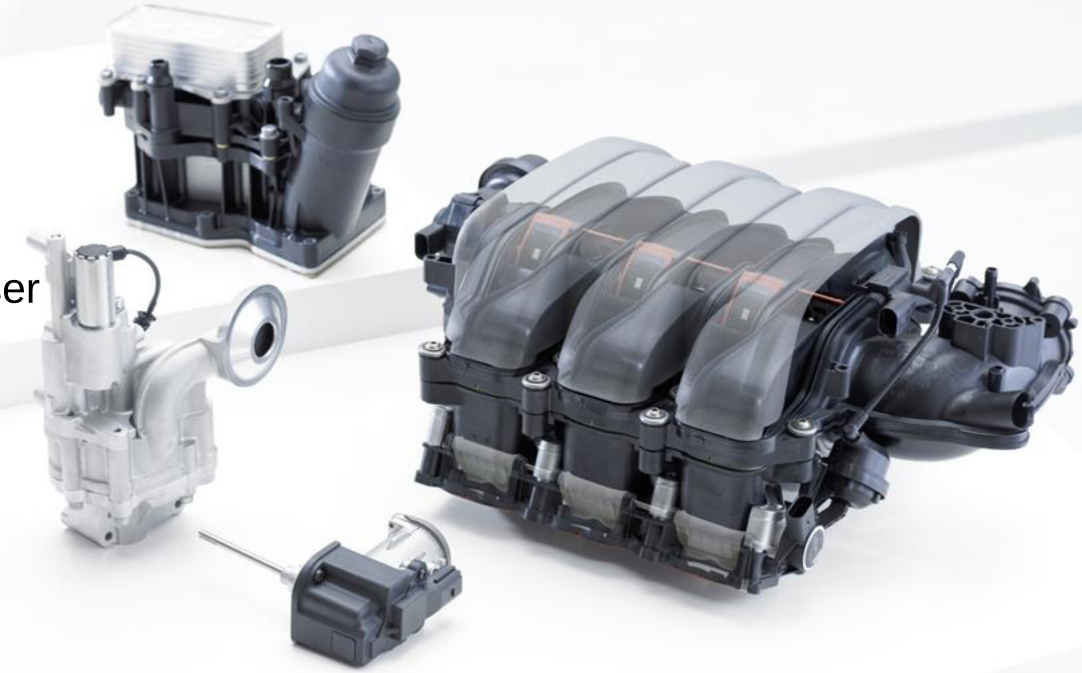
PERMAS User Conference 2018

The PERMAS-DIGIMAT interface – Accurate structural analysis of reinforced plastic components



Rainer Handel, Jeffrey Van Delden, Tilman Kaiser
Acoustics & Simulation
BED1SA

Agenda

MAHLE

Driven by performance

Agenda

1. **Introduction of fiber reinforced plastics and integrative simulation**
2. The DIGIMAT interface
3. Application examples
4. Summary

Introduction fiber reinforced plastics

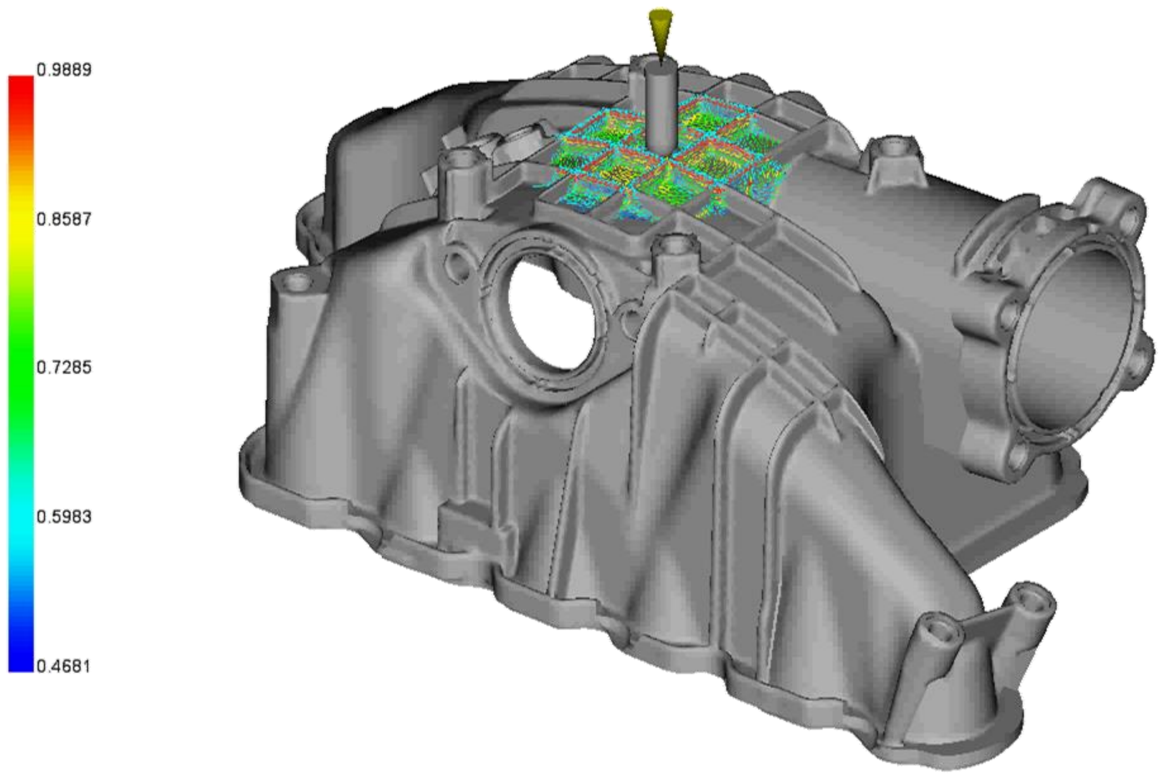
Driven by performance

Advantage of FRP components:

- Very high design flexibility
- Allow realization of lightweight parts with integrated functions

Within the development it is mandatory to perform injection molding simulations:

- Define molding parameters and ensure required machine size
- Optimize filling behavior
- Optimize position of joint lines
- Optimize final warpage
- Optional:
  Modification of tool geometry
  to further reduce warpage



