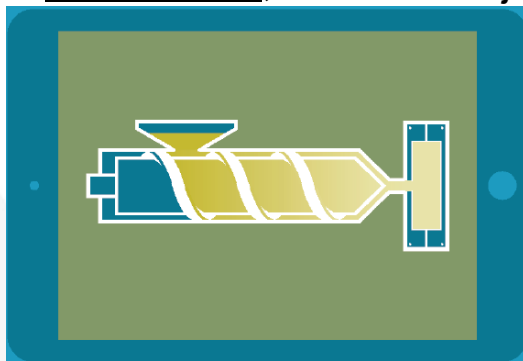


Simulation von kurz- und langfaserverstärkten Kunststoffen mit LS-DYNA

P. Reithofer, A. Fertschej (4a engineering GmbH)



26. Leobener Kunststoff-Kolloquium

Innovative Spritzgießtechnologie
Trends und aktuelle Entwicklungen

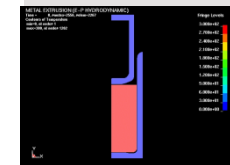
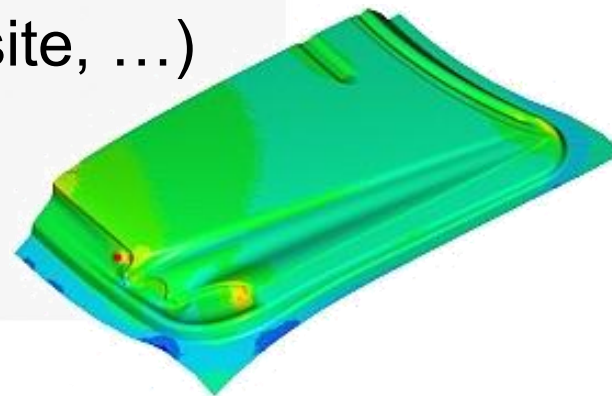
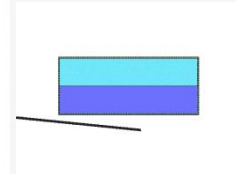
20. - 21. April 2017

- Einleitung
- Materialmodelle
- Dynamische Materialcharakterisierung
- Case Study
- Zusammenfassung

Einleitung

LS-DYNA – Ein Code für viele Anwendungen

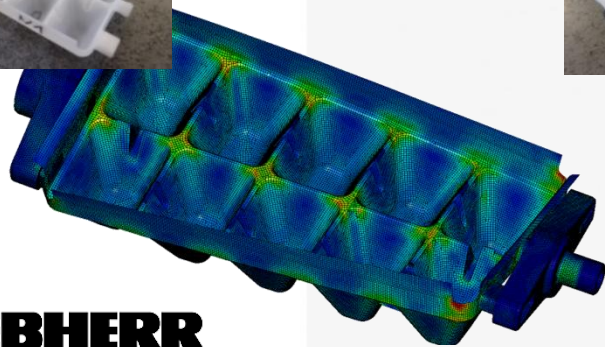
- **Expliziter** und impliziter Solver
- Nichtlinear – Kontakt, Material
- Multiphysics
- Anwendungen
 - Crash Simulation
 - Drop Tests
 - Verarbeitungssimulation
 - Umformen (Metall, Composite, ...)
 - Composite Halbzeug
 - CFD
 -



Einleitung Kunststoffe – zeitabhängiges Materialverhalten



Quelle: <http://mobiwatch.de>



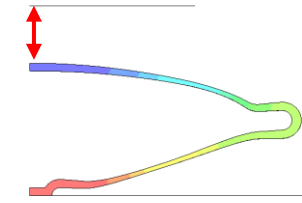
LIEBHERR



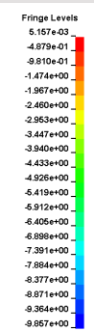
FLEXIMA®
feel the comfort.at

3 Tage

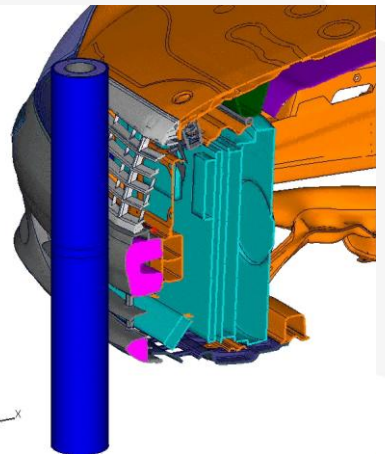
9.8 mm



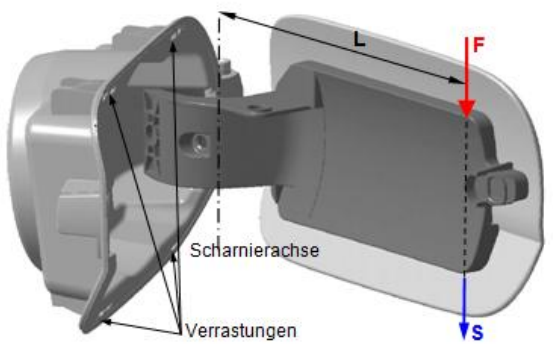
Quelle: [Wimmer, TT 2012](#)



μs ms s min h t w y



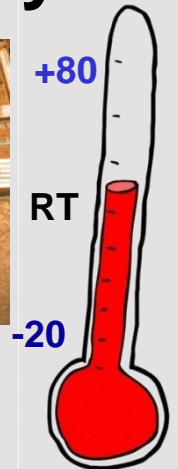
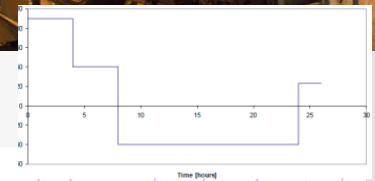
Quelle: [Kolling, TT 2010](#)



Quelle: [Gramling, TT 2012](#)

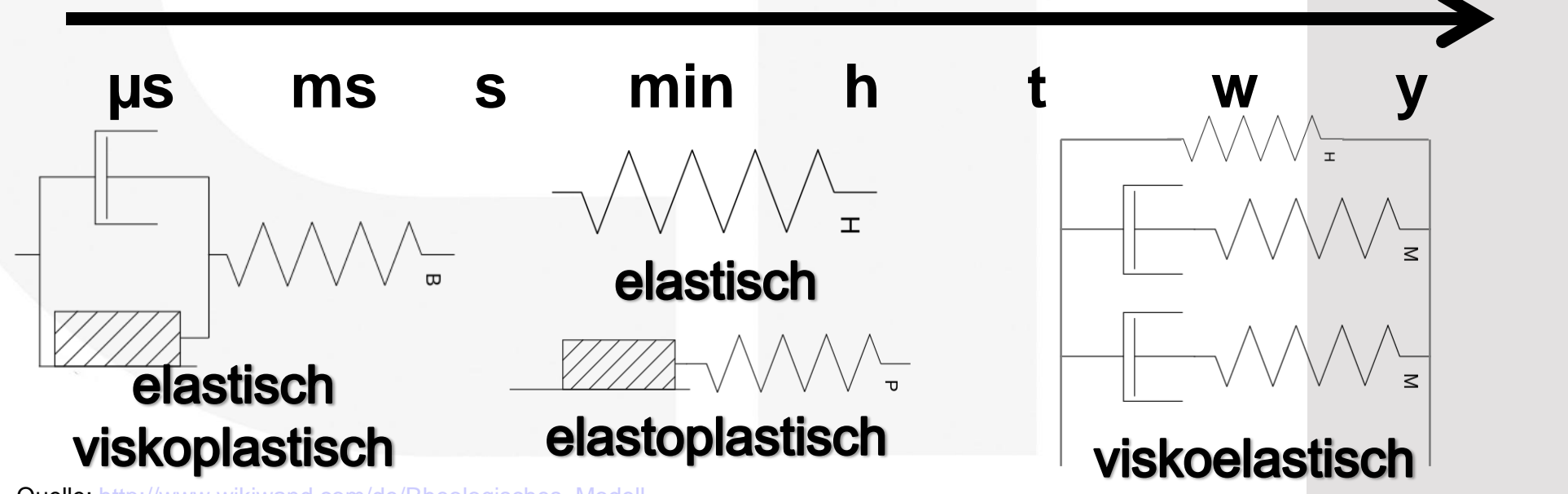
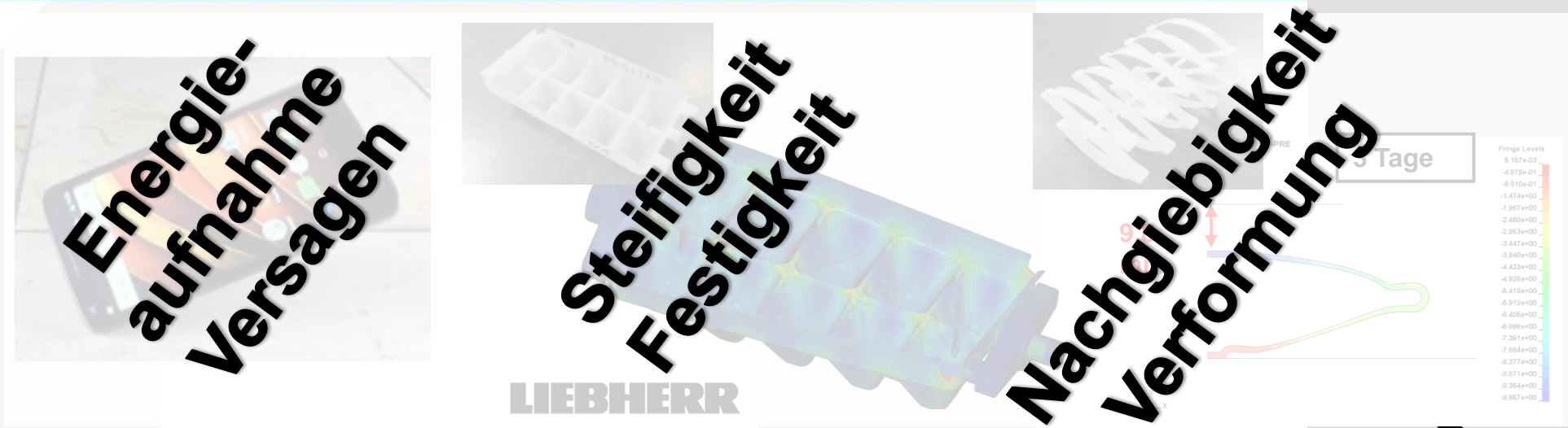


