

Failure modeling of unreinforced and fiber reinforced thermoplastics

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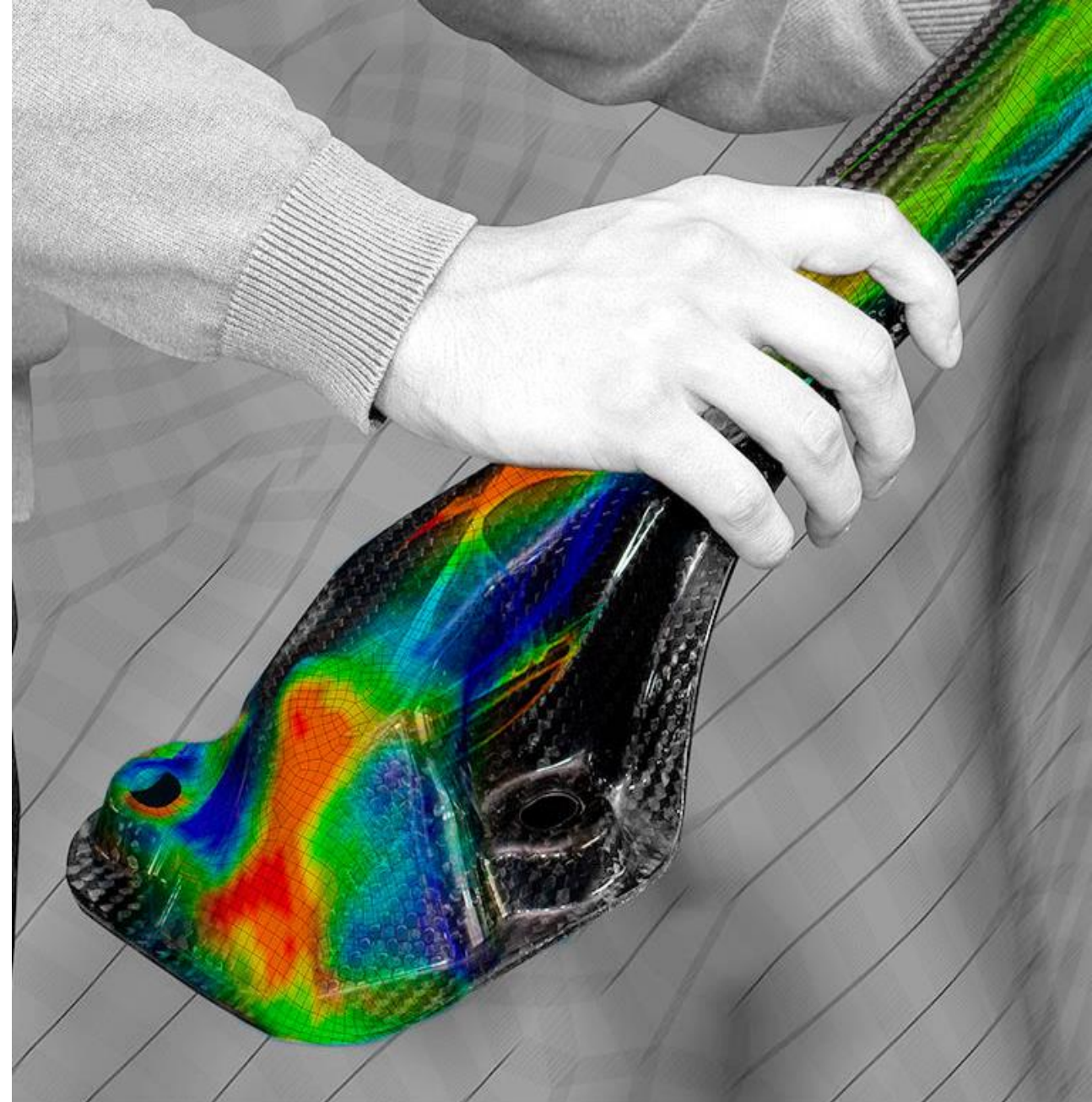
14-16th May 2019, Koblenz

Outline

- introduction 4a
- motivation
- material characterization
 - IMPETUS™ - dynamic impact tensile testing
 - typical test results PP T10
- material / failure models
 - GISSMO vs. SAMP vs. DIEM
- first results
- outlook / summary

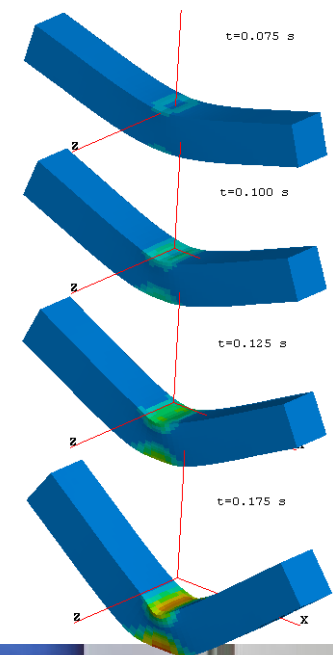
4a engineering GmbH

- polymer and materials
- product development
- fiber reinforced plastics and composites
- numerical simulations methods
- method and software development



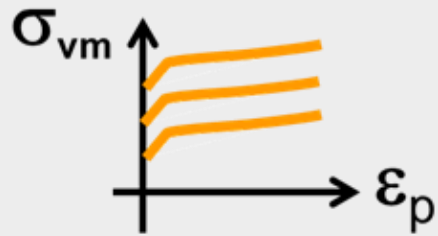
Material characterization - services

- efficient highly-dynamic testing
- dynamic material behaviour
- plastics, foams, composites, ...
- **validated material card ready to use for your crash-simulation**

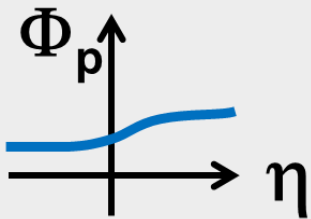


Intelligent reliable solutions for plastics, composites, metals, foams, ...