Process simulation:
Glass fiber orientation during injection molding

Introduction fiber reinforced plastics

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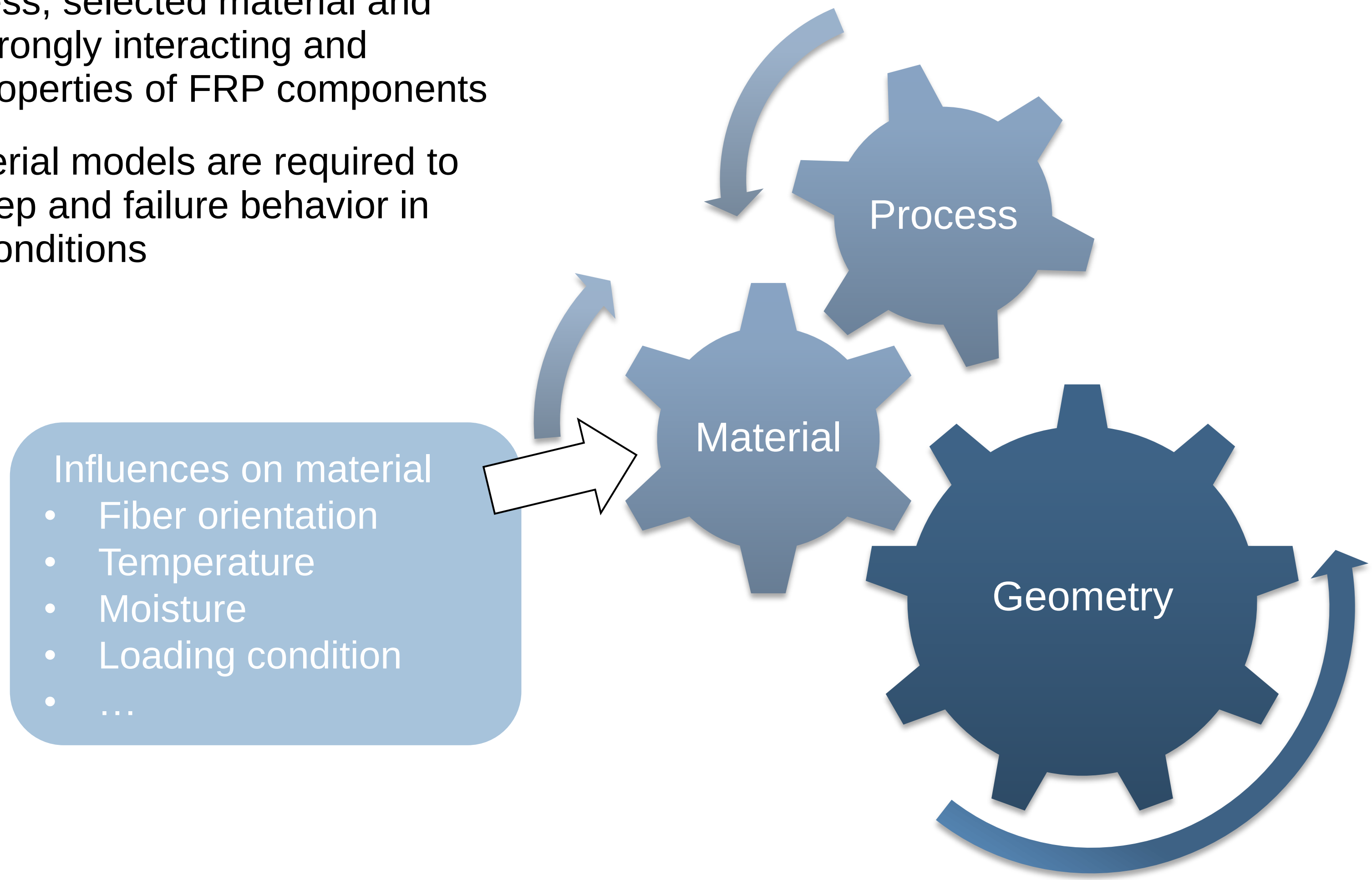
- Manufacturing process, selected material and part geometry are strongly interacting and influence the final properties of FRP components
- Highly complex material models are required to predict stiffness, creep and failure behavior in different operation conditions



PERMAS-DIGIMAT interface

Standard approach to define material properties for CAE

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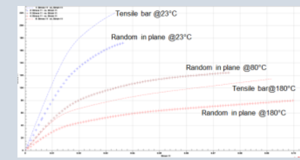
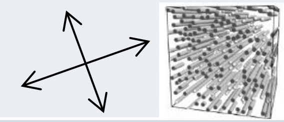
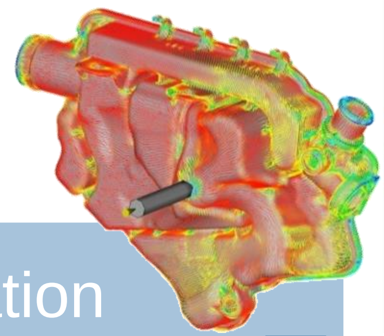
Isotropic Property	How determined
Young’s modulus	Use initial gradient of stress-strain curve from CAMPUS and subtract x% due to unknown GF orientation or correlate Young’s modulus by panel frequencies of real parts 
Thermal expansion	Mean value of the two expansion coefficients along fiber and across fiber direction 
Material damping	Fixed or frequency depending value according to experience
Non-linear material behavior and creep	According to availability of data from material suppliers, CAMPUS data are usually not sufficient, isotropic properties not useful
Fatigue and crash	Hard to determine, isotropic properties not useful

→ Standard approach based on averaged and isotropic material properties is not accurate enough to virtually predict absolute results

→ **Integrative simulation required**

Workflow for injection molded parts

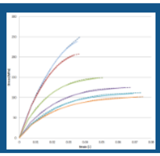
Digimat



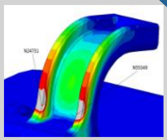
Process simulation

Mapping of fiber orientation and warpage to structural mesh

Material model



FEA Structural model



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e-Xstream engineering

e-Xstream, The material modeling company
60 PhDs & MS Engineering 100% focused on advanced material modeling
+ 20 TBH in 2018

Digimat, The material modeling platform
Tools, Solutions & Expertise for modeling Plastics & Composites
Wide & Deep Material & Process coverage

Global Market leader in Multi-Scale Modeling (CAGR = +34%)
Market Leader in Automotive (Top OEM & Tier 1), Material Suppliers, E&E
Fast Growing in Aerospace & Defense (OEM & Suppliers)

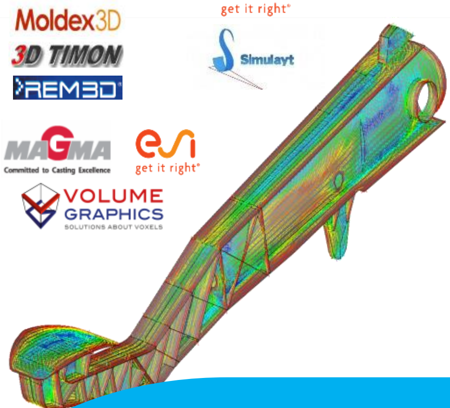
MSC Software, 55 years of CAE (Nastran, Adams, …)
Large potfolio of software solutions
1,200 Engineers in 20 Countries

Hexagon, Leader of IT solutions to drive productivity & Quality
3.2B€, 17,000 people (3,400 R&D) in 50 countries
MSC /e-Xstream is part of Hexagon MI (Digital Thread)

DIGIMAT Technology
Bridging the gap between the manufacturing process and the structural finite element analysis

- Digimat offers interfaces to all key FE solvers (process & structure)