Quelle: <http://www.rad-ab.com/tag/opel-astra/>



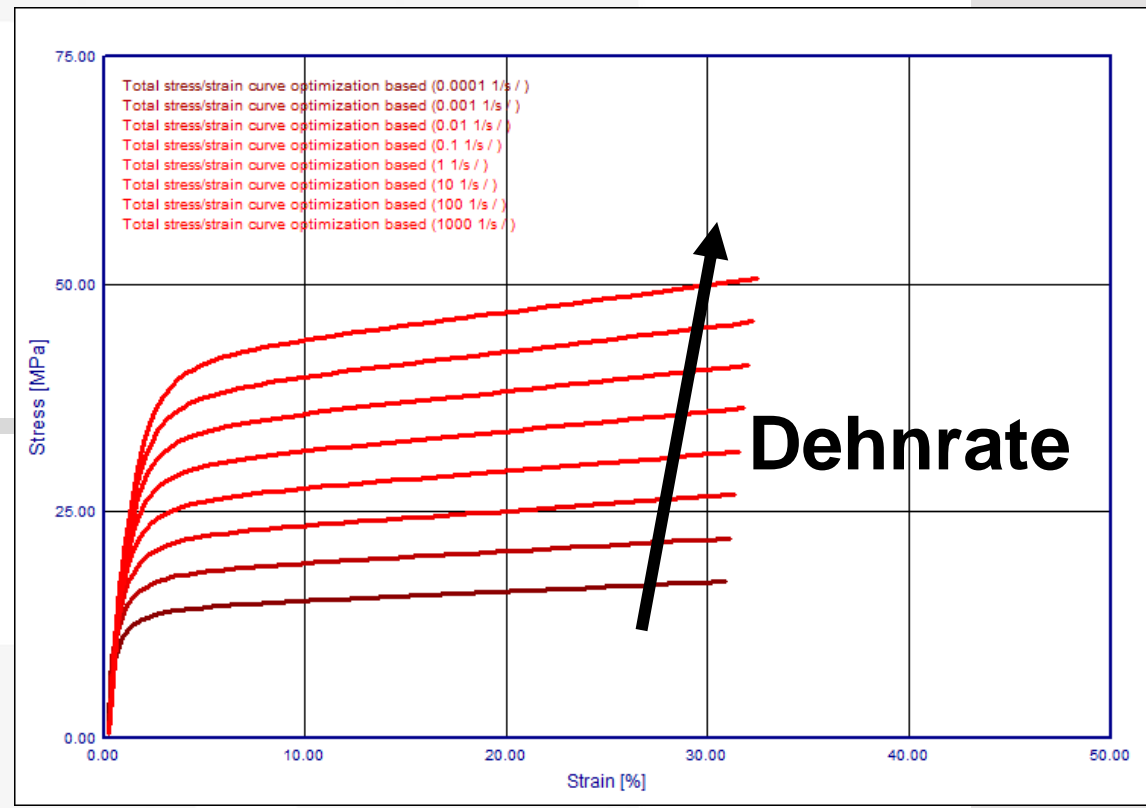
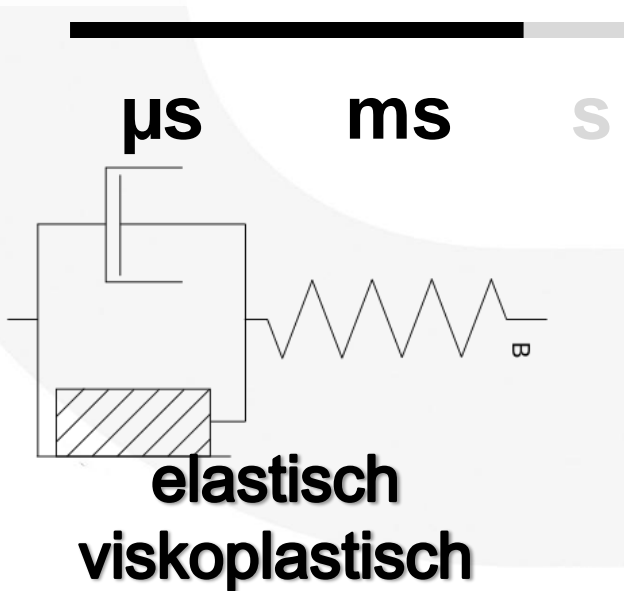
Einleitung

Kunststoffe – zeitabhängiges Materialverhalten



Quelle: http://www.wikiwand.com/de/Rheologisches_Modelle

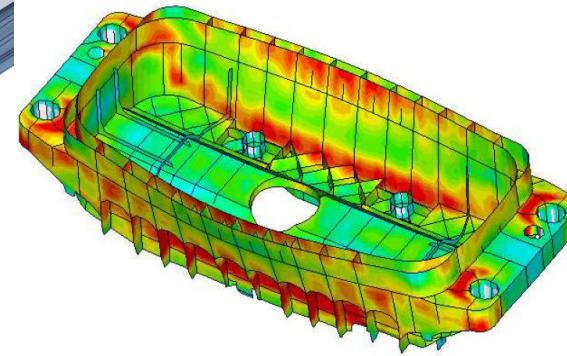
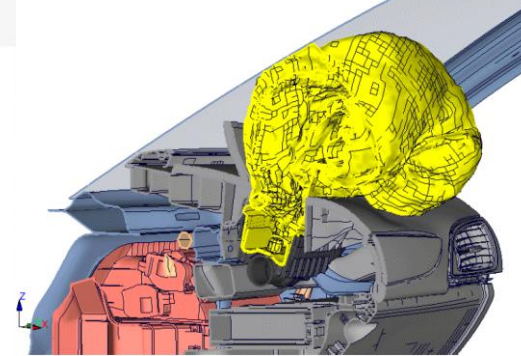
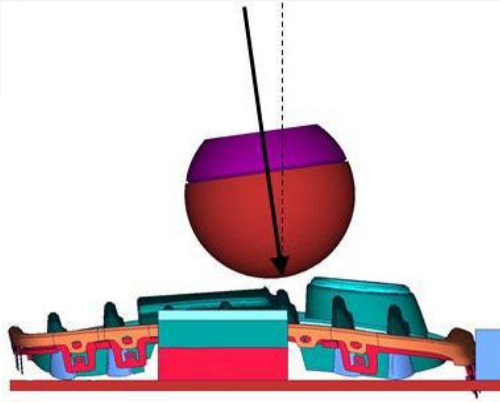
**Energie-
aufnahme
Versagen**



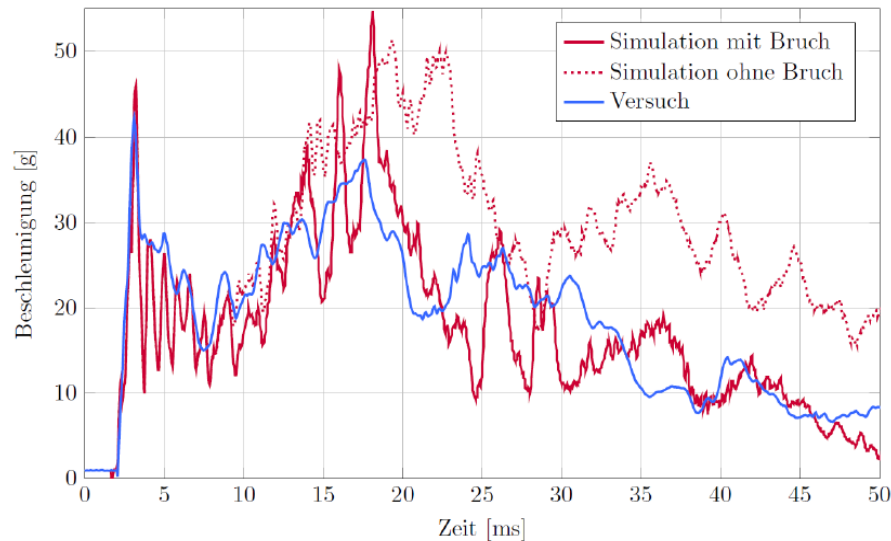
Quelle: http://www.wikiwand.com/de/Rheologisches_Modell

Fußgängerschutz - Kopfimpaktor

Insassenschutz - Airbagmodul



Bildquelle: R. Luijckx, Audi AG: *Pragmatische Vorgehensweise bei der Materialkartenerstellung von glasfaserverstärkten Kunststoffmaterialien, TT11 Schladming*



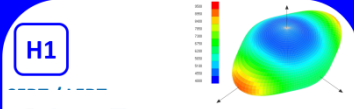
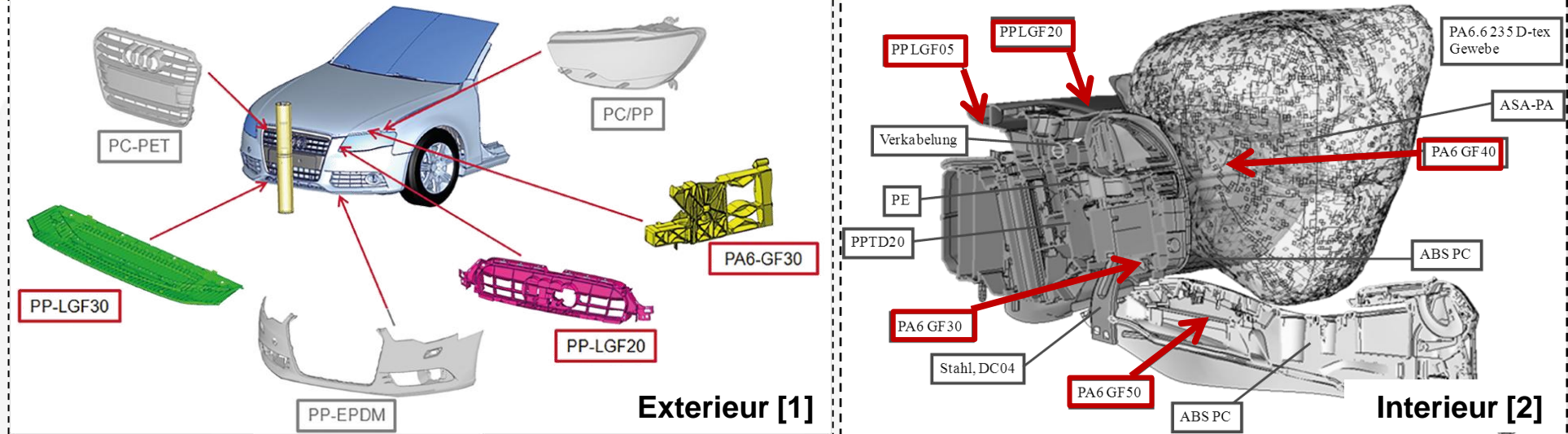
Bildquelle: H. Staack, Audi AG: *Anforderungsgerechte Material- und Bruchmodellierung für die Fahrzeugsicherheit, TT16 Schladming*



