MPIP - Material parameter identification process with 4a impetus

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(4a engineering GmbH)

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powered by 4a engineering GmbH

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Agenda

- **Company presentation**
- Introduction 4a impetus
- New 4a impetus features
- Material Parameter Identification Process (MPIP)
- Material card generation – Autofit workflow for *MAT_024
- Material card generation – Anisotropic materials *MAT_157
- Summary and outlook, discussion

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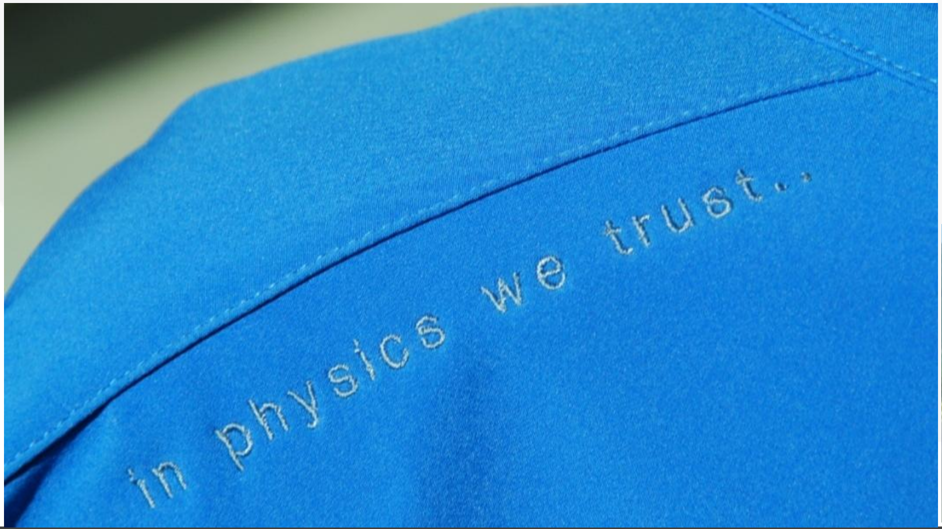
4a technology group

- 4a technology-group: founded in 2002
- Location: Traboch, Austria
- Number of employees > 80
- Field of operation: global
- Certificates: ISO 9001
- more than 2000 projects
- more than 400 customers



4a technology group

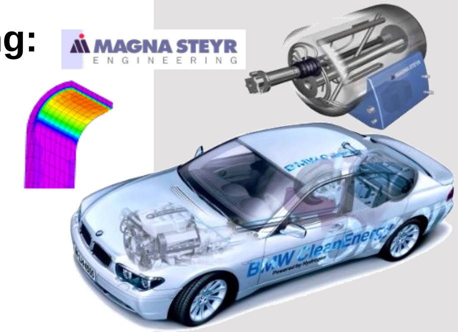
4a ENGINEERING GmbH

4a engineering GmbH

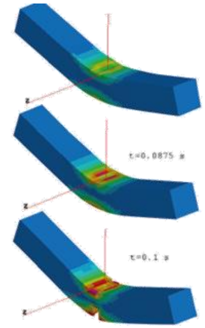
- polymer and materials science
- numerical simulation methods
- fiber reinforced plastics and composites
- product development
- method and software development
- material characterization

strut bar:

LH_2 – tank mounting:



4a IMPETUS

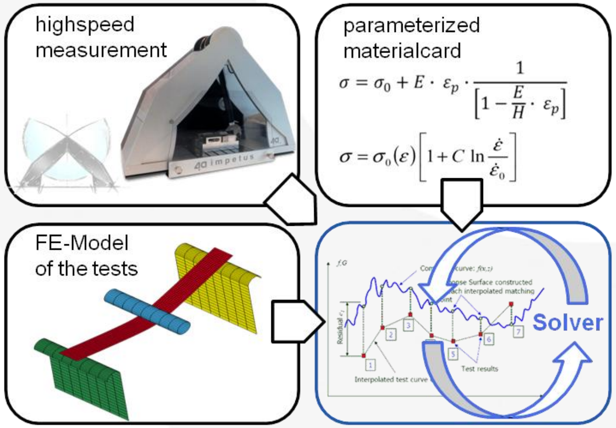


validated material cards for plastics, composites, metals, foams, ….

4a engineering GmbH
Licensing

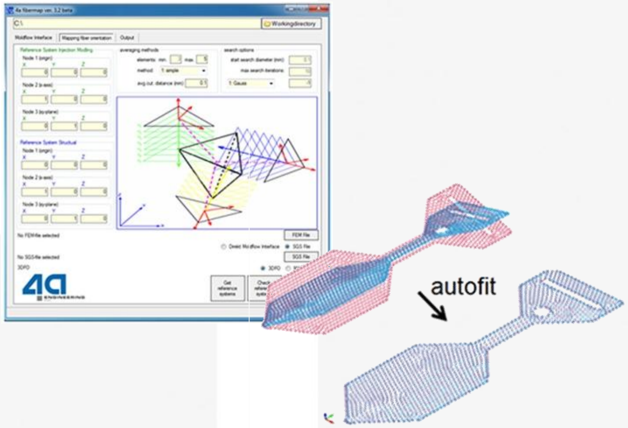
- Introducing new token concept
- Software products **4a impetus, 4a fibermap, 4a micromec** and their modules are now accessible

IMPETUS



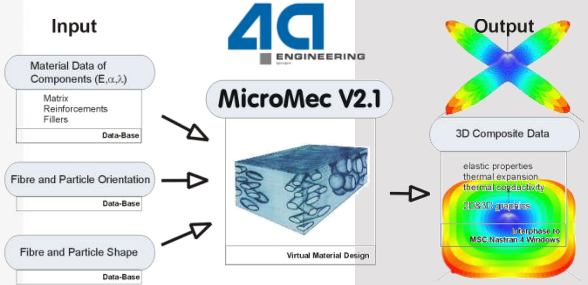
validated material cards

FIBERMAP



individual mapping process information

MICROMEC



3D thermo elastic anisotropic material cards

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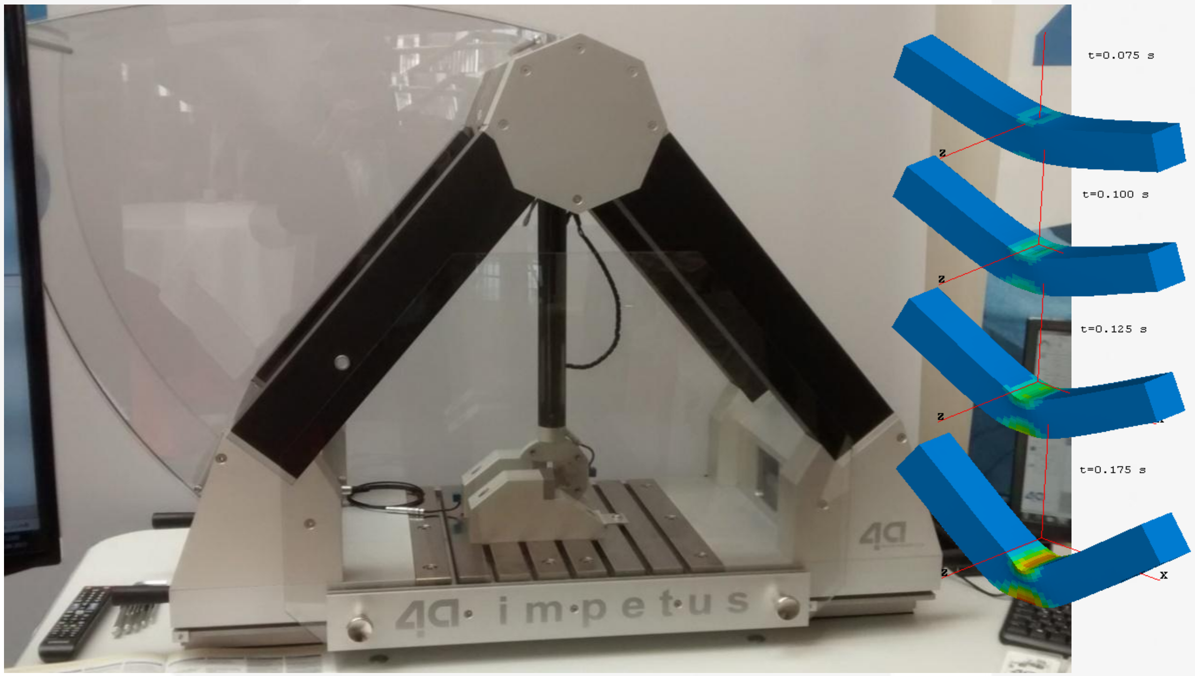
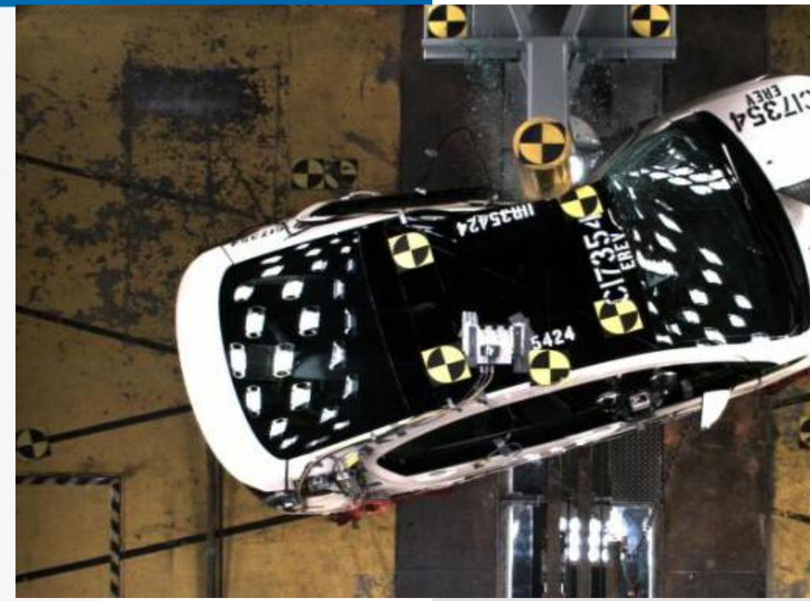
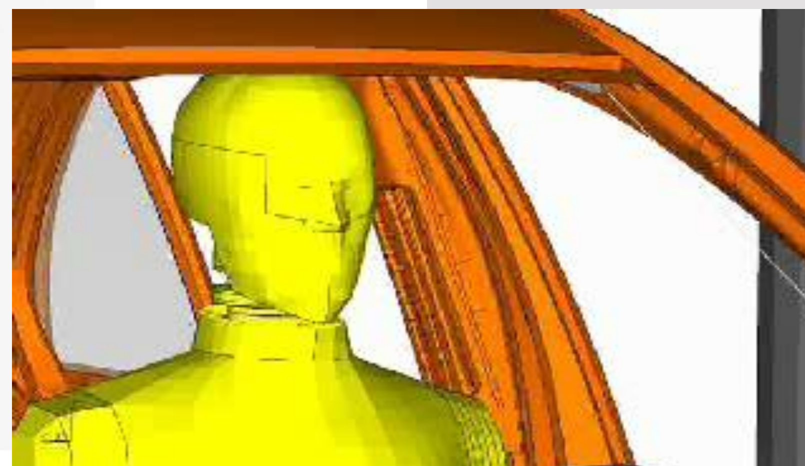
4a impetus
Testing system

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





source: http://gm-volt.com/



source: Dynamore GmbH

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4a impetus
Material characterization