Process



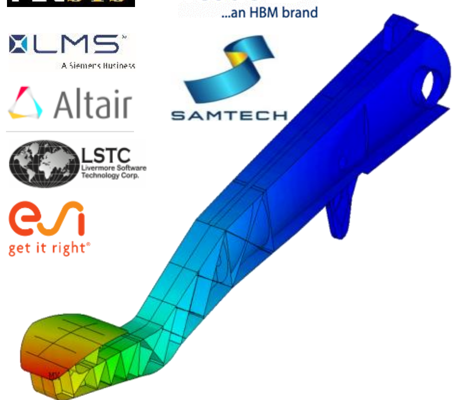
Multi-Processes
Injection molding,
Compression molding
Drape molding, RTM
Metal Casting
CT scanning

Material

Phase Materials
Composite Microstructure
- Fiber Orientation
- Fiber Shape
- Fiber Weight Fraction
- Fiber Length Distribution
- Porosity

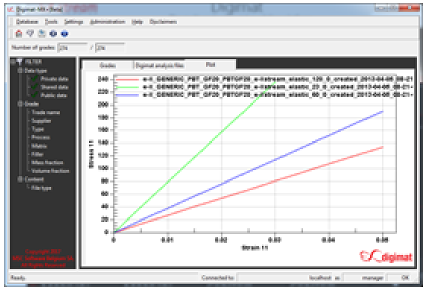
Flexible
Supports all key process and structural FE solver on the market

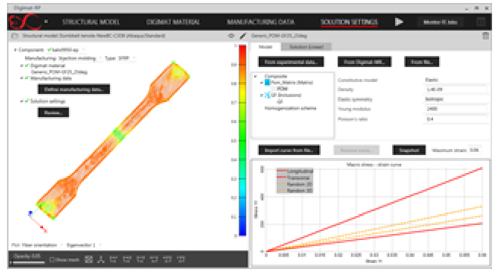
Structure

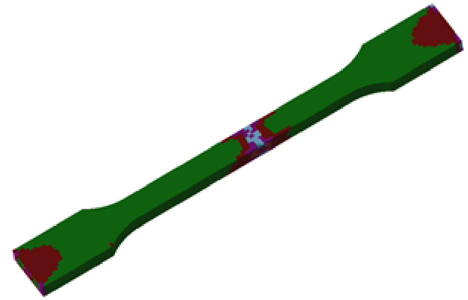


Multi-Performances
Static, Crash, Durability, NVH

Linear solution background
Entry level Digimat solution for SFRP structural analysis



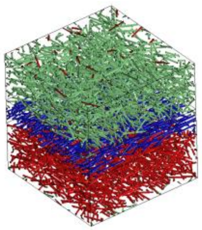


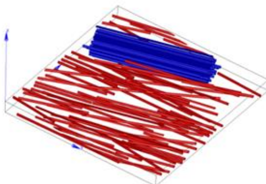


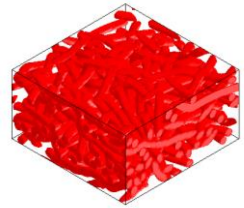
MF / MX	RP GUI / MAP / CAE/Structural CAE/Linear	FEA
Material engineering	As-manufactured structural analysis prepro	FEA run

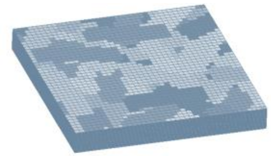
- **Methodology**
  - Digimat-RP writes native FEA orthotropic material cards corresponding to the local fiber orientation tensor family
  - Limitation: linear (thermo-)elasticity and single component only

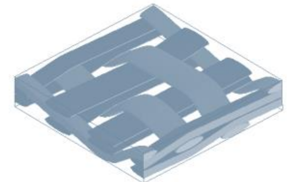
Technology integration in Digimat-RP solution
New: As of 2018.0

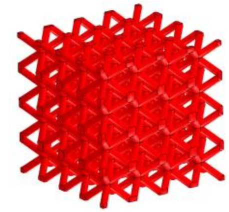












SFRP / injection molding
- Fiber orientation
- Weldlines
- Residual stresses

LFRP / injection molding
- Fiber orientation
- Fiber volume fraction
- Fiber length
- Weldlines

SFRP / MicroCellular
- Fiber orientation
- Porosity volume fraction

SMC / Compression molding
- Fiber orientation
- Fiber volume fraction
- Weldlines
- Fiber waviness

DFC / Compression molding
- Chip orientation
- Chip volume fraction
- Chip waviness

CFRP / Draping, RTM, AFP
- Fiber orientation
- Porosity

Unfilled & reinforced polymer / AM
- Toolpath
- Residual stresses

Agenda

Example 1: Oil Filter Module
Digimat User Interface Screenshot

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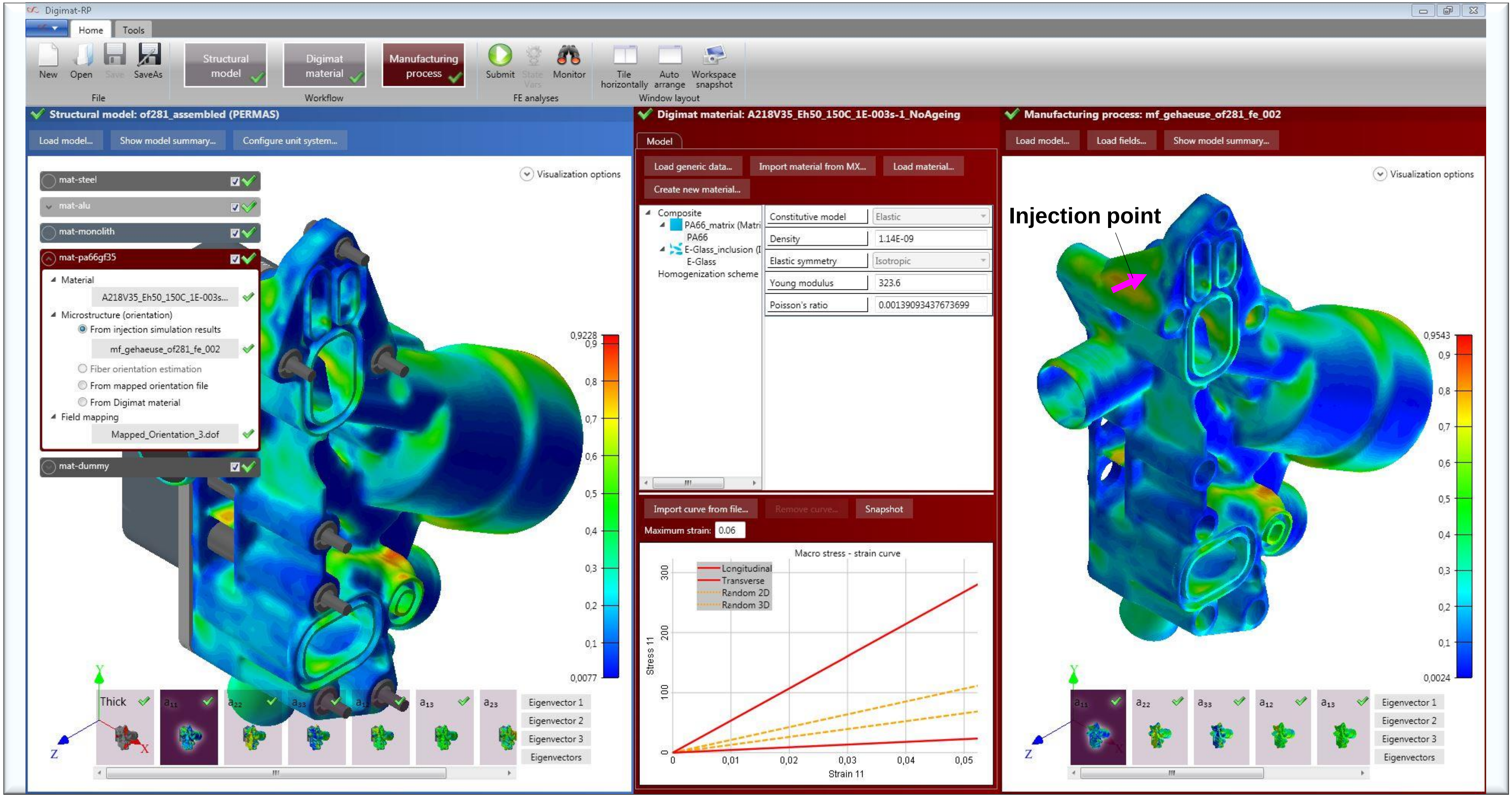