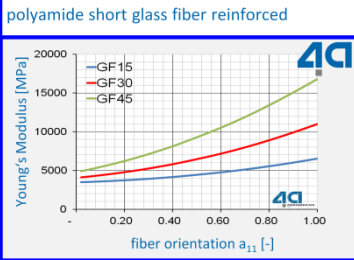
Bildquelle: R. Luijckx, Audi AG: *Kunststoffmaterialverhalten - Anforderungen an die virtuelle Abbildung, TT12 Schladming*

Einleitung

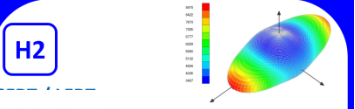
Kunststoffe – Einsatzgebiete Automotive



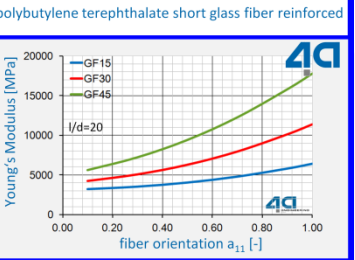
H1
PA6GF30



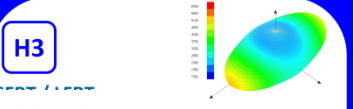
P: 3.4 €/kg	ρ : 1.4 g/cm ³
E_1 : 9700 MPa	α_1 : 64·10 ⁻⁶ 1/K
σ_y : 140 MPa	ϵ_B : 4%
T_G : 50 °C	a_c : 100(15) kJ/m ²



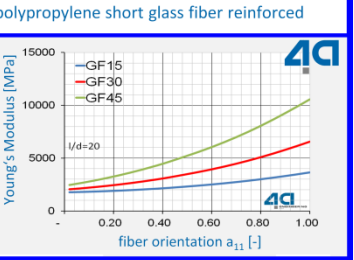
H2
PBTGF30



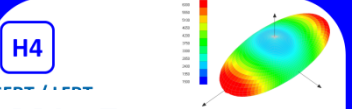
P: 3 €/kg	ρ : 1.5 g/cm ³
E_1 : 9500 MPa	α_1 : 25·10 ⁻⁶ 1/K
σ_y : 92 MPa	ϵ_B : 3%
T_G : 30 °C	a_c : 67(11) kJ/m ²



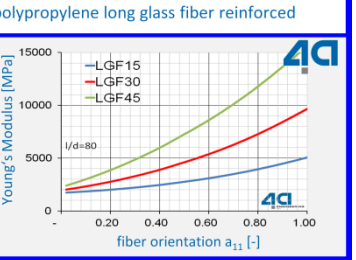
H3
PPGF30



P: 2.3 €/kg	ρ : 1.1 g/cm ³
E_1 : 6000 MPa	α_1 : 38·10 ⁻⁶ 1/K
σ_y : 70 MPa	ϵ_B : 4%
T_G : -10 °C	a_c : 20(5) kJ/m ²



H4
PPLGF30



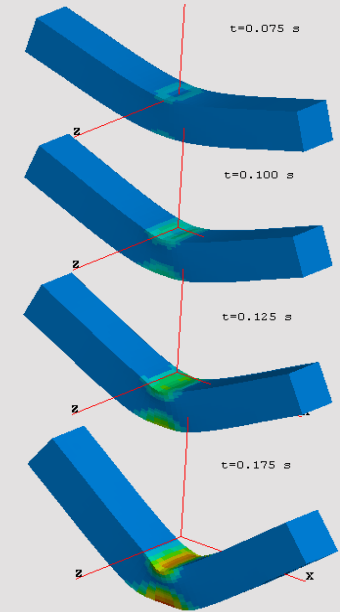
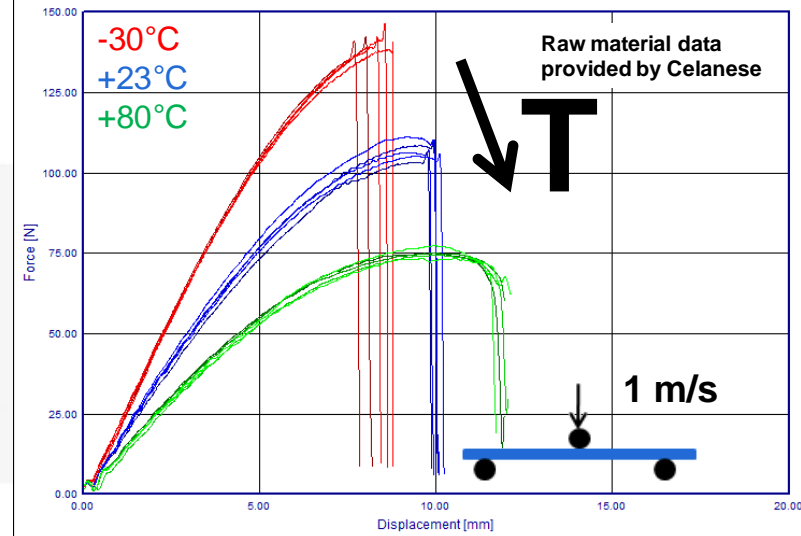
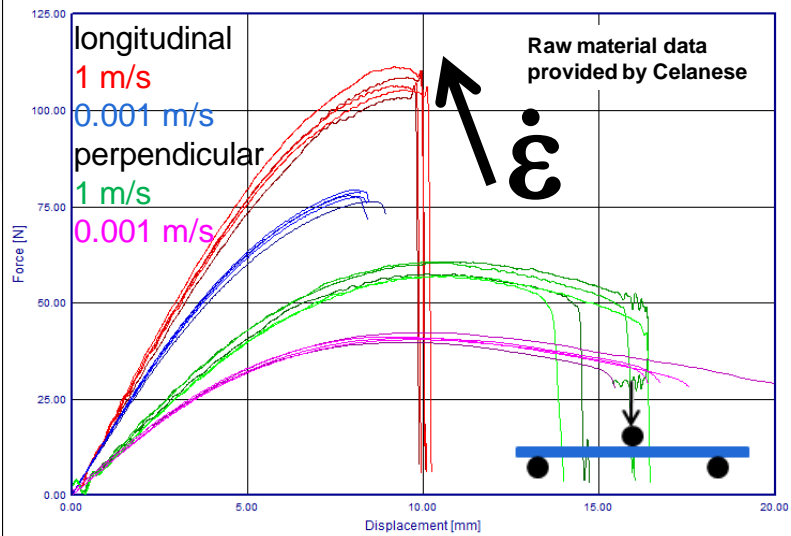
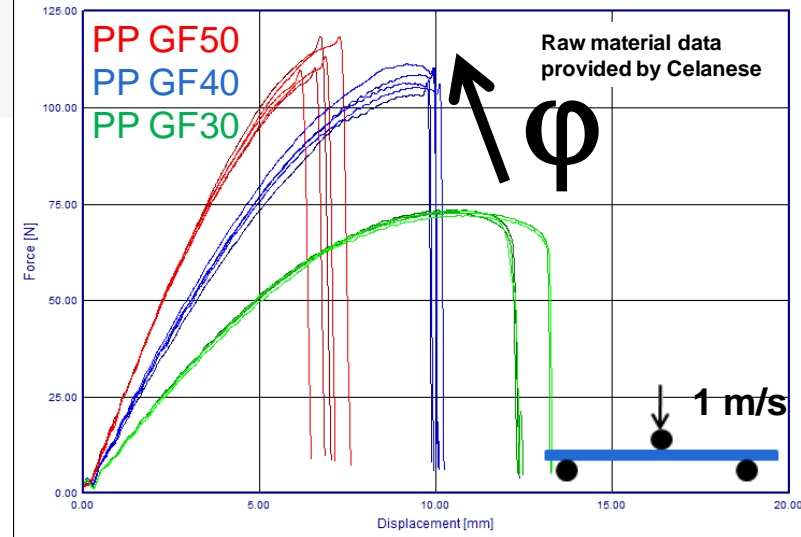
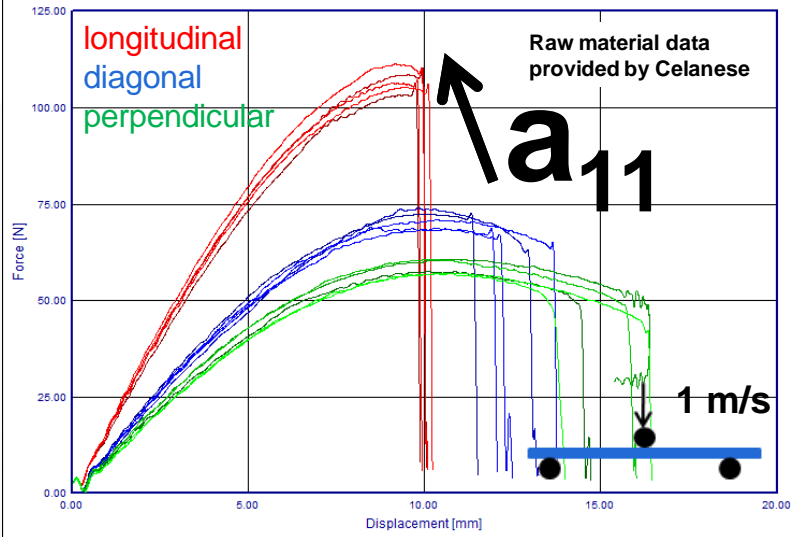
P: 2.5 €/kg	ρ : 1.1 g/cm ³
E_1 : 6900 MPa	α_1 : 40·10 ⁻⁶ 1/K
σ_y : 76 MPa	ϵ_B : 5%
T_G : -10 °C	a_c : 70(18) kJ/m ²

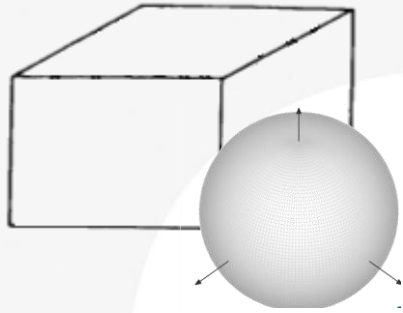
[1] A. Koukal, Audi AG - *Crash- und Bruchverhalten von Kunststoffen im Fußgängerschutz von Fahrzeugen*, TU München, 2014

[2] R. Luijckx, Audi AG - *Kunststoffmaterialien in der Interieur Funktionsauslegung bei Audi AG, 4a* Technologietag 2010