4a ENGINEERING GmbH

static

External Testing

gom Optical Measuring Techniques

Zwick / Roell

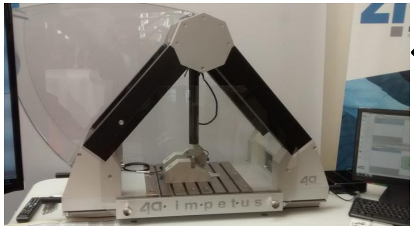
MTS

INSTRON

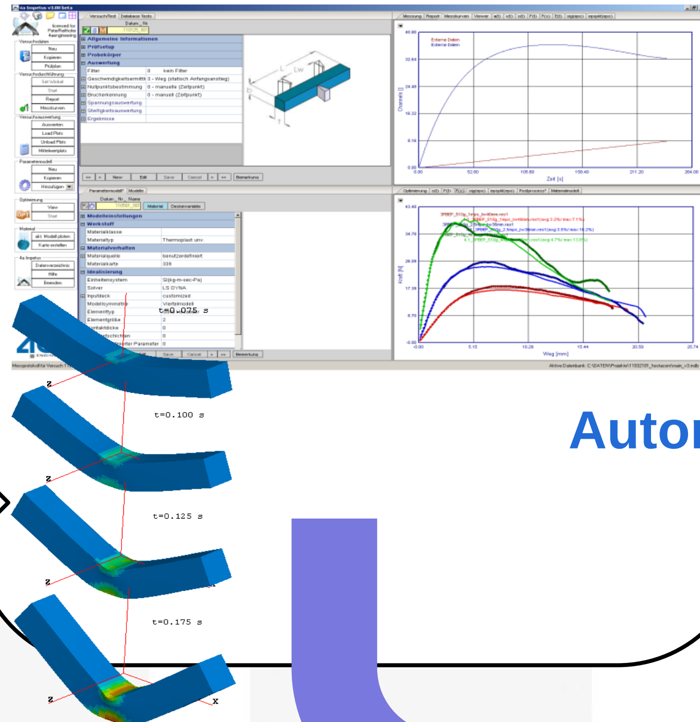
SHIMADZU

dynamic

4a impetus Hardware



4a impetus Software



Automatic*

Testresults

Reports

Workflow

LS PP

Postprocess

LS-OPT

Reverse Engineering

Optimizer

Materialcards

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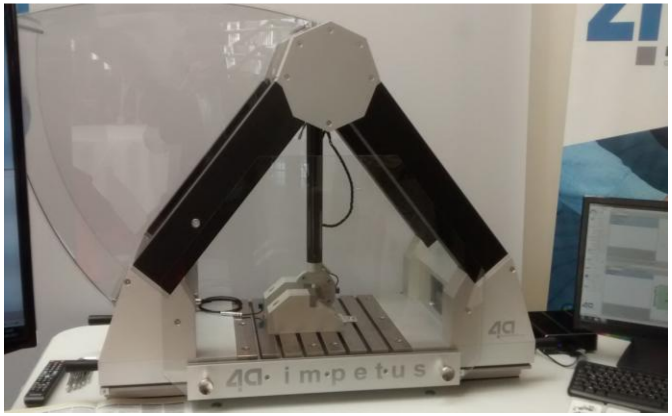
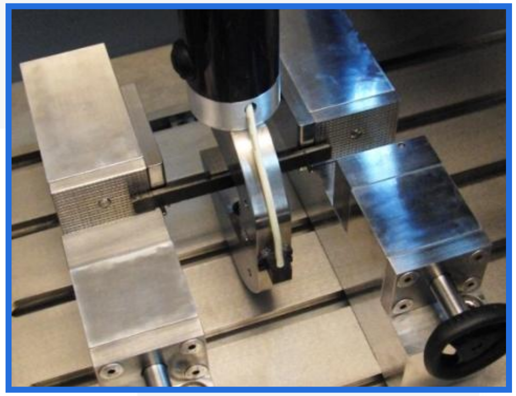
4a impetus

Software solution from the test to the material card

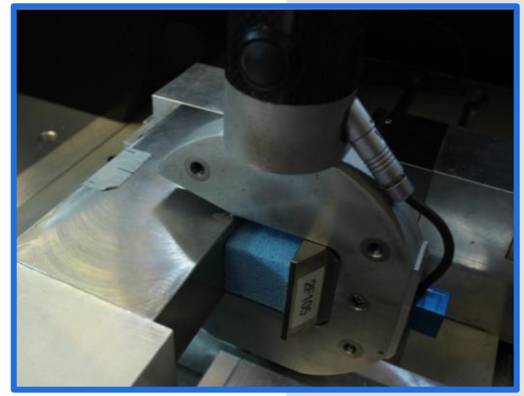
4a impetus Hardware



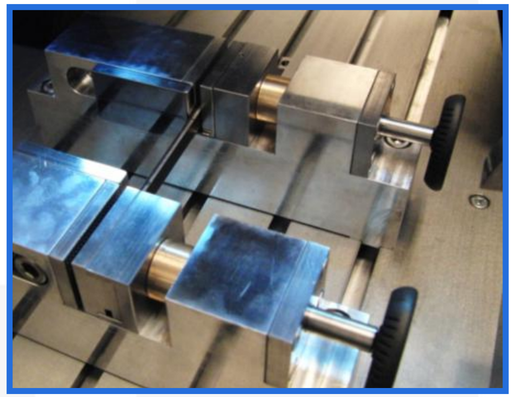
- single pendulum up to 4.5 m/s
- double pendulum up to 8 m/s
- **standard test methods**
- **specialized test methods**
- component testing



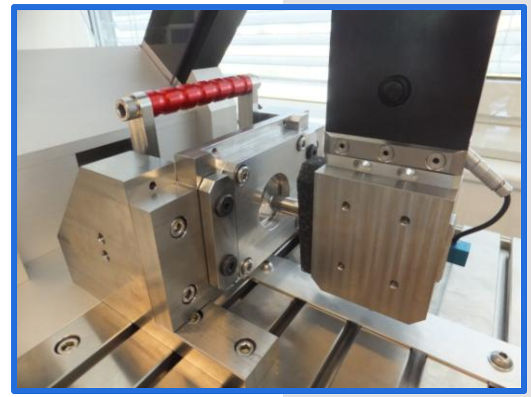
bending test



compression test

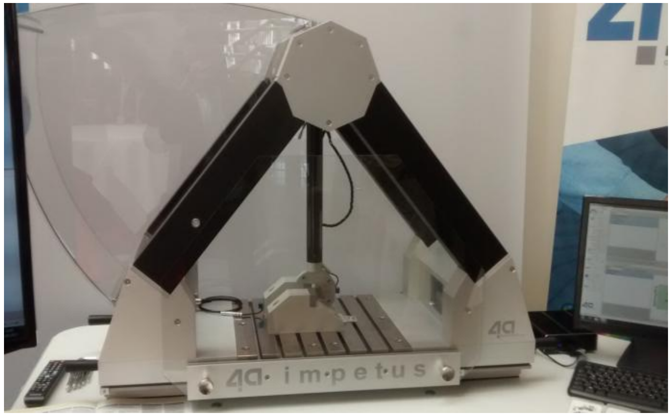


clamped bending test

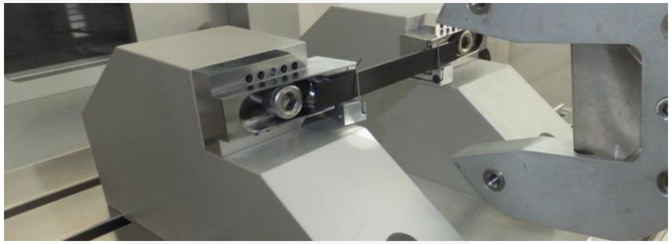
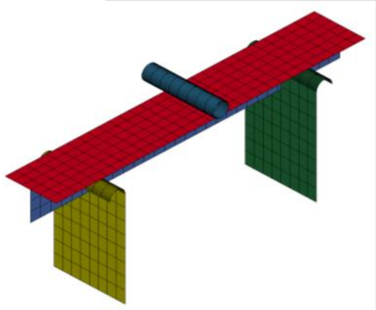


puncture test

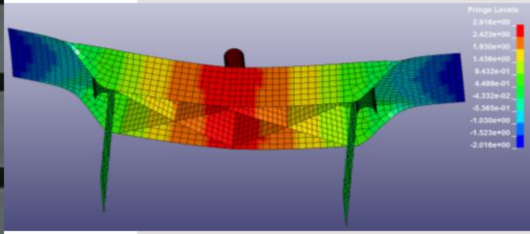
4a impetus Hardware



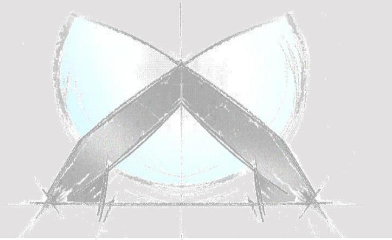
- single pendulum up to 4.5 m/s
- double pendulum up to 8 m/s
- standard test methods
- **specialized test methods**
- component testing