✓ VALIMAT



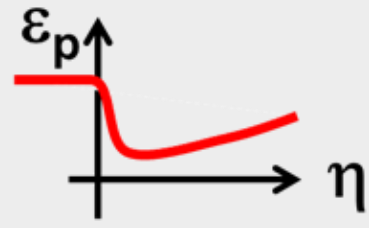
Hardening



Triaxiality



Anisotropic

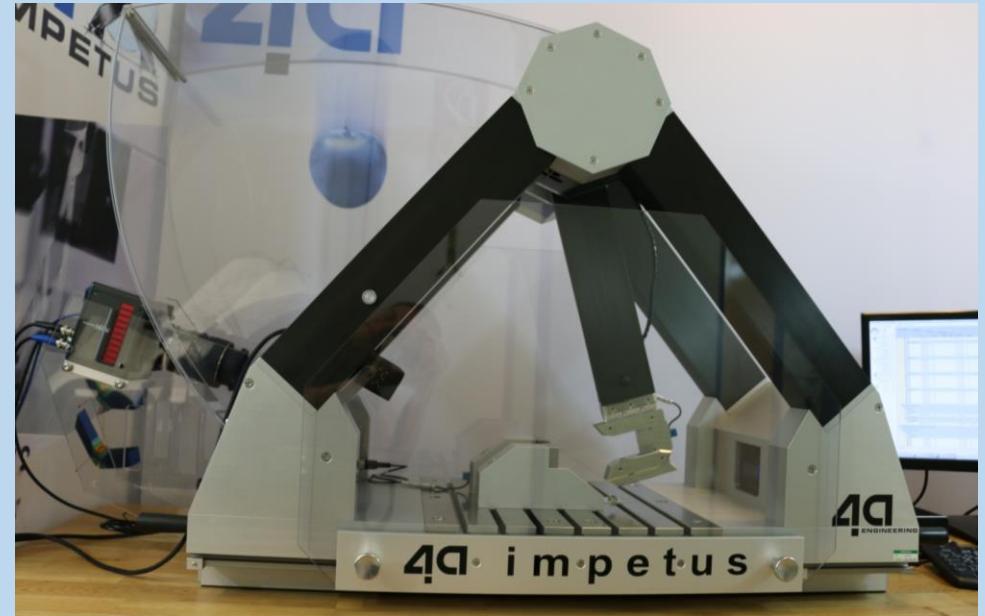


Damage/Failure

for all material types

from test to validated material cards

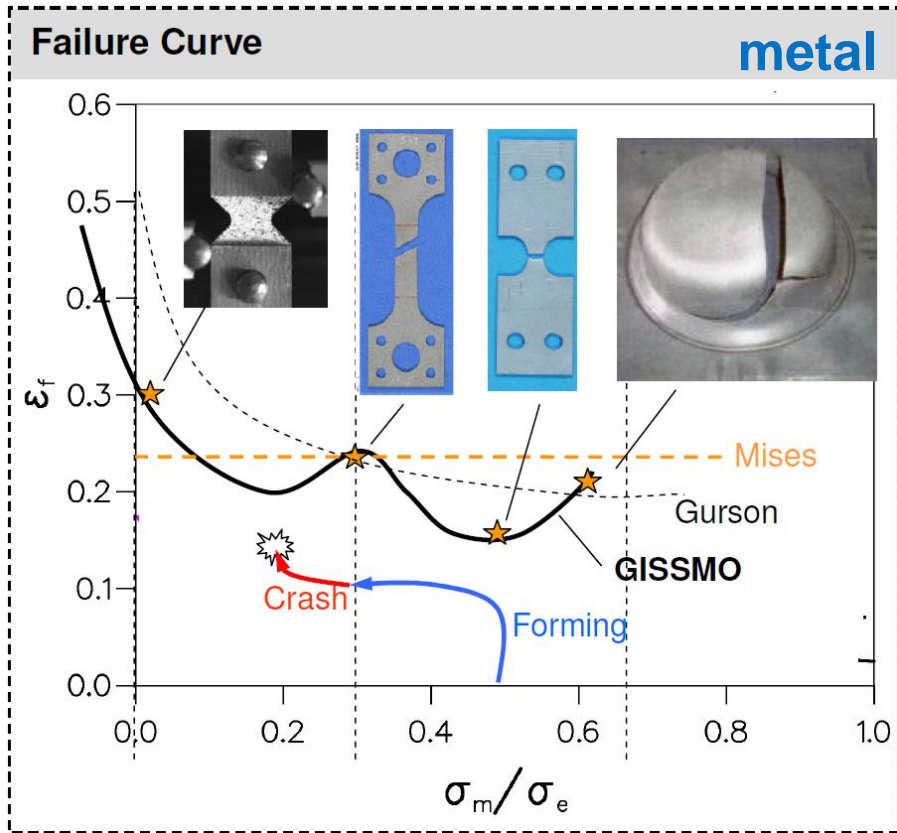
◀ IMPETUS



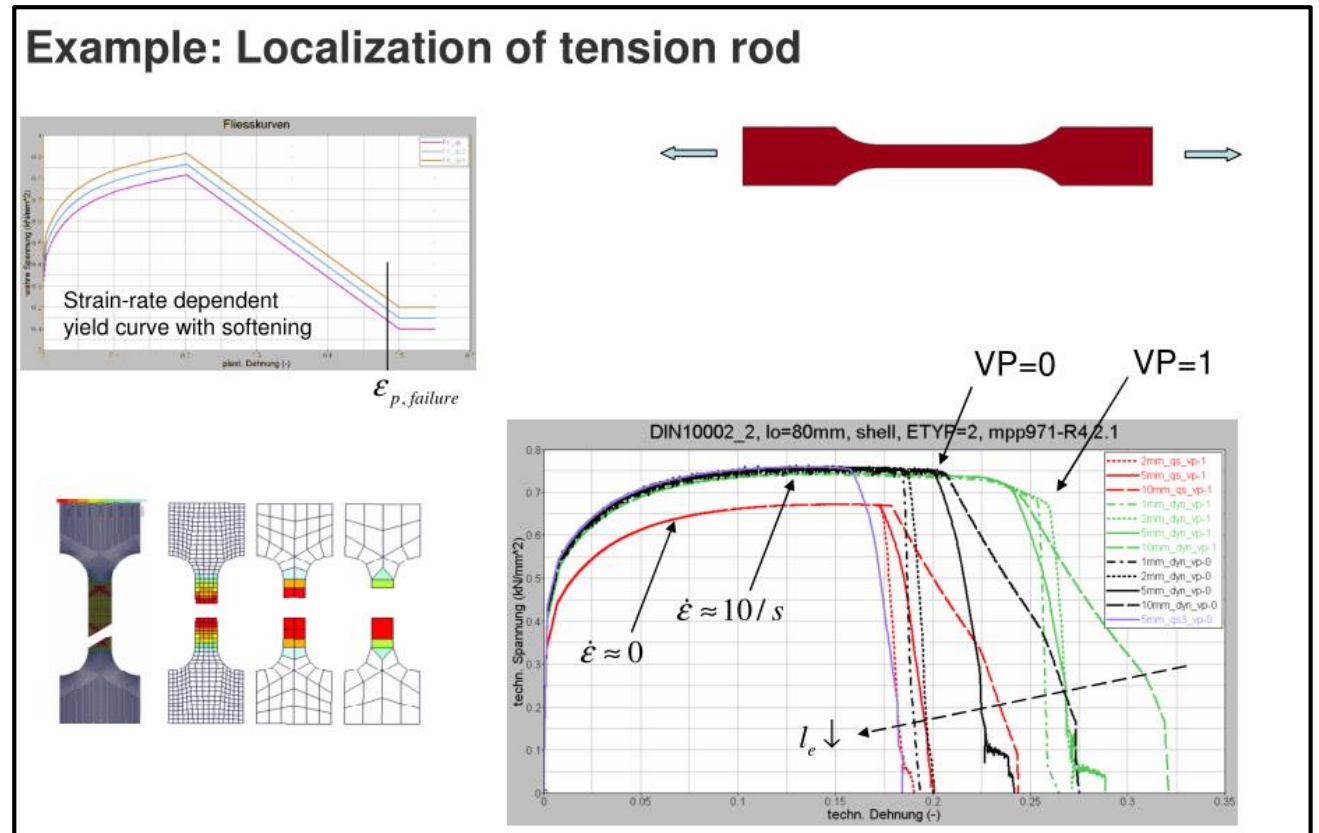
efficient dynamic testing
plastics and composites

Motivation

- typical customers request for plastics
 - **GISSMO with *MAT_024** (***MAT_187** internal failure model)



source: F. Neukamm – GISSMO – Material modeling with a sophisticated failure criteria, LS-Dyna Developer Forum 2011, Stuttgart



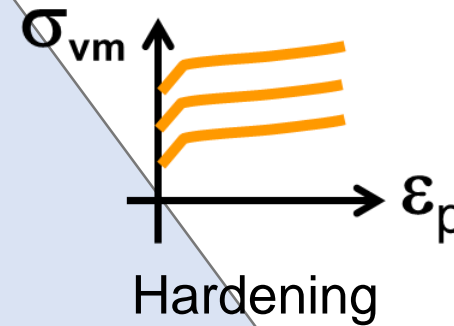
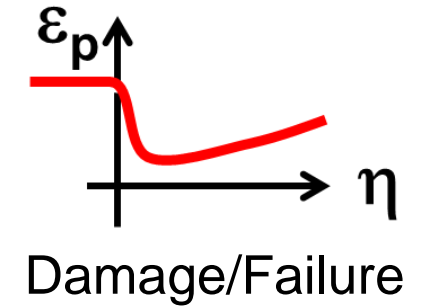
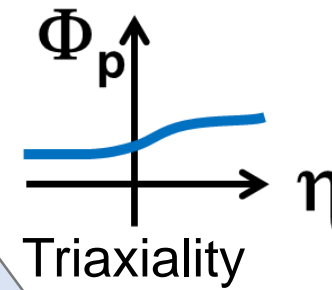
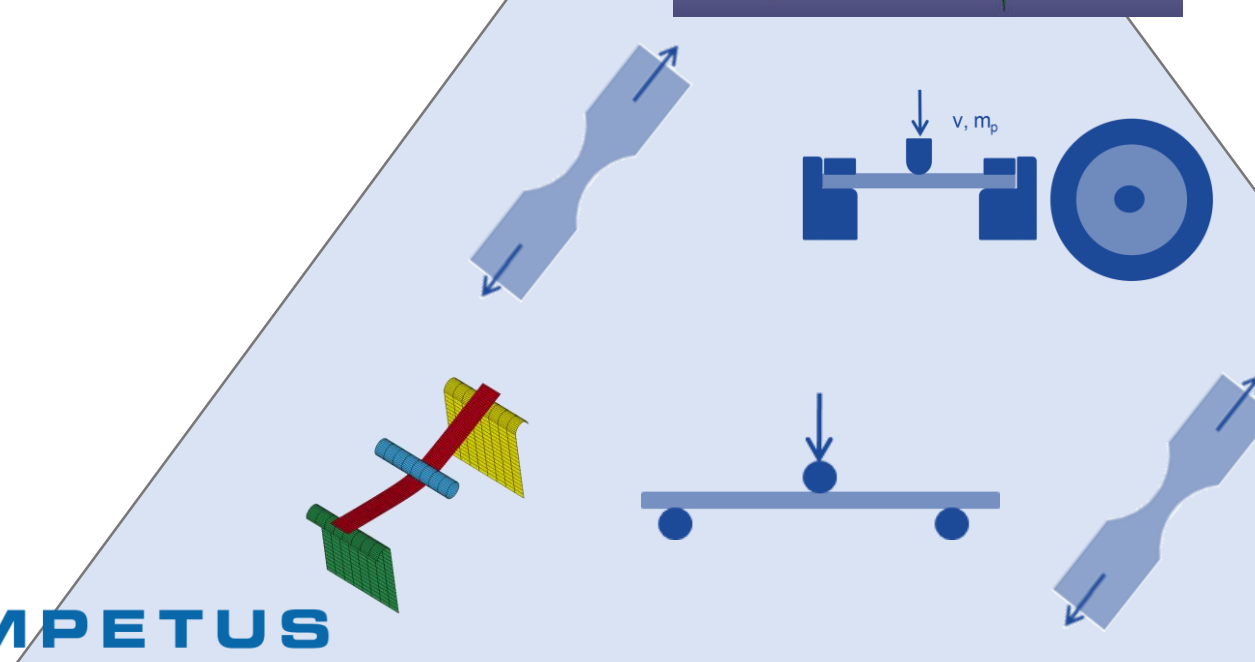
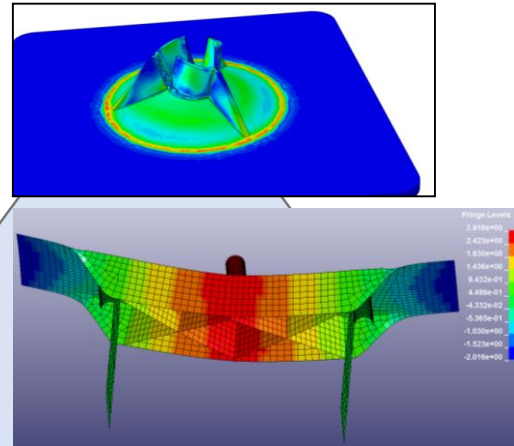
source: Damage and Failure Models in LS-DYNA; M. Feucht; A. Haufe ;(2009)

From test to material card



VALIMAT

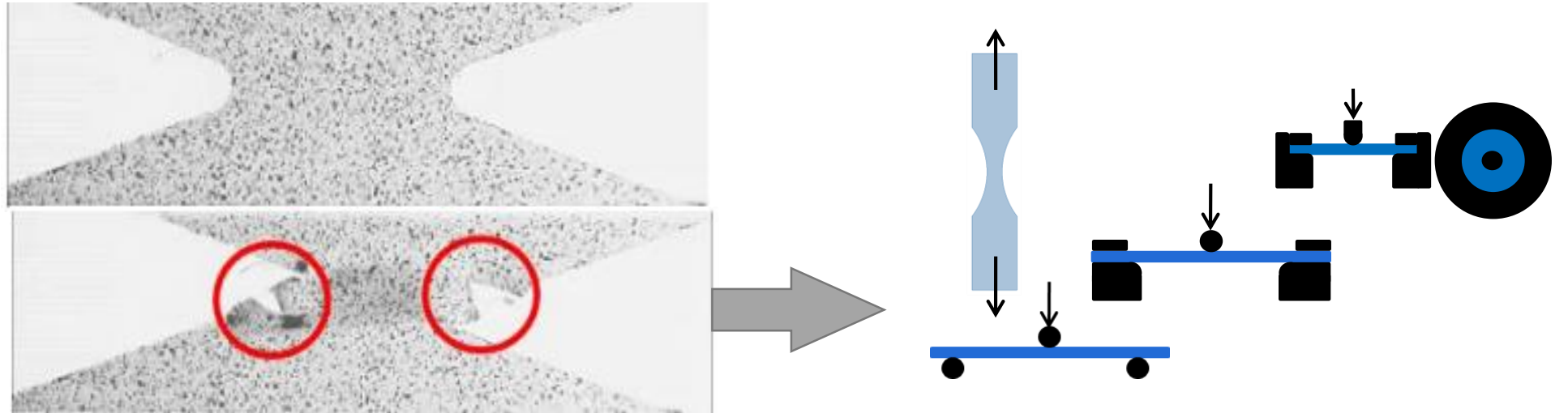
Deformation → Failure
 Creep → Static → Crash
 ISOTROPIC → ANISOTROPIC



IMPETUS



From test to material card



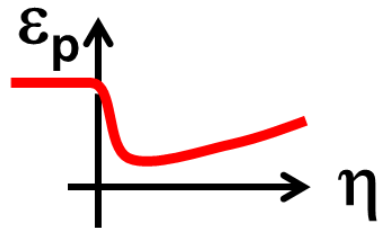
- 0.33

0

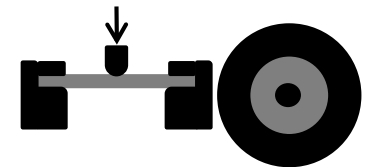
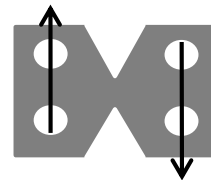
0.33