PERMAS-DIGIMAT interface

Example 1: Oil Filter Module

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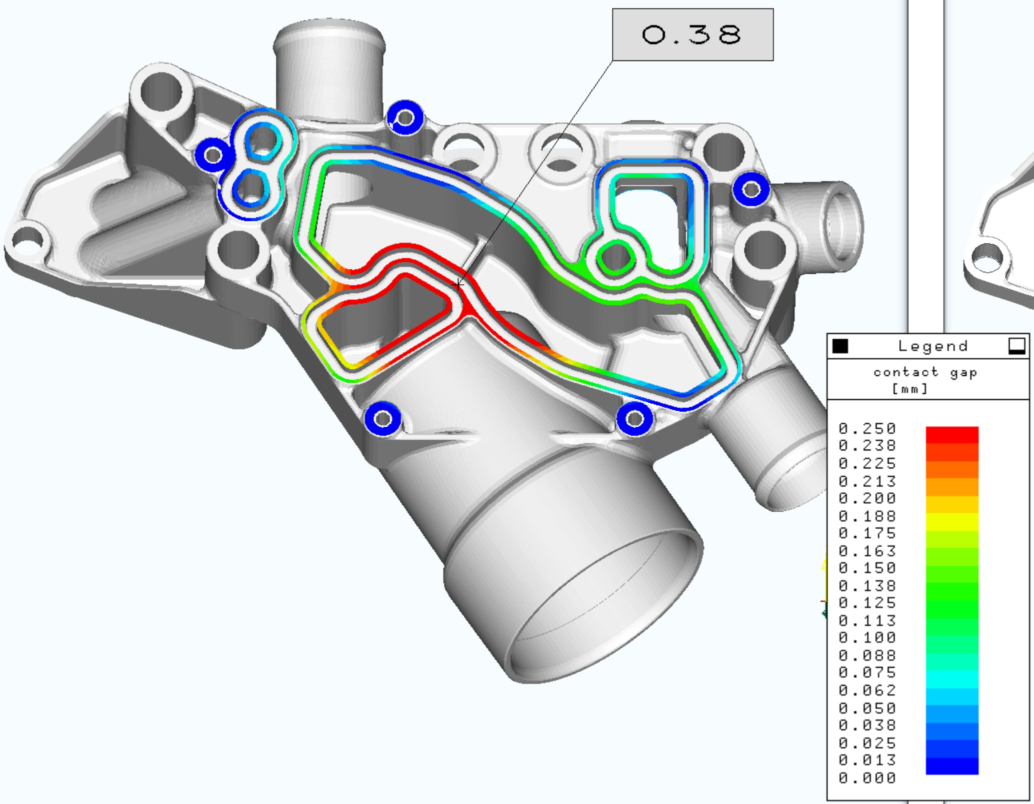
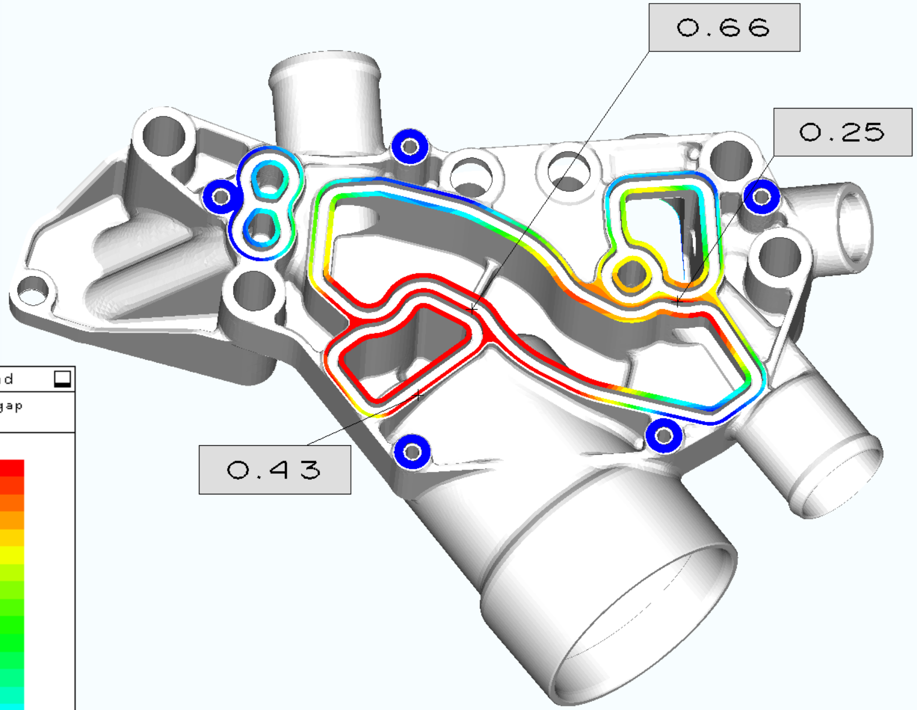
Driven by performance

Isotropic material	Anisotropic material
Contact gap [mm]	Contact gap [mm]