T-rib

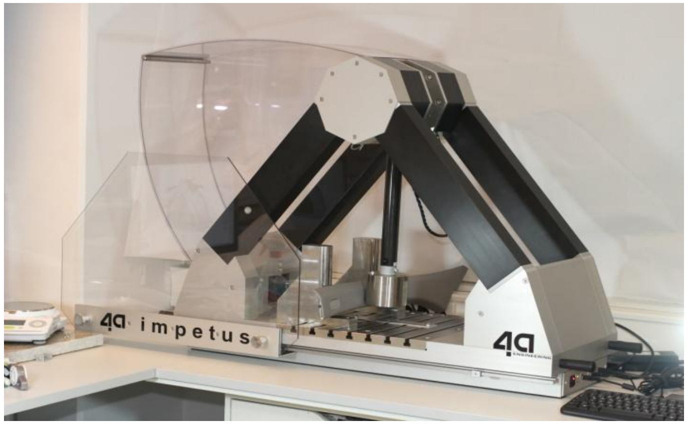



double X-rib



4a impetus
Software solution from the test to the material card

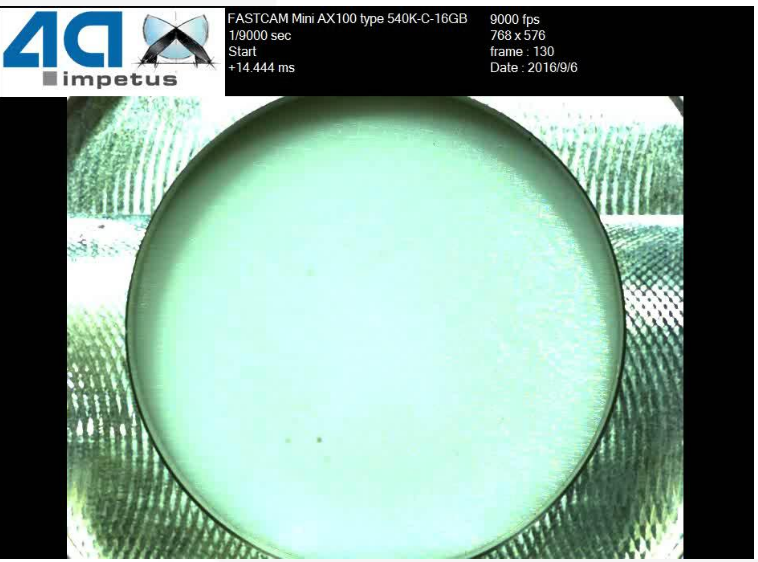
4a impetus Hardware

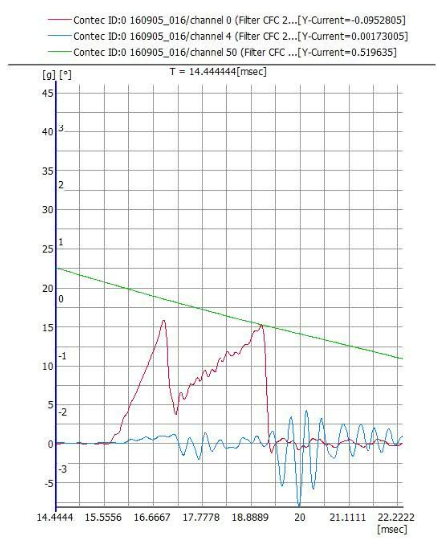


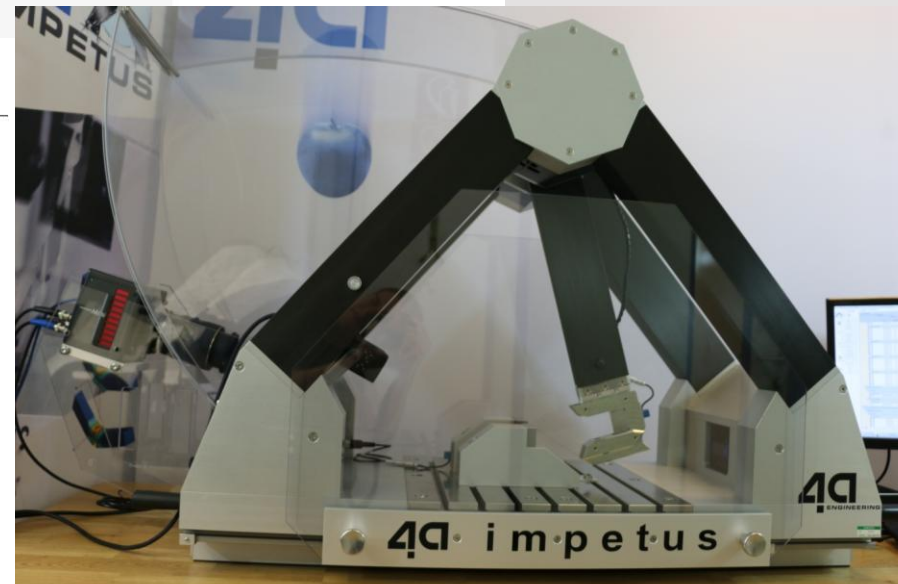
- single pendulum up to 4.5 m/s
- double pendulum up to 8 m/s
- standard test methods
- specialized test methods
- **component testing**

4a impetus
High-speed camera

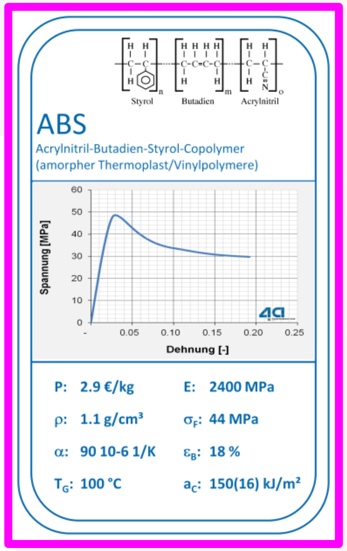
- **Visualization of dynamic behavior** of the material during test (crack initiation and propagation)
- Easy view, different angles possible
- Trigger signal from 4a impetus → **synchronizing**

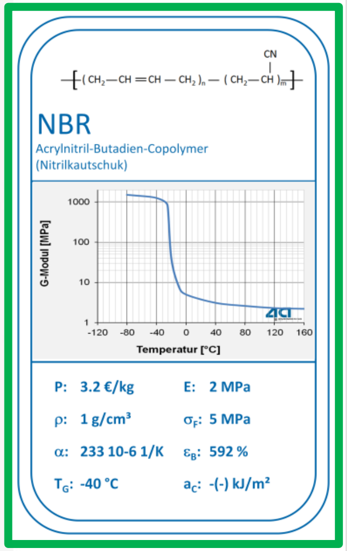




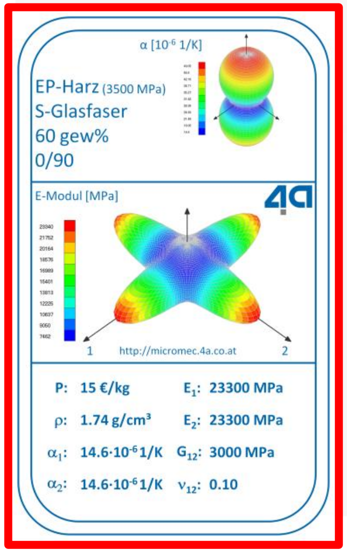


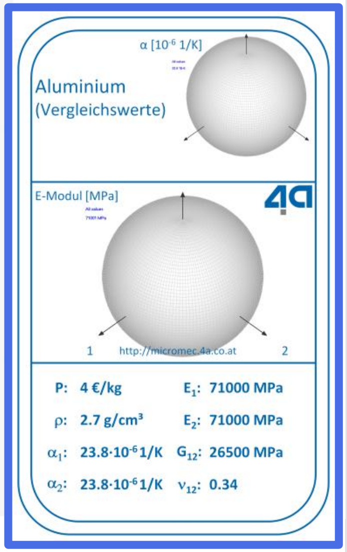
- 4a has already tested a wide range of
  - thermoplastics (ASA, ABS+PA; ABS+PC; PA6; PA6(6) GF30..50; PA66+P6; PBT GF30; PC; PE; PP; PP+ varnish; PP rubber modified; PP GF20..40; PP Impact modified; PP MX10; PP MX20; PP MX40; PP CF; PP+EPDM; MuCell-materials, …)
  - foams (EPP30..80; PU RG 55, PU RG 65)
  - rubbers (EPDM, silicone)
  - thermoset materials (CFRP, GFRP with epoxy resin)
  - metals (aluminum, DC04, high strength steels, …)
  - wood (beech, multiplex, chipboards, MDF)





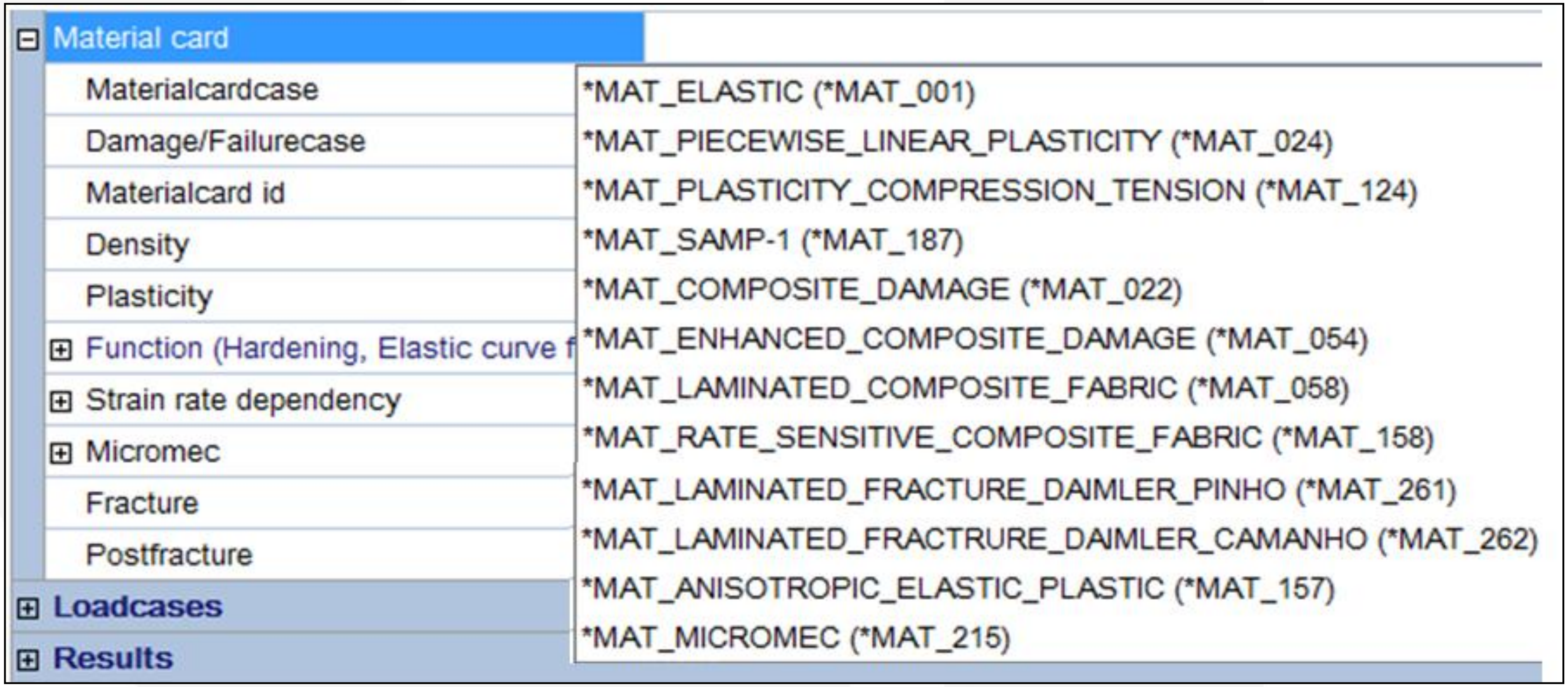
from:
4a Quartet card game “plastics”





from:
4a Quartet card game “composites”

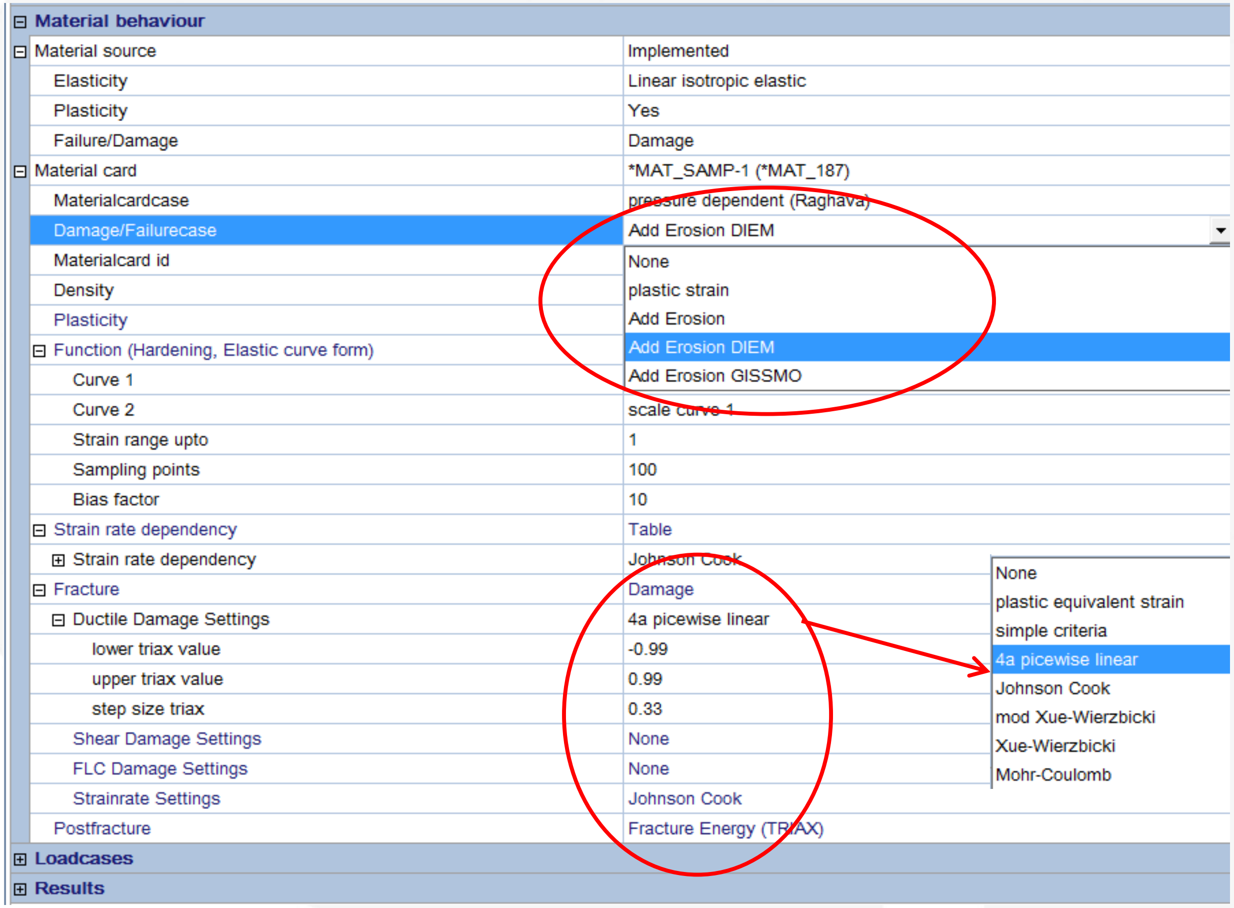
- Plenty of direct implemented **LS-Dyna material models** (also Abaqus, PamCrash)