0.66

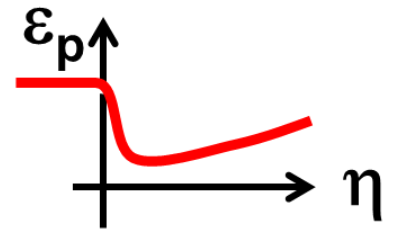
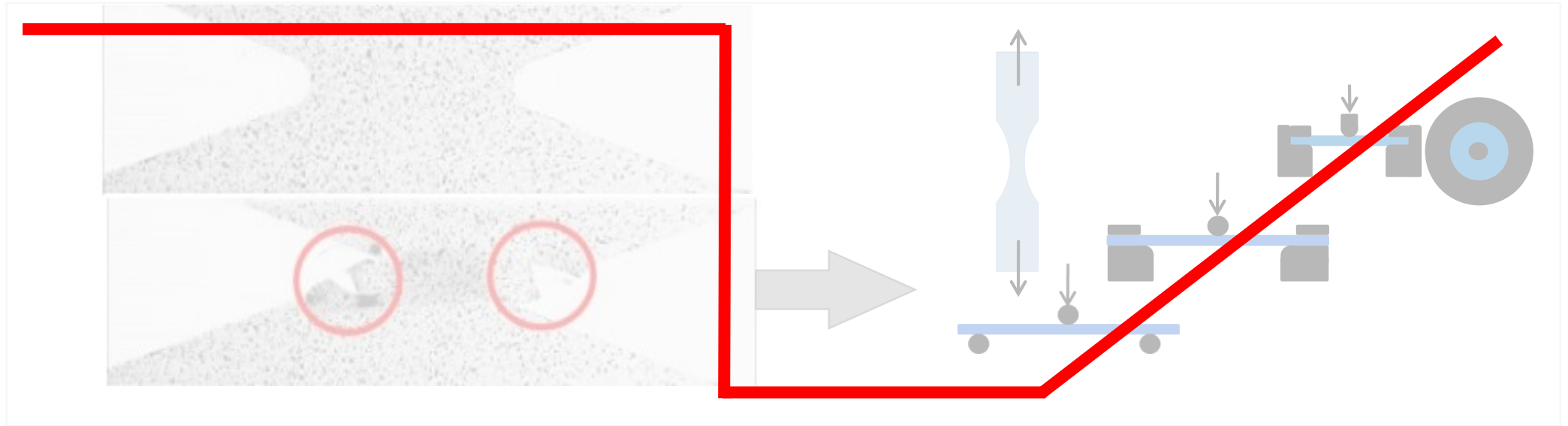
η



Damage/Failure



From test to material card



Damage/Failure

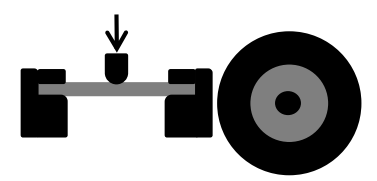
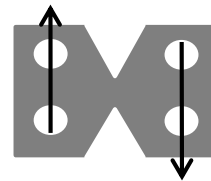
- 0.33

0

0.33

0.66

η



IMPETUS™ - efficient dynamic testing



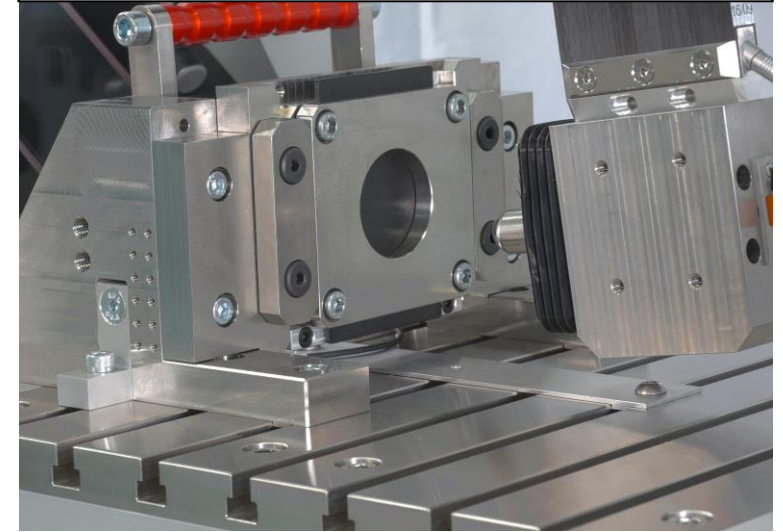
bending test



tensile test



puncture test



tension bending test



IMPETUS™ ~ 3 m/s
static ~ 1mm/s

IMPETUS™ - efficient dynamic testing



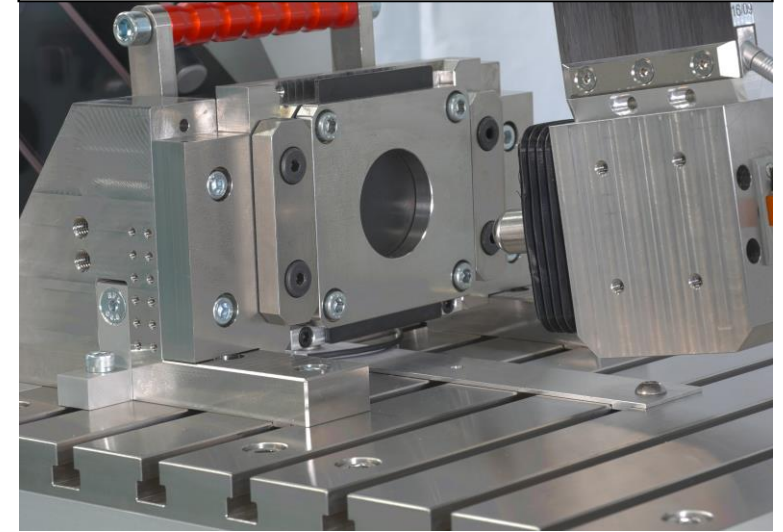
bending test



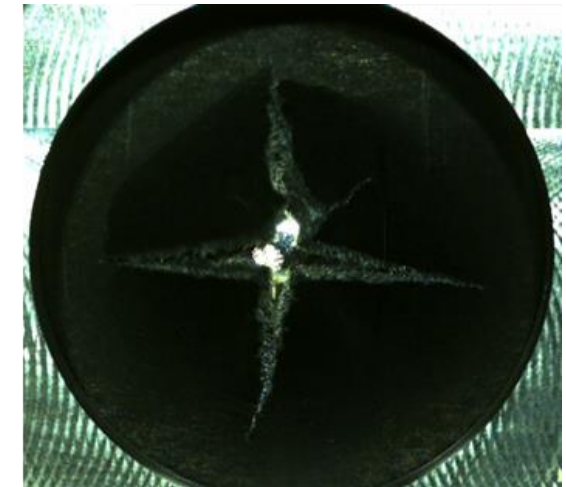
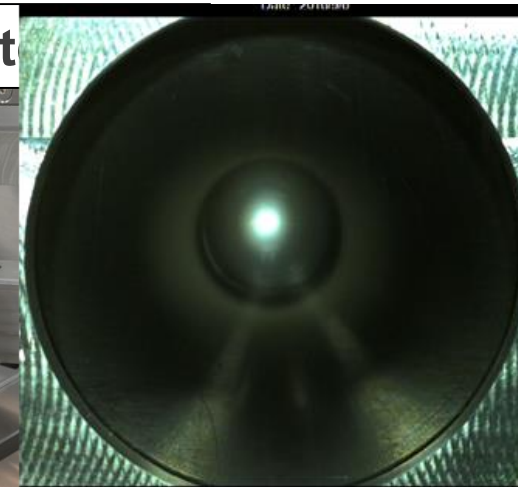
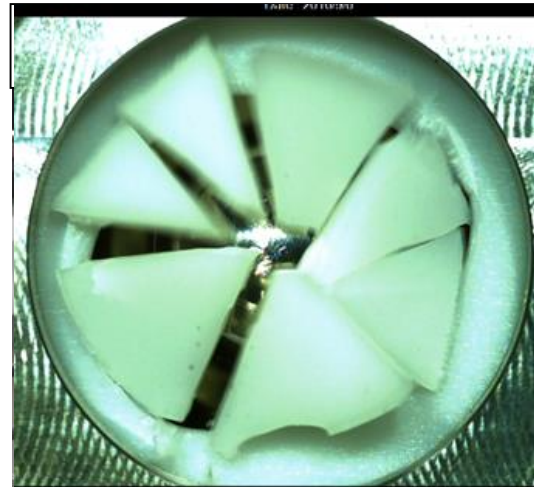
tensile test