Einleitung

Kunststoffe – Einfluss Faser/Matrix

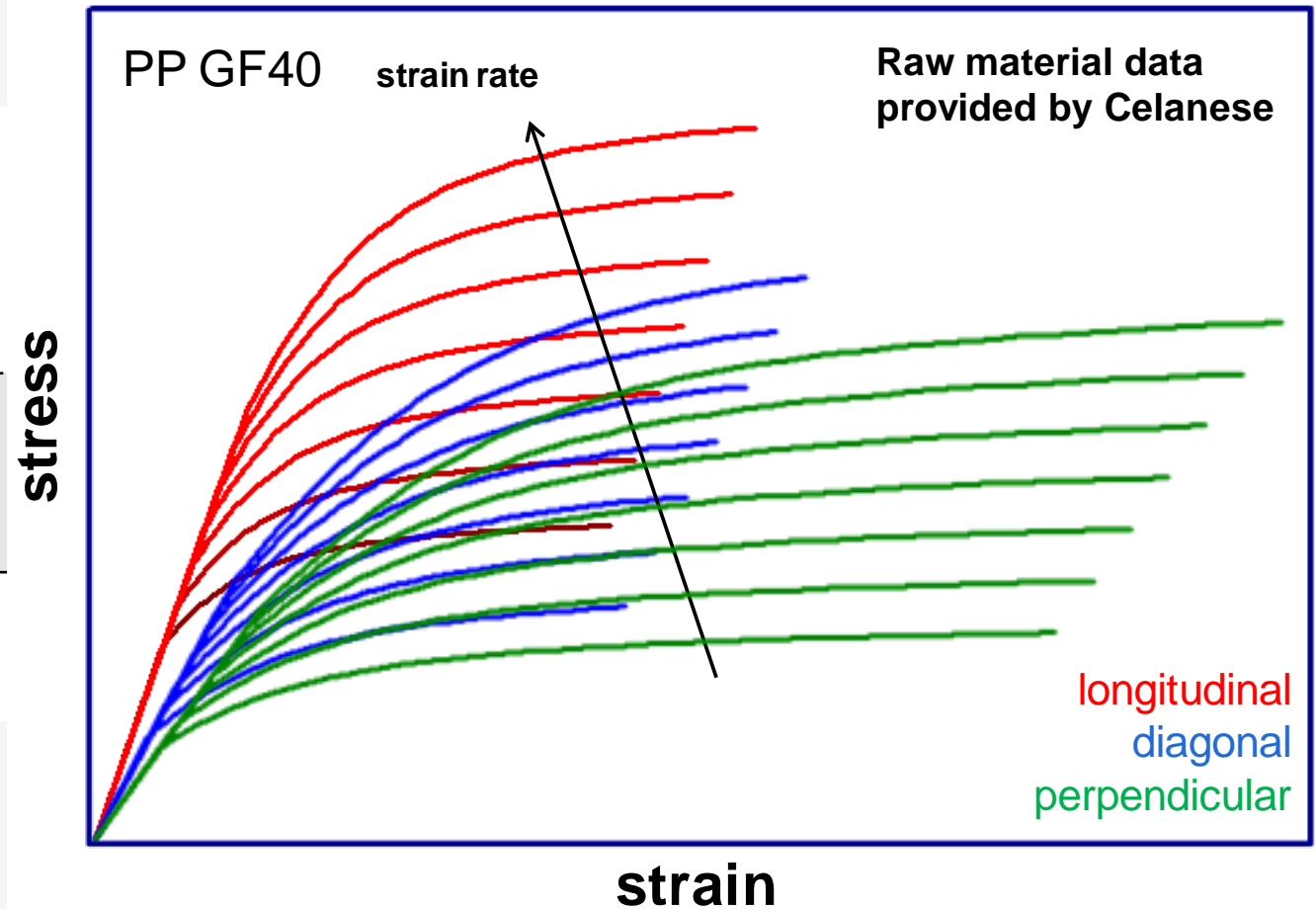
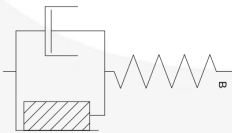


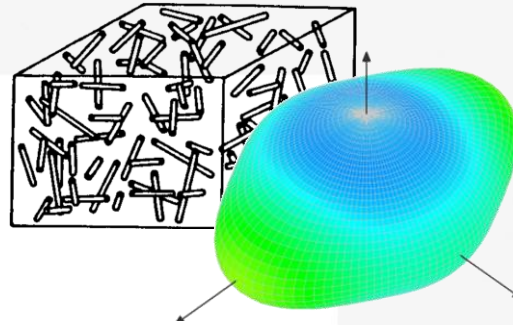
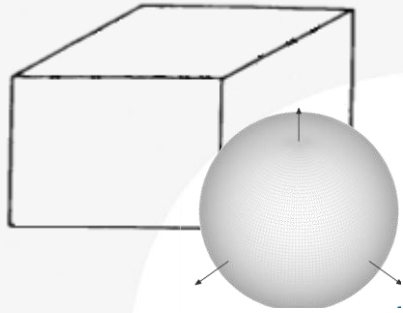


macro scale
constitutive law

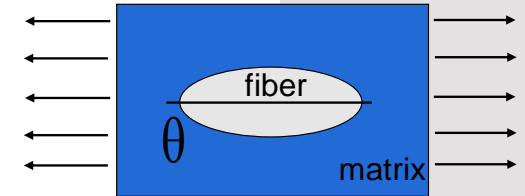
Mises plasticity

- quick & dirty
- critical loading transversal to fiber orientation





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



Eshelby Tensor

macro scale
constitutive law → composition

micro scale
homogenization

Mises plasticity

- quick & d...
- criti...
- orientation

***MAT_024**

elastic

- orthotro...
- anis...

elastic plastic

- city

***MAT_157**

M... matrix

- isotropic elas...
- viscoplast...

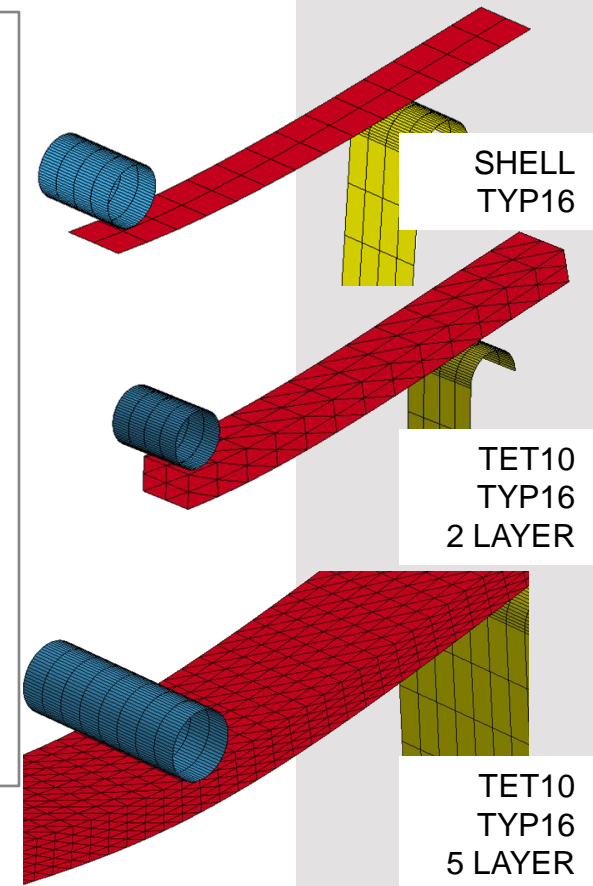
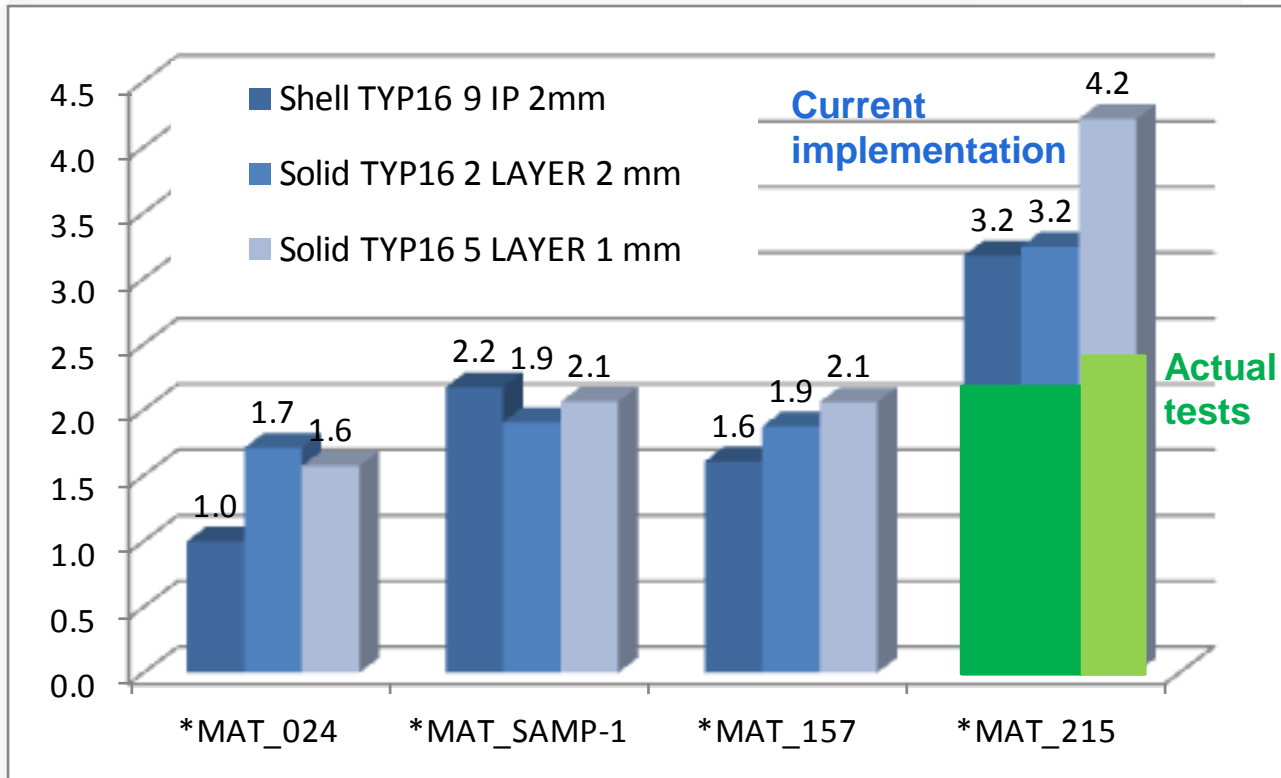
F... fiber