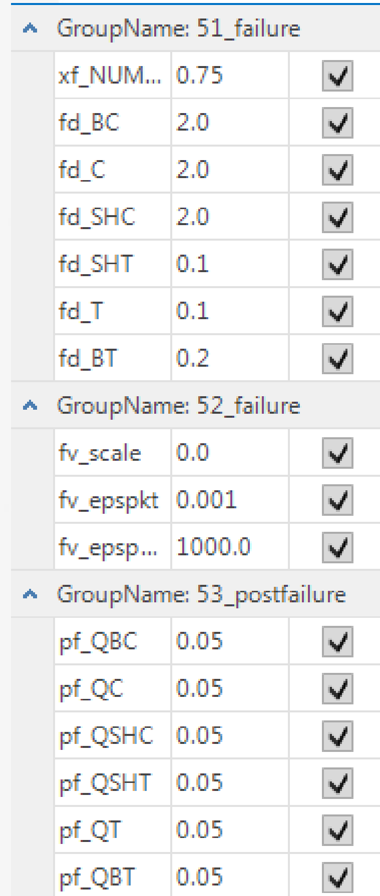


- Whole number of LS-Dyna material models is available through userdefined material card

Failure models

- Many possibilities to consider failure





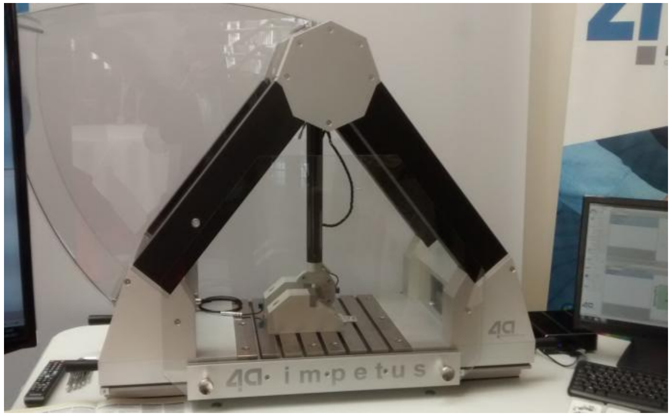
Triaxiality

Strain rate dependency

Post failure

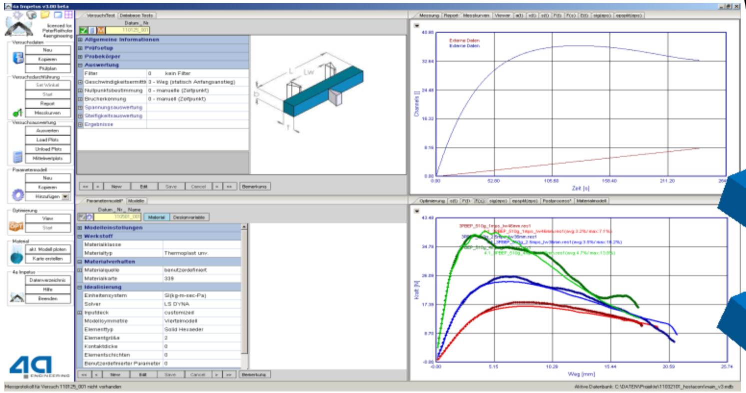
4a impetus
Software solution from the test to the material card

4a impetus Hardware

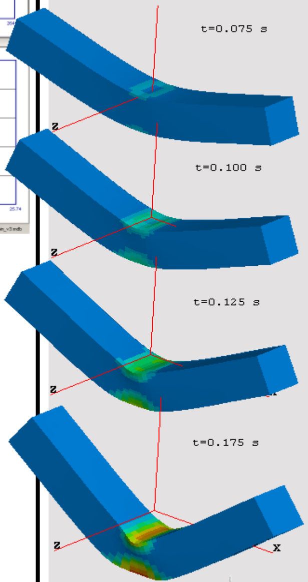


- single pendulum up to 4.5 m/s
- single pendulum up to 8 m/s
- standard test methods
- specialized test methods
- component testing
- advanced measurement

4a impetus Software



- manage test results
  (import, export, filter, evaluate)
- statistics
- automatic report
- materialcard generation
- materialcard validation



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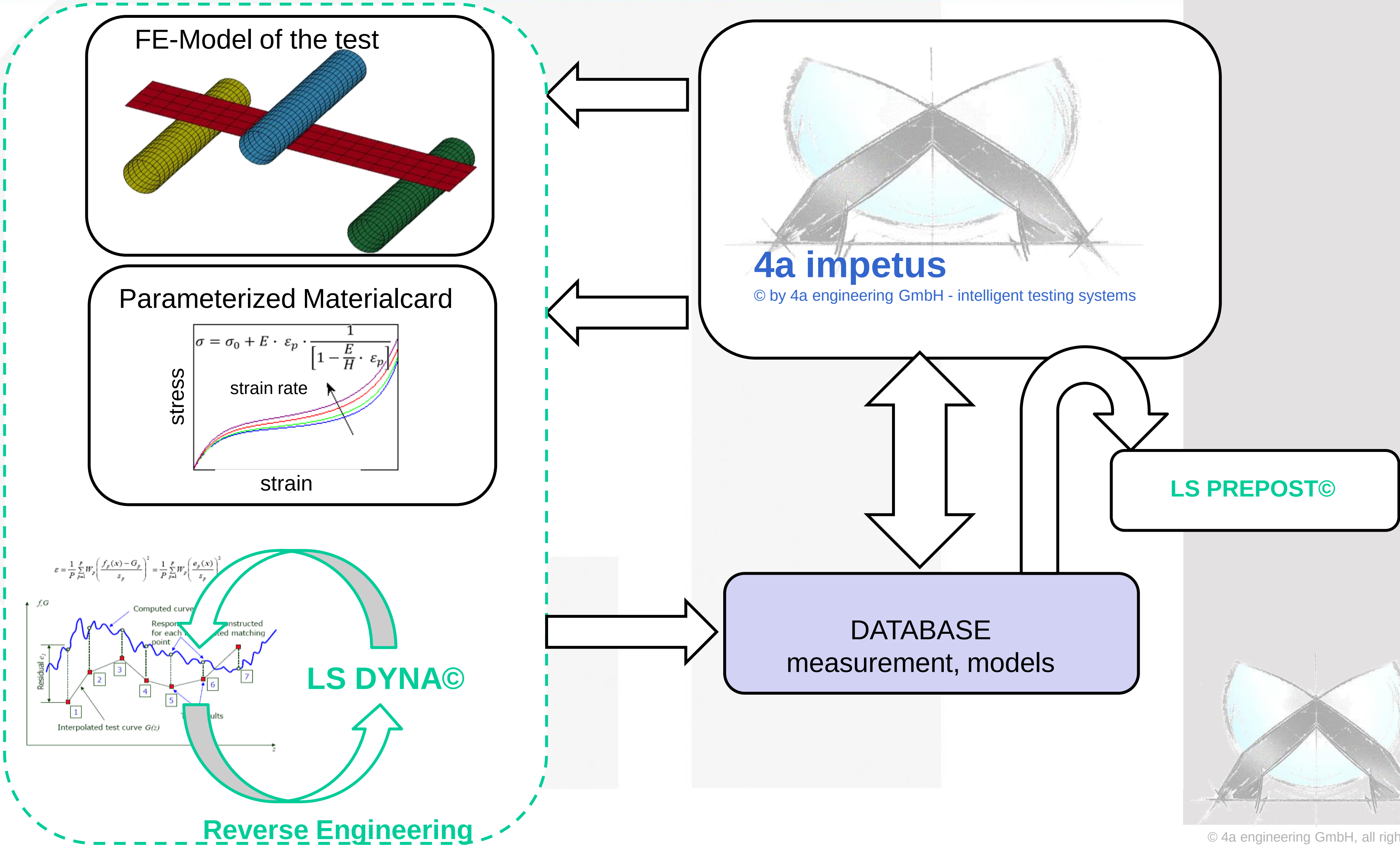
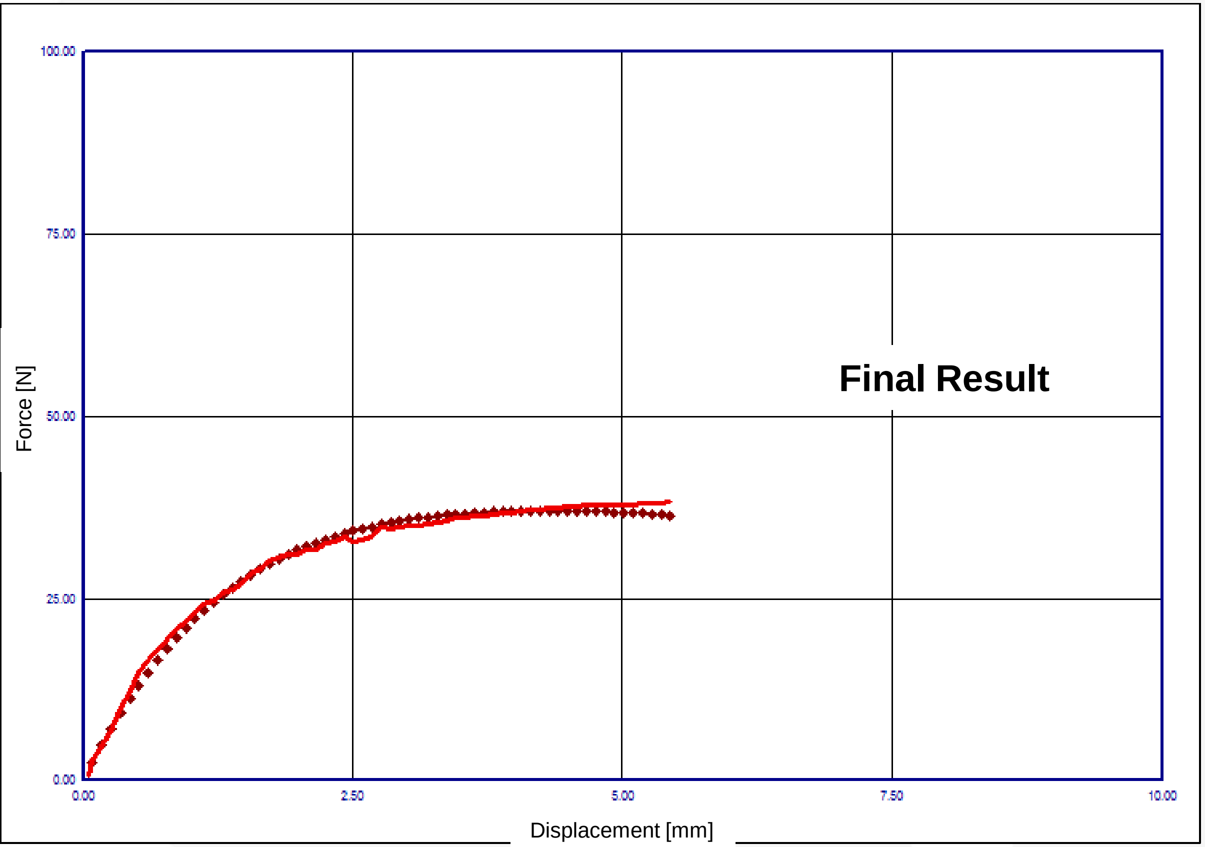
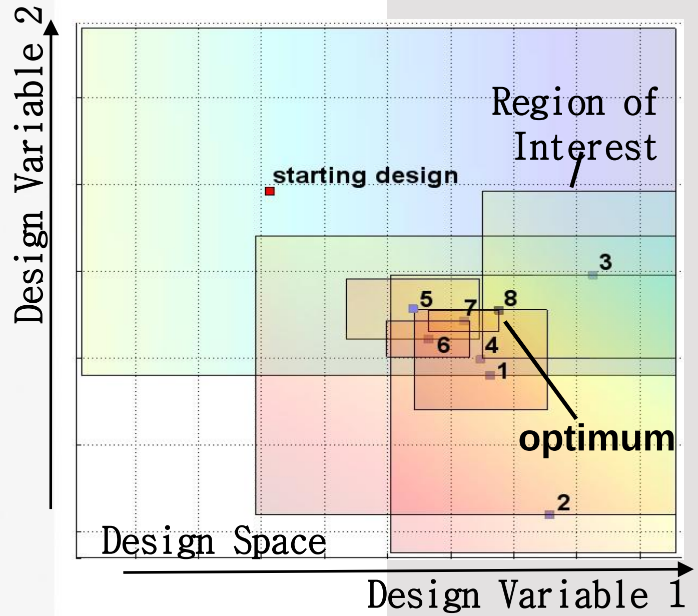
4a impetus
Reverse Engineering



