May 23rd-24th, 2011

LS-DYNA®*

8th European Users Conference

Optimizing Thermoplastic Parts in Crash Applications - Status and Vision

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OPEL

Wir leben Autos.

■•BASF

The Chemical Company

Content

- Motivation

- Material modelling of Short fibre reinforced thermoplastics for Crash

- ULTRASIM™ examples and applications at OPEL

- Modelling Energy absorbing structures out of glass-filled thermoplastic materials

- Vision → Integrative Approach

- Summary

Motivation
Application of Polymers

- More and more structural components are made of polymers
  (e.g. short fiber reinforced polymers)

- These materials show significant anisotropy due to fiber
  orientation caused by injection molding

- In order to predict component behavior, kinematics and
  structural response with required accuracy,
  anisotropy must be captured
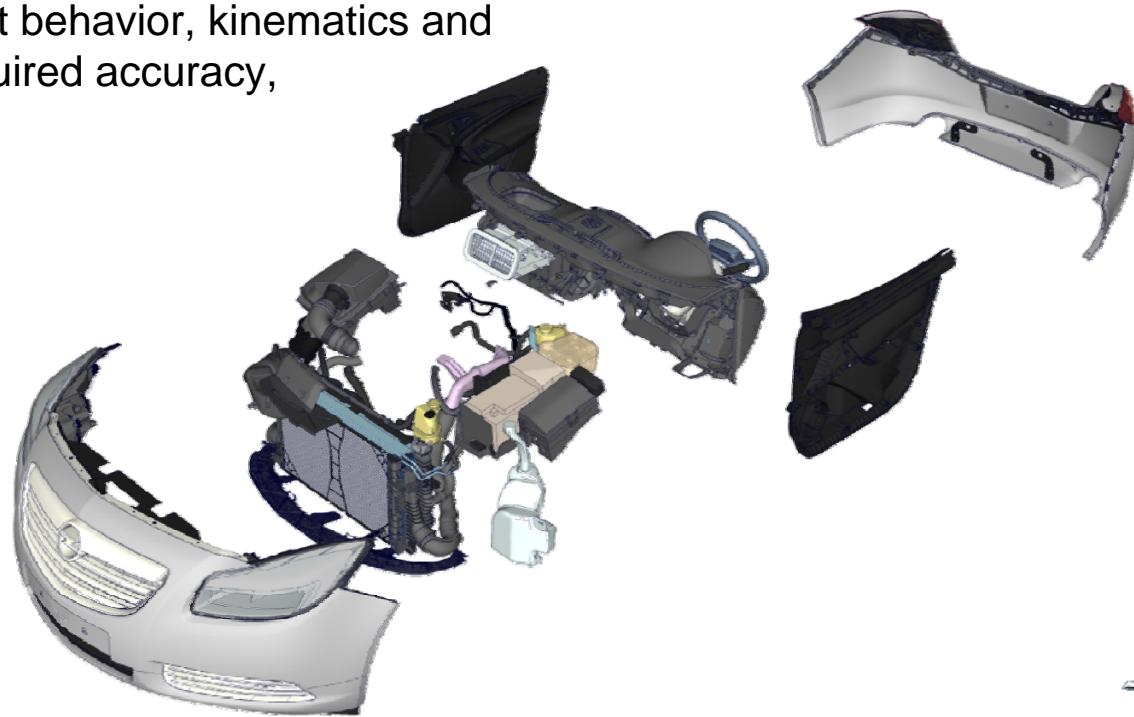
Lower Bumper Support

Development targets:

- Optimized, ribbed plastic structure to provide sufficient support for lower leg during the impact
- Needs to fail in a controlled manner during RCAR impacts in order not to damage other components
- Low weight at reasonable costs
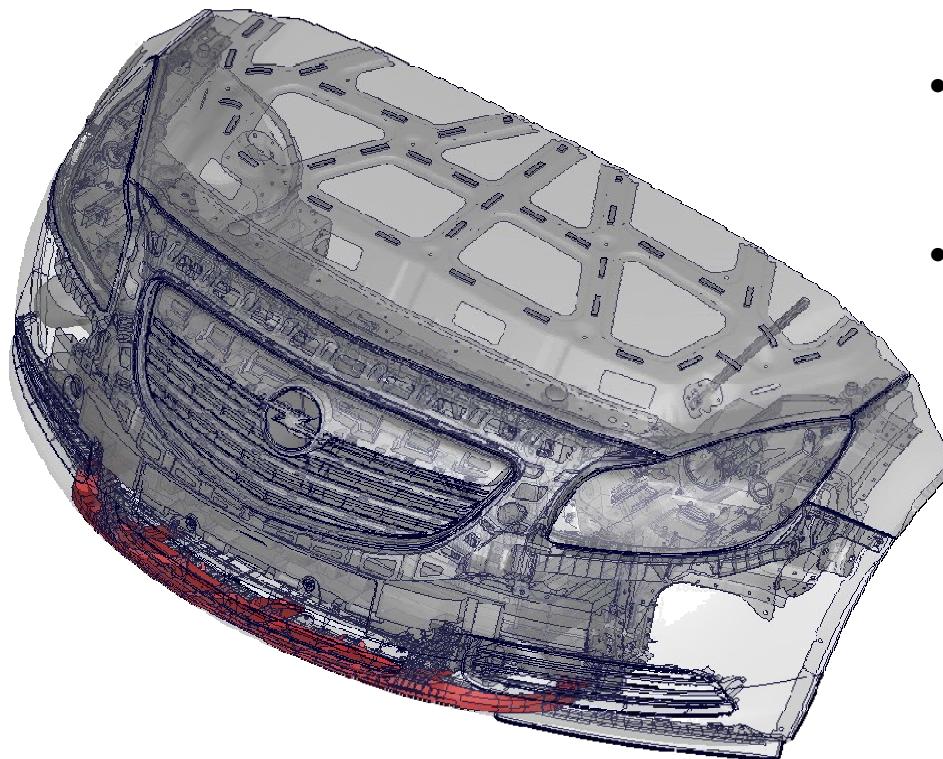
# Lower Leg Impact Kinematics

Without Lower Bumper Support
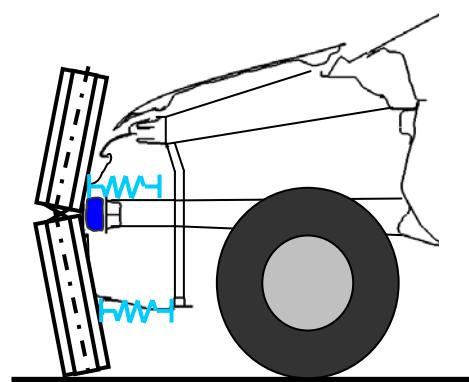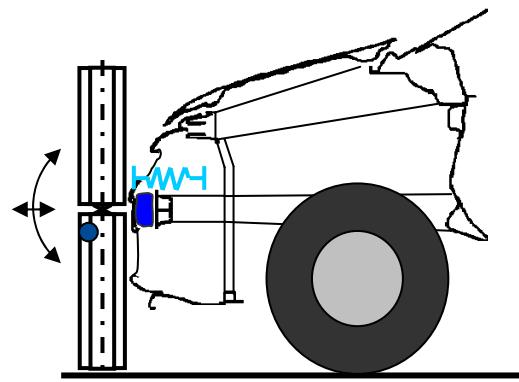
With Lower Bumper Support

No support of lower leg
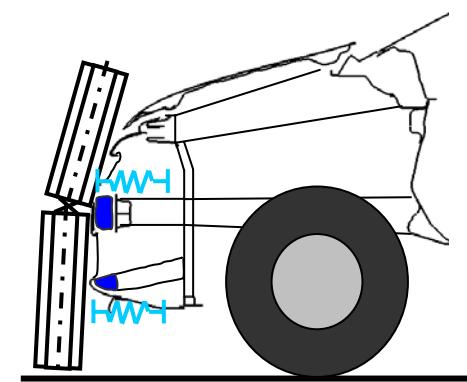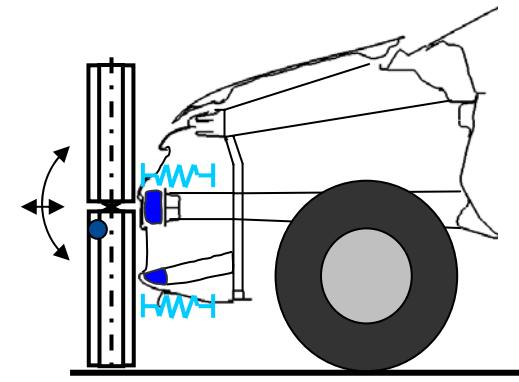
Support lower leg,
reduce knee bending angle