- isotropic

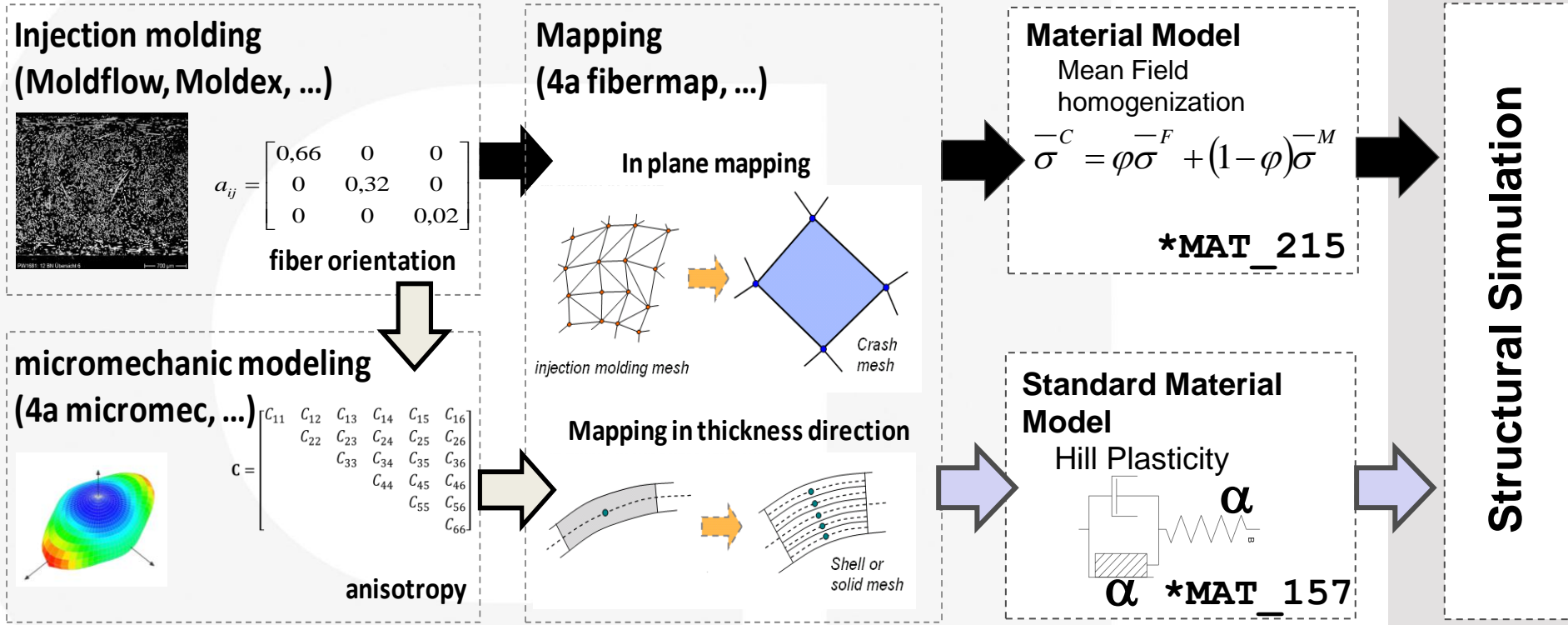
***MAT_215**

α – orientation dependent

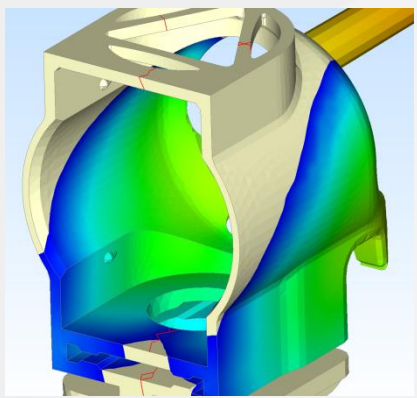
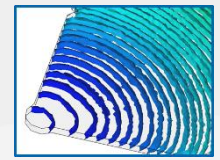
Materialmodelle unterschiedliche Herangehensweisen



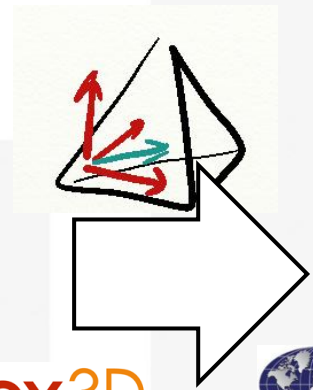
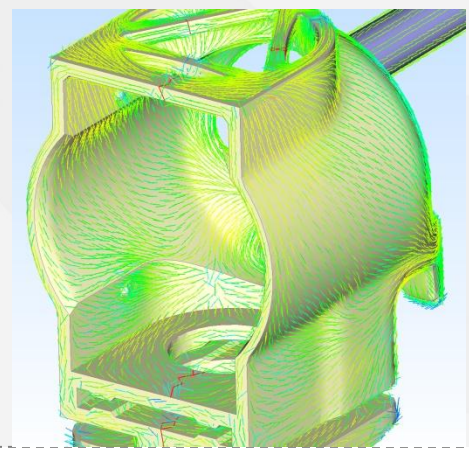
- CPU-Time → große robuste Rechenmodelle
- Abbildungsgenauigkeit



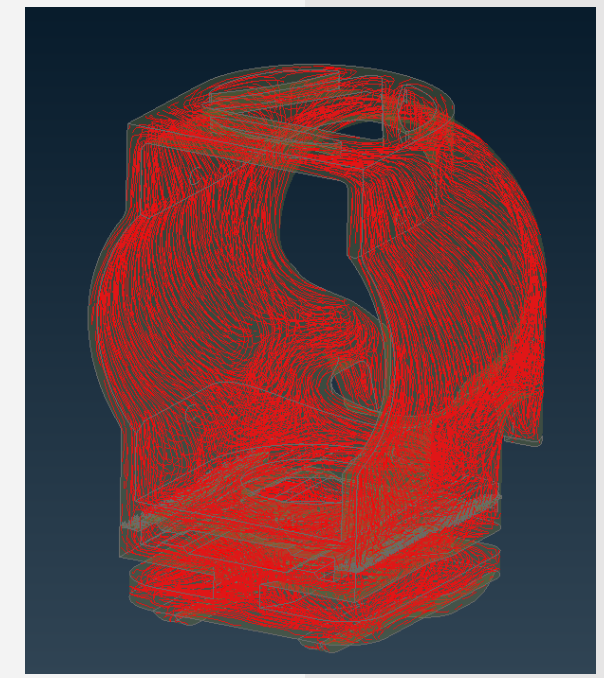
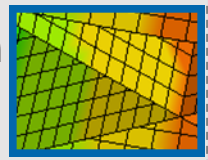
Process simulation Filling



Fiber orientation



Structural simulation Drop test

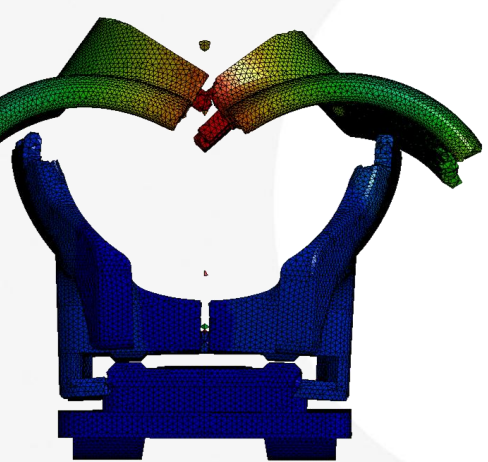


Fiber orientation

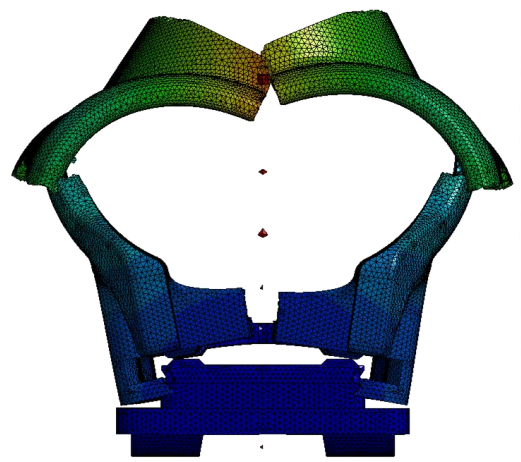
***ELEMENT_SOLID_ORTHO**

more: R. Steinberger, et.al. Hirtenberger Automotive Group – *Considering the Local Anisotropy of Short Fiber Reinforced Plastics*, European Dynaforum 2017 © 4a engineering GmbH, all rights reserved