Determining the plastic characteristics

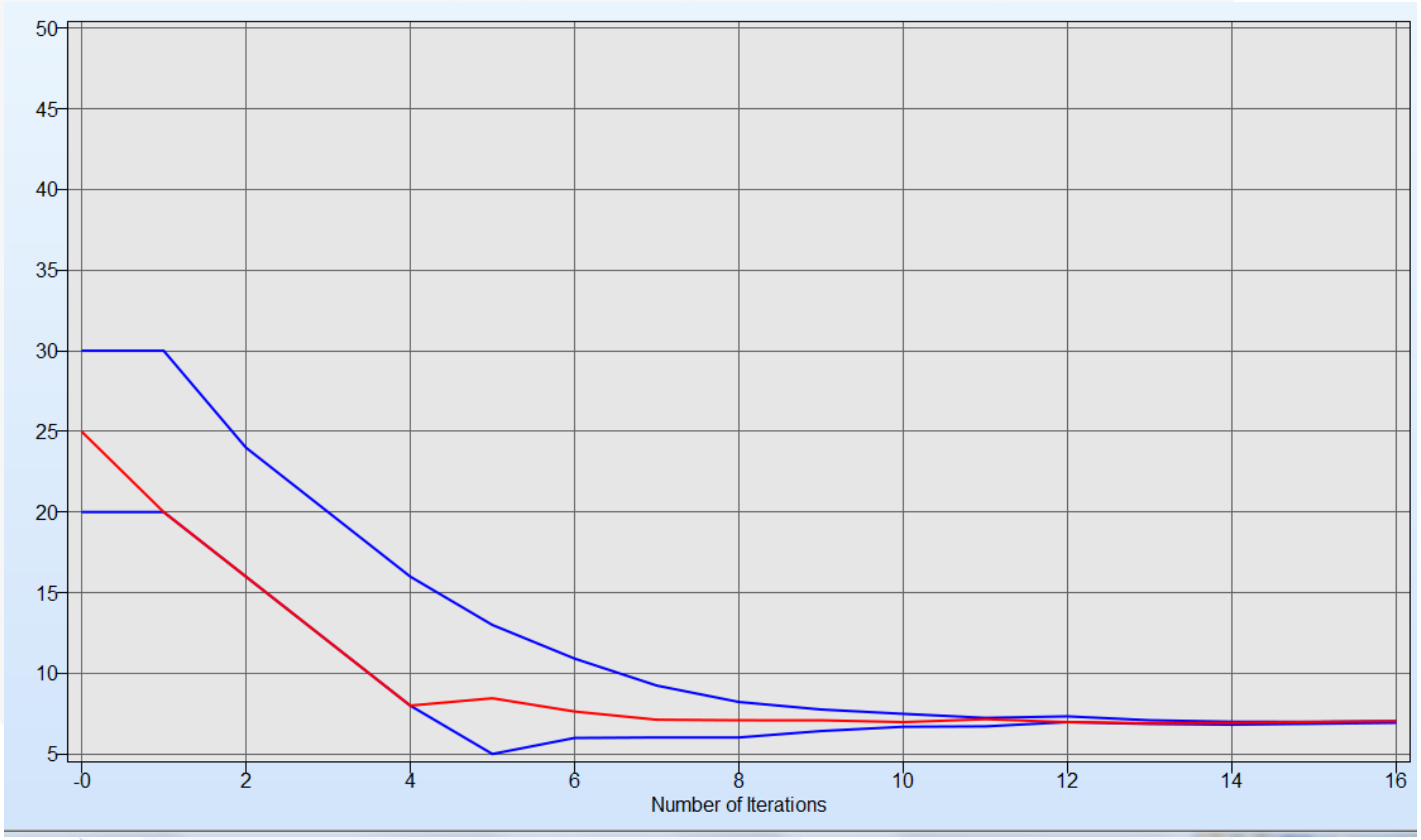


— simulation result
♦ ♦ ♦ mean value curve of tests



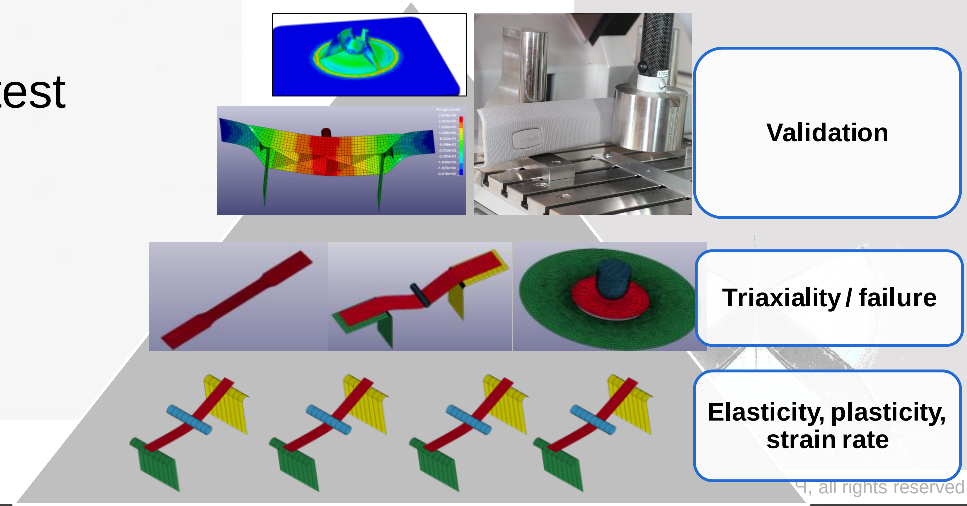
Source: A. Förderer (DYNAmore GmbH) - Anpassung von Werkstoffmodellen für Polymere mittels dynamischer Pendelversuche; Dynaforum 2013; LS-OPT® User's Manual v3.3 Mär 2008

Development of the design variable σ_y



- Modeling of a material card – suggestions for testing:

- Material model *MAT_024:
  - 2 quasi-static and 2 dynamic bending tests, 3rd dynamic bending test for validation → capturing strain rate dependency
- Material model *MAT_24 with simple failure / *MAT_124 (tension/compression asymmetry):
  - Additional 1 dynamic clamped bending test and/or 1 quasi static tensile test
- Material model *MAT_24 with complex failure / *MAT_187 (general yield surface):
  - Additional 1 static and 1 dynamic puncture test



Source: Reithofer P. - Time dependent material behavior of plastics; 4a Technologietag 2016