Integrative Simulation ULTRASIM™
for fiber reinforced thermoplastics

Process

Measurement

BASF Material model

Part

- Anisotropic
- Nonlinear
- Strain-rate sensitive
- Tensile-compression asymmetric
- Failure modelling
- Temperature dependent
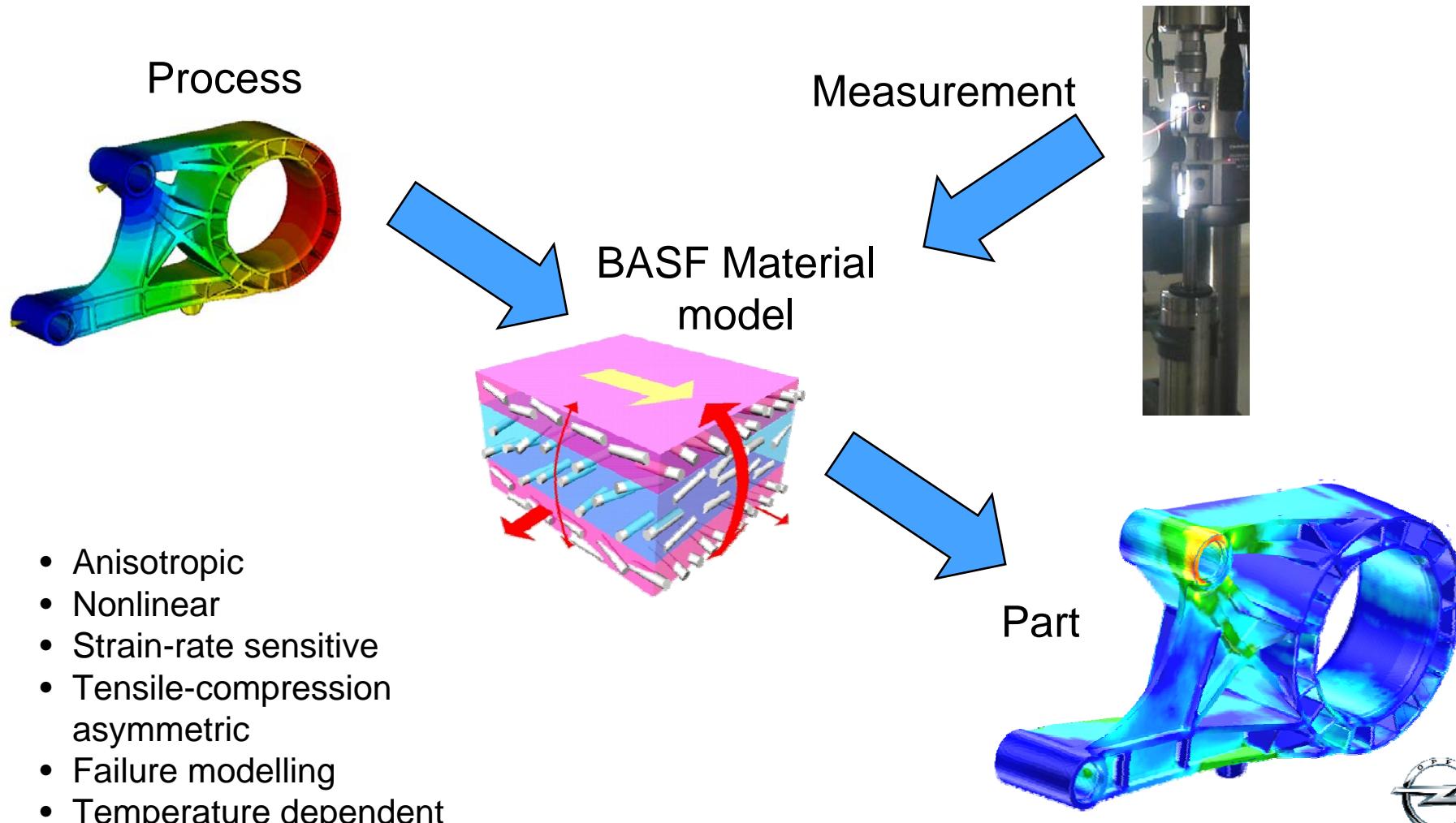
Integrative Simulation ULTRASIM™
Fiber orientation and material behaviour

**Calculated glass fiber orientation based on optimum processing conditions**

Fiber orientation tensor (3D)_1 = 1.000

Orientation of fibers

Fiber orientation of 0,5

Local true stress strain at a fiber orientations of 0.5

Fiber orientation of 0,9

Local true stress strain at a fiber orientations of 0.9 and 0.1

Fiber orientation of 0.7

Local true stress strain at a fiber orientations of 0.7 and 0.3
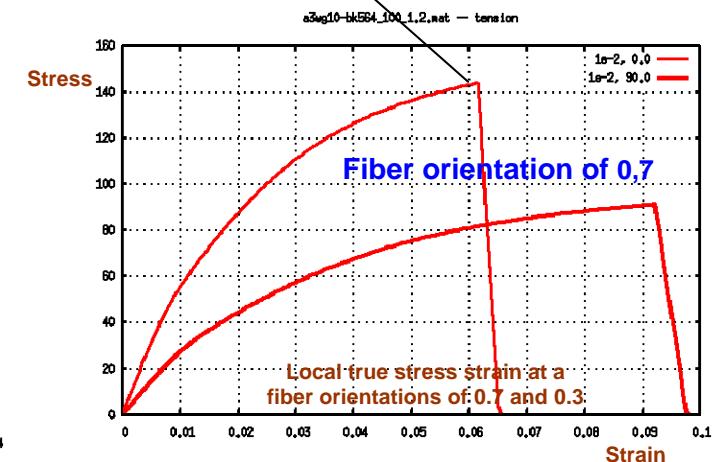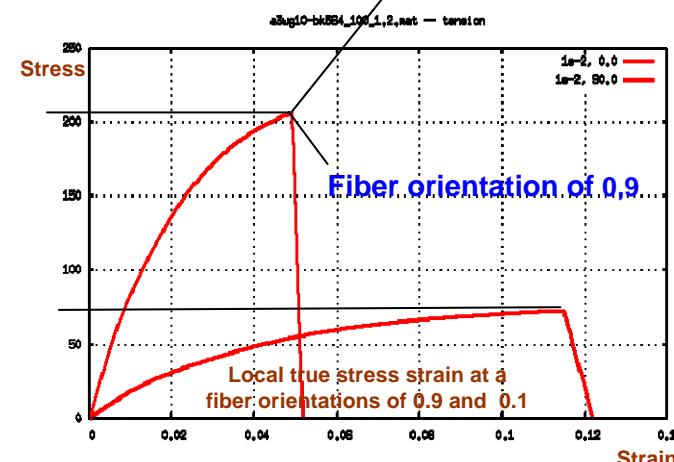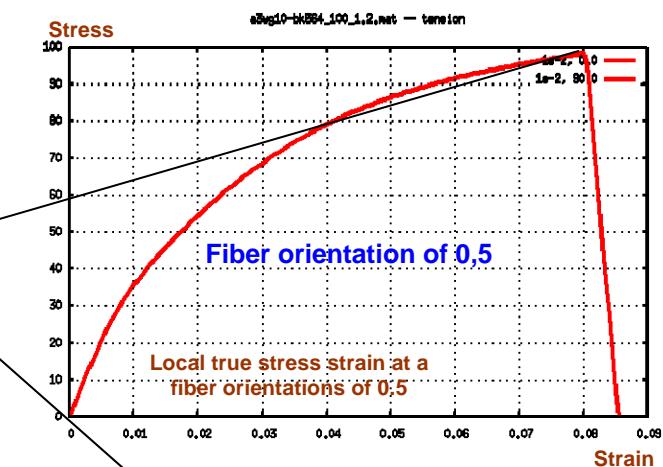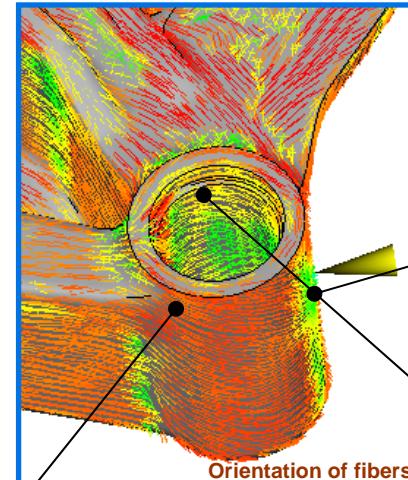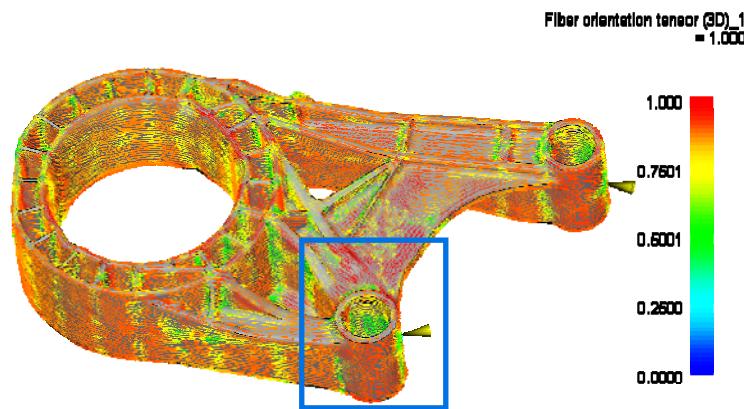
Lower Leg Impact (Full Model)