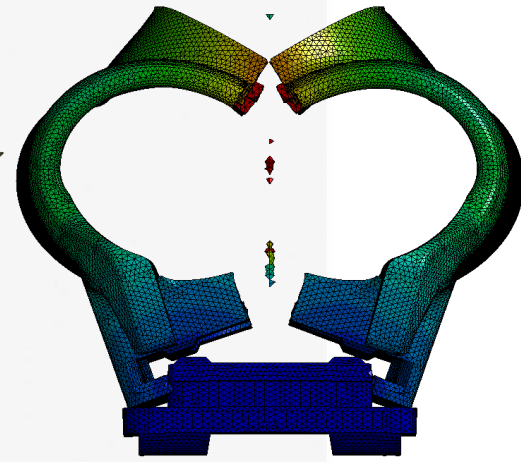
Case study Drop test Sleeve



***MAT_24**
transversal



***MAT_24**
longitudinal



***MAT_215**
local anisotropy



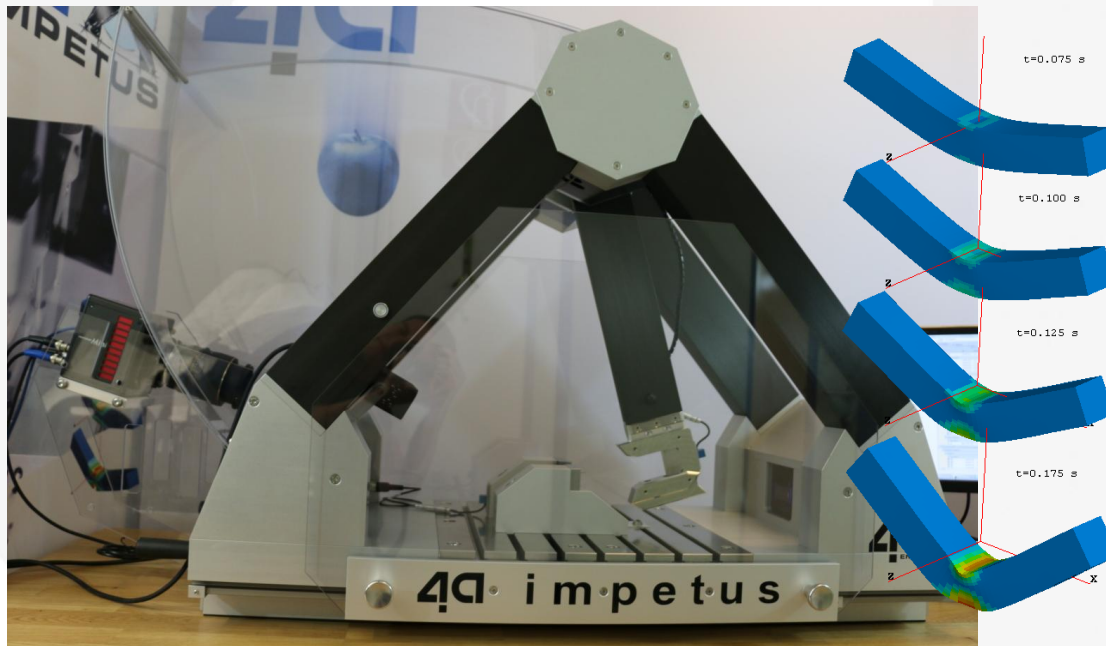
test



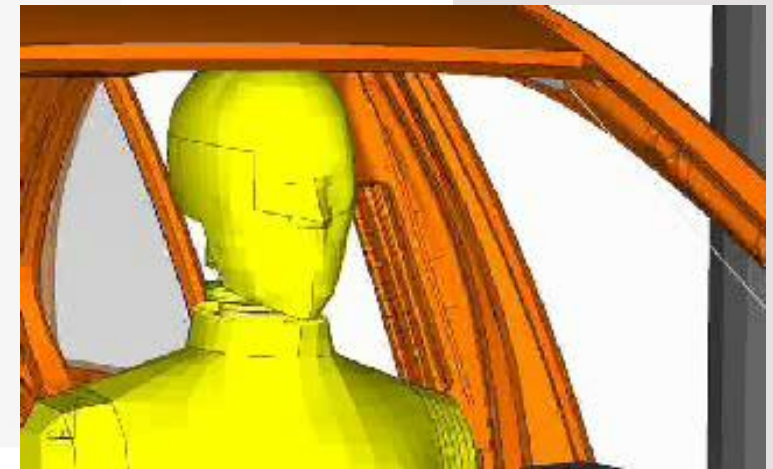
more: R. Steinberger, et.al. Hirtenberger Automotive Group – *Considering the Local Anisotropy of Short Fiber Reinforced Plastics, European Dynaforum 2017*

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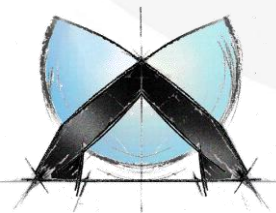
- efficient high-dynamic testing
- crash-behavior of plastics
- material data for simulation



Quelle: <http://gm-volt.com/>



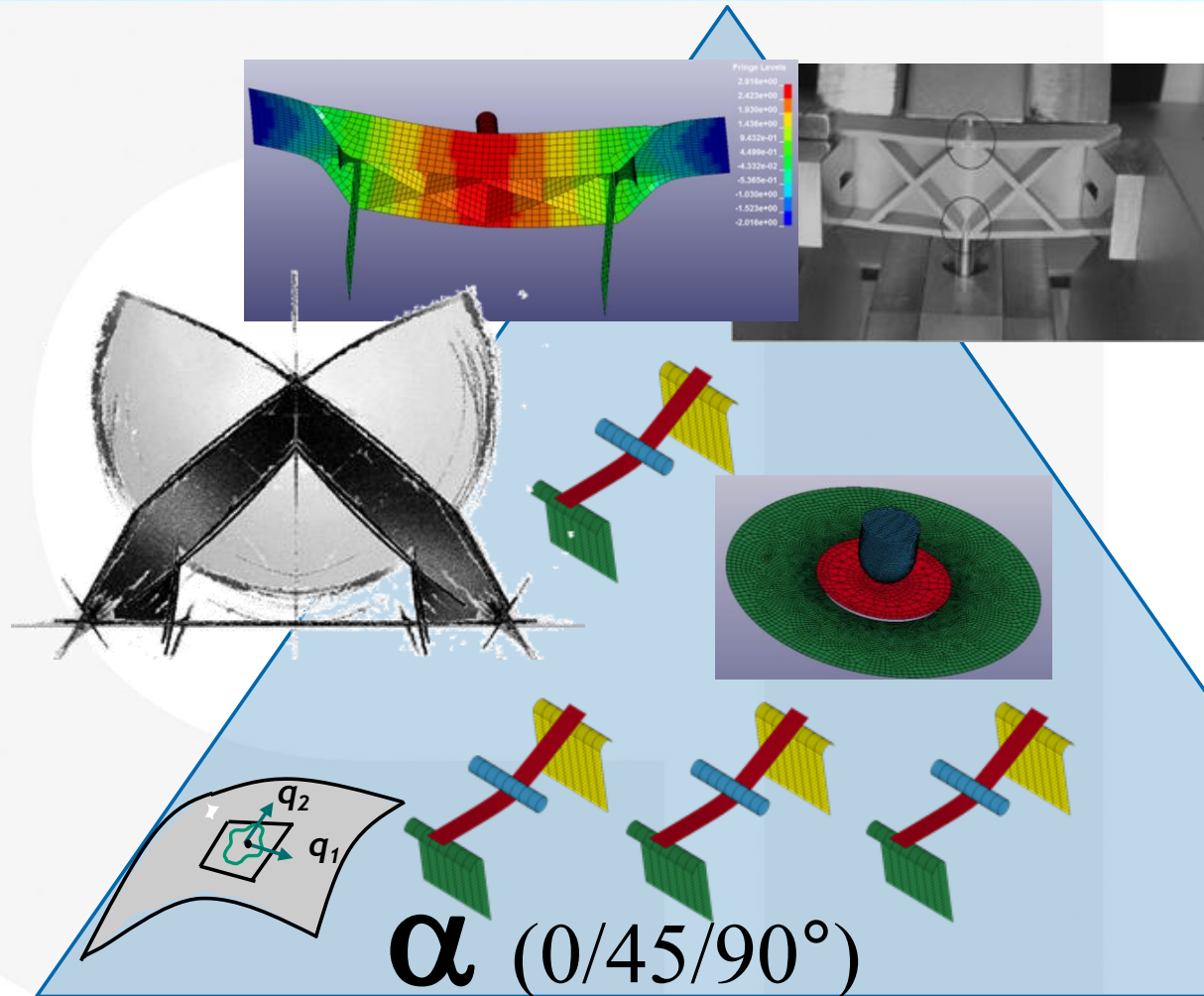
Quelle: [Dynamore](#)



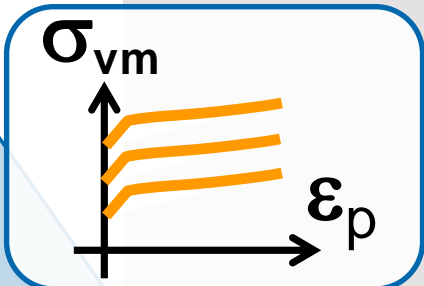
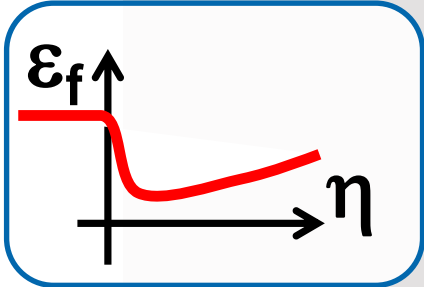
**4a impetus - intelligent testing systems
powered by 4a engineering GmbH**

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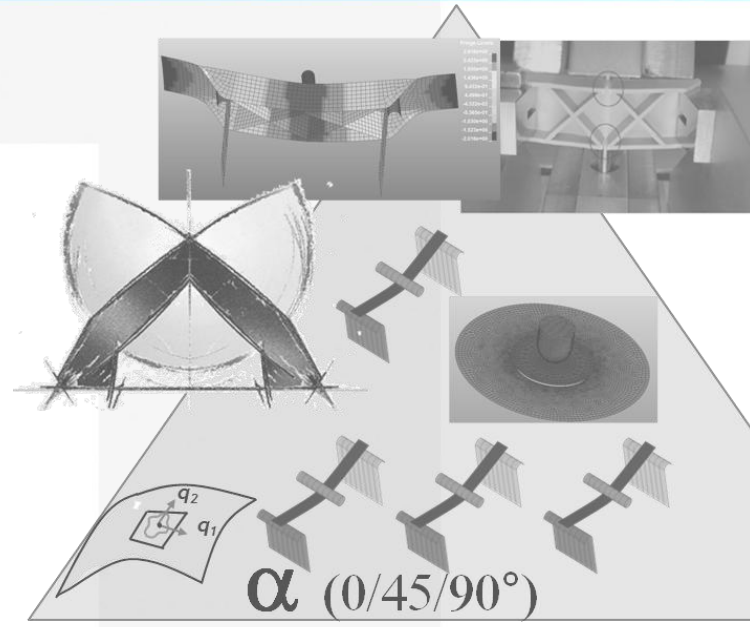
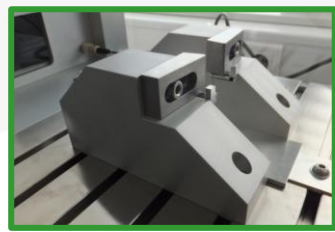
Dynamische Materialcharakterisierung Charakterisierungspyramide – SFRT & LFRT