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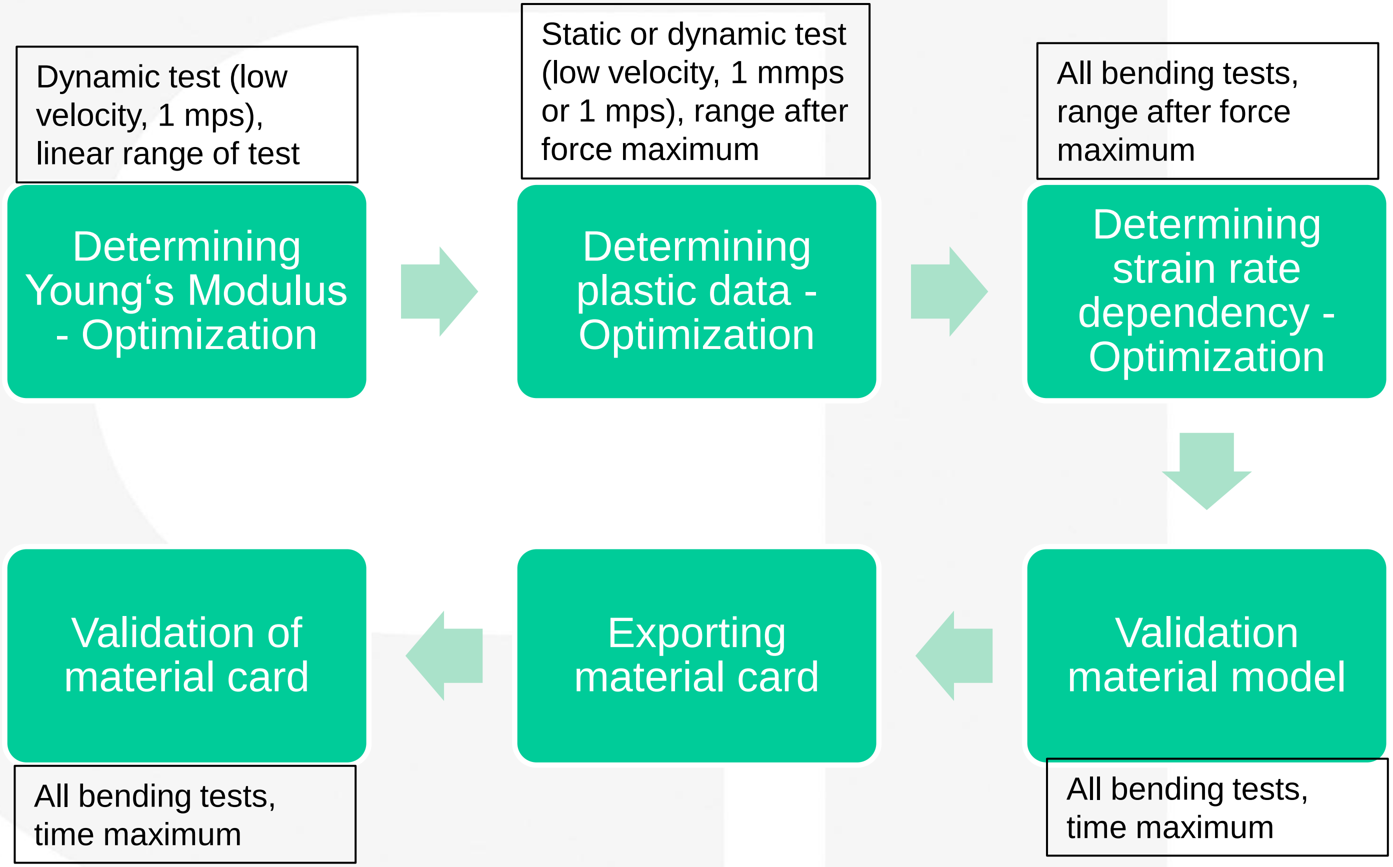
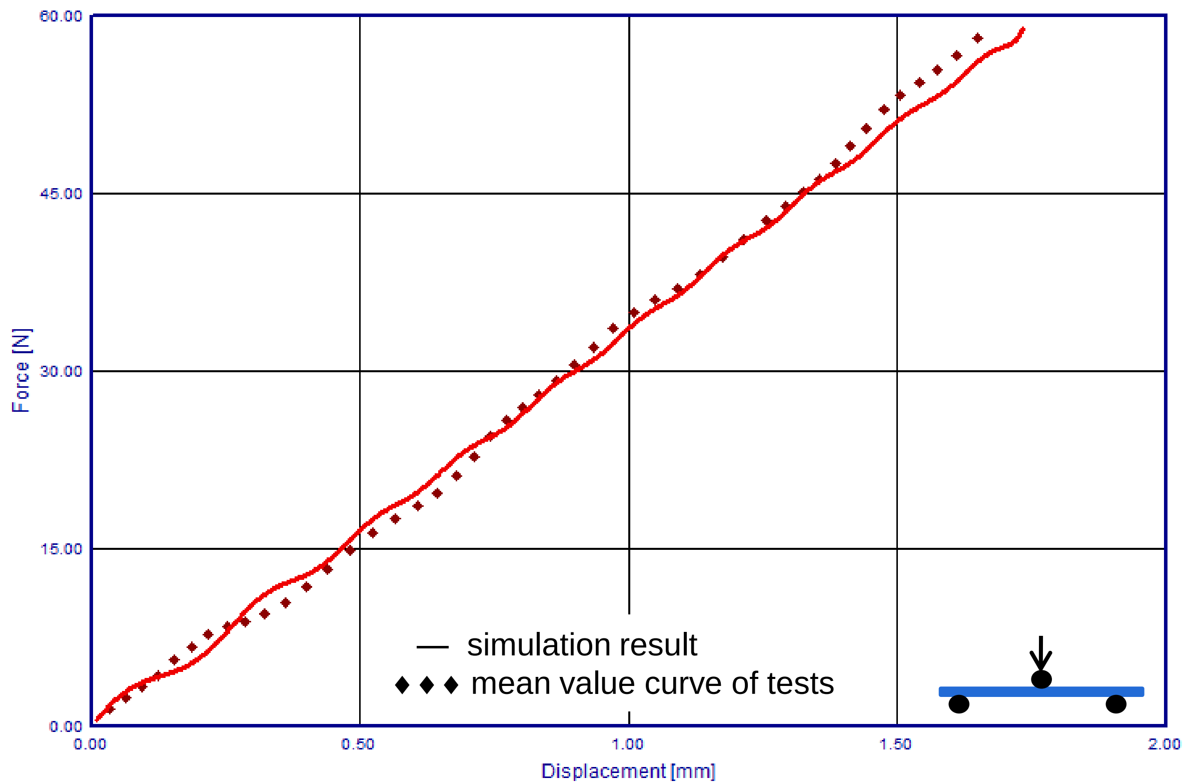
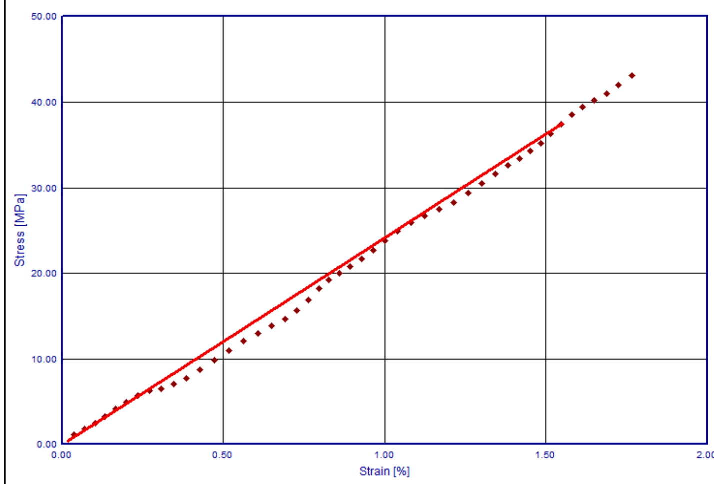
MPIP - Workflow

Overview of the workflow to generate a material card *MAT_024 (for crash application):



MPIP – Reverse engineering, PC/ABS





v_0 [m/s]	l_w [mm]	$m_{Pendular}$ [g]	b [mm]	t [mm]	l [mm]
1	**40**	**1977**	**10**	**2.8**	**50**

Model 170503_021
Solver: LS DYNA, Metamodel: MAT_001, Element size: 2mm,
Element type:16: Fully integrated shell element (very fast), Number of integration points: 5
Assumption: Poisson's number 0.3, Friction coeff. 0.1

The first step is to determine the **Young's modulus** out of the 3-point-bending test at the velocity of 1mps.

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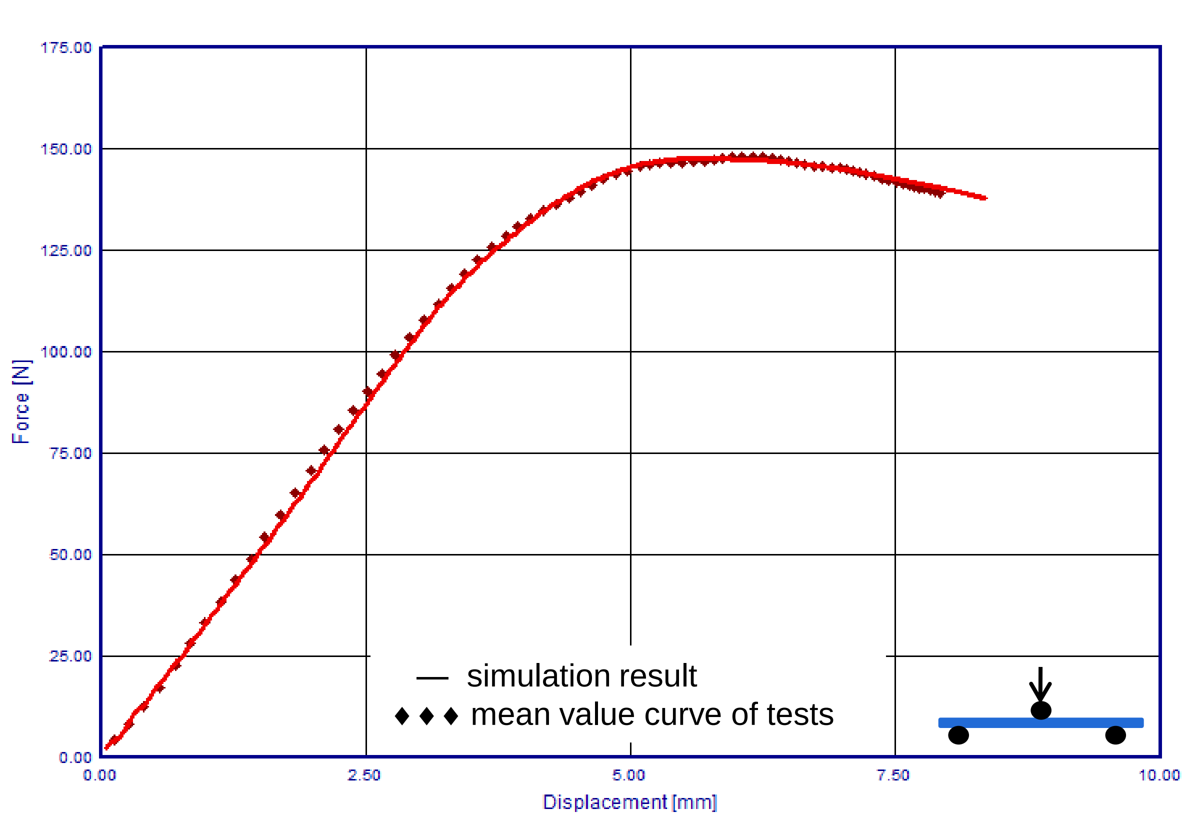
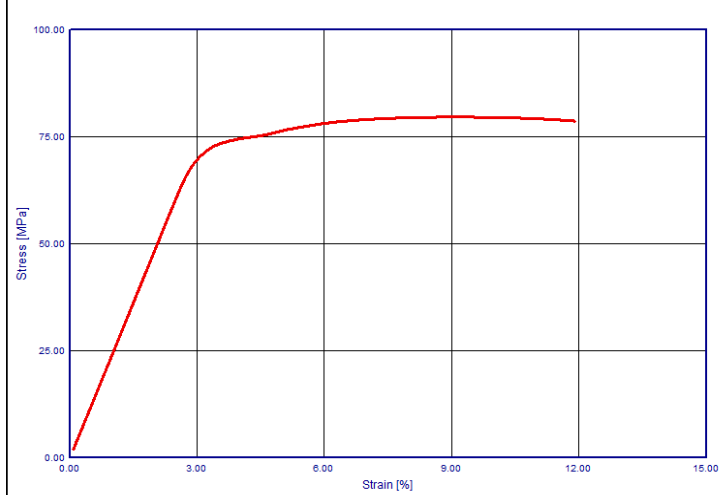
MPIP – Reverse engineering, PC/ABS