European LS-Dyna Meeting 2011
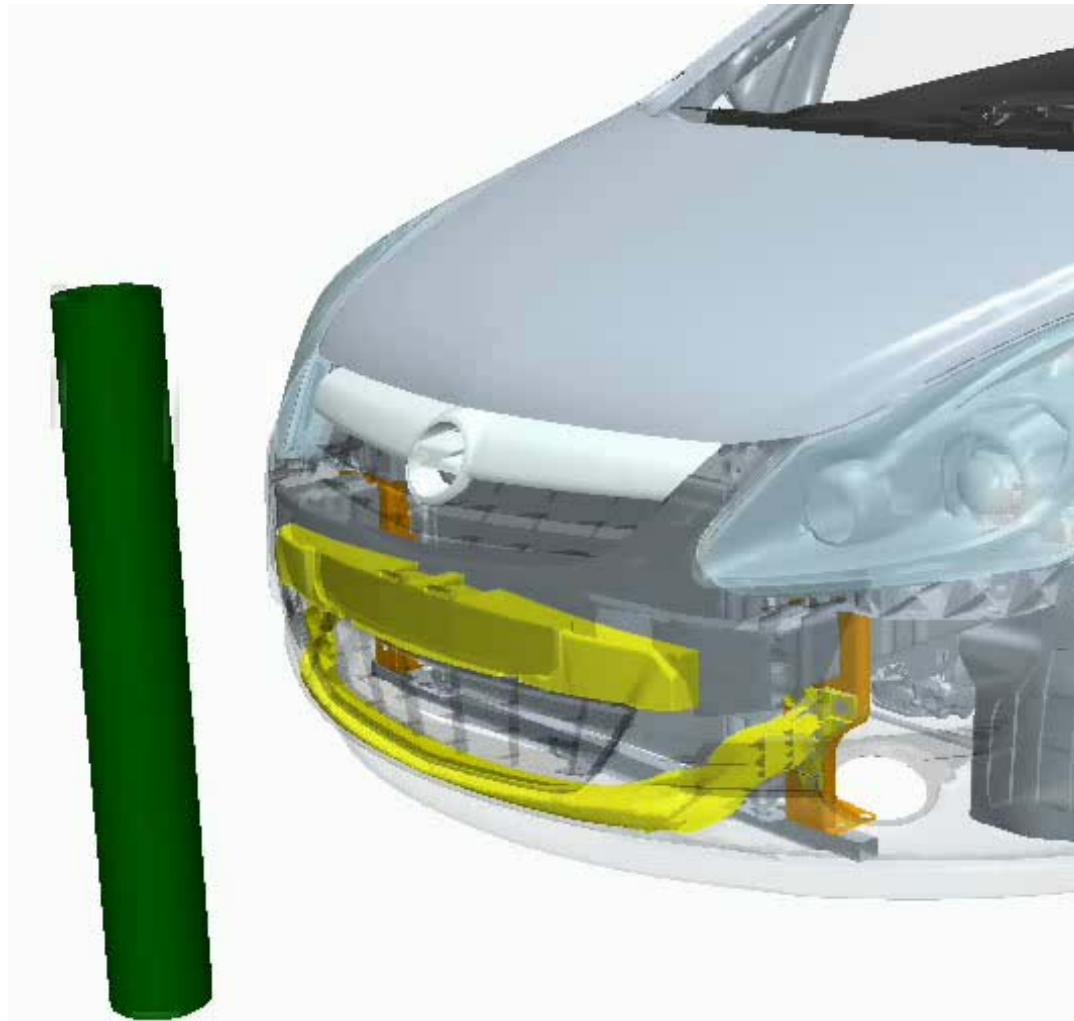
Simulation Results
Impact on stiffness and rupture

Lower Legform 40kph:
Tibia Acceleration

TEST Tibia Acc. normalized
LBS isotropicTibia Acc. normalized
LBS anisotropic Tibia Acc. normalized

Normalized acceleration

Time [ms]
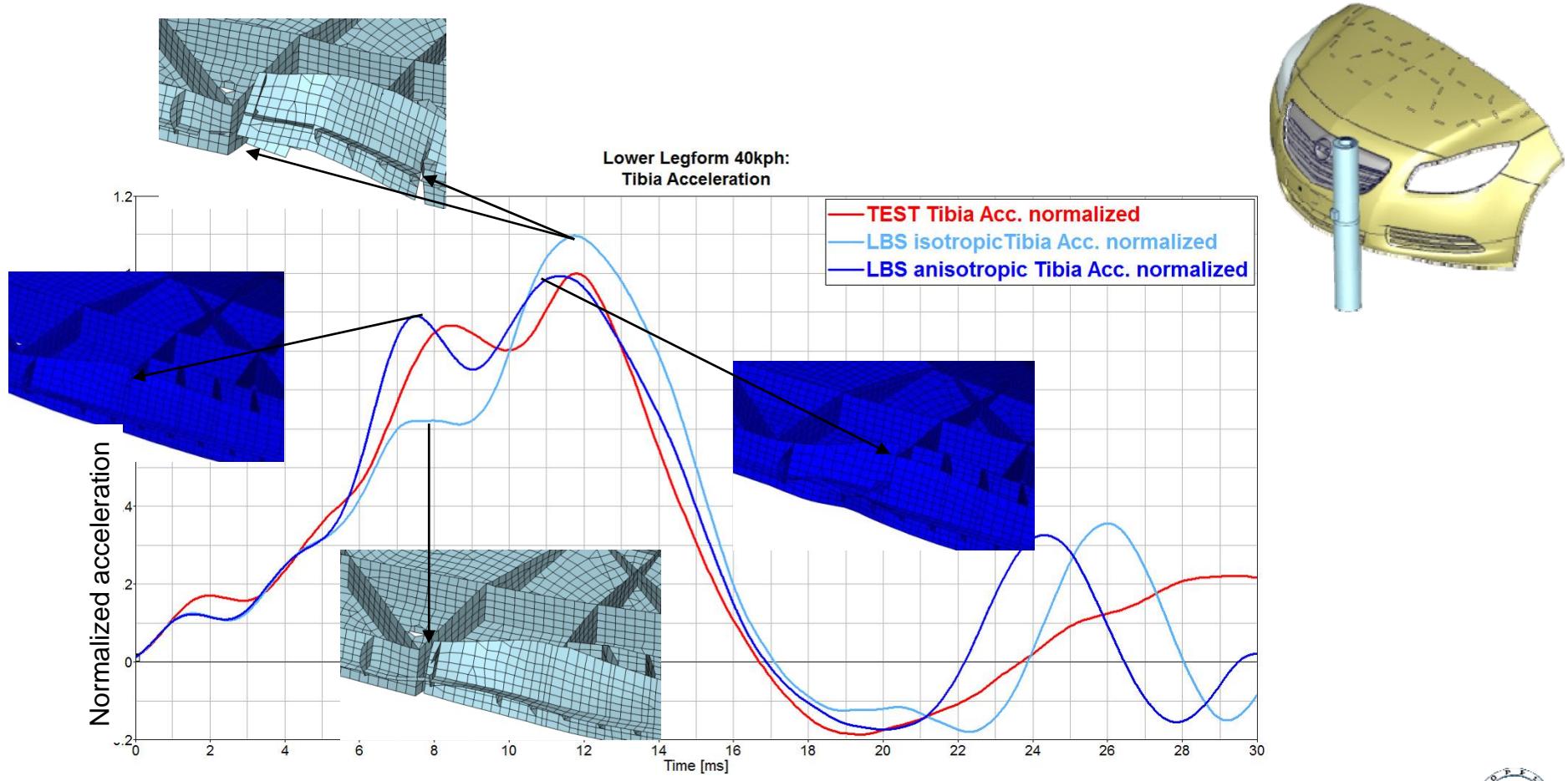
Integrative Simulation ULTRASIM™
Data flow structure

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ABAQUS, LS-Dyna, PAM, RADIOSS, NASTRAN

Geometry, Boundary Cond. → Finite Element Simulation

MOLDFLOW
MOLDEX

FIBER

anisotropic material model

Filling-simulation

$\psi(p)$

→ homogenization of orientation

Material-parameter → homogenization of fibers and polymer

Material-parameter → Material model for fibers

Material model for polymer

- elastic
- brittle

- elastic
- lastic-plastic
- viscoplastic

LBS Implementations
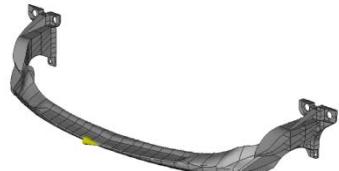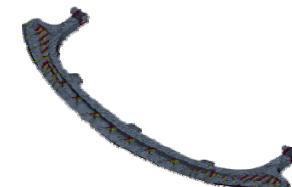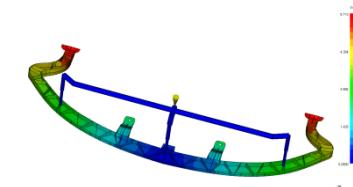
2006   2008   2009   2010

Additional Applications

■ Engine Mounts (e.g. Insignia)

■ Seats (e.g. Insignia OPC)

Stress-Strain behaviour
Tension-Compression Asymmetry

BASF
The Chemical Company

influence: fiber orientation and hydrostatic stress state

Injection moulded plate

Stress [MPa]

Compression

120

100

Tension

80

60

Tension

40

Compression

20

0

Strain [%]

