic plastic
- Rate dependent plasticity
- Hardening
- Damage initiation & evolution

Computer Tomography (CT)

to get best information:

- Wall thickness
- Real bottle shape



Material characterization tests

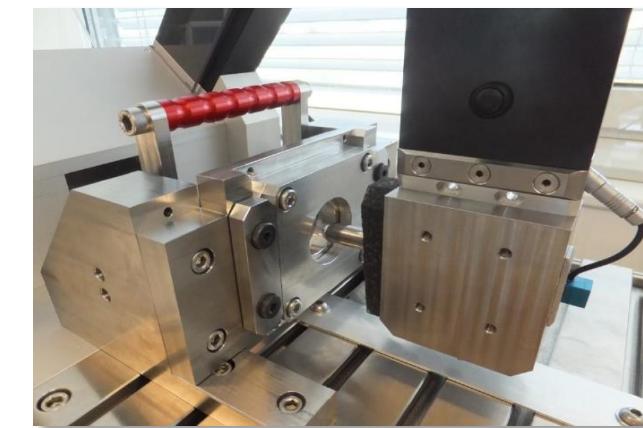
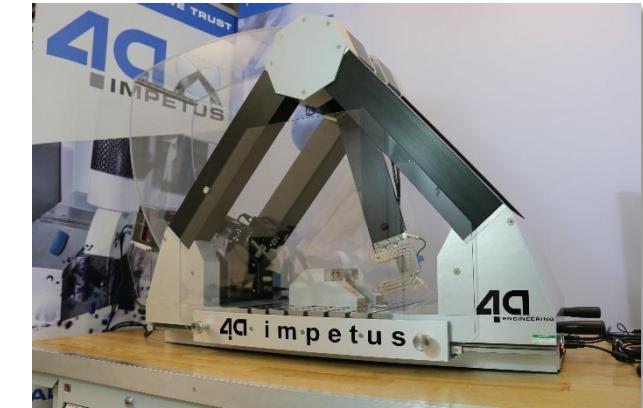
to get material data



- Quasi static 3-point bending
- Quasi static penetration
- Dynamic 3-point bending
- Dynamic 3-point bending + tensile
- Dynamic penetration

⇒ Strain rates tested:
0.0004 – 190 s⁻¹

- Material parameters for material card by reverse engineering approach using 4a impetus



By courtesy of
4a engineering GmbH

Drop test

Simulation of drop test

- Validation

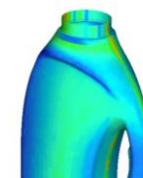
Material model

- Piecewise linear elastic plastic
- Rate dependent plasticity
- Hardening
- Damage initiation & evolution

Computer Tomography (CT)

to get best information:

- Wall thickness
- Real bottle shape

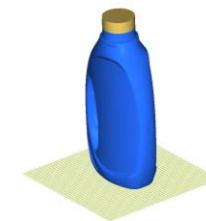


Material characterization tests

to get material data

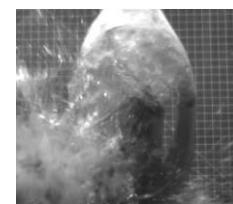


Drop test simulation



Experiment: Drop test

to get real behavior



Validation of simulation

Drop test

ALPLA

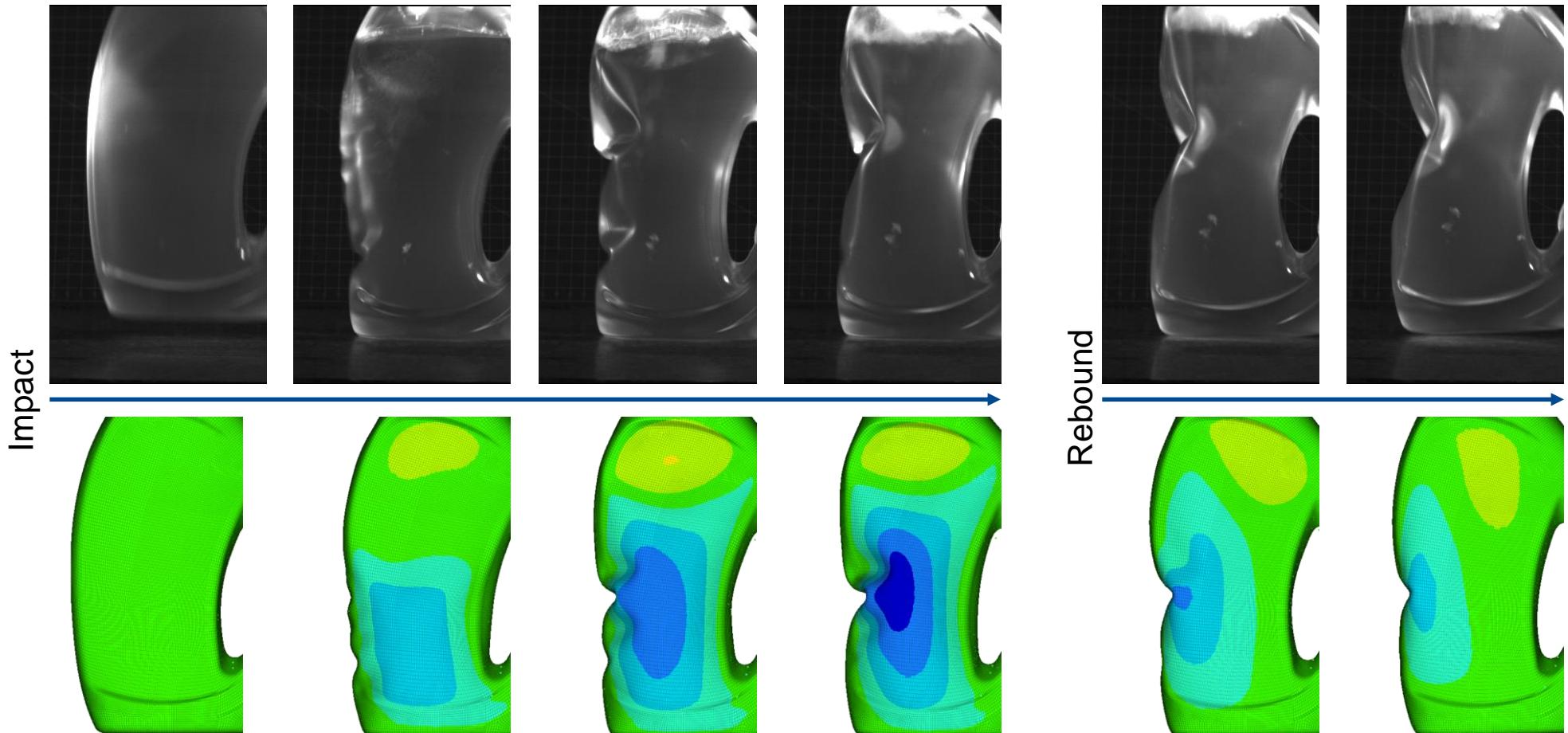
Simulation of drop test

- Validation – Deformation pattern (Drop height = 165 cm)

Material model

- Piecewise linear elastic plastic
- Rate dependent plasticity
- Hardening
- Damage initiation & evolution

Validation of simulation



Drop test

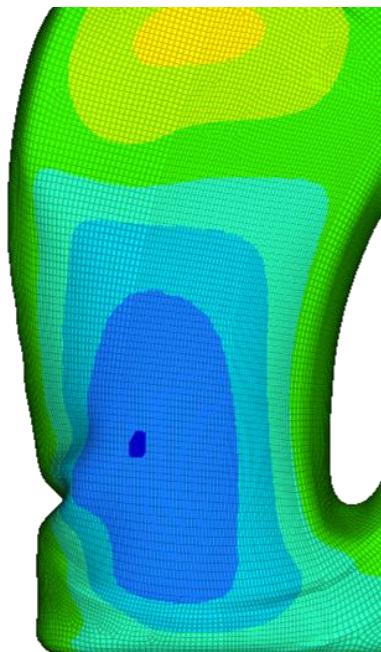
Simulation of drop test

- Validation – Deformation pattern (Drop height = 165 cm)

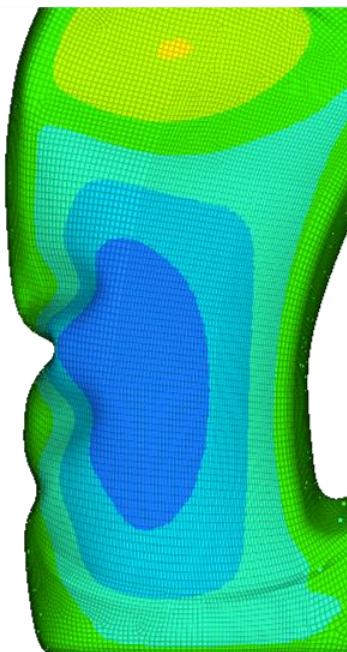
Material model

- Piecewise linear elastic plastic
- Rate dependent plasticity
- Hardening
- Damage initiation & evolution