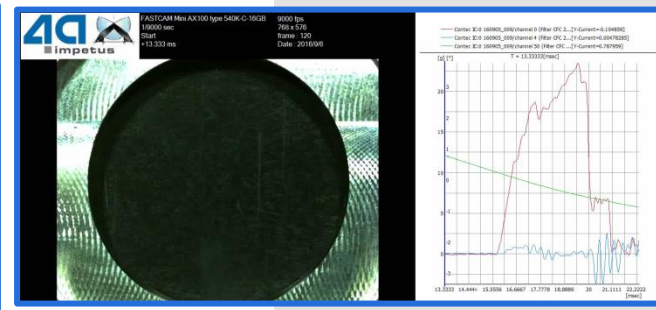
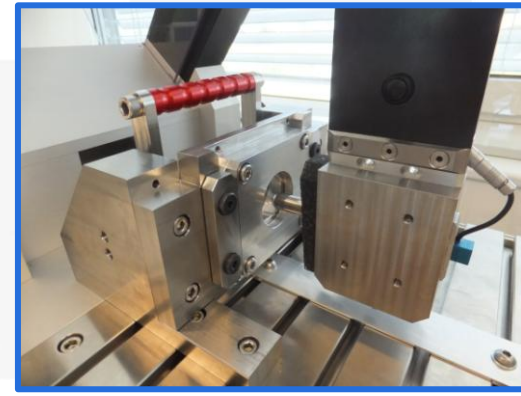
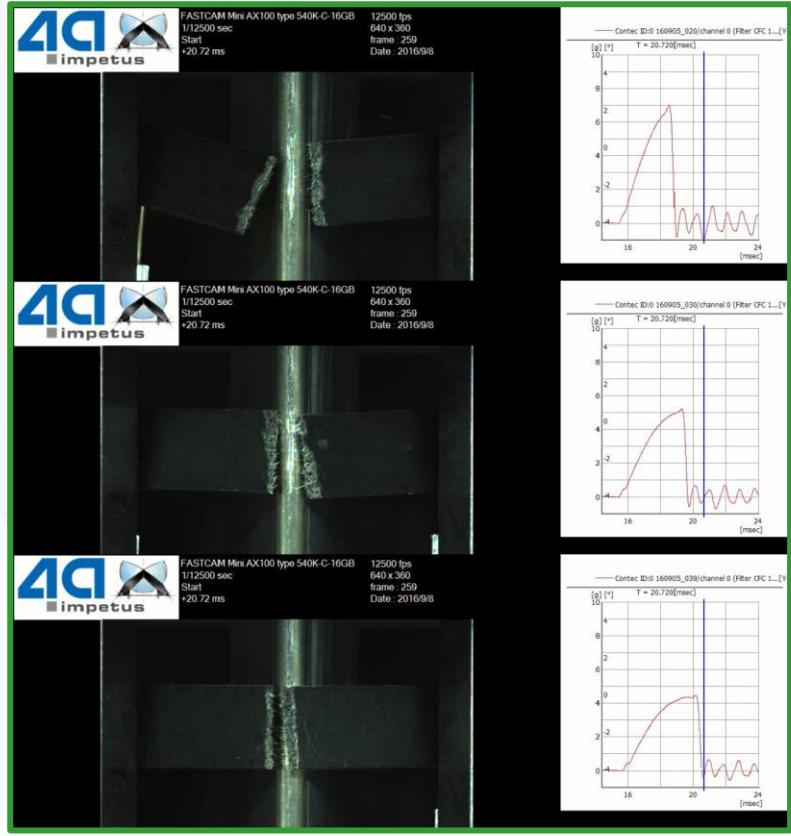
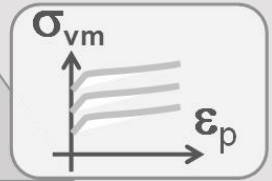
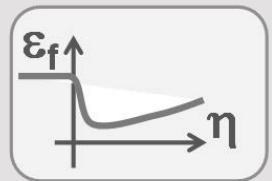
**component
validation**



Biegung



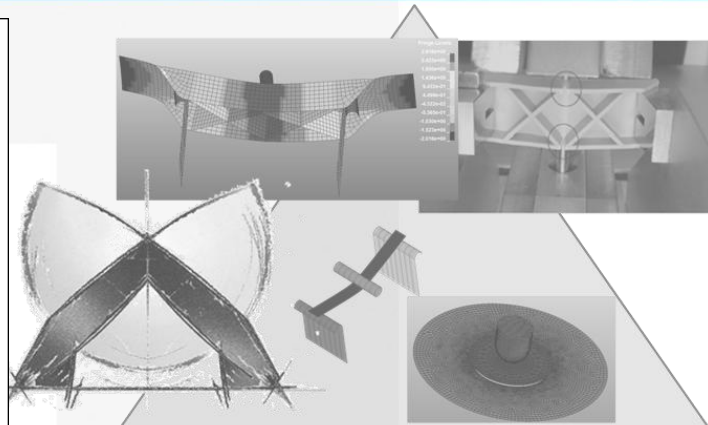
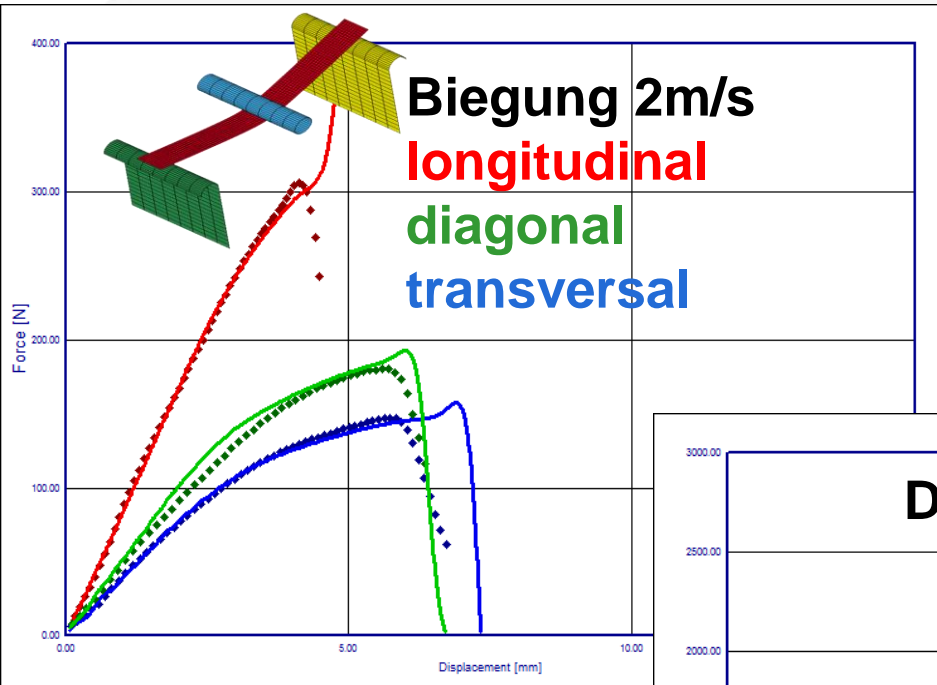
component validation



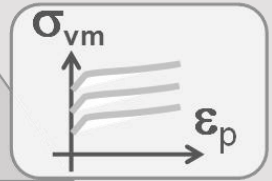
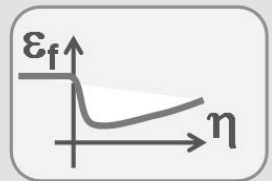
Durchstoß

Dynamische Materialcharakterisierung

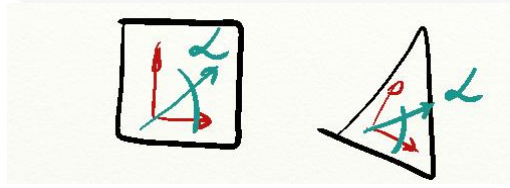
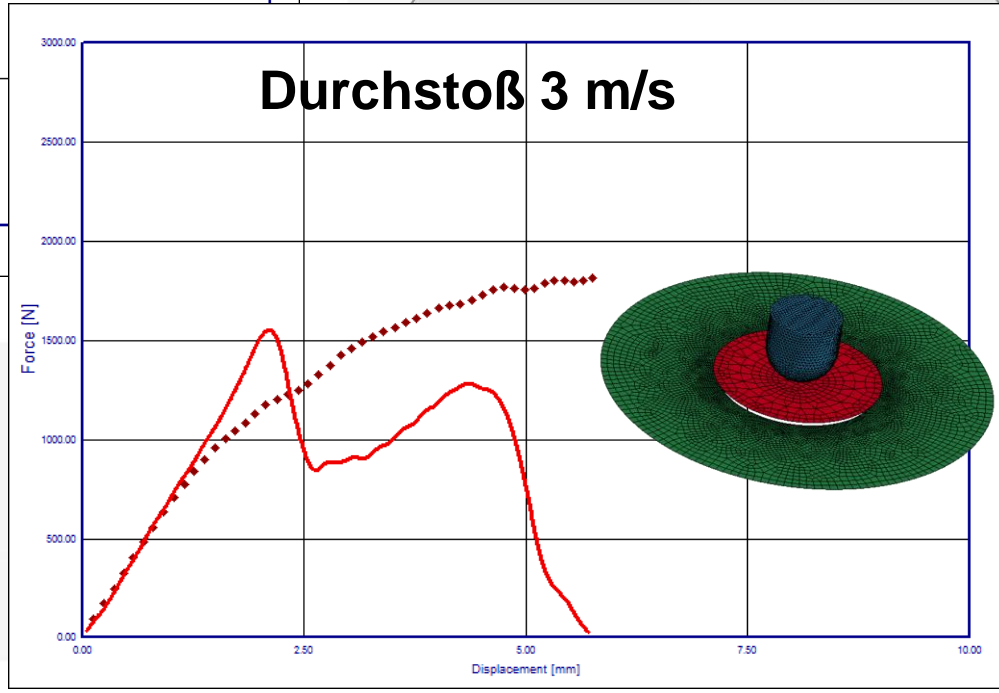
Materialkarte Shell – SFRT & LFRT



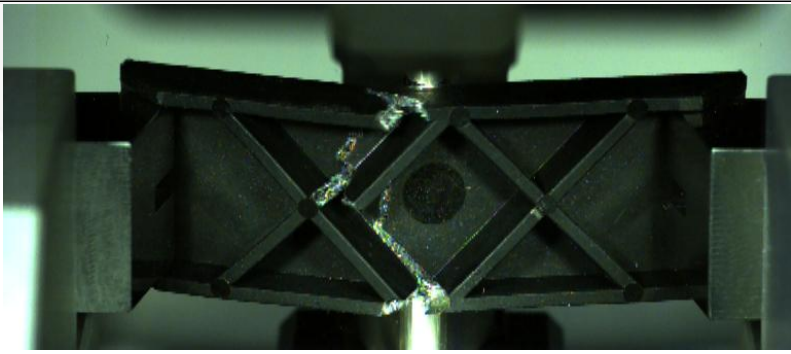
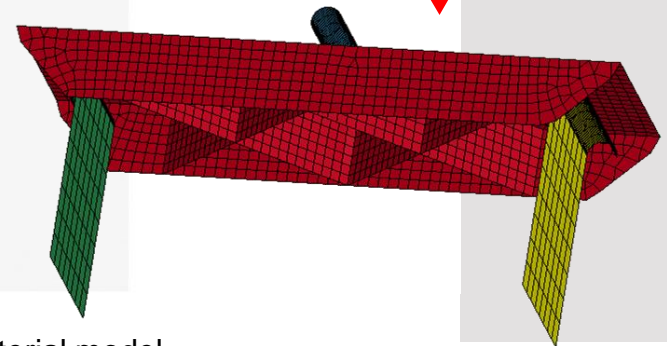
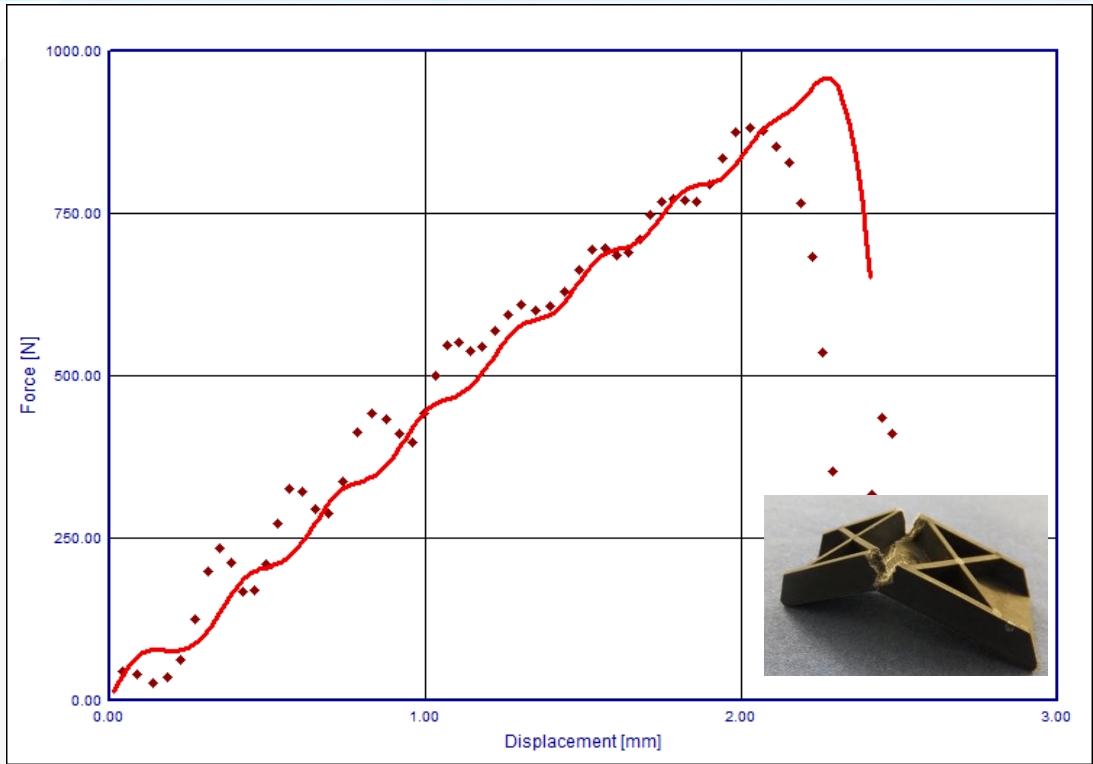
component validation