0   2   4   6   8   9   10
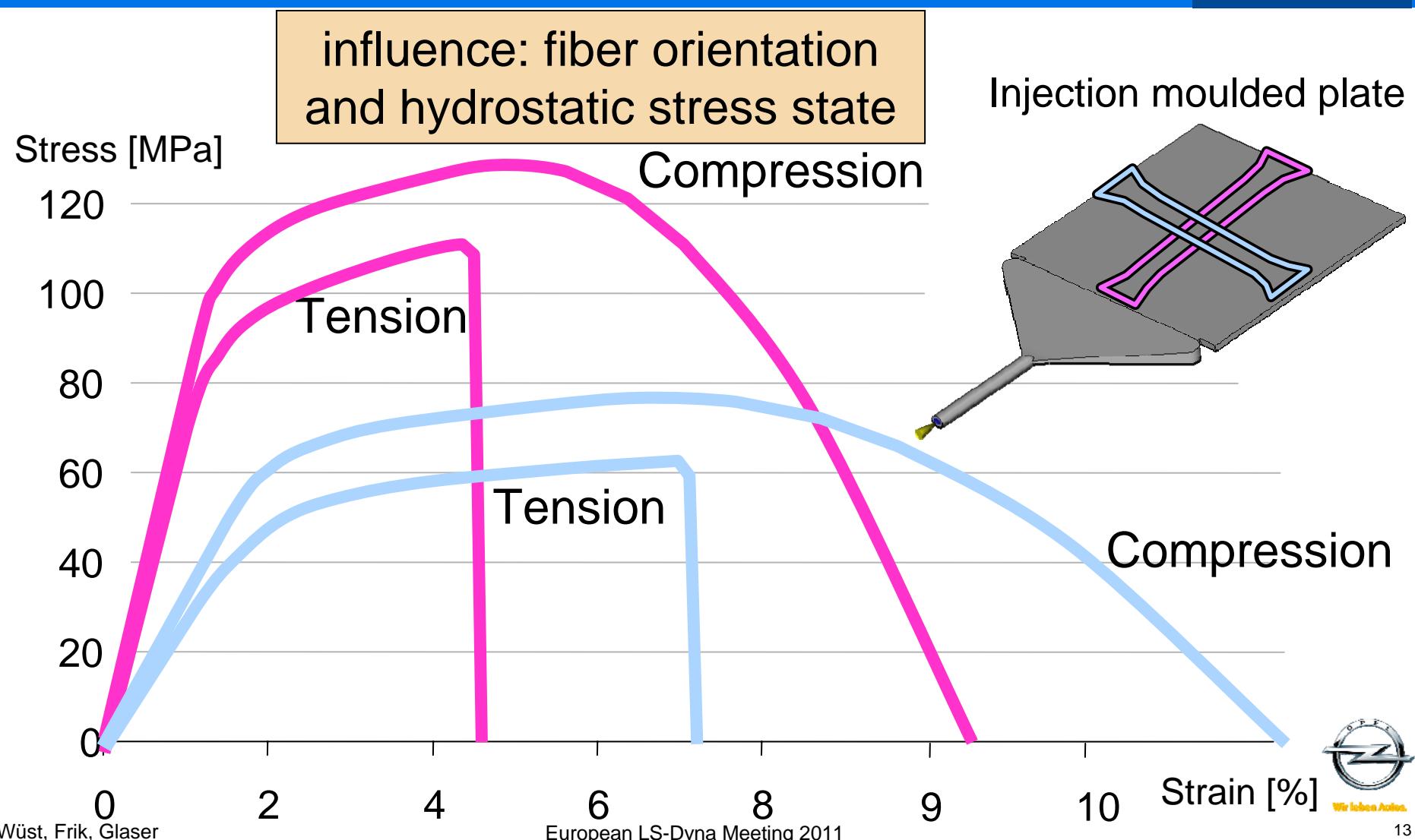
Example for an Energy absorbing plastics structure – BASF Test Specimen for compression load Needed for Calibrating Failure Simulation Parameters

BASF
The Chemical Company

Specimen is designed for controlled collapse

Material: B3WG6 CR (PA6 GF30%)

sliding barrier
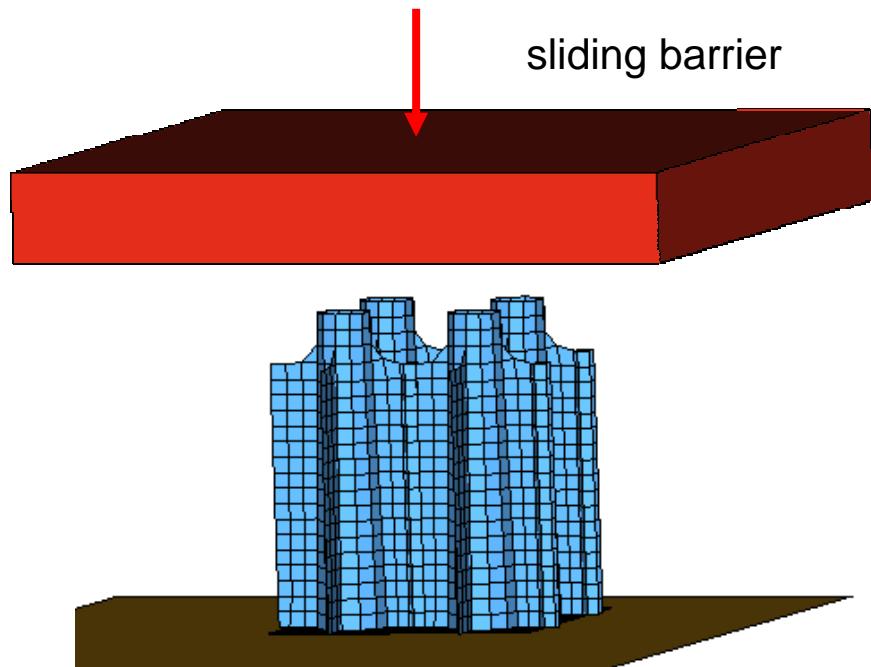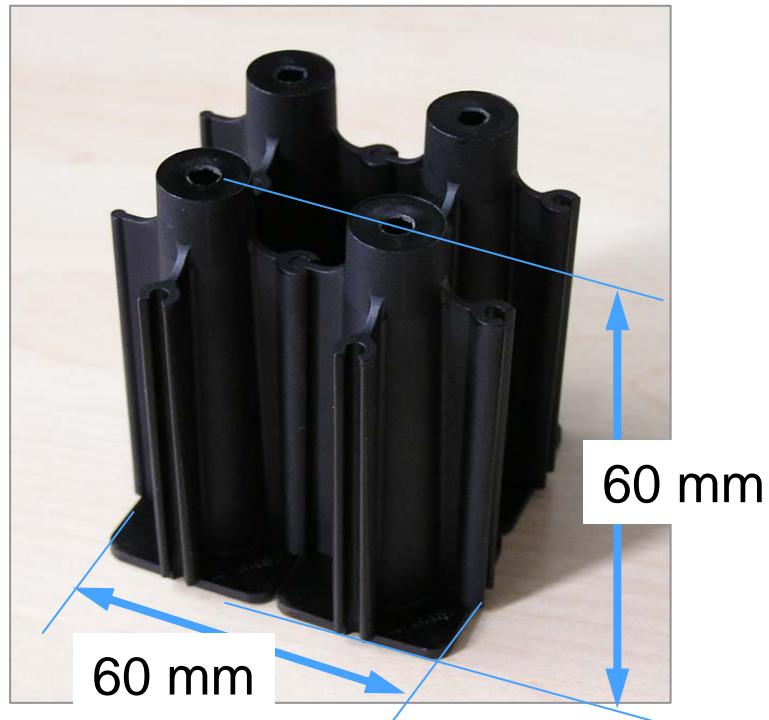
60 mm

60 mm

Plastic specimen under compression load
## Simulation and Experiment
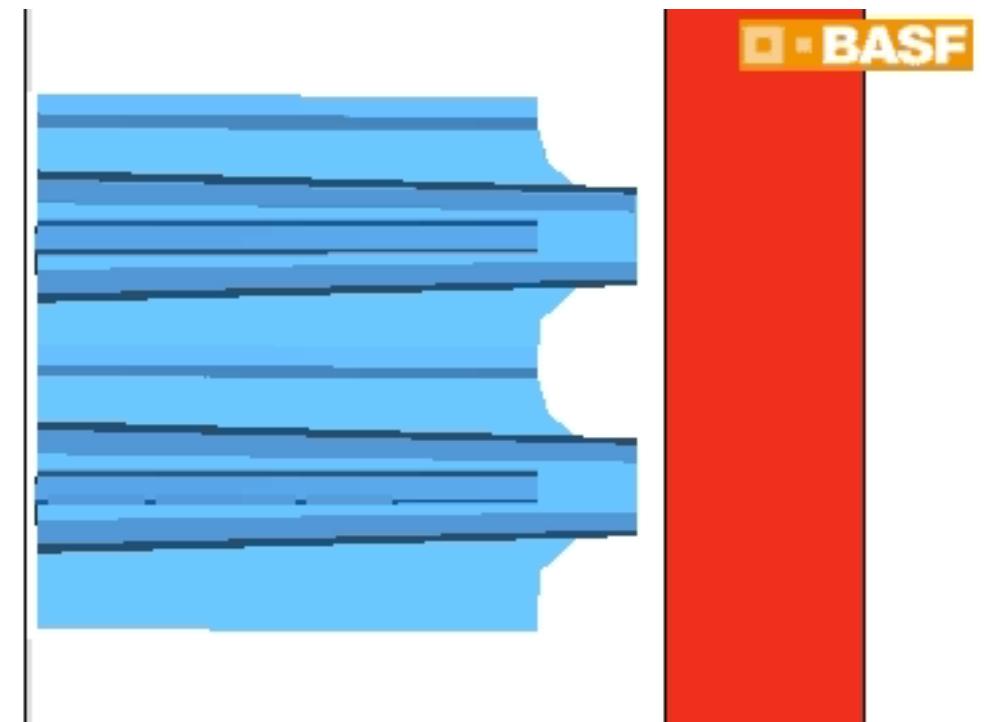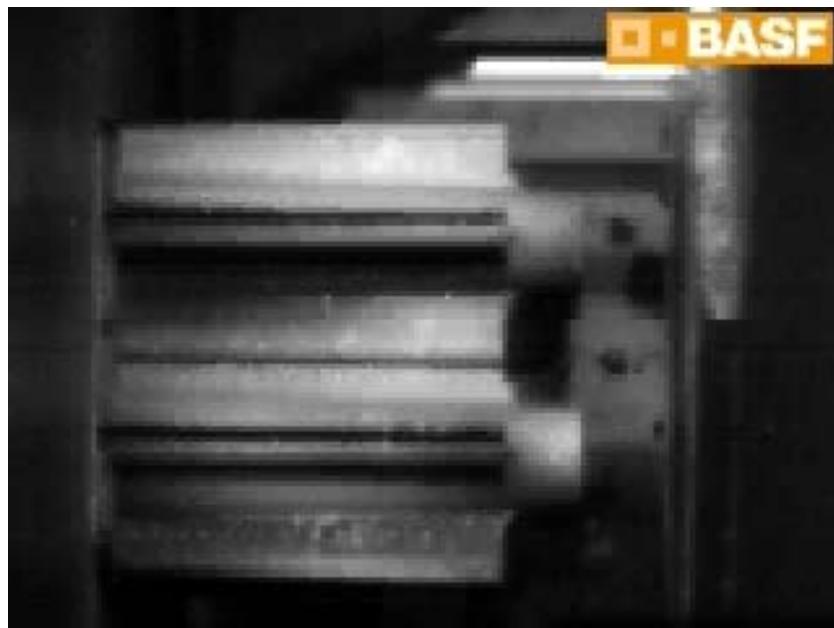
# Test-specimen under compression load
Simulation and Experiment