PERMAS-DIGIMAT interface

Example 2: Pressurized Oil Filter Cap

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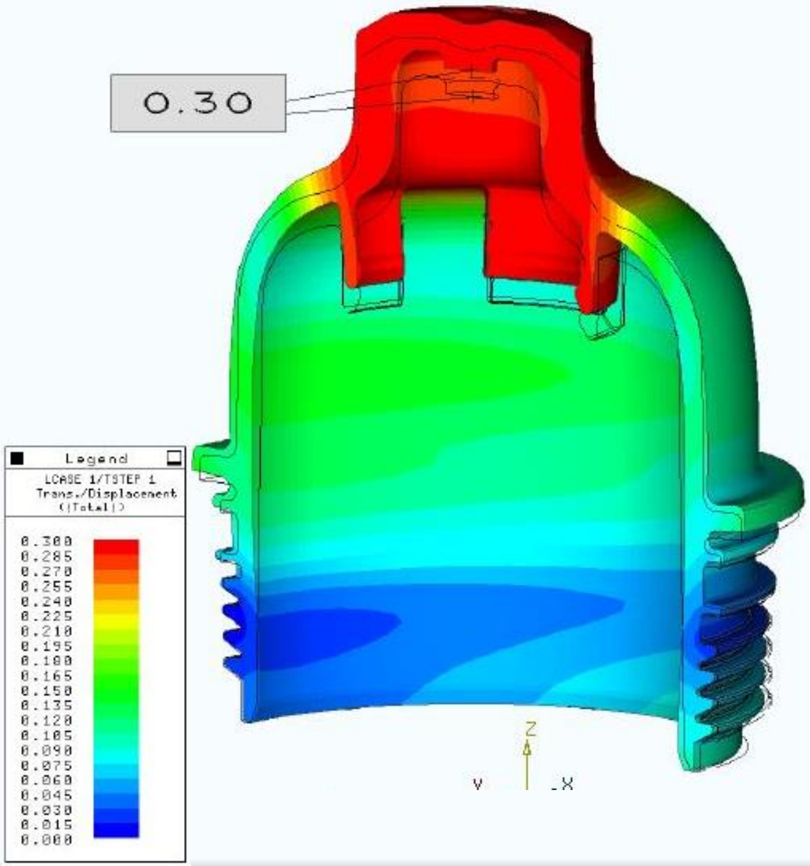
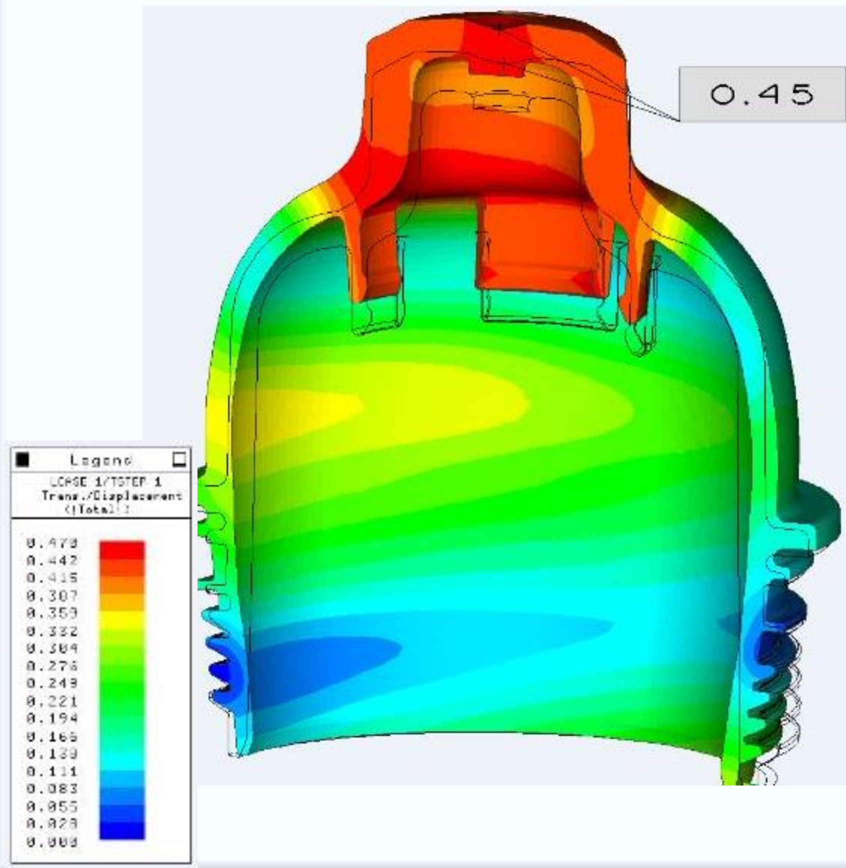
Isotropic material	Anisotropic material
Deformation [mm]	Deformation [mm]