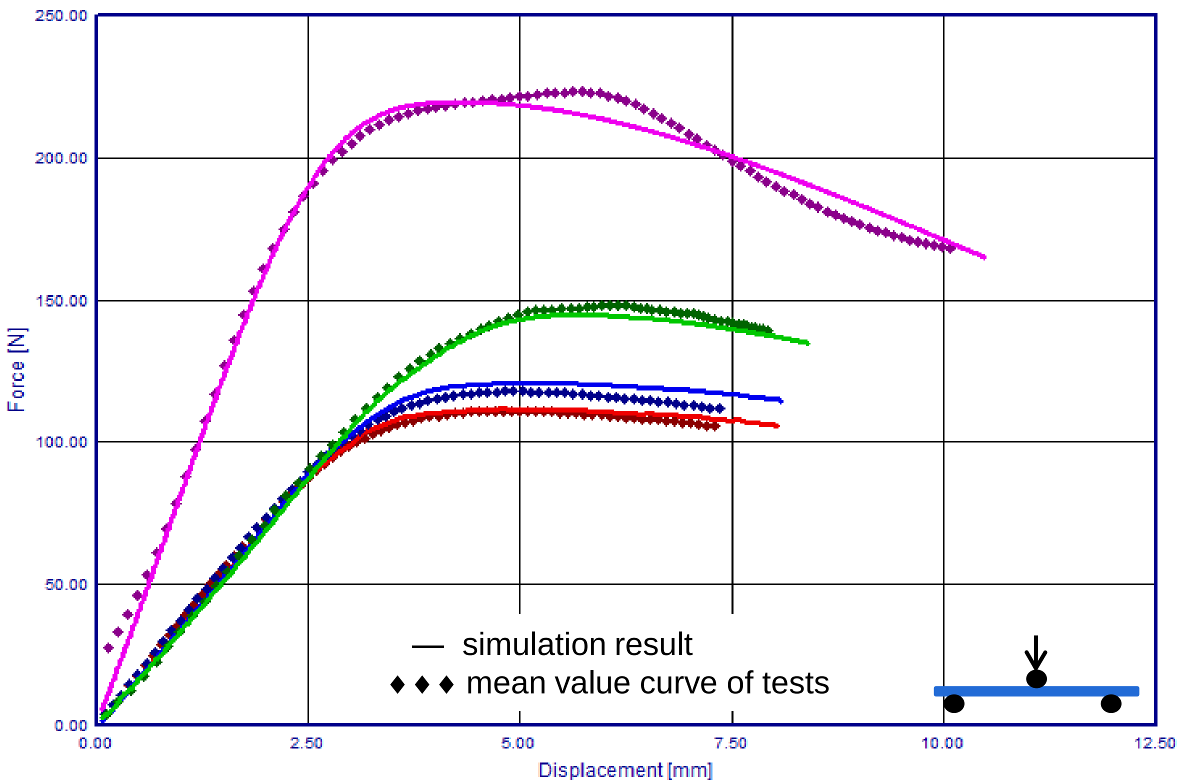


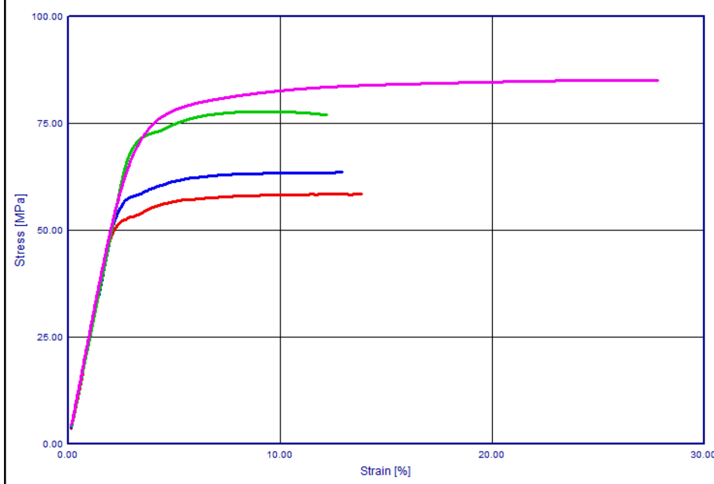
v_0 [m/s]	l_w [mm]	$m_{Pendular}$ [g]	b [mm]	t [mm]	l [mm]
1	**40**	**1977**	**10**	**2.8**	**50**

Model 170503_022
Solver: LS DYNA, Metamodel: MAT_024, Element size: 2mm,
Element type:16: Fully integrated shell element (very fast), Number of integration points: 5
Assumption: Poisson's number 0.3, Friction coeff. 0.1

Afterwards the **specific plastic values** are identified using the dynamic low 3-point-bending test.

MPIP – Reverse engineering, PC/ABS

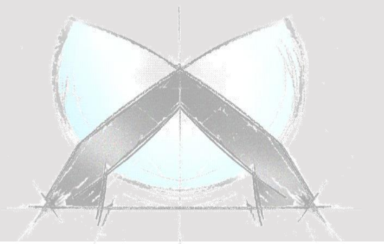




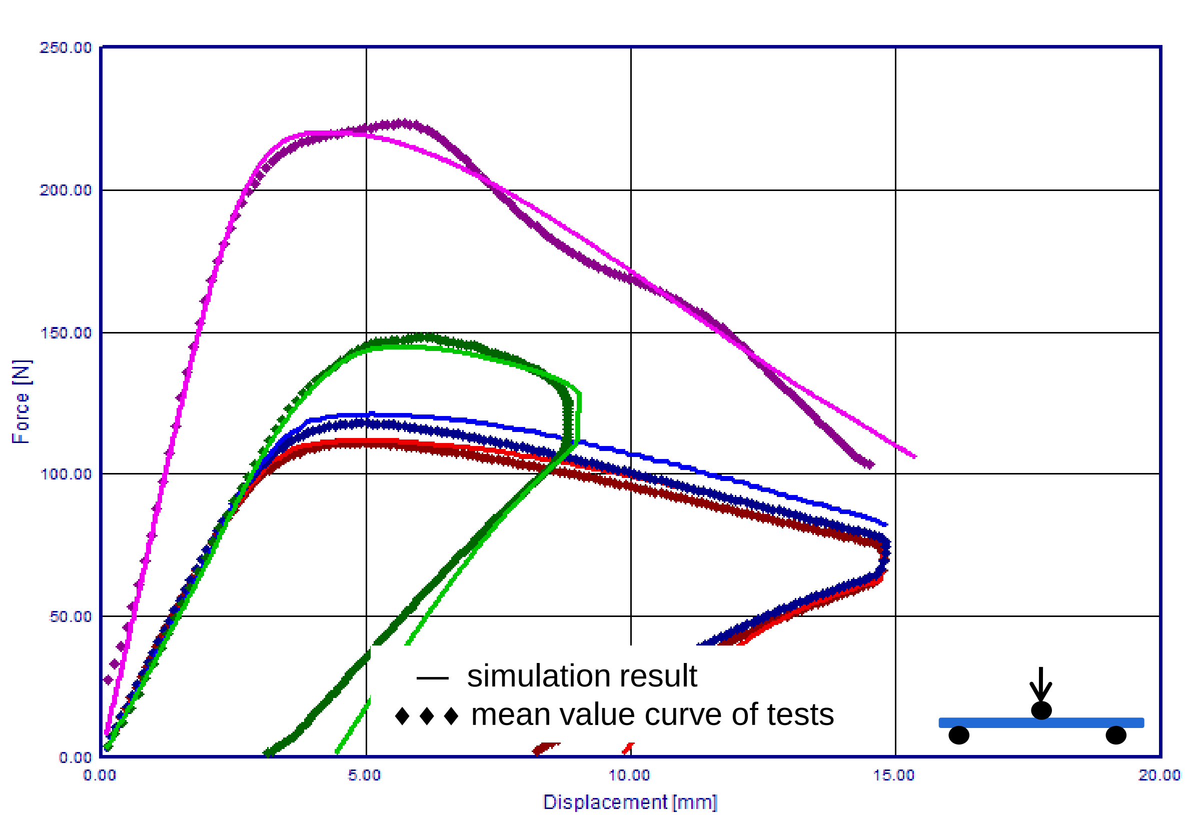
v_0 [m/s]	l_w [mm]	$m_{Pendular}$ [g]	b [mm]	t [mm]	l [mm]
0.0001	**40**	**0**	**10**	**2.8**	**50**
0.001	**40**	**0**	**10**	**2.8**	**50**
1	**40**	**1977**	**10**	**2.8**	**50**
4.4	**30**	**1977**	**10**	**2.8**	**40**

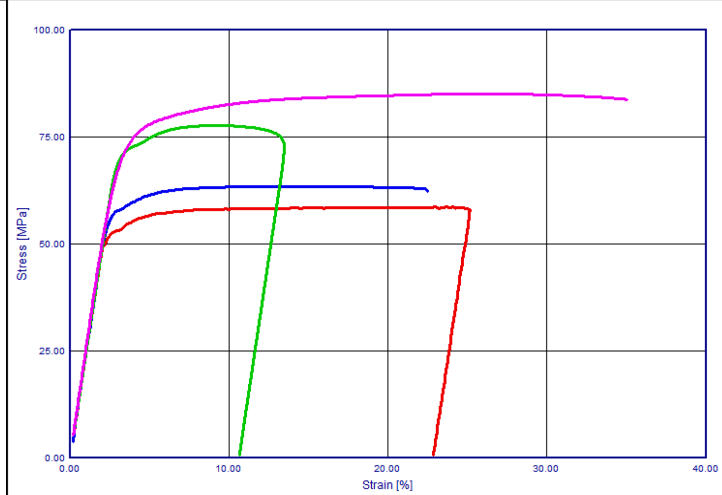
Model 170503_023
Solver: LS DYNA, Metamodel: MAT_024 Plasticity Table Rate Table, Element size: 2mm,
Element type:16: Fully integrated shell element (very fast), Number of integration points: 5
Assumption: Poisson's number 0.3, Friction coeff. 0.1

Using the 3-point-bending tests the **strain rate dependency** of Johnson-Cook was determined. The force/displacement-curves of the simulation show a good conformance with the test curves.



MPIP – Reverse engineering, PC/ABS





v_0 [m/s]	l_w [mm]	$m_{Pendular}$ [g]	b [mm]	t [mm]	l [mm]
0.0001	40	0	10	2.8	50
0.001	40	0	10	2.8	50
1	40	1977	10	2.8	50
4.4	30	1977	10	2.8	40

Model 170503_024
Solver: LS DYNA, Metamodel: MAT_024 Plasticity Table Rate Table, Element size: 2mm,
Element type:16: Fully integrated shell element (very fast), Number of integration points: 5
Assumption: Poisson's number 0.3, Friction coeff. 0.1

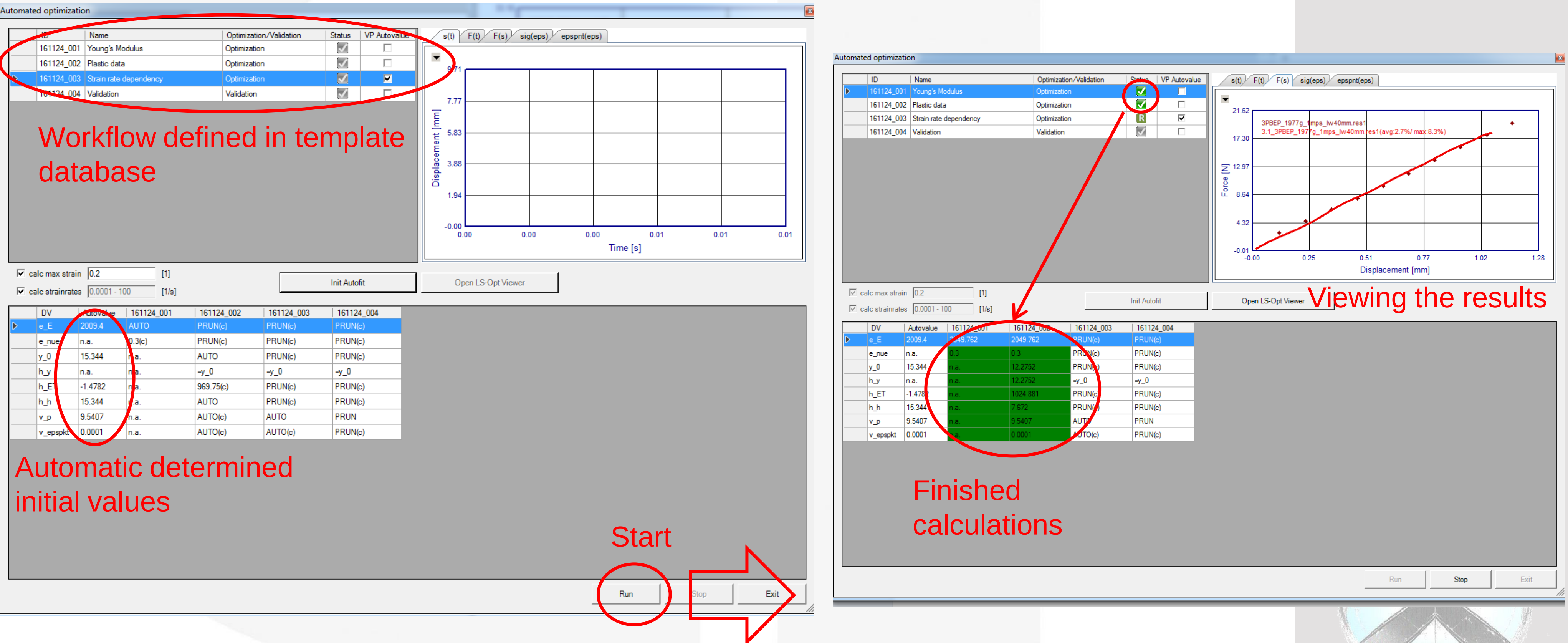
Finally the found material model is validated on the 3-point-bending tests.