.... averaged test curves
 — result of simulation



Dynamische Materialcharakterisierung Validierung Simulation – SFRT & LFRT



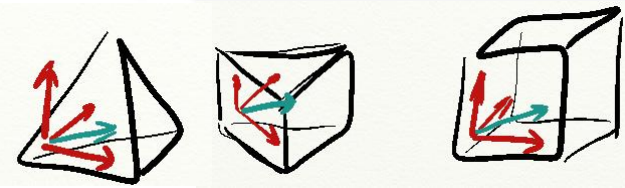
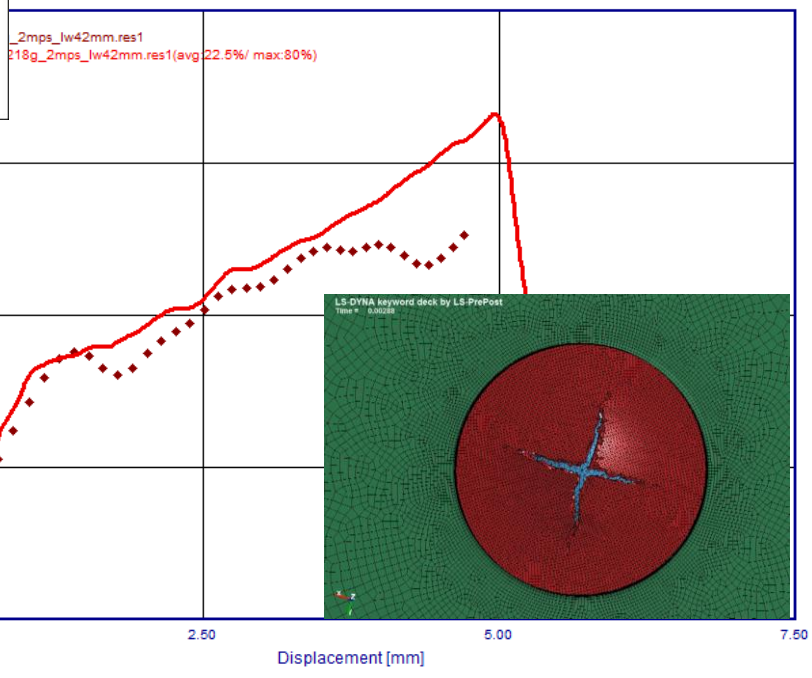
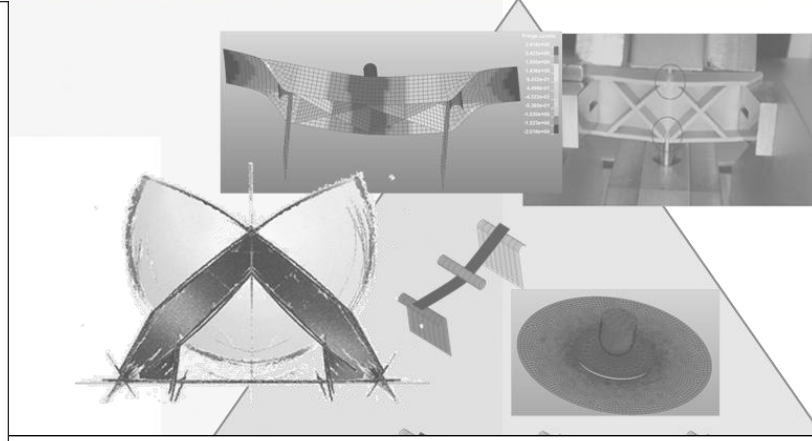
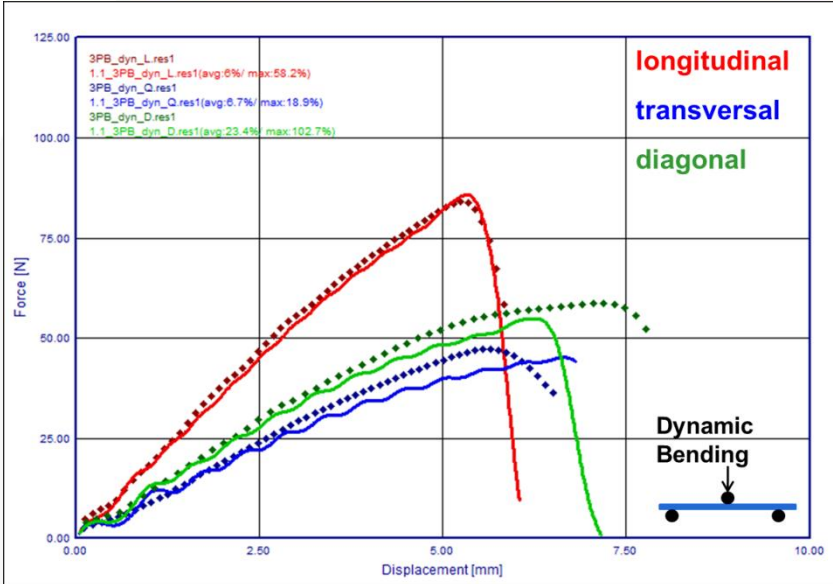
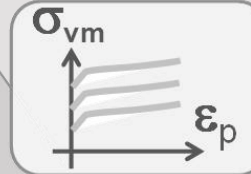
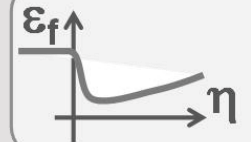
Source: LS DYNA Forum 2016 - *MAT_4A_MICROMECH – micro mechanic based material model

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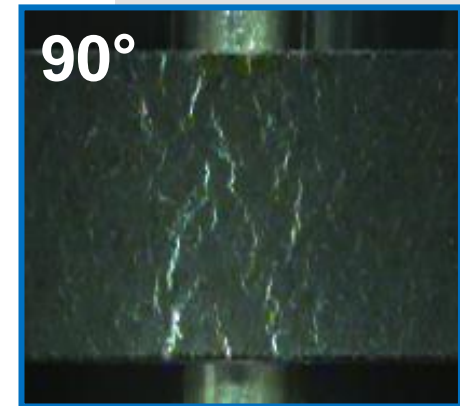
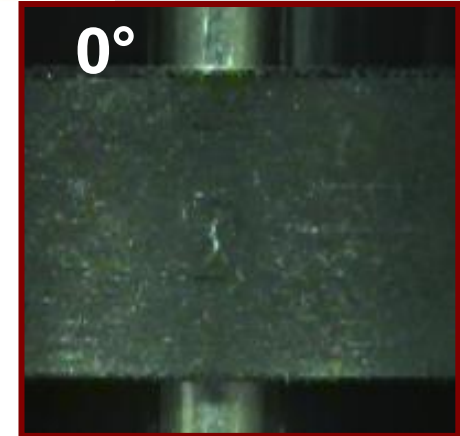
Dynamische Materialcharakterisierung

Materialkarte Solid – SFRT & LFRT

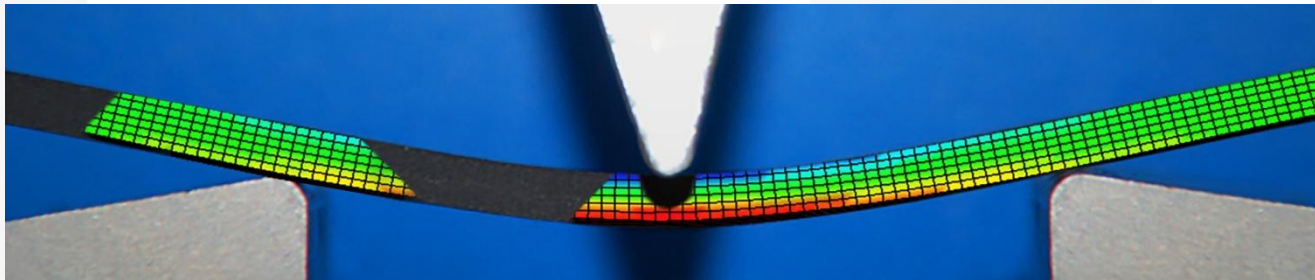
component validation



- kurz- und langfaserverstärkte Kunststoffe
 - Zeit- / Temperaturabhängigkeit
 - Richtungsabhängigkeit
- Simulation – LS-DYNA
 - viele Materialmodelle → untersch. komplex
 - Auswahl → Material / Anwendung / Zielsetzung
 - Mapping Workflow davon gesteuert
- Materialcharakterisierung
 - zielgerichtet sein
 - wesentliche Effekte → Simulation



Vielen Dank für die Aufmerksamkeit !



15. **4a**
TECHNOLOGIETAG

28. Februar - 1. März 2018
in Schladming, Austria

„Kunststoffe auf dem Prüfstand - Testen und Simulieren“
weitere Informationen: <http://technologietag.4a.co.at/>