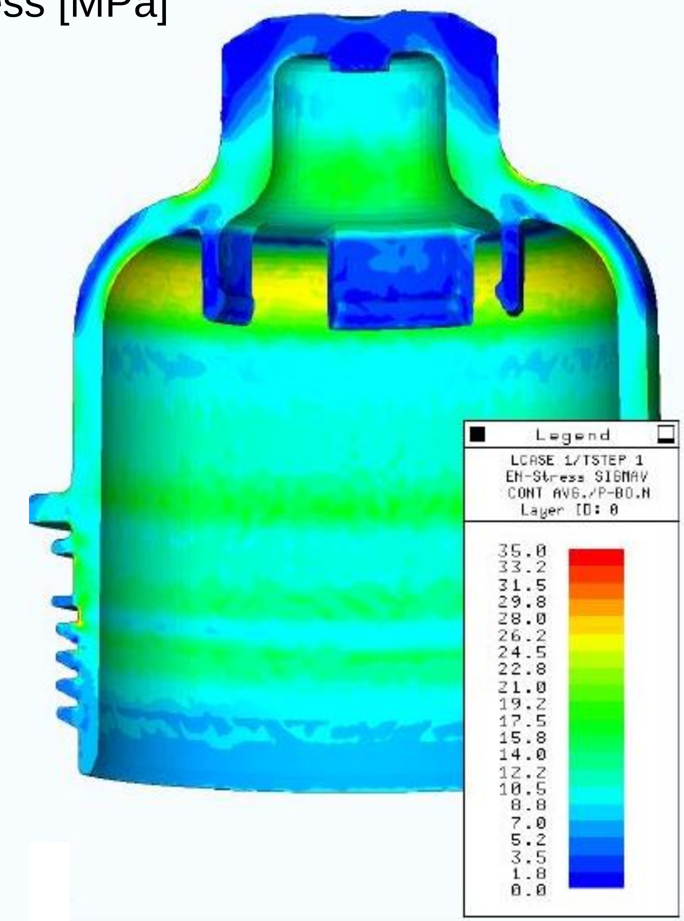


Example 2: Pressurized Oil Filter Cap

Driven by performance

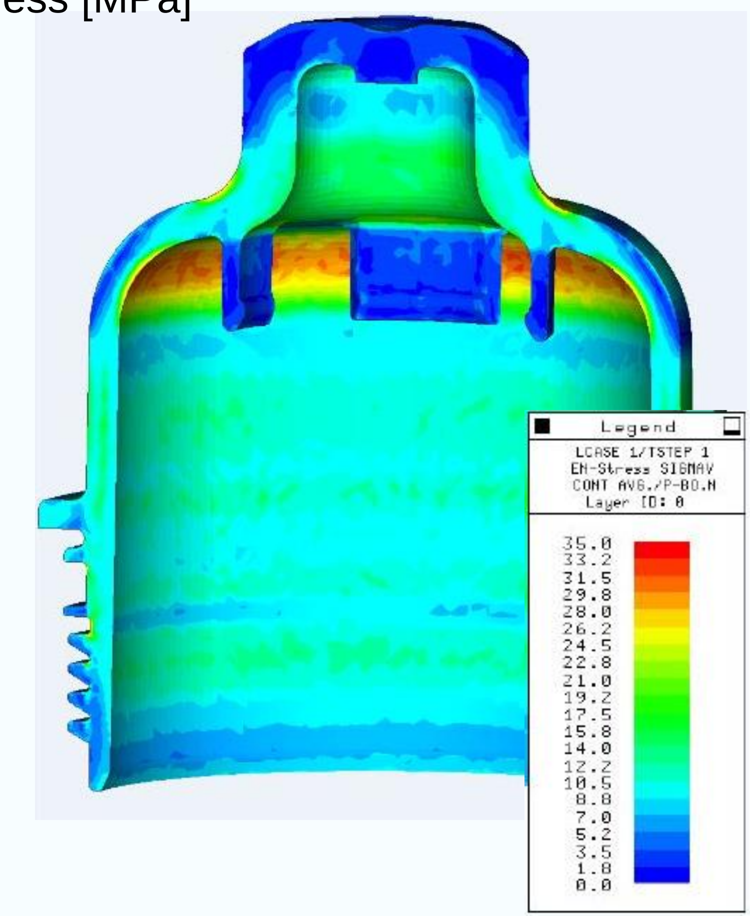
Isotropic material

Stress [MPa]



Anisotropic material

Stress [MPa]



Example 3: Thermal Expansion of a Valve Cover
Free Thermal Expansion

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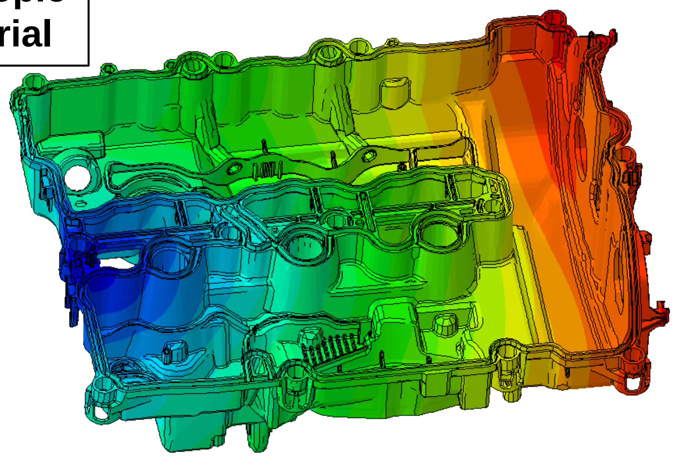
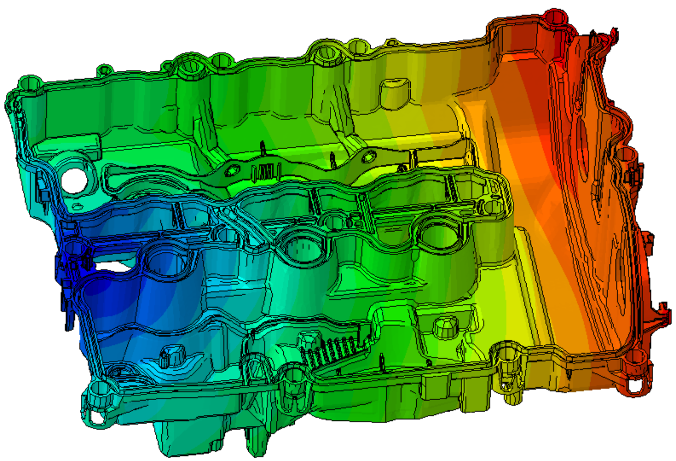
Isotropic material