60 mm
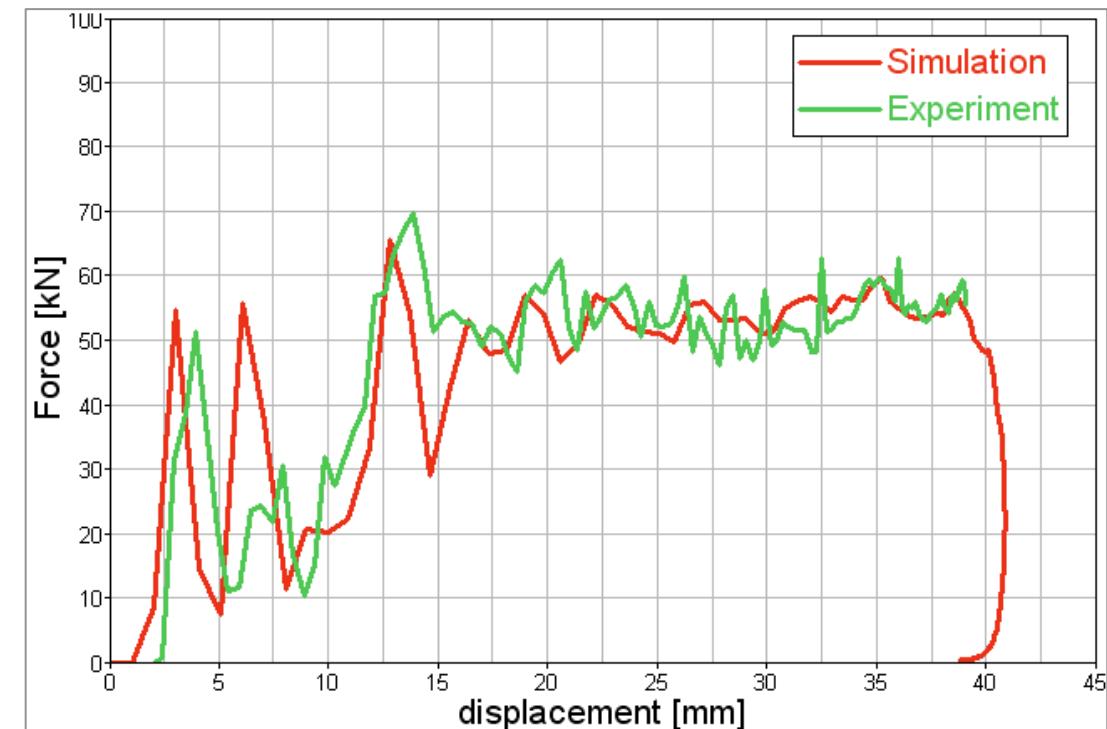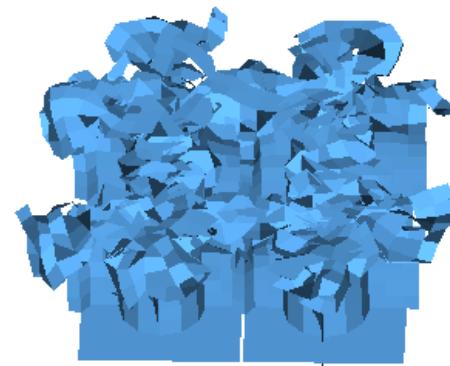
Lower Loadpath
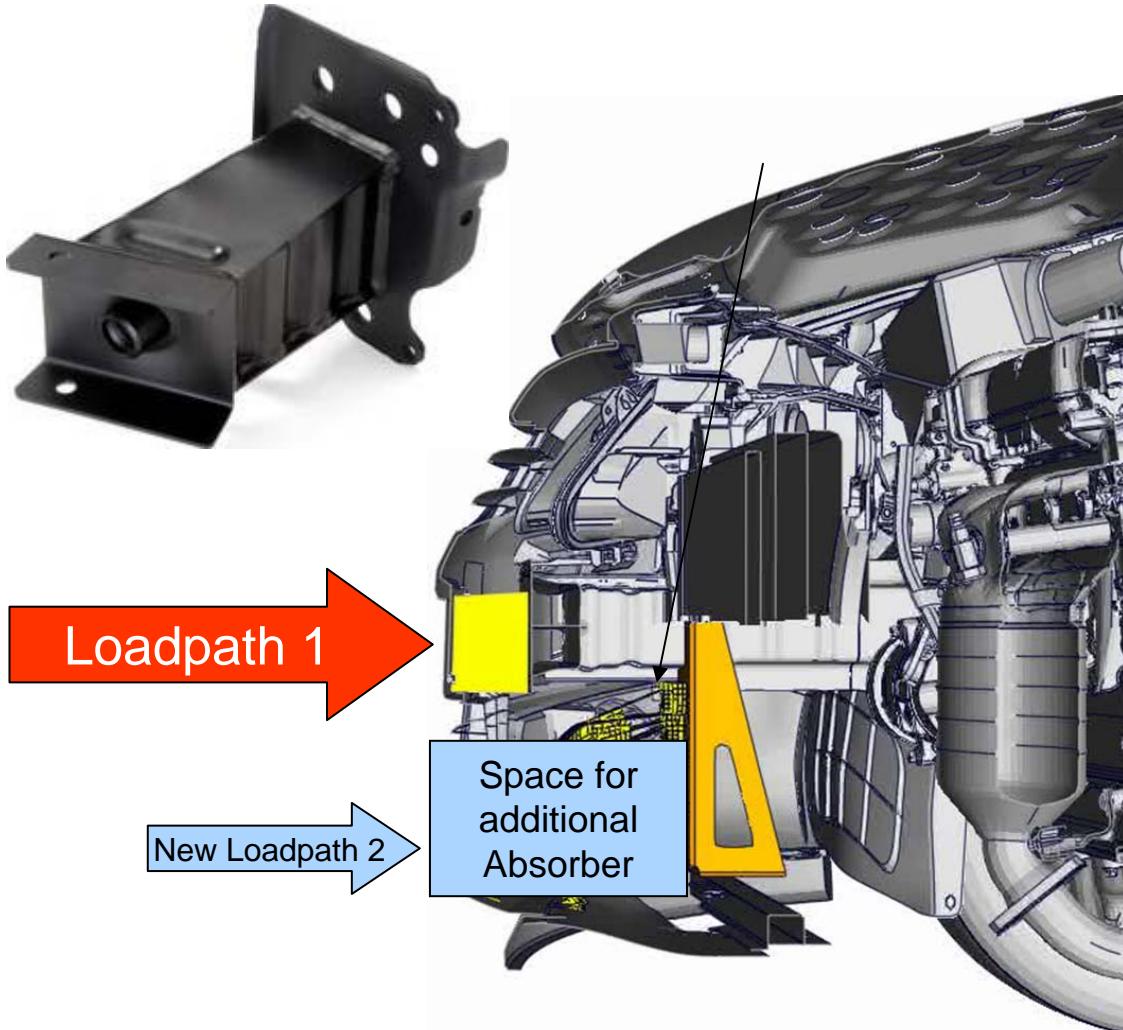
Traditional
Metal Crashbox:

Loadpath 1

New Loadpath 2

Space for
additional
Absorber
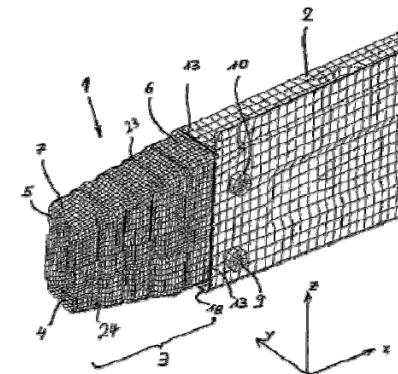
Videocomparison Absorber
→ enhanced ULTRASIM™ failure modelling

ULTRASIM™

Integrative Simulation

Math. Optimierung

Vergleich Simulation mit 3 Tests

gefiltertes Signal Simulation F(s)
Versuch_60mm_s_V02
Versuch_60mm_s_V03
Versuch_60mm_s_V04

Kraft [N]