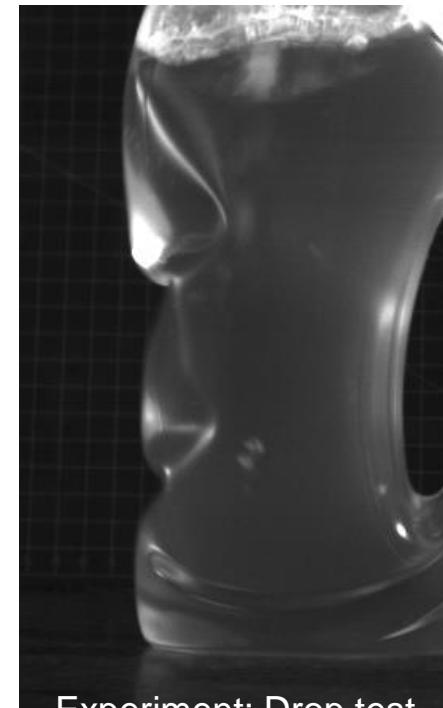
Validation
of
simulation



No
rate dependency
(old)



With
rate dependency
(new)



Experiment: Drop test

Drop test

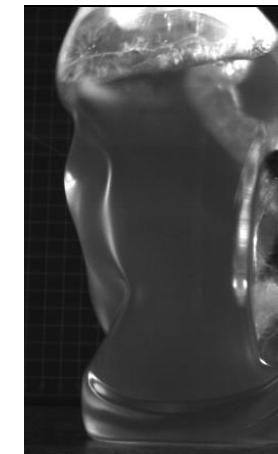
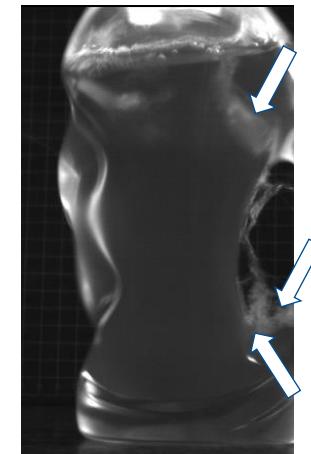
Simulation of drop test

- Validation – Failure pattern – First failure mode

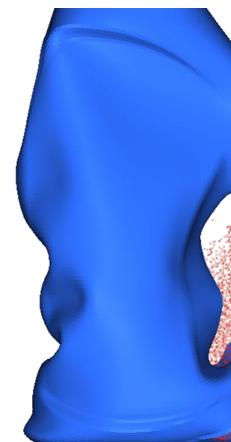
Material model

- Piecewise linear elastic plastic
- Rate dependent plasticity
- Hardening
- Damage initiation & evolution

Real drop test
Drop height = 165 cm



Simulation
Drop height = 620 cm
(first failure height)



Validation of simulation

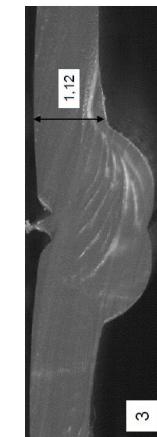
Region of first failure is captured well.



Critical drop height is NOT captured well.



Failure occurs at notches.
Notches are not represented in the FEM-mesh.



Drop test

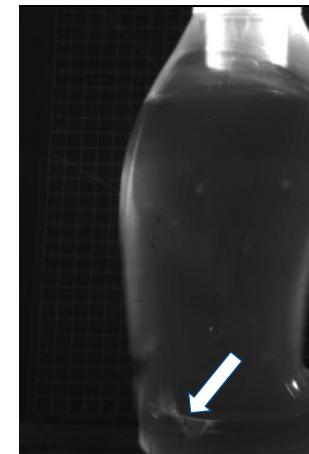
Simulation of drop test

- Validation – Failure pattern – Second failure mode

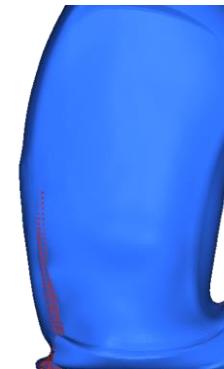
Material model

- Piecewise linear elastic plastic
- Rate dependent plasticity
- Hardening
- Damage initiation & evolution

Real drop test
Drop height = 180 cm



Simulation
Drop height = 999 cm
(second failure height)



Validation of simulation

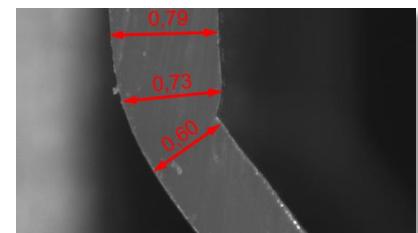
Region of second failure is captured almost well.



Critical drop height is NOT captured well.



Failure occurs at notches.
Notches are not represented in the FEM-mesh.