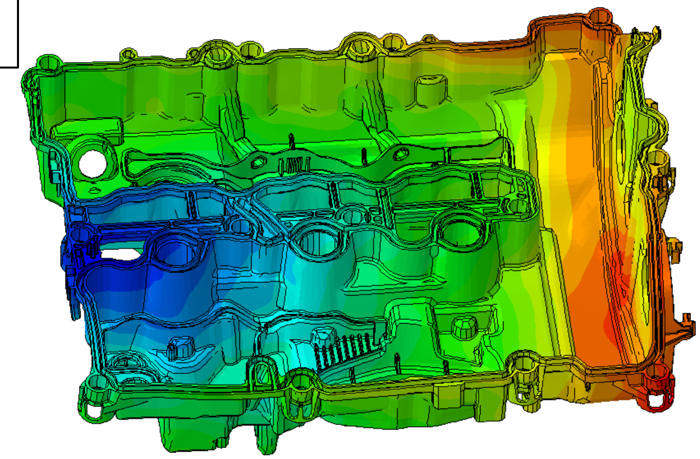
T=-40°C



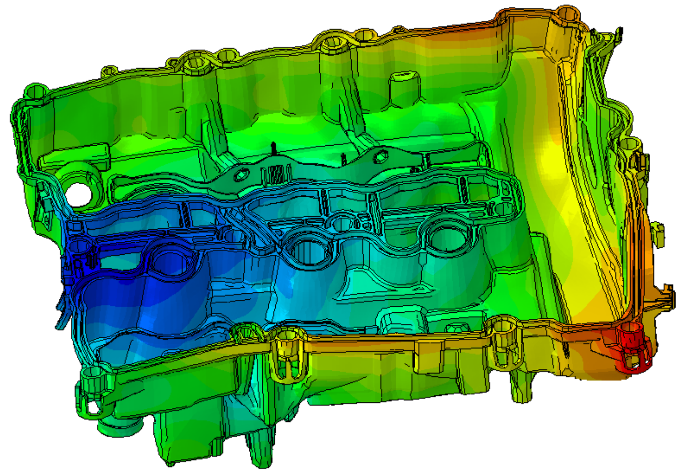
T=150°C

➢Deformation overscaled

Orthotropic material



T=-40°C



T=150°C

Example 3: Thermal Expansion of a Valve Cover
Mounted Thermal Expansion

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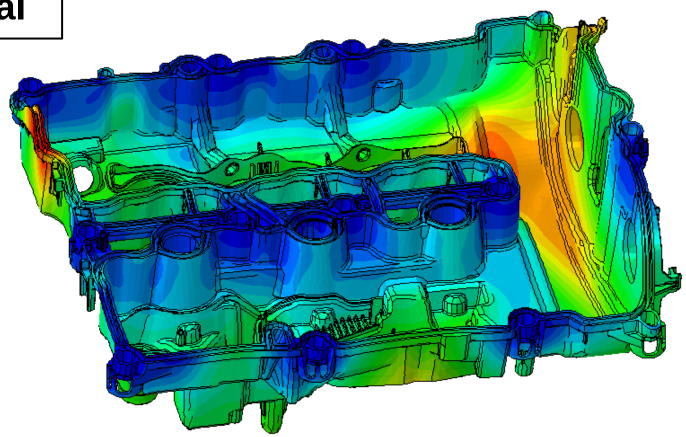
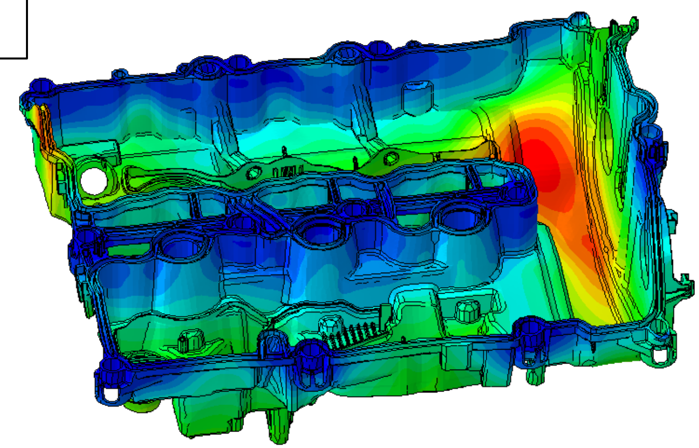
Isotropic material



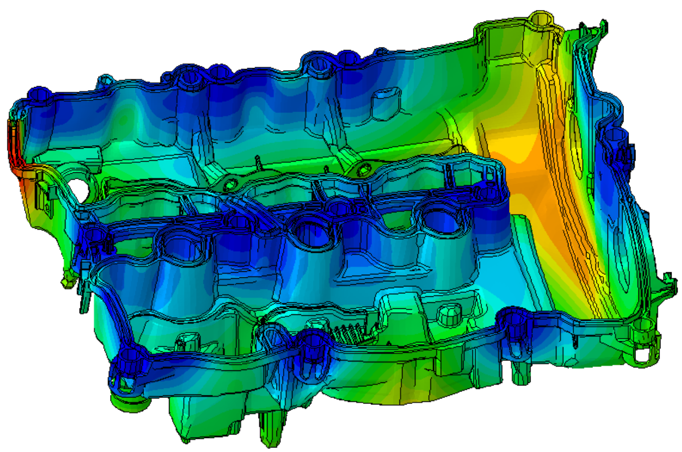
T=-40°C

Orthotropic material

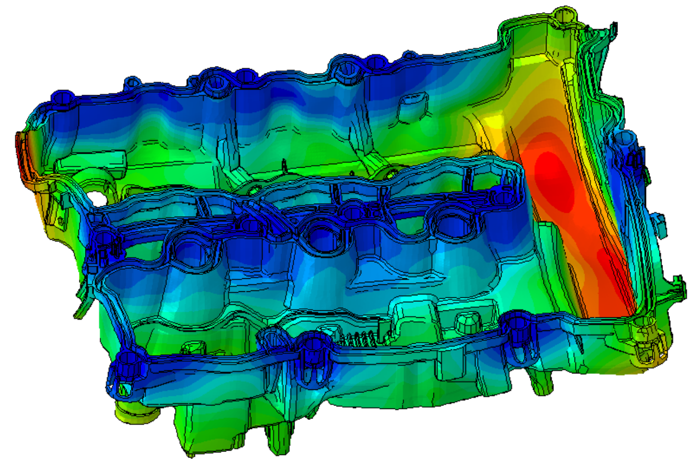


T=-40°C

➢Deformation overscaled



T=150°C



T=150°C

Example 3: Thermal Expansion of a Valve Cover

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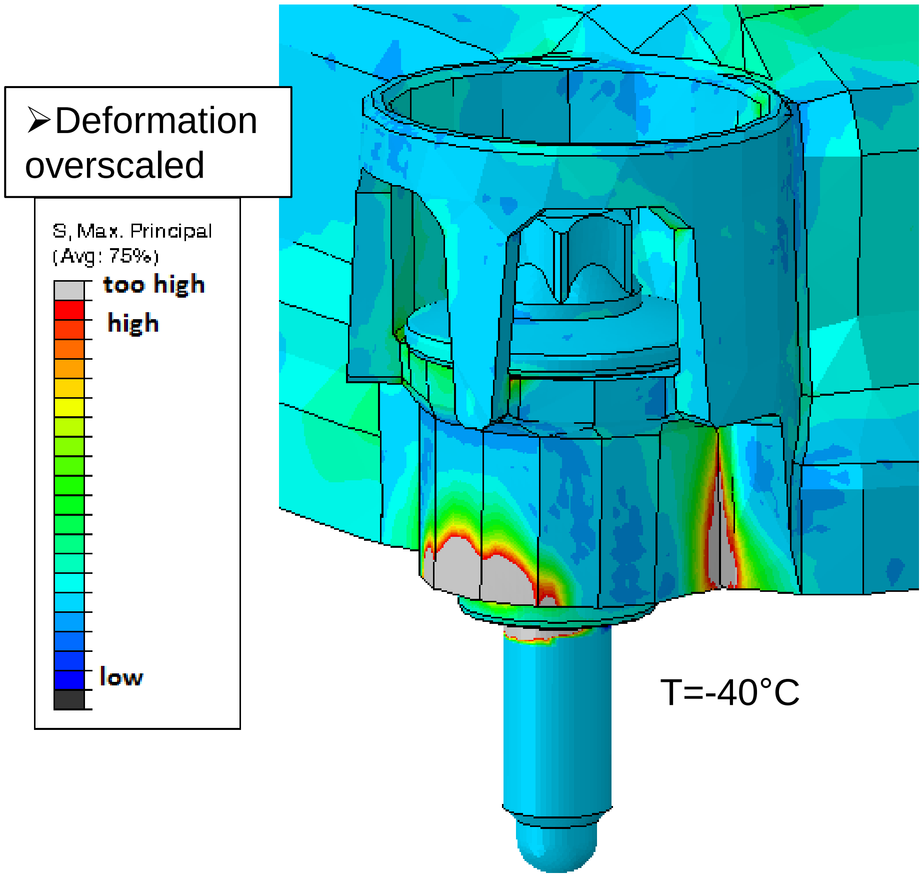
Thermo Cycle Test results