Weg [mm]
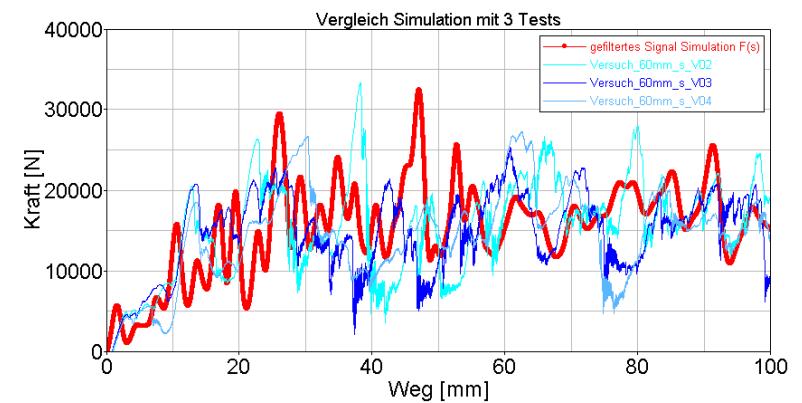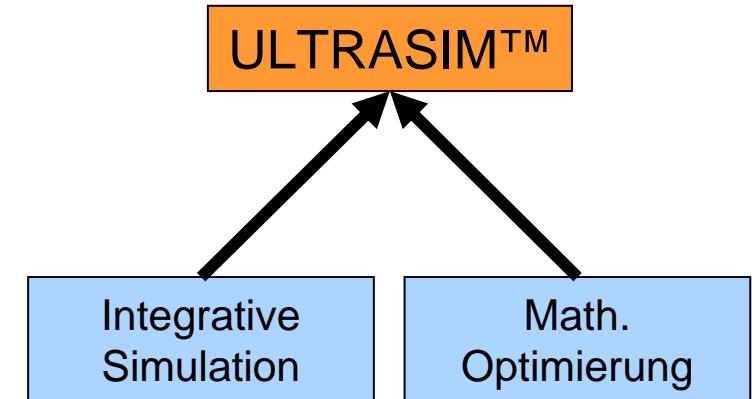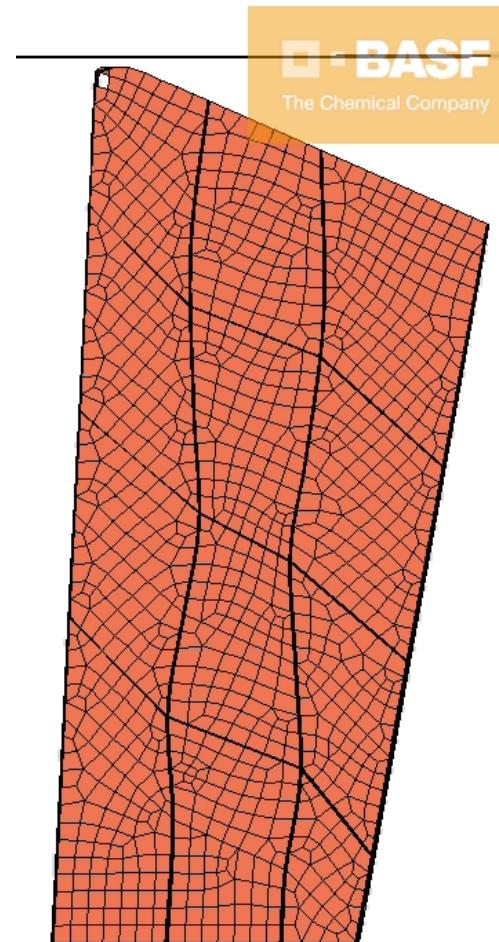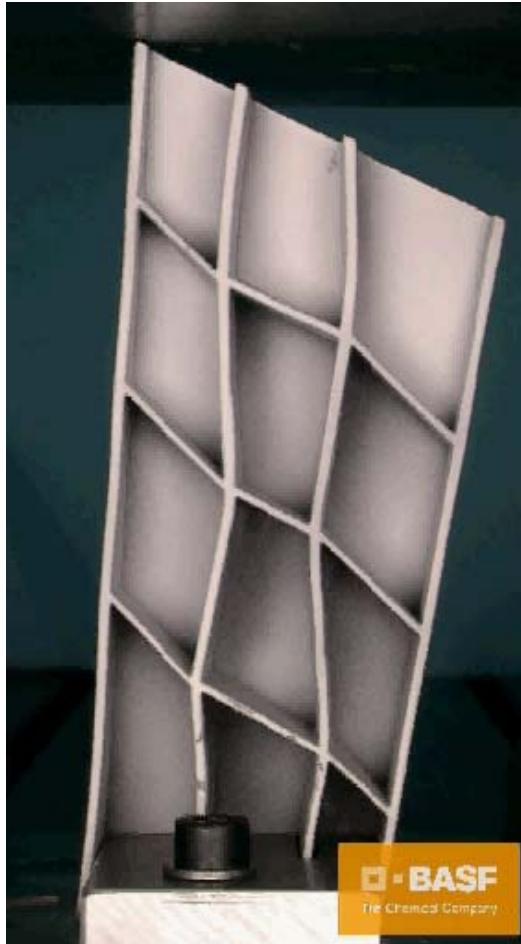
Dynamic Test Video
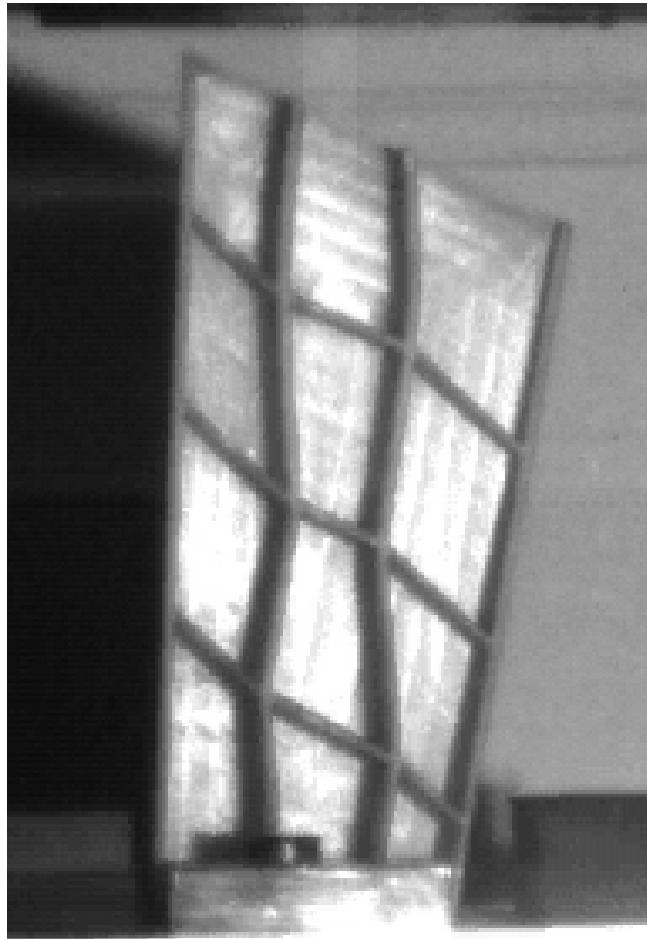
Drop mass: 60 kg
Drop height: 2.5 m
Drop Energy: 1.47 kJ
Duration: $\approx$ 25 msec
Displacement: $\approx$ 75 mm
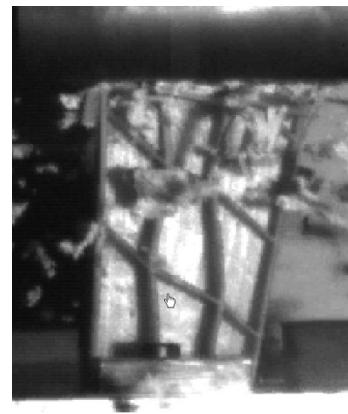
Parameter Optimization in CAE
Iterative process based on mathematical optimization methods

Design Variables

Mathematical Optimization Methods

FE-Solver

System responses
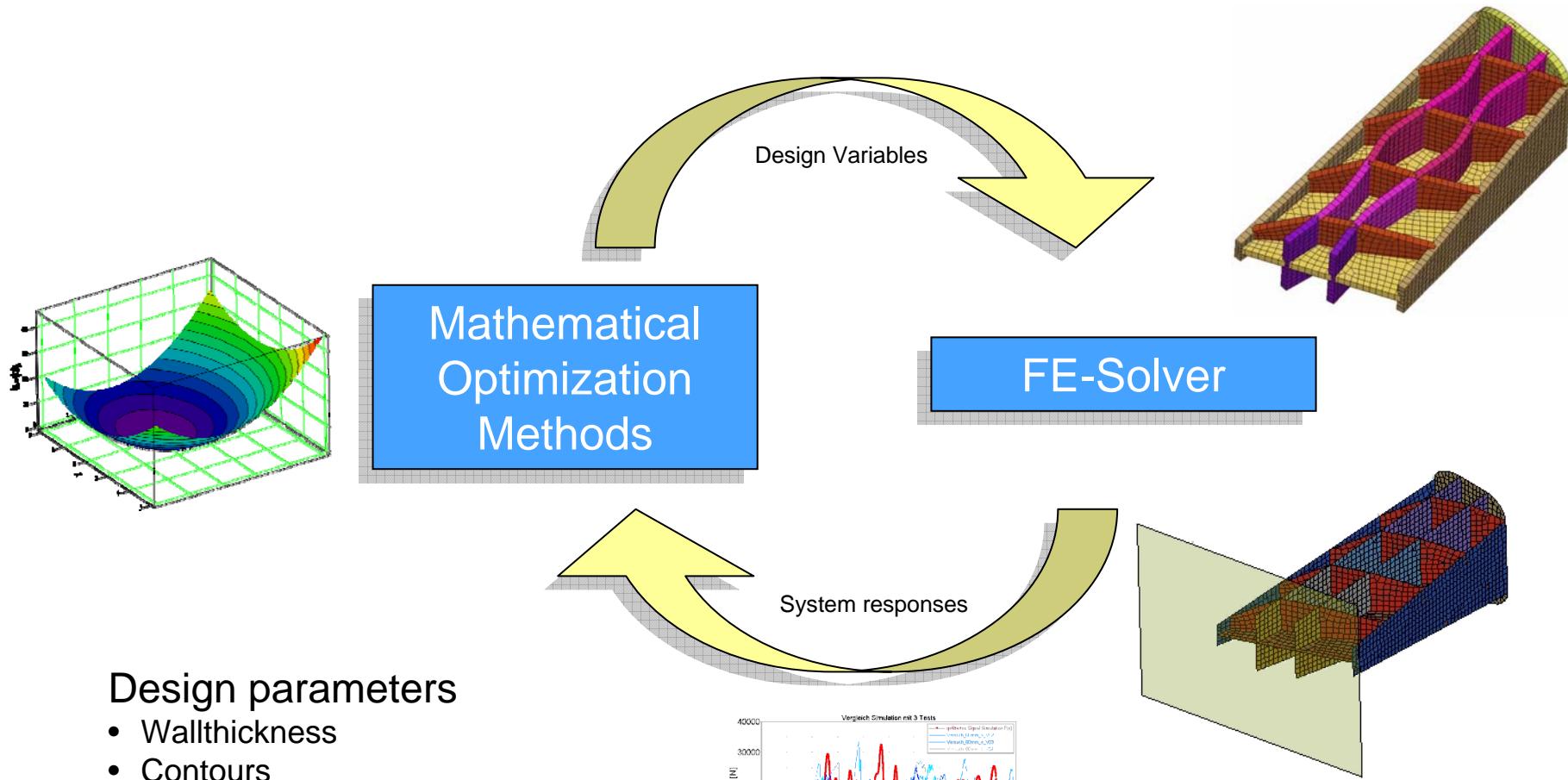
Design parameters
- Wallthickness
- Contours
- Rib heights
- …