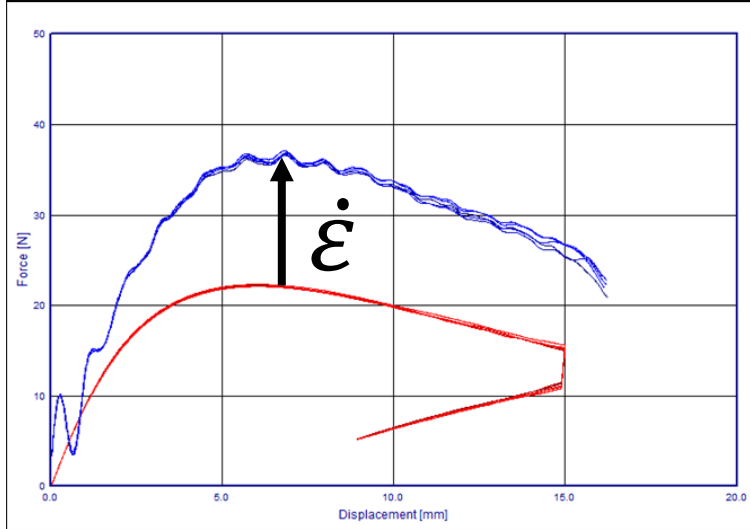
puncture test



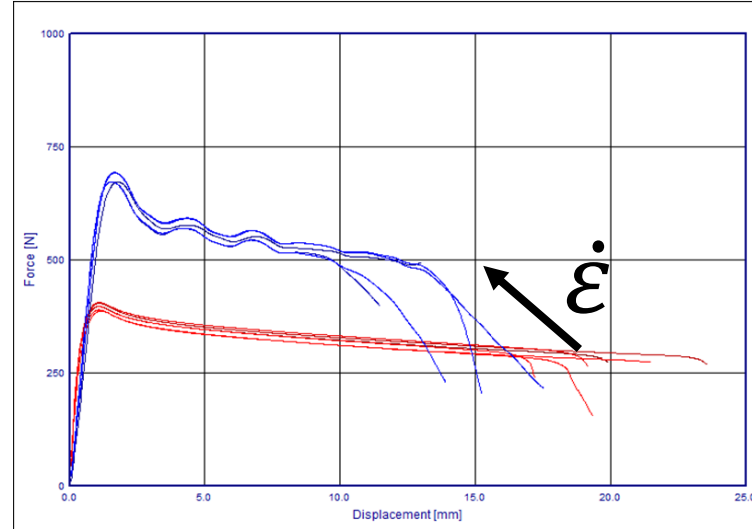
IMPETUS™ ~ 3 m/s
static ~ 1mm/s



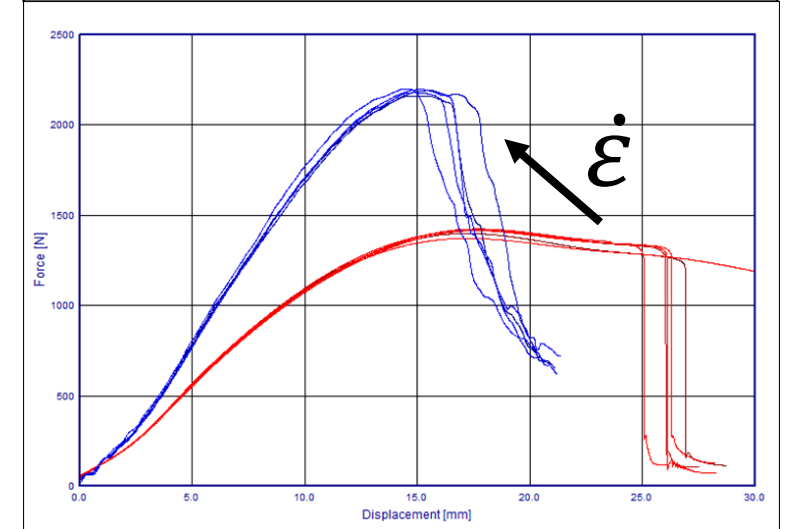
bending test



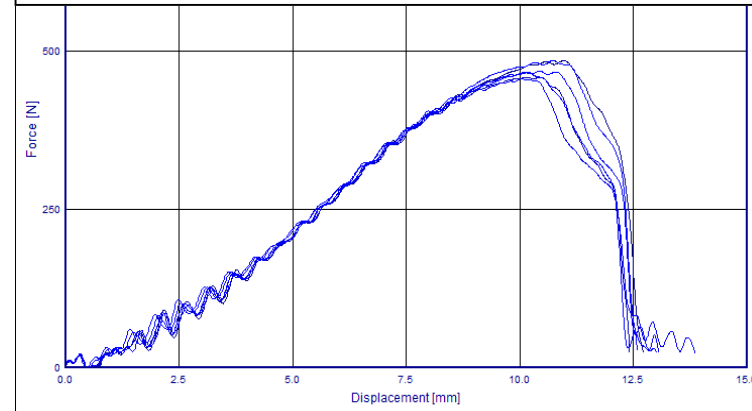
tensile test



puncture test



tension bending test



IMPETUS™ ~ 3 m/s
static ~ 1mm/s

Commonly used material models for plastics

(un)reinforced plastics

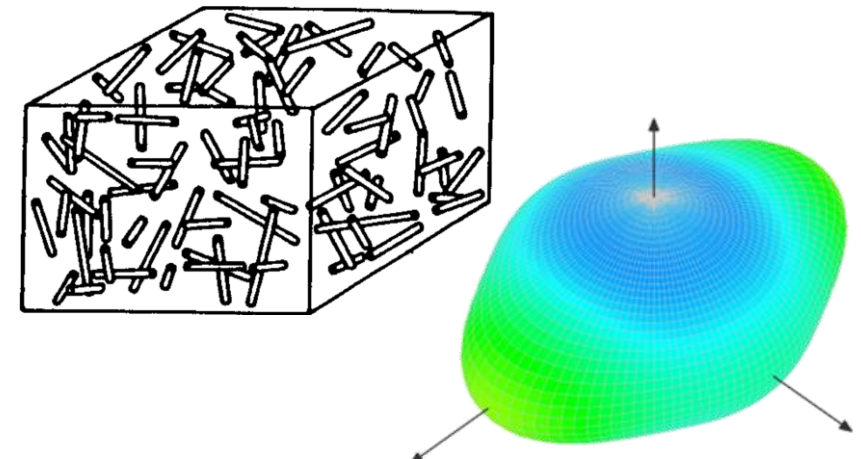
- ***MAT_024 - the workhorse**
(**MAT_081, *MAT_089, *MAT_123, ...*)
- ***MAT_124 - the hidden**
- ***MAT_187 - the plastic expert**

Material model	Yield surface	Visco-elasticity	Visco-plasticity	comp./tension asymmetry	plastic Poisson's ratio
*MAT_024	von Mises	✘	✓	✘	0.5
*MAT_124	2x von Mises	✓ Pronyseries	✓	✓	0.5
*MAT_187	General over triaxiality	✓ Table	✓	✓	✓

See more: P. Reithofer et. al. – *Material Models For Thermoplastics In LS-DYNA® From Deformation To Failure*, int. LS-Dyna Forum 2018, Detroit

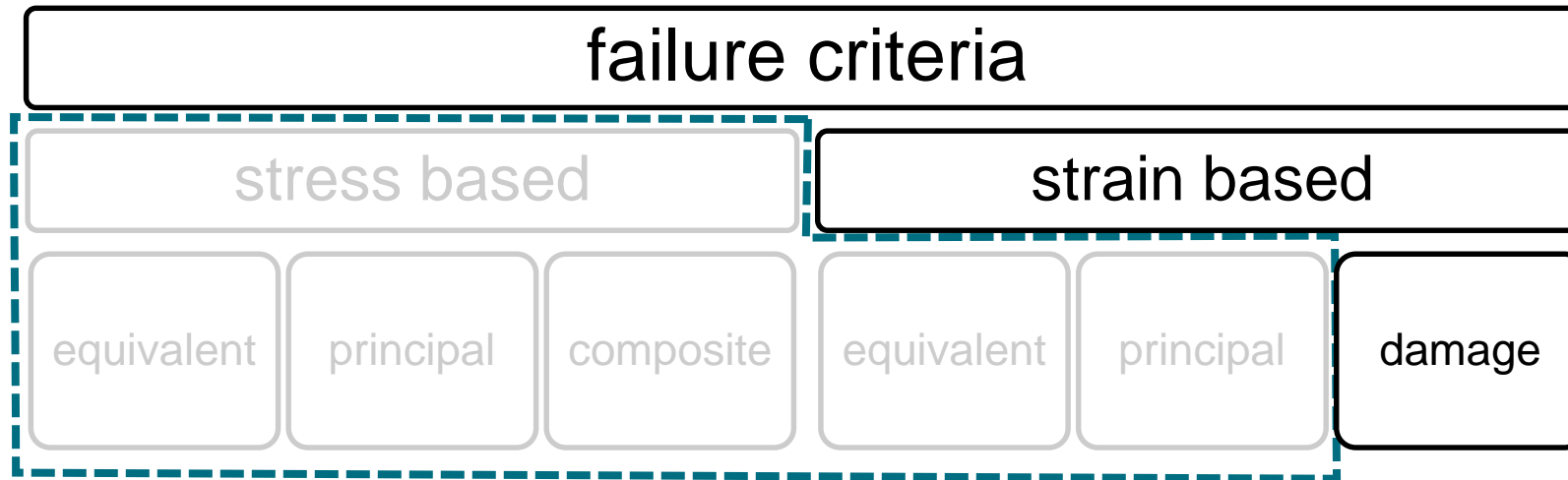
fiber reinforced plastics

- ***MAT_157 - the workhorse**
(orthotropic elasticity + hill plasticity)
- ***MAT_215 – the new one**



See more: P. Reithofer et. al. – **MAT_4A_MICROMECH – Generating Material Card and Considering Fiber Orientation*, Geman LS-DYNA Forum 2018, Bamberg

Available failure models in LS-DYNA®



additional failure models

****MAT_ADD_EROSION***

strain damage based

- *before R11 optional DIEM / GISSMO*
- *since R11 *MAT_ADD_DAMAGE_DIEM*
- *since R11 *MAT_ADD_DAMAGE_GISSMO*