Integrative simulation results

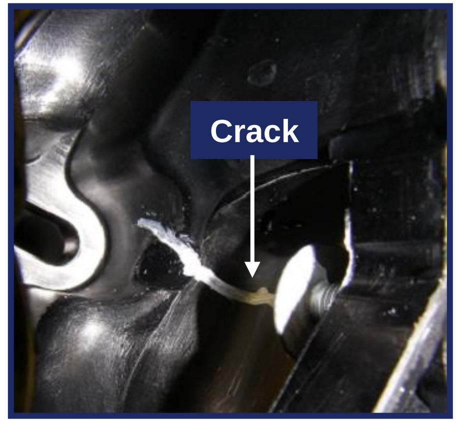
➢Deformation overscaled



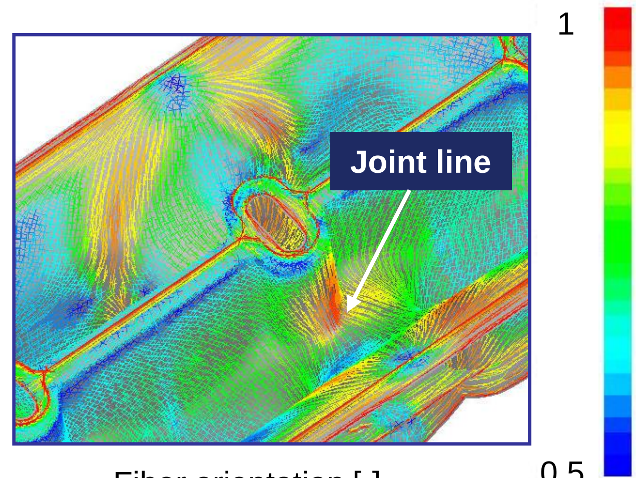
Example 4: Burst test of Intake Module Failure Criterion

For static simulations a target for maximum stress is no longer applicable

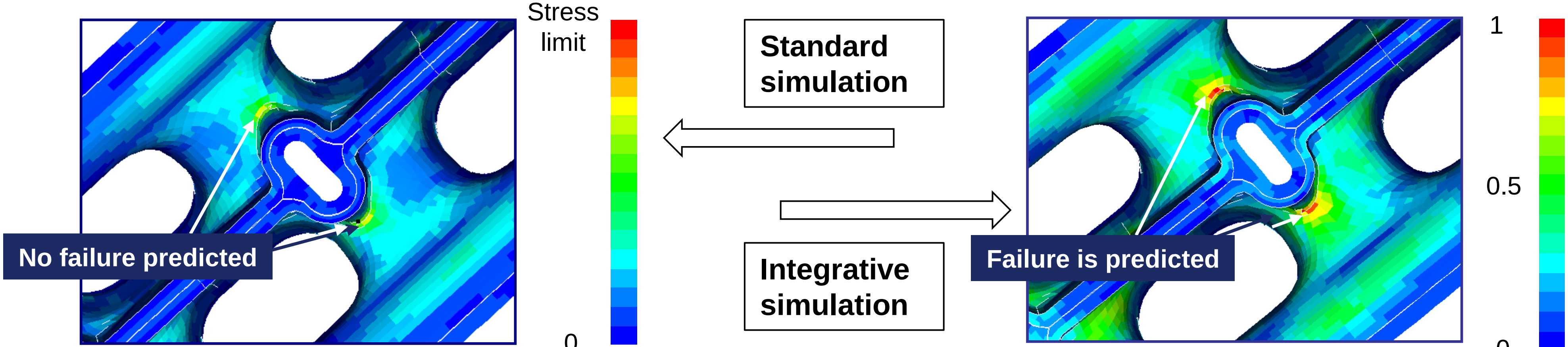
Definition of failure criterion is required



Crack after burst pressure test



Fiber orientation [-]



Principal stress [MPa]

Tsai-Wu failure criterion [-]

Example 5: Fatigue

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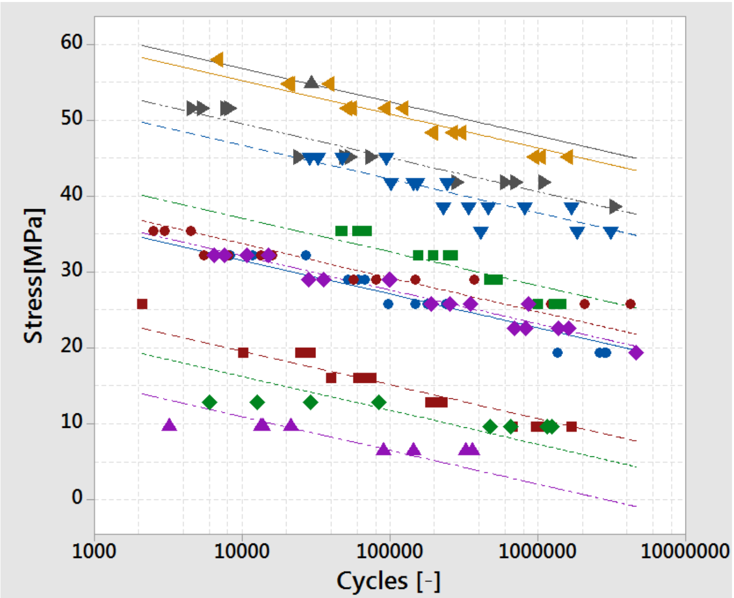
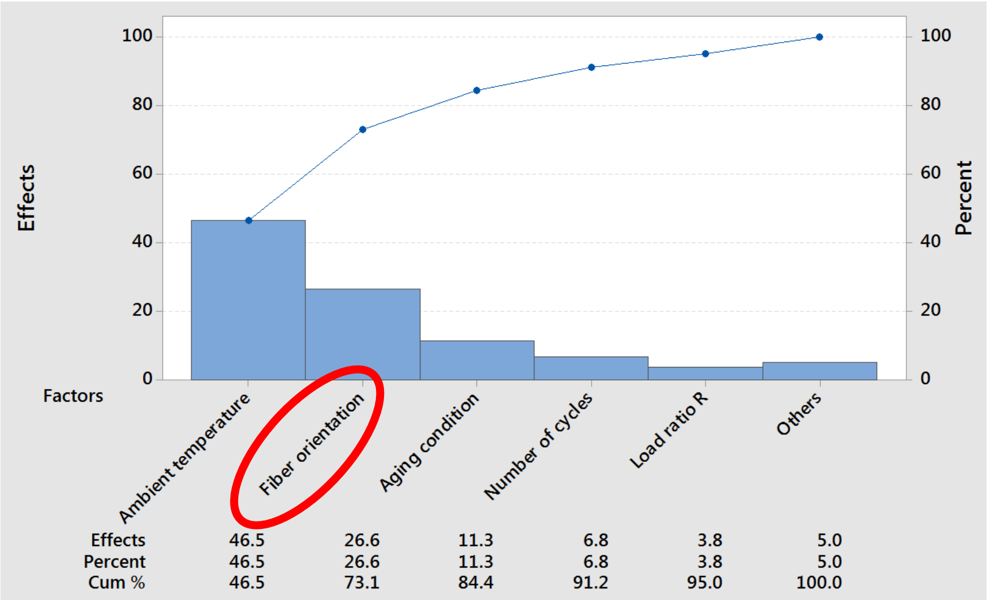
Orthotropic material models for FRP components are mandatory for fatigue evaluation



Regression analyses



Woehler curves of a PA66GF35
Dependent on temperature,
aging condition and fiber orientation

Influences on fatigue limit

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Summary

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- Integrative simulation for plastic components improves the simulation accuracy
- SFRP material properties for static analyses are mostly included in the DIGIMAT database
- PERMAS interface is currently available for linear thermo-elastic properties
- Enhancement of PERMAS interface to non-linear material behavior planned within 2018
- Further simulation tasks (fatigue, crash, creep…) require specific data to feed the material models

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Questions?