Shape Optimization using Morphing

Morphing
parameter 1

Morphing
parameter 2
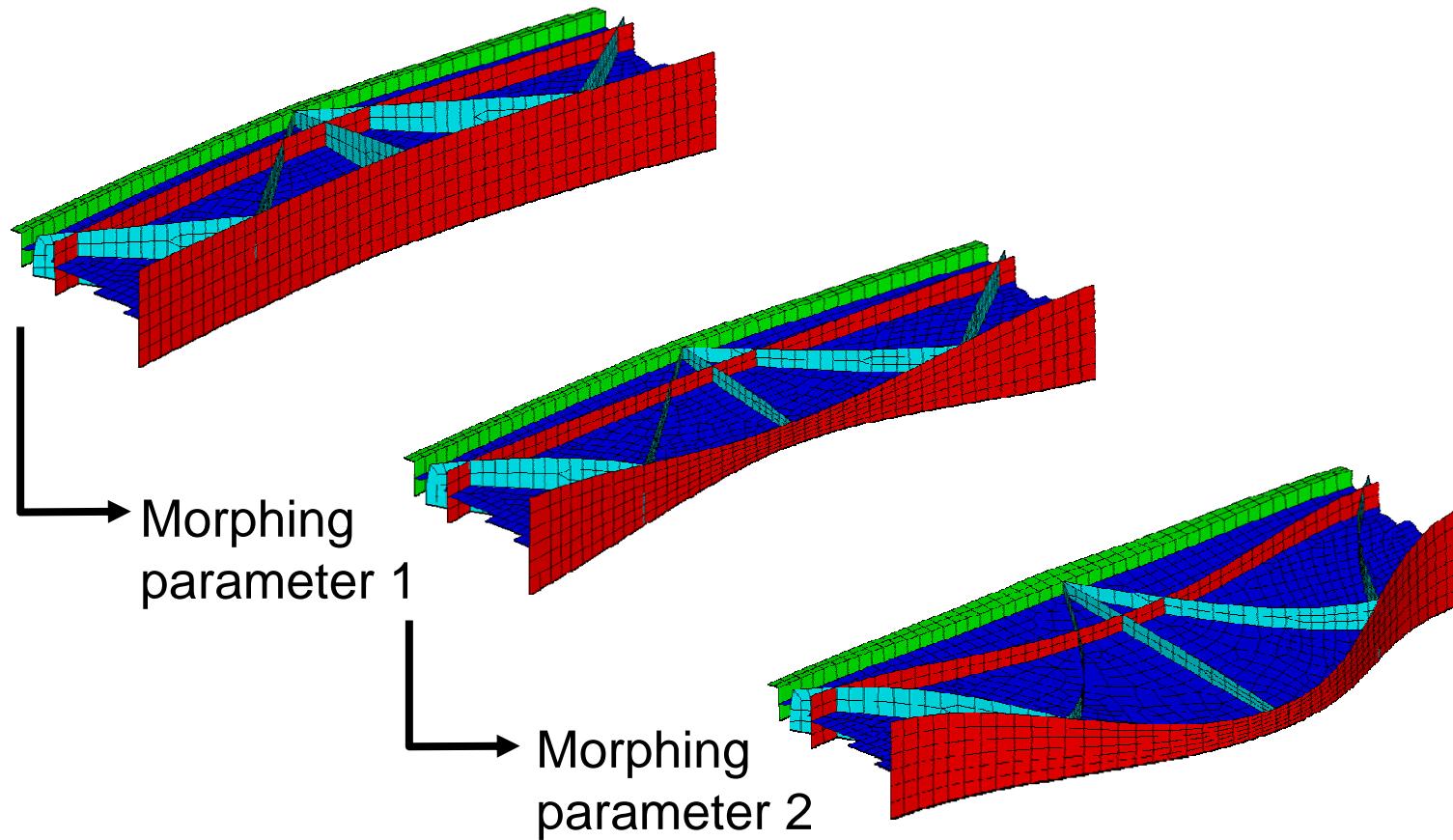
Vision – Integrative Optimization
Standard Optimization and Integrative Approach

Plastics granulate with glass fibers

Injection molding process

Part

Assembly

Product in use

BASF ULTRASIM

- Crash
- Static Loads
- NVH
- Warpage
- …

Standard Approach

Integrative Optimization Approach
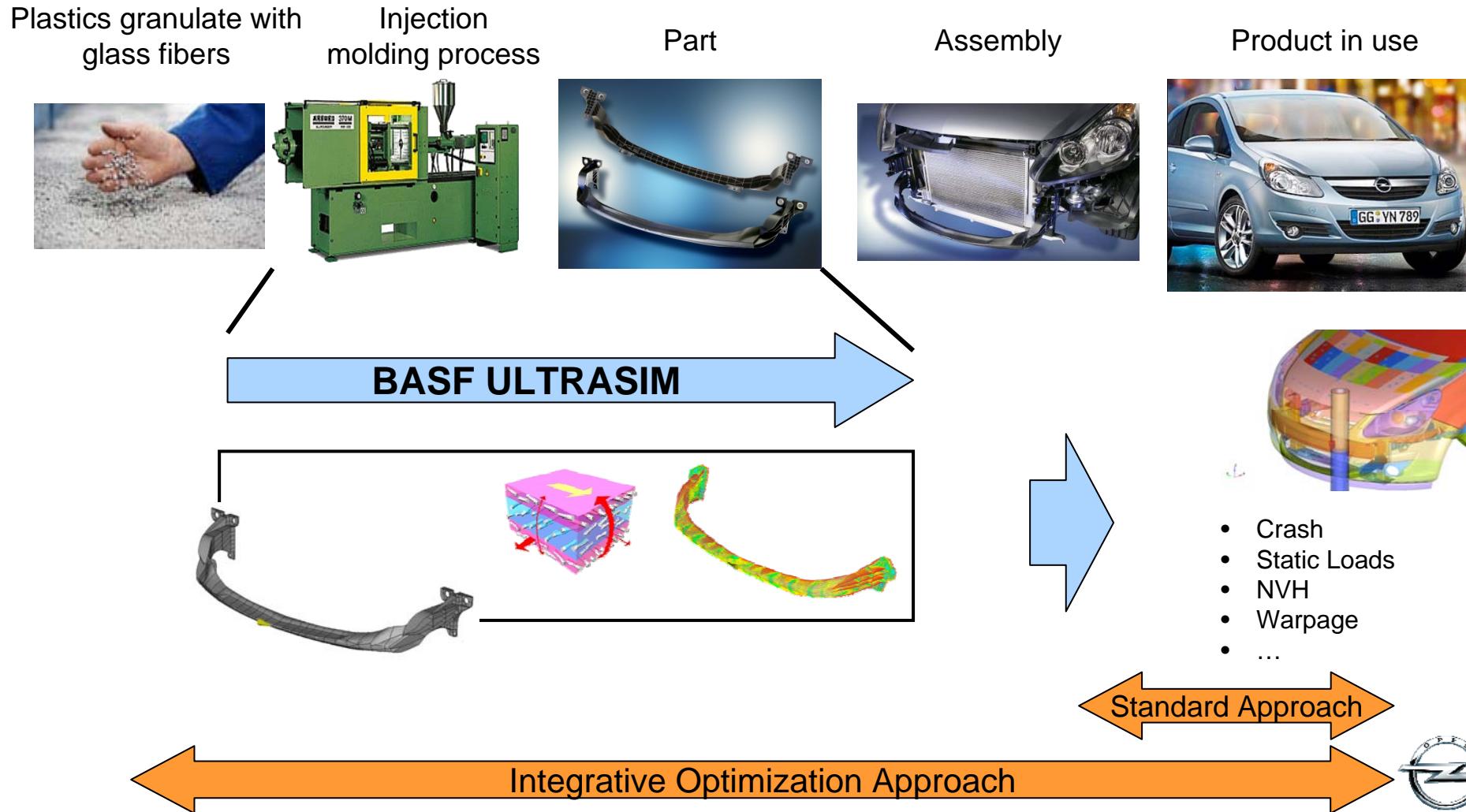
Workflow for Standard Optimization Approach

Mathematical Optimizer

Vector of Design Variables $\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix}$