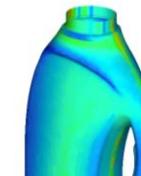
Summary

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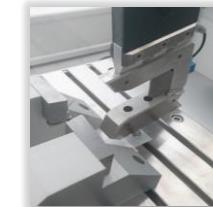
- Sampling bottles for material tests



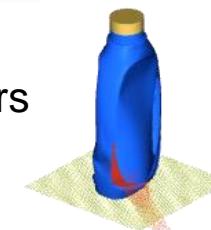
- Wall thickness and shape out of CT



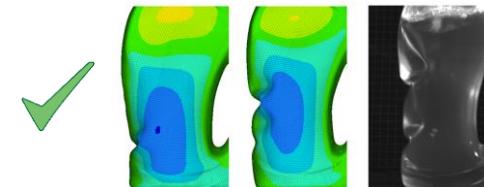
- Material characterization tests @ low and high strain rates



- Drop test simulation with gained thickness, shape and material parameters



- Validation simulation by comparing with experimental drop test



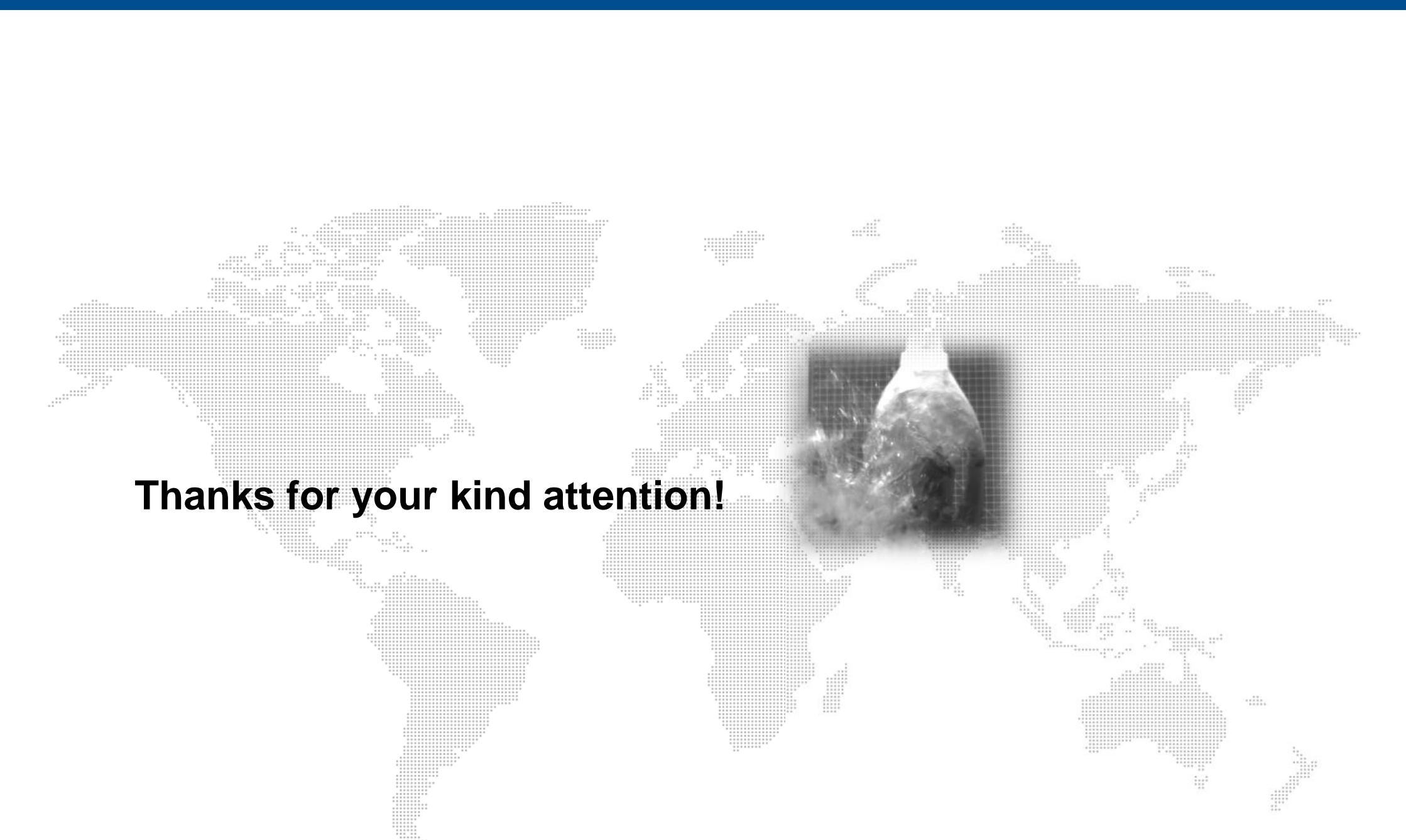
- Deformation captured well



- Rate dependent failure captured well



- Critical drop height not captured well



Thanks for your kind attention!

ALPLA