included damage model in

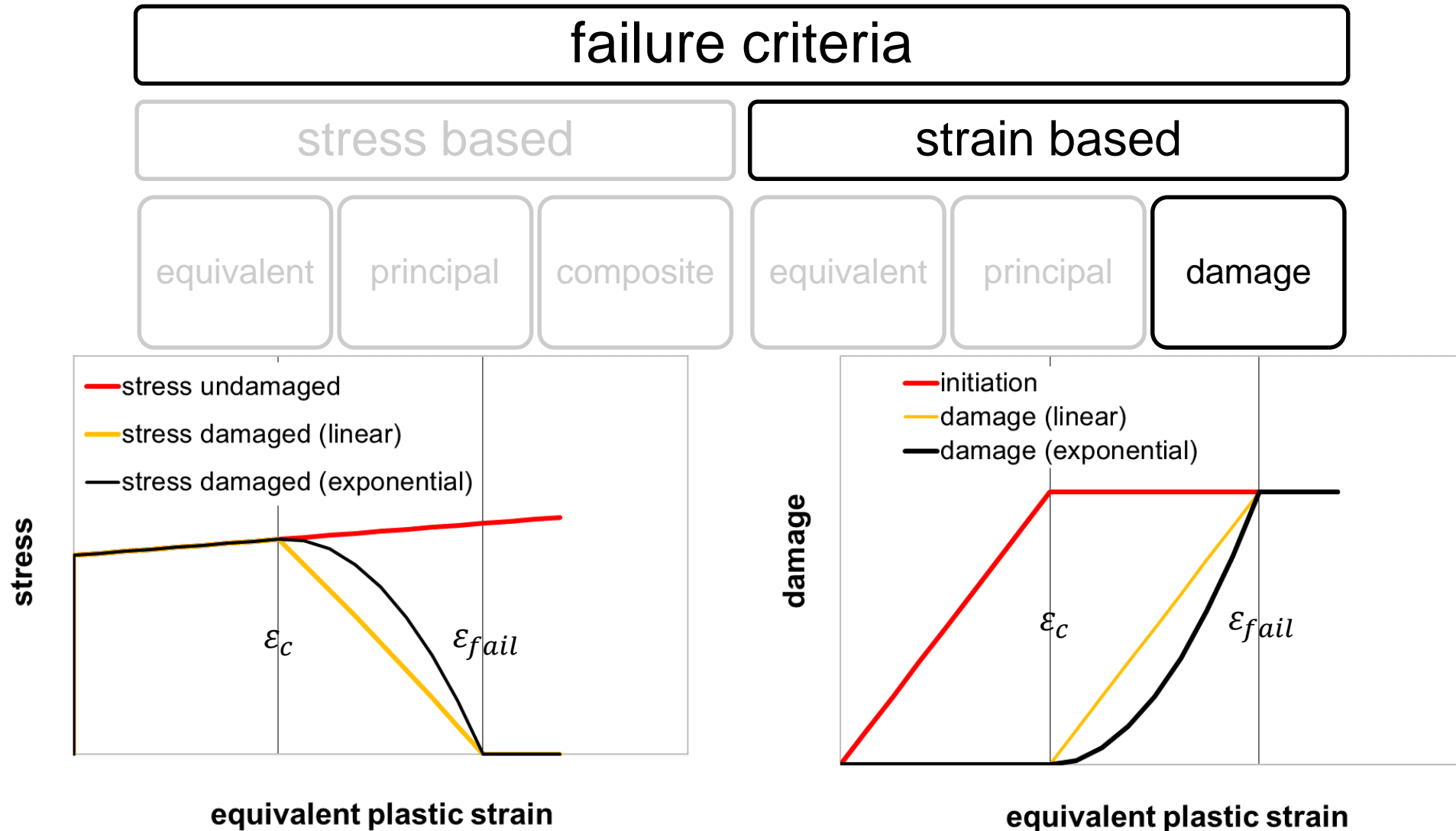
****MAT_SAMP-1***

GISSMO like

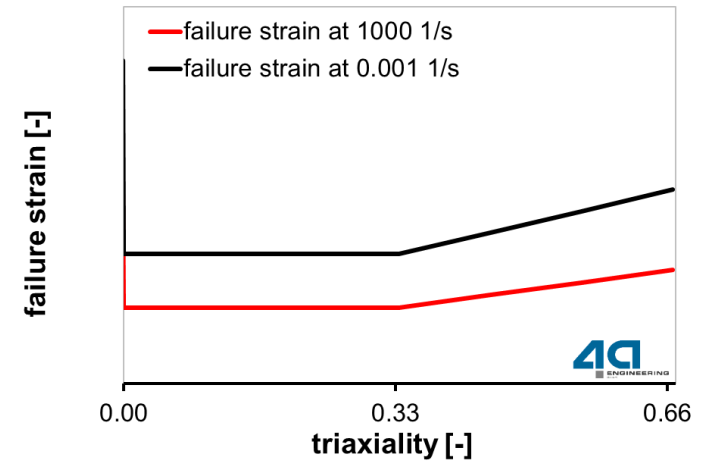
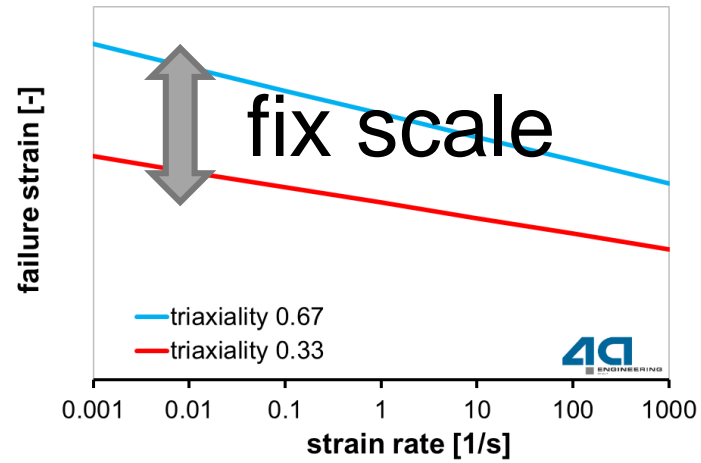
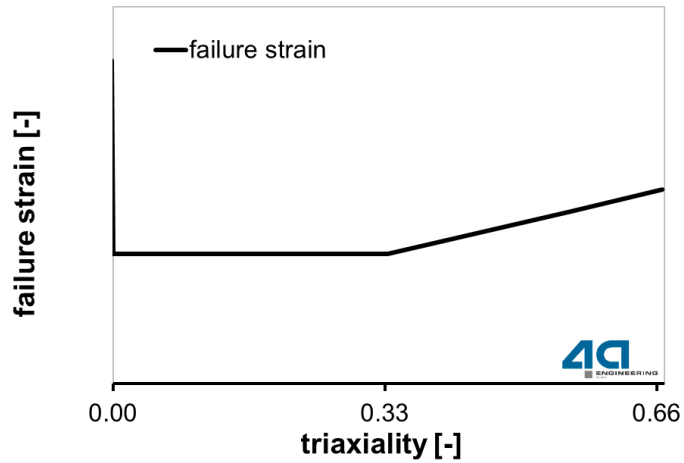
****MAT_4A_MICROMECH***

DIEM for matrix failure

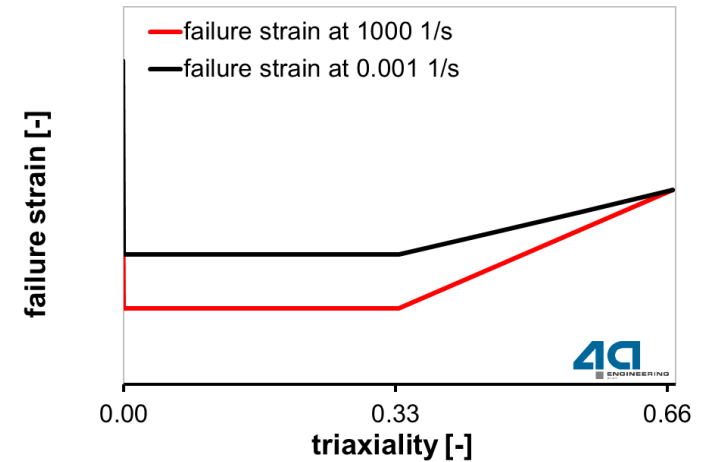
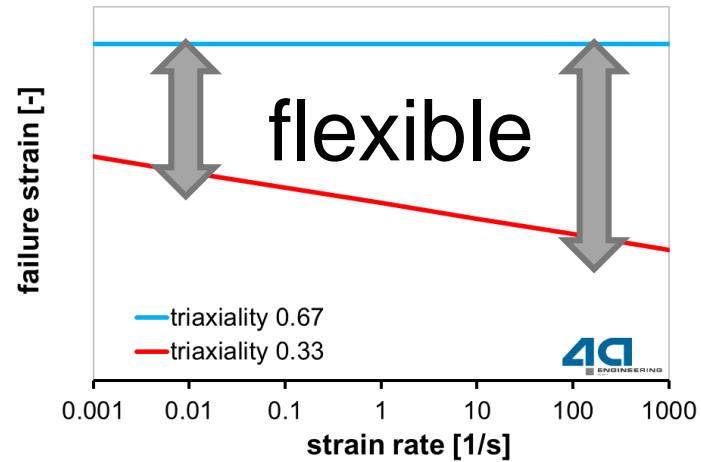
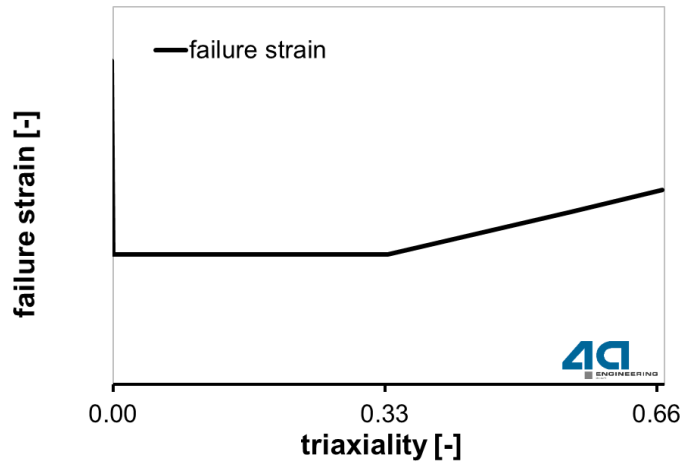
Available Failure Models – incremental damage formulation



Comparison DIEM-GISSMO visualized



GISSMO



DIEM

Comparison DIEM-GISSMO

GISSMO	SAMP-1 FM	DIEM
	one damage initiation ($D_{crit}(\varepsilon_p)$) and failure criterion (ε_p)	multiple damage initiation and failure criteria possible
	stress coupling by one damage variable	maximum or multiplicative coupling of damage variables
damage evolution exponent	linear damage evolution	damage evolution defined by table
element regularization failure strains and/or critical strains	element regularization of critical strains	indirect element size compensation by plastic displacement
	failure strain scaling factor table $\varepsilon_f(\dot{\varepsilon}_p)$	failure strainrate dependency over triaxiality $\varepsilon_f(\dot{\varepsilon}_p, \eta)$

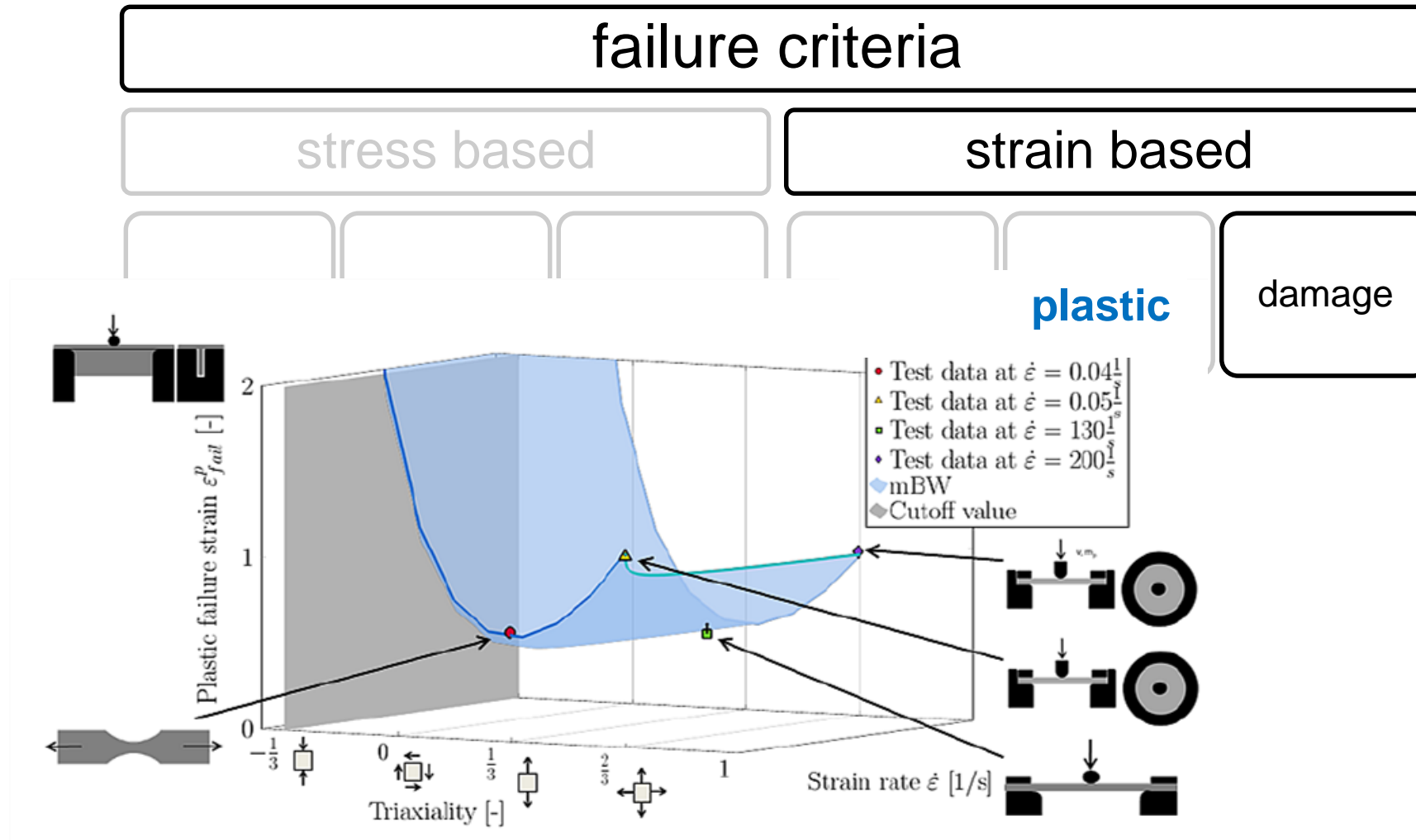
Generalized Incremental Stress State dependent damage Model (GISSMO**)**