System parameters e.g. wallthicknesses

Modified FE-Inputfile

vector of Responses $\begin{pmatrix} r_1 \\ r_2 \\ r_3 \end{pmatrix}$

FE-Solver
ABAQUS, LS-Dyna, PAM

FE-Results

Response Extraction
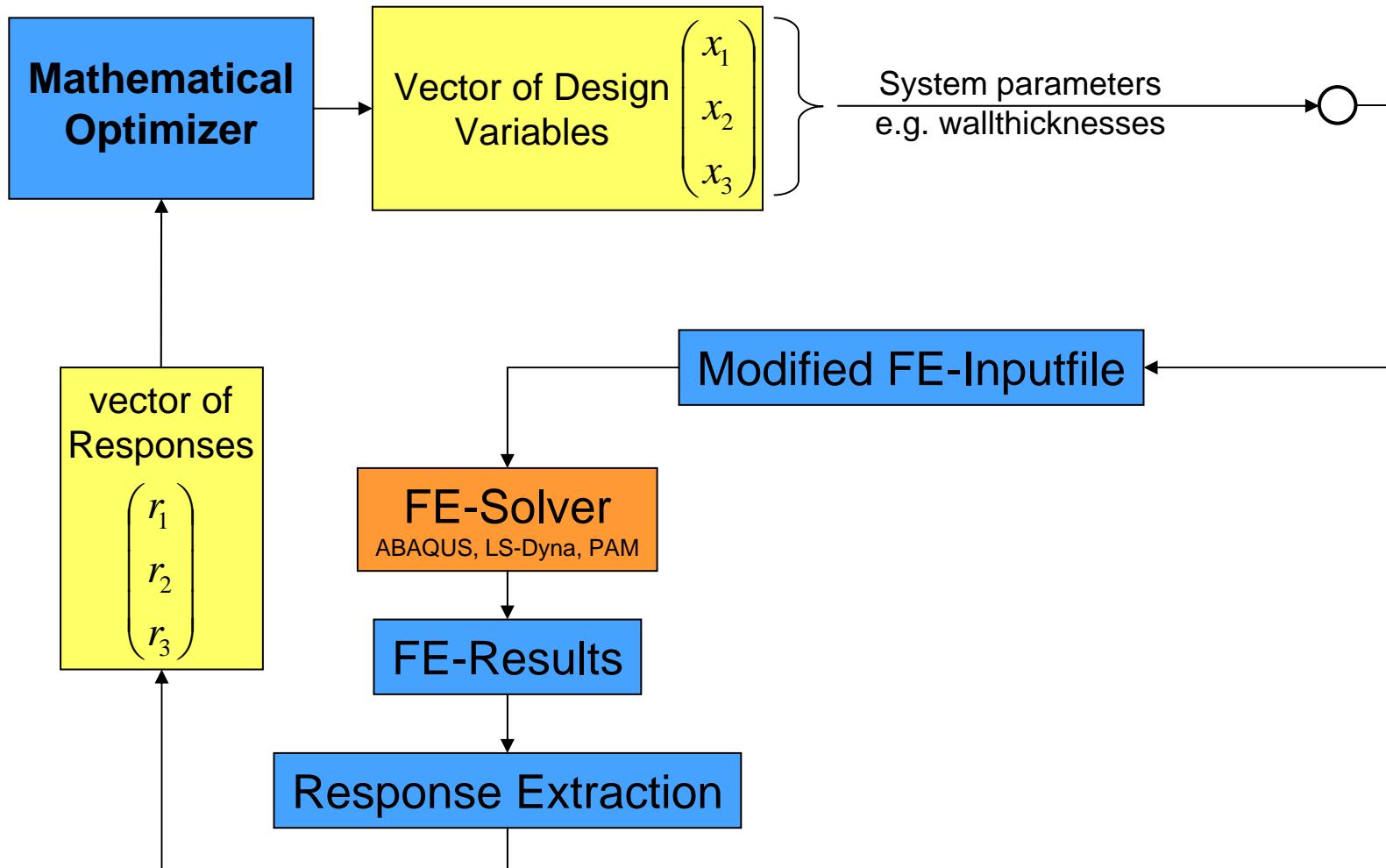
Workflow for Integrative Optimization Approach
Single disciplinary (without morphing)

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Mathematical Optimizer

Vector of Design Variables $\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix}$

General system parameters

Wallthickness, Injection time and location, temperatures, gate delay times, …

Wallthickness, …

vector of Responses $\begin{pmatrix} r_1 \\ r_2 \\ r_3 \end{pmatrix}$

Discipline „0": Process Simulation *Manufacturing*

Intermediate Mesh for mapping

BASF ULTRASIM™ Fiber Orientation Mapping

Discipline 1: Mechanical FE Simulation

Workflow for Integrative Optimization Approach
Multi disciplinary (with morphing)

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The Chemical Company

Mathematical Optimizer → Vector of Design Variables $\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix}$ → General system parameters → Morphing

Wallthickness, Injection time and location, temperatures, gate delay times, …

vector of Responses $\begin{pmatrix} r_1 \\ r_2 \\ r_3 \end{pmatrix}$

Process Simulation *Manufacturing* → **BASF ULTRASIM™ Fiber Orientation Mapping**

Intermediate Mesh   *Intermediate Mesh*   *Intermediate Mesh*

Static Load   Crash   NVH

Discipline „0"   Discipline 1   Discipline 2   …   Discipline n

Integrative Optimization Example

**Filling, Warpage, Impact, Static Load, Shape Optimization by Morphing
LS-OPT, MOLDFLOW, LS-Dyna, ANSA, ABAQUS**

Filling

Warpage

Integrative Optimization

Static Load

Impact

Morphing

Summary
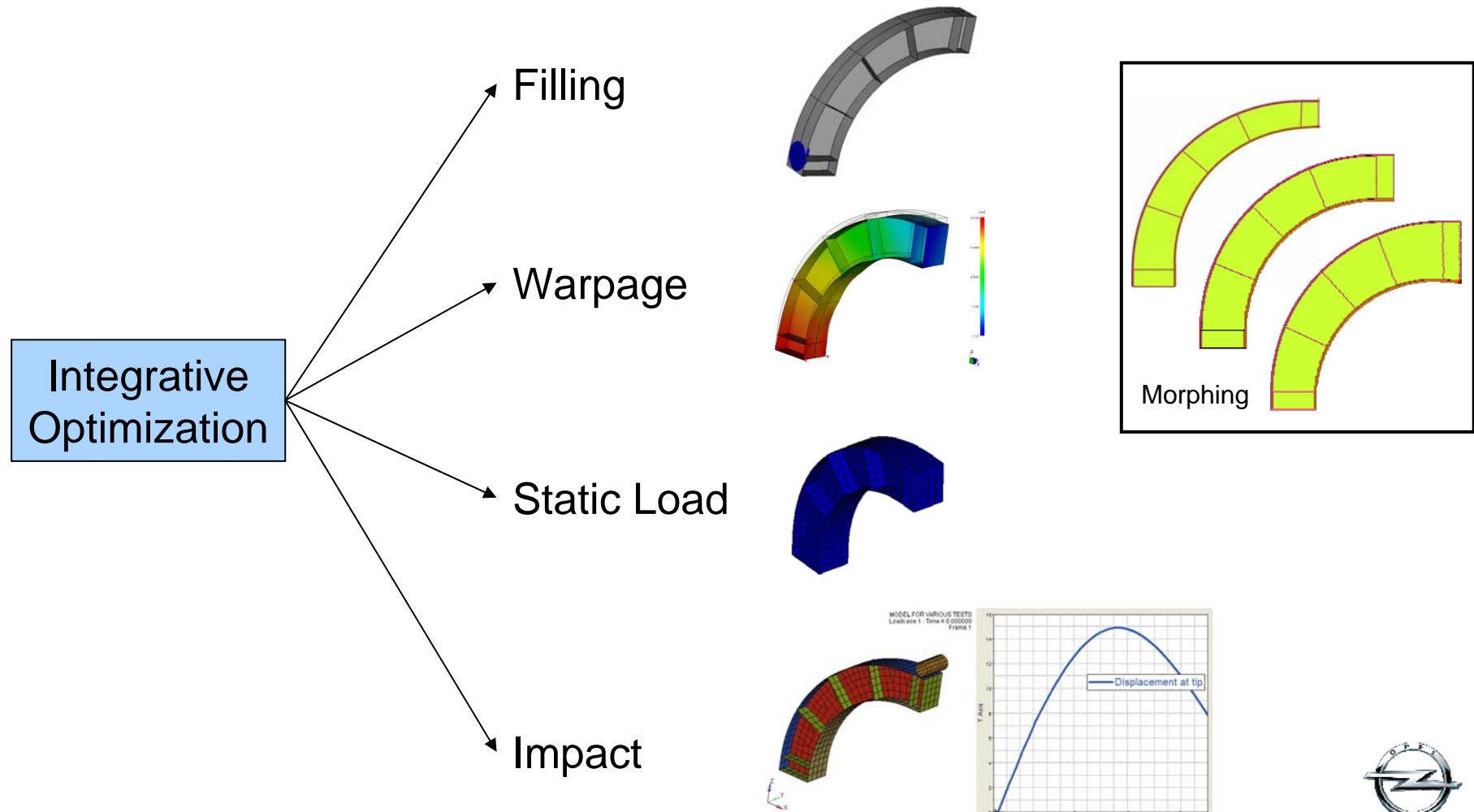
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- **More and more structural vehicle parts are made of anisotropic polymers**

- **Injection molding process determines fiber orientation and thus local mechanical properties**

- **ULTRASIM™ approach has been applied for numerous applications**

  - **Initially: Lower bumper support for pedestrian protection**

  - **Extended to engine mounts and seats**

- **Simulation results show excellent correlation with physical tests**

- **Extended ULTRASIM™ failure model is crucial for the accurate design of energy absorbing structures**

- **Integrative Optimization Approach allows simultaneous optimization of process and mechanical characteristics**