Damage Initiation and Evolution Model (DIEM**)**

MAT_187 internal failure model (**SAMP-1 FM**)

Q: “Ductile material failure in LS-DYNA“; Mikael Schill;

Available failure models – typical curves



source: H. Staack, - Application oriented failure modeling and characterization for polymers in automotive pedestrian protection, COMPLAS 2015, Barcelona

Fracture models → *MAT_ADD_EROSION



Parameter model* Model database

170503_024 Material Designvariables Layers

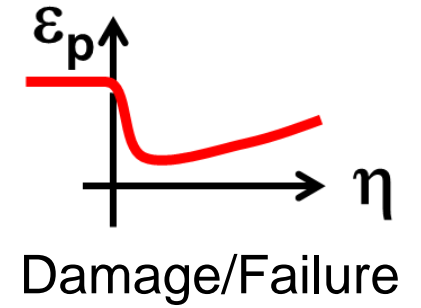
Materialcard MMEC
Image Comment

- Material behaviour
 - Material source
 - Elasticity
 - Plasticity
 - Failure/Damage
 - Material card
 - Materialcardcase
 - Damage/Failurecase
 - Materialcard id
 - Density
 - Plasticity
 - Function (Hardening, Elastic curve form)
 - Curve 1
 - Curve 2
 - Strain range upto
 - Sampling points
 - Bias factor
 - Strain rate dependency
 - Strain rate dependency
 - Fracture
 - Ductile Damage Settings
 - lower triax value
 - upper triax value
 - step size triax
 - Shear Damage Settings
 - FLC Damage Settings
 - Strainrate Settings
 - Postfracture
 - Loadcases
 - Results

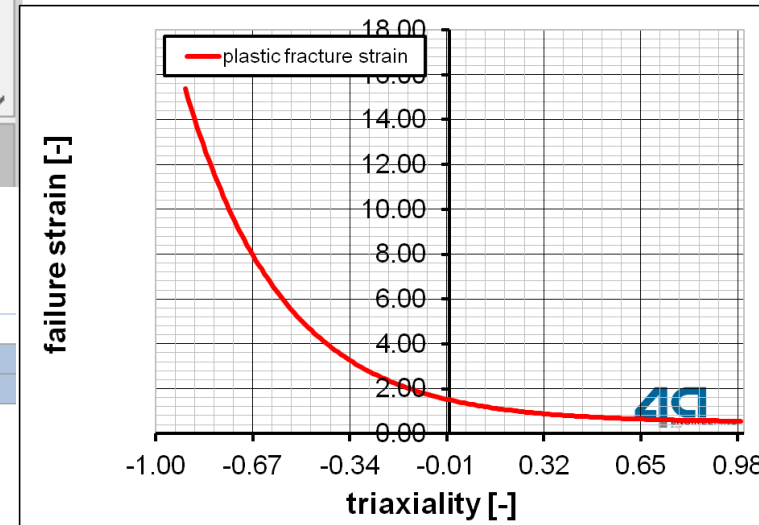
Density	-1
Plasticity	vonMISES
Function (Hardening, Elastic cur	
Strain rate dependency	Table
Fracture	Damage
Ductile Damage Settings	Johnson Cook
Shear Damage Settings	None
FLC Damage Settings	plastic equivalent strain
Strainrate Settings	simple criteria
Postfracture	4a picewise linear
Loadcases	Johnson Cook
Casename	mod Xue-Wierzbicki
Tests	Xue-Wierzbicki
Settings optimization	Mohr-Coulomb
Weighting case	1

Ductile Damage Settings

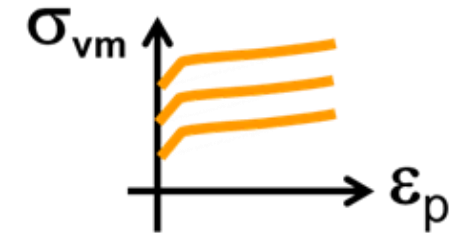
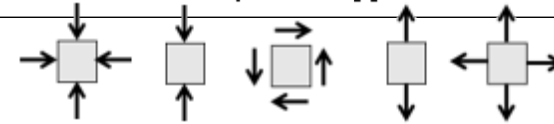
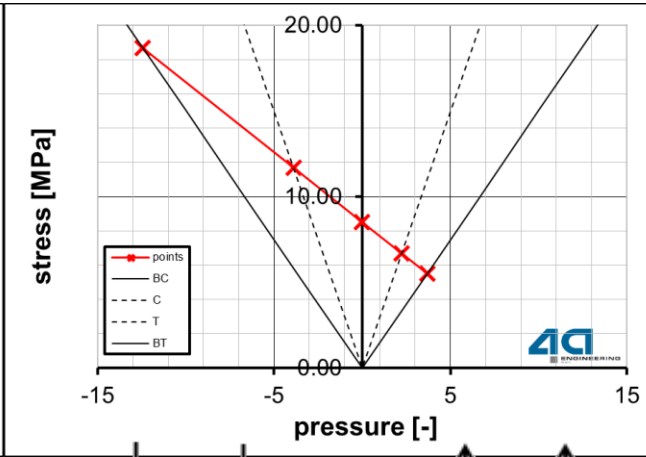
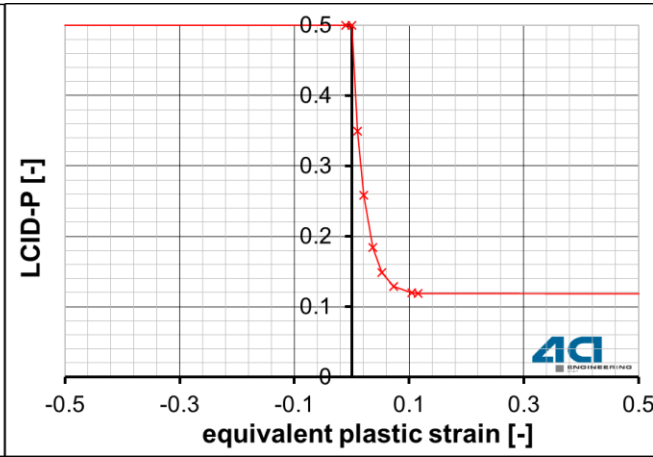
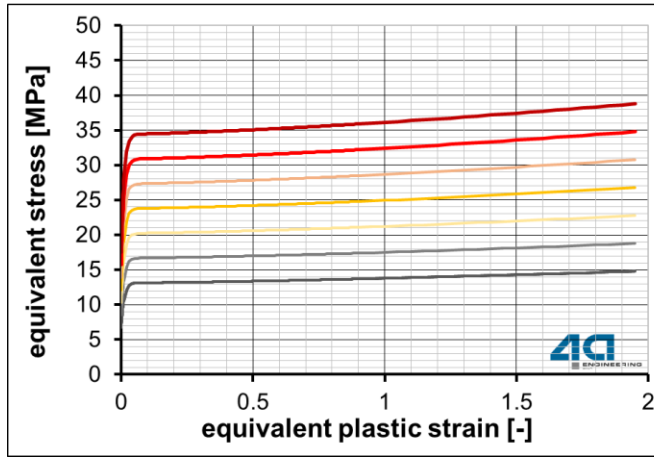
	0.33	Johnson Cook
	None	mod Xue-Wierzbicki
	None	Xue-Wierzbicki
	Johnson Cook	Mohr-Coulomb
	Fracture Energy (TRIAx)	



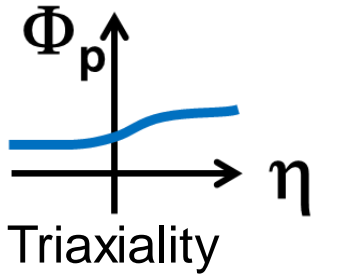
$$f_{d_{JCD1}} + f_{d_{JCD2}} \cdot e^{-f_{d_{JCD3}} \cdot \eta}$$



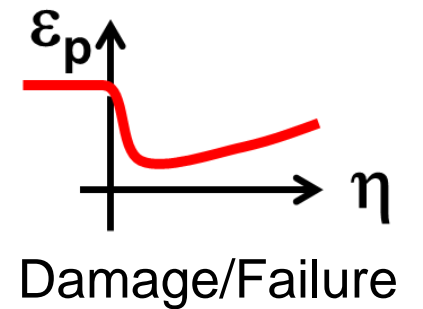
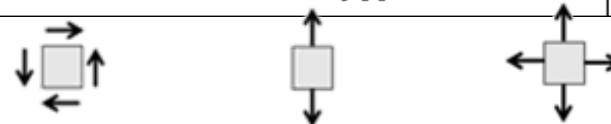
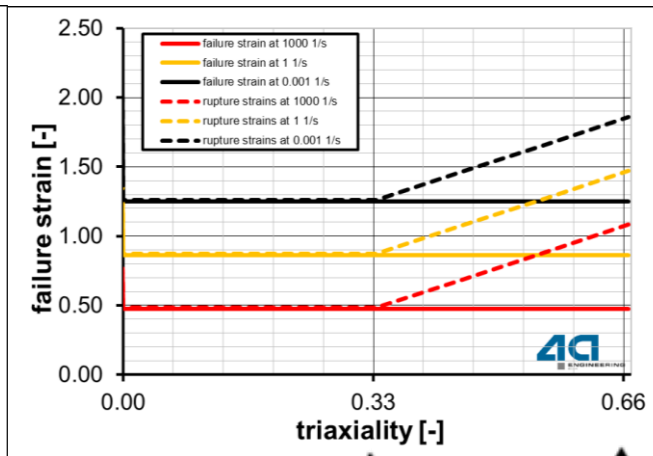
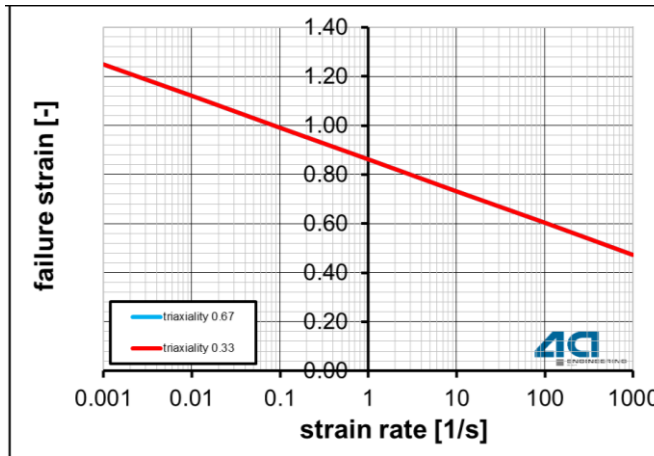
*MAT-SAMP 1 with internal FM – result AUTOFIT



Hardening



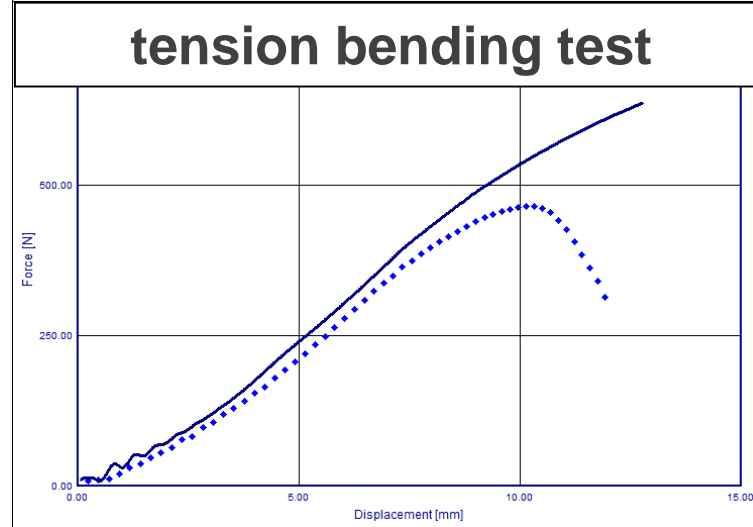
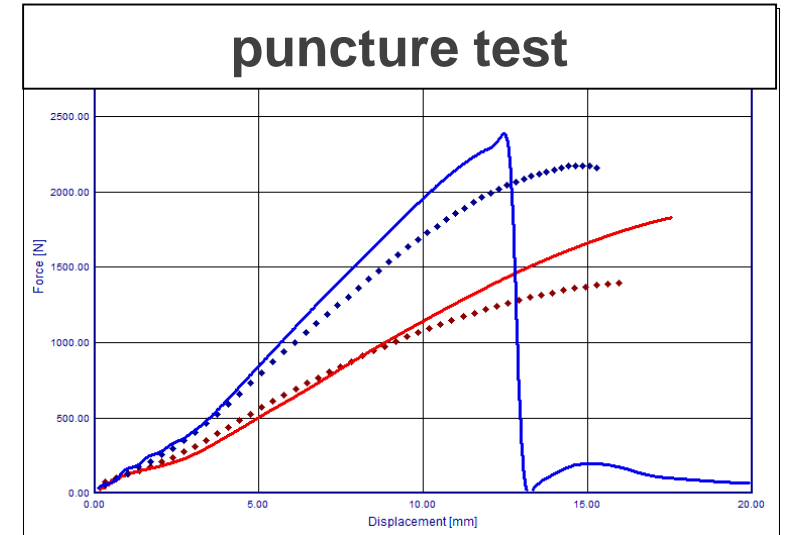
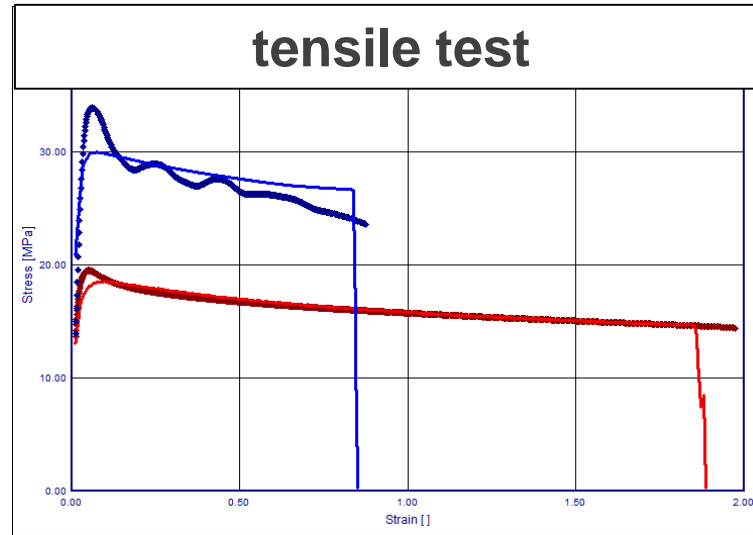
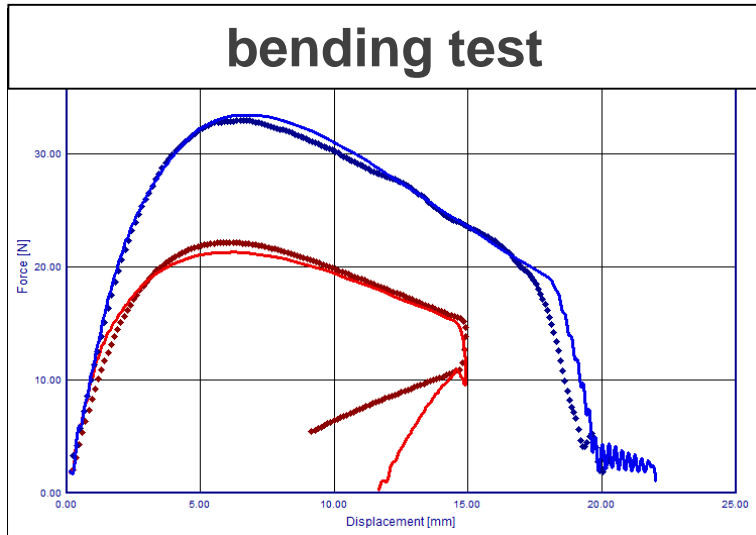
Triaxiality



Damage/Failure

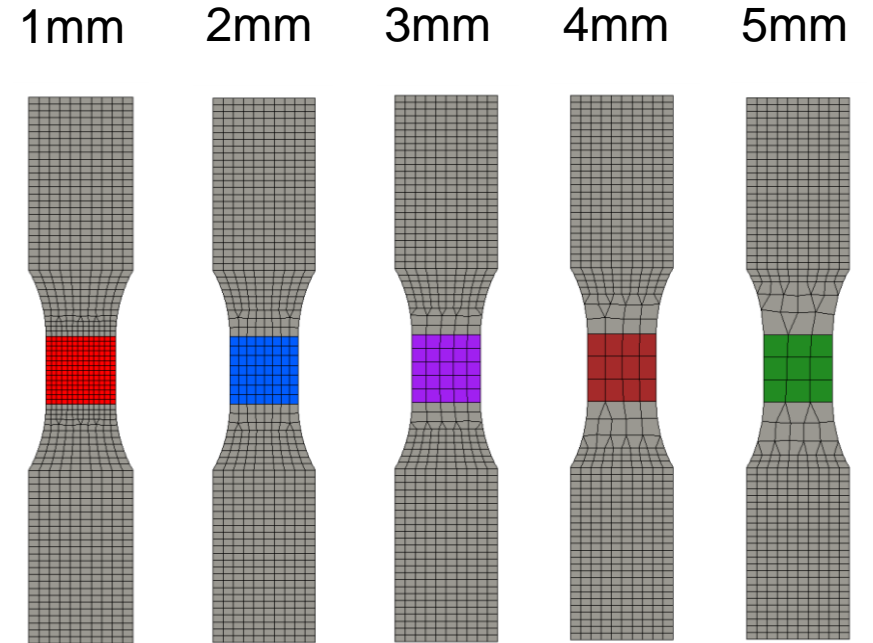
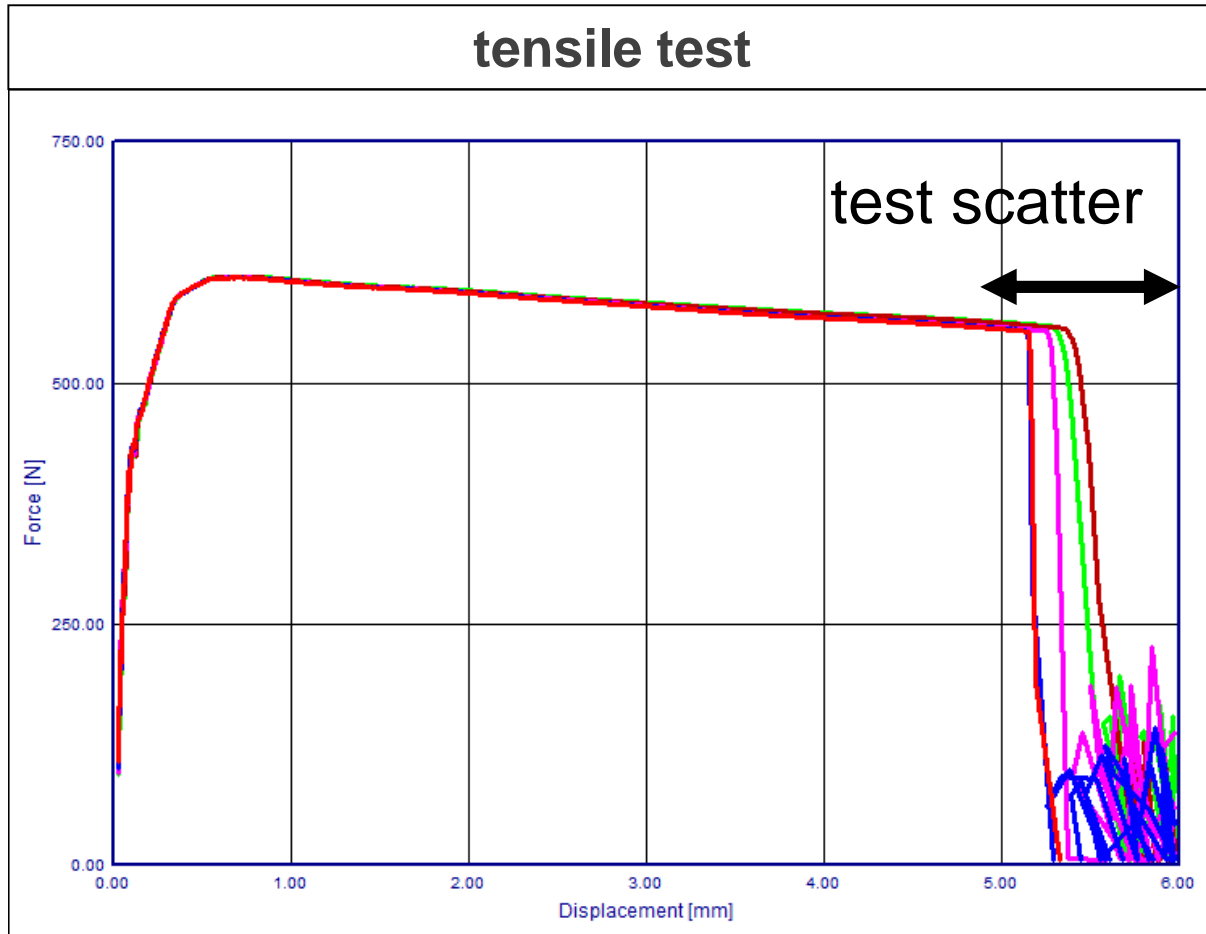


*MAT-SAMP 1 with internal FM - validation

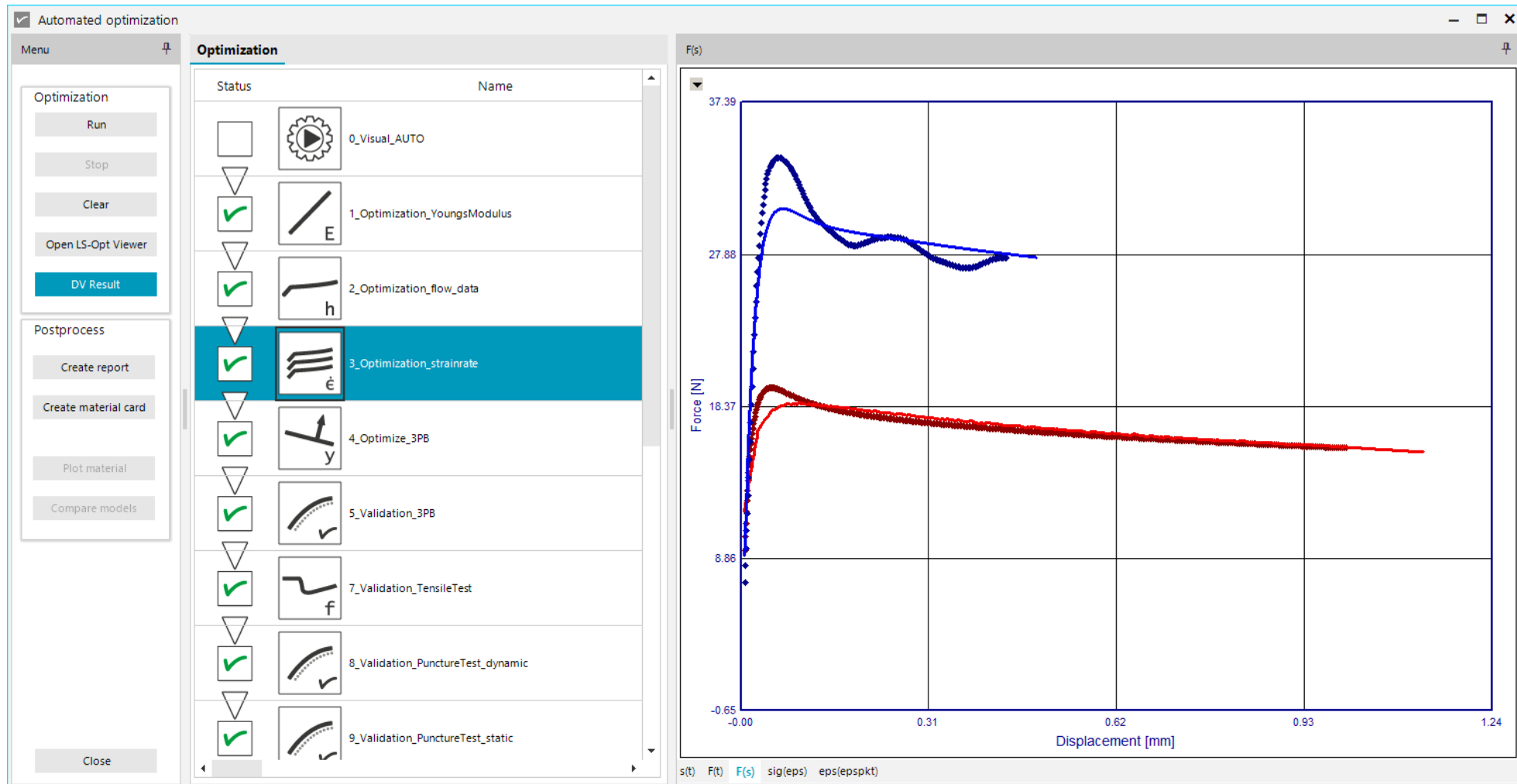


IMPETUS™ ~ 3 m/s
static ~ 1mm/s

*MAT-SAMP 1 with internal FM – influence elementsize



Outlook – NEW AUTOFIT FEATURE

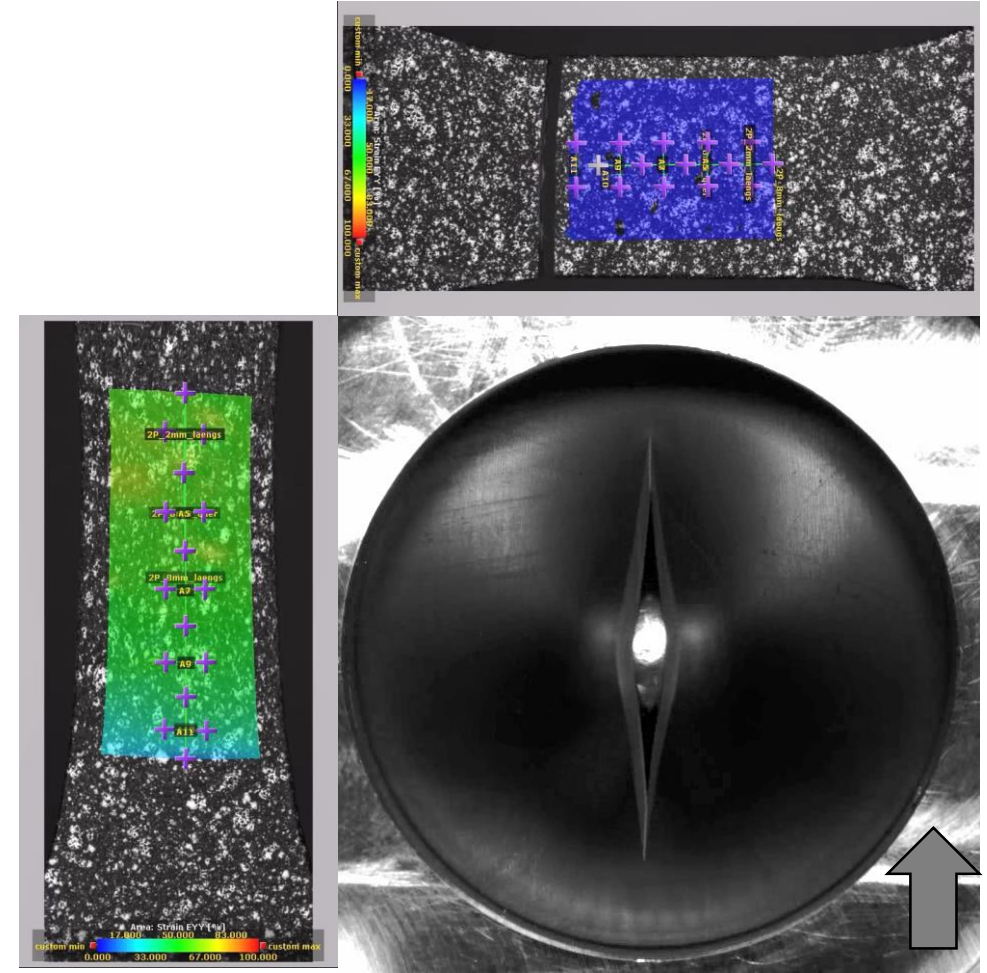
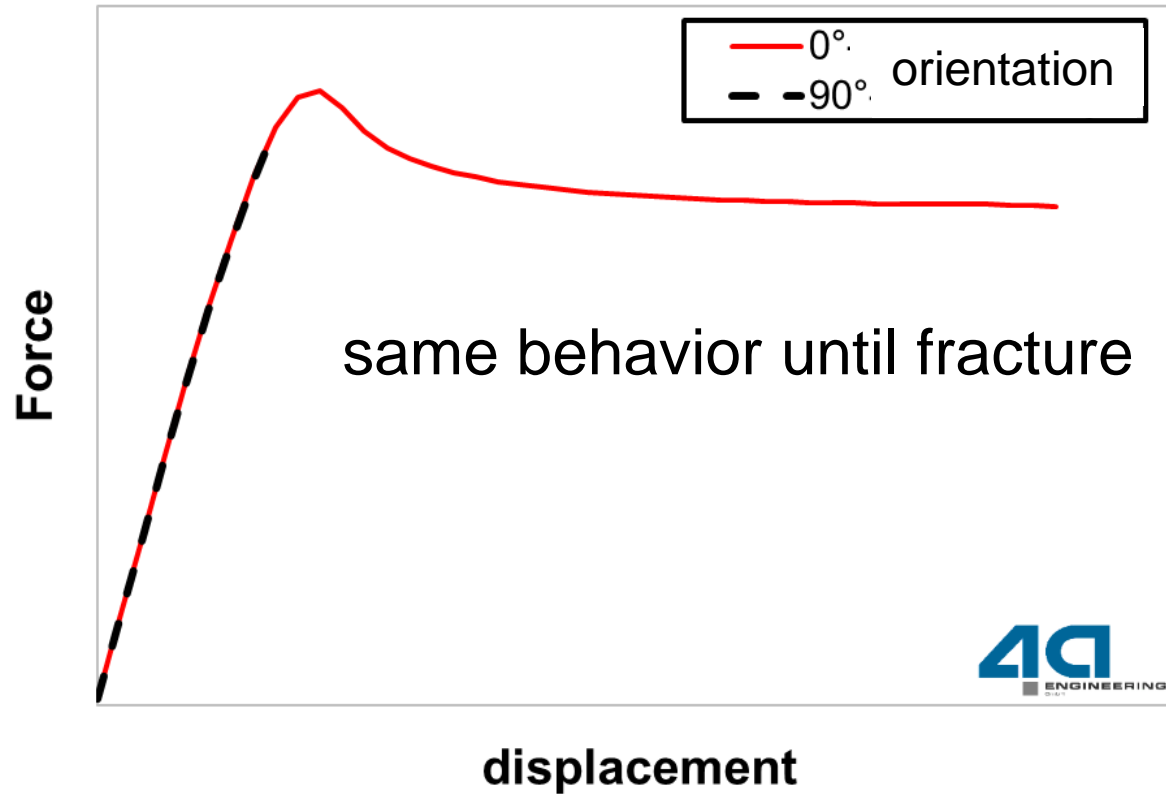


****MAT_ADD_GENERALIZED_DAMAGE***

Plastics ?

Influence of manufacturing process on failure

- example: ABS
 - The induced orientation by the injection molding process leads to an anisotropic failure behavior.



Summary

- material characterization
 - in the triaxiality range of 0.33 to 0.66
- GISSMO \neq DIEM (each model has some specialties)
- GISSMO can be used for plastics
 - benefits of model often not used for plastic materials
- DIEM → table input for initial failure enables more flexibility
 - over triaxiality
 - over strain rate → BIAX
- tools needed to handle data and to fit complex failure models