4a impetus

MPIP – AUTOFIT

- Automatic workflow on 3-point-bending

  Standard material cards (e.g. *MAT_024)



- **Few clicks to generate a material card**

  Choose model for strainrate dependency – Init Autofit – Start Optimization

Agenda

- Company presentation
- Introduction 4a impetus
- New 4a impetus features
- Material Parameter Identification Process (MPIP)
- Material card generation – Autofit workflow for *MAT_024
- **Material card generation – Anisotropic materials *MAT_157**
- Summary and outlook, discussion

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

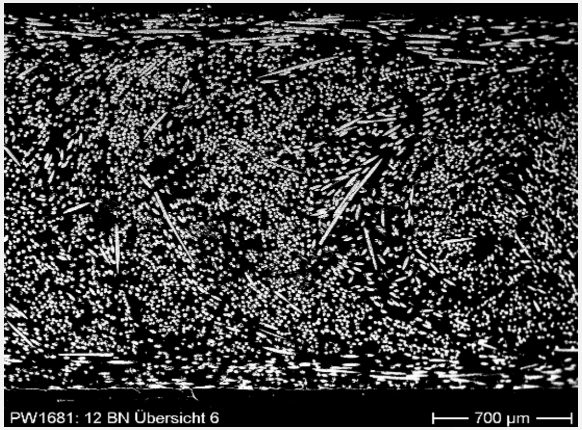
IN PHYSICS WE TRUST

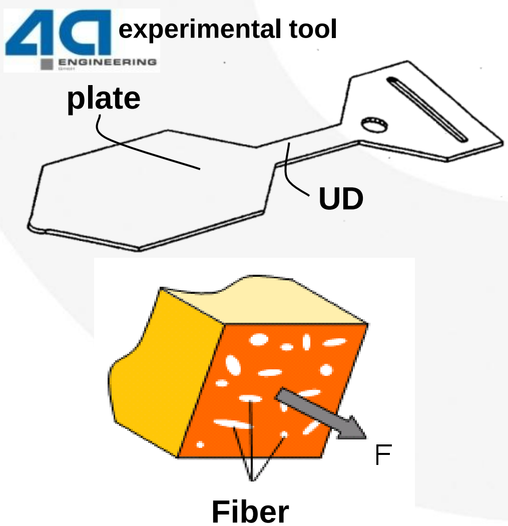
Fiber reinforced thermoplastics

Characteristic structure of reinforced plastics

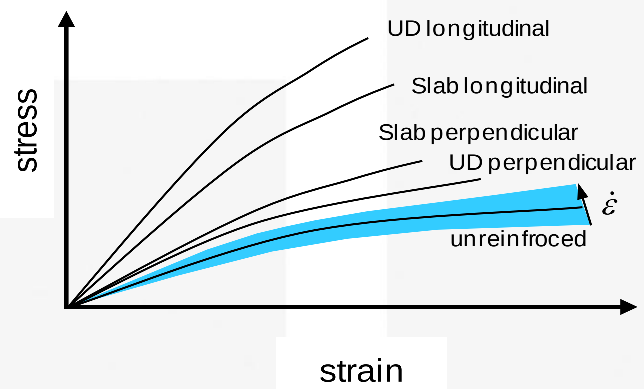
Fiber size and geometry → significant influence on part performance

Increasing fiber content → orthotropic properties increase & effect of strain rate diminishes (less content of matrix material)

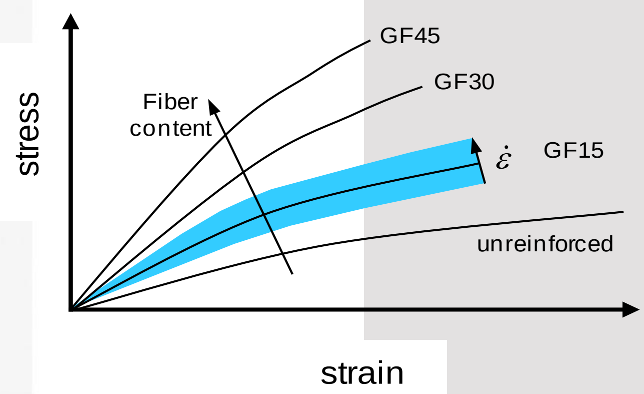




dependence on fiber orientation

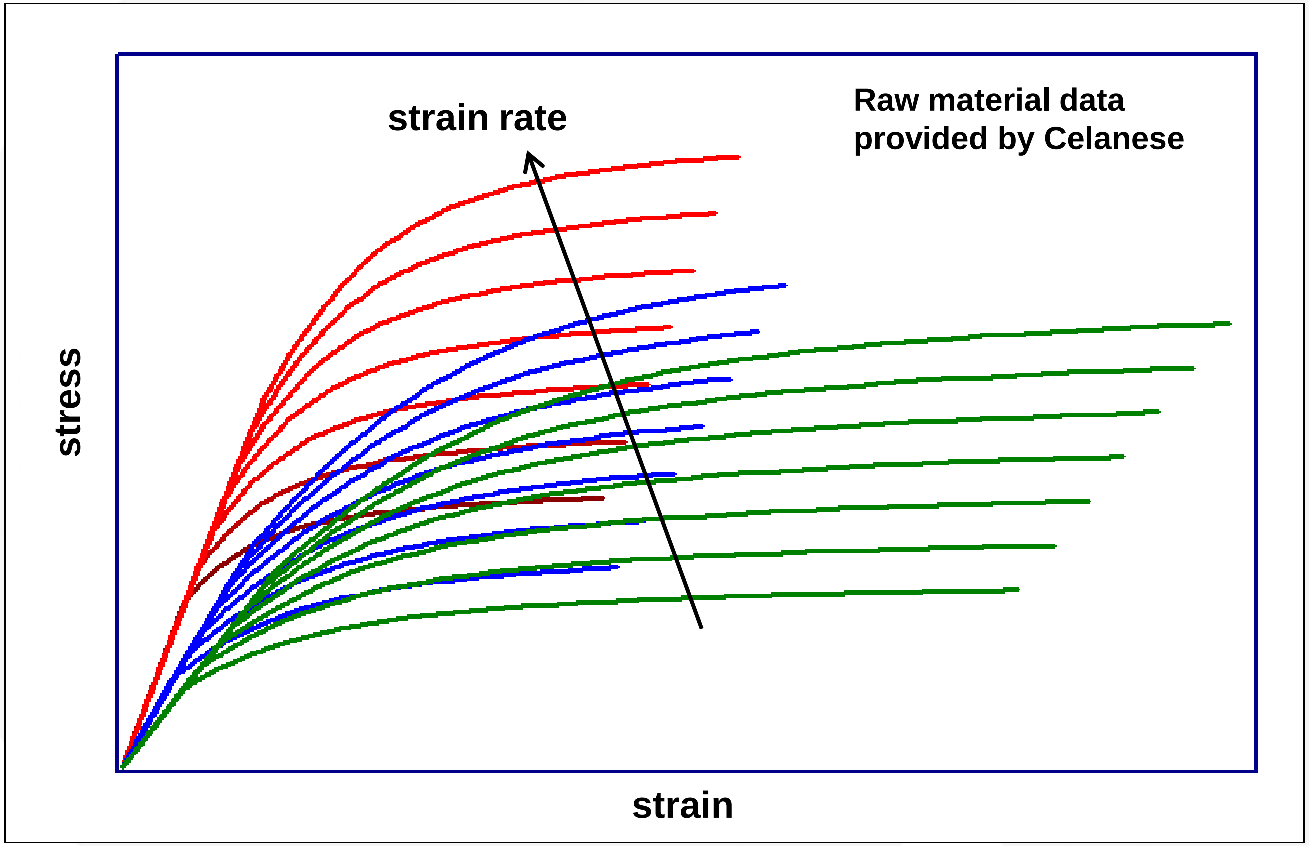


dependence on fiber content



*MAT_024 – typical approach

Separate for each direction



PP GF40

longitudinal
diagonal
perpendicular

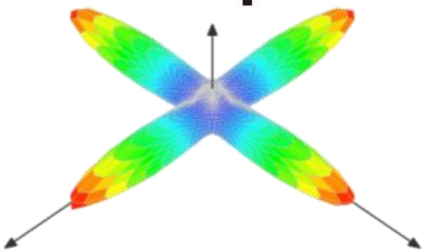
Micro mechanic based material models

4a micromec: Calculating the elastic values

Input

since 1999

Output



Material Data of Components (E,α,λ)

Matrix
Reinforcements
Fillers

Data-Base

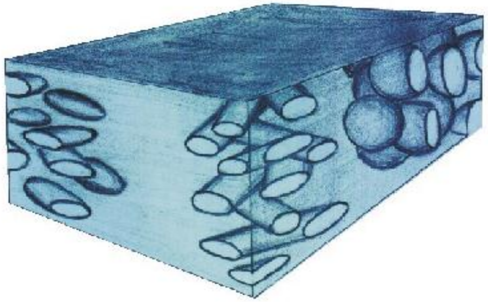
Fibre and Particle Orientation

Data-Base

Fibre and Particle Shape

Data-Base

4a micromec



Virtual Material Design

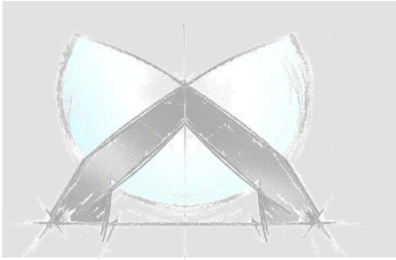
3D Composite Data

elastic properties
thermal expansion
thermal conductivity

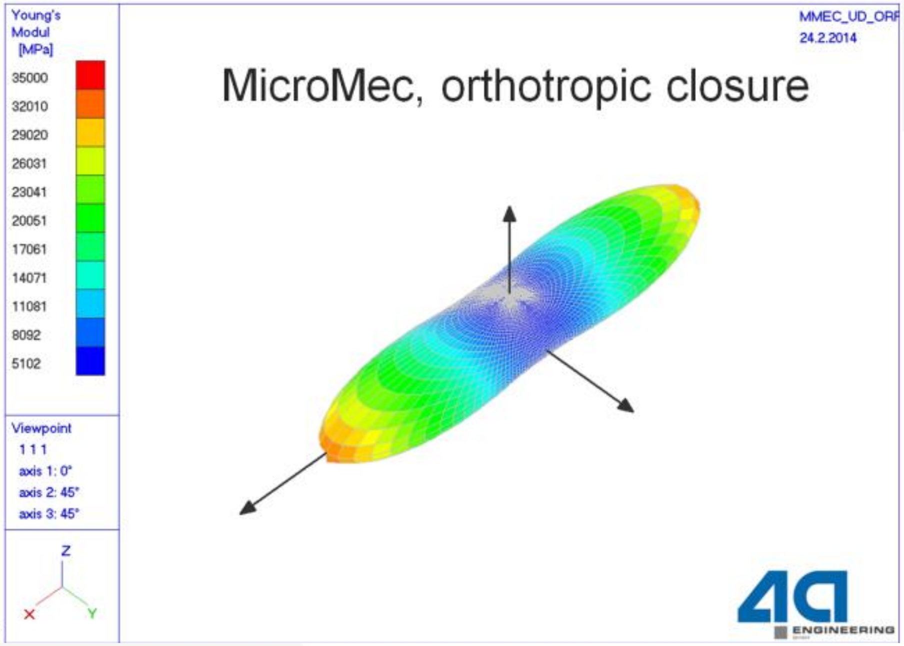
2D&3D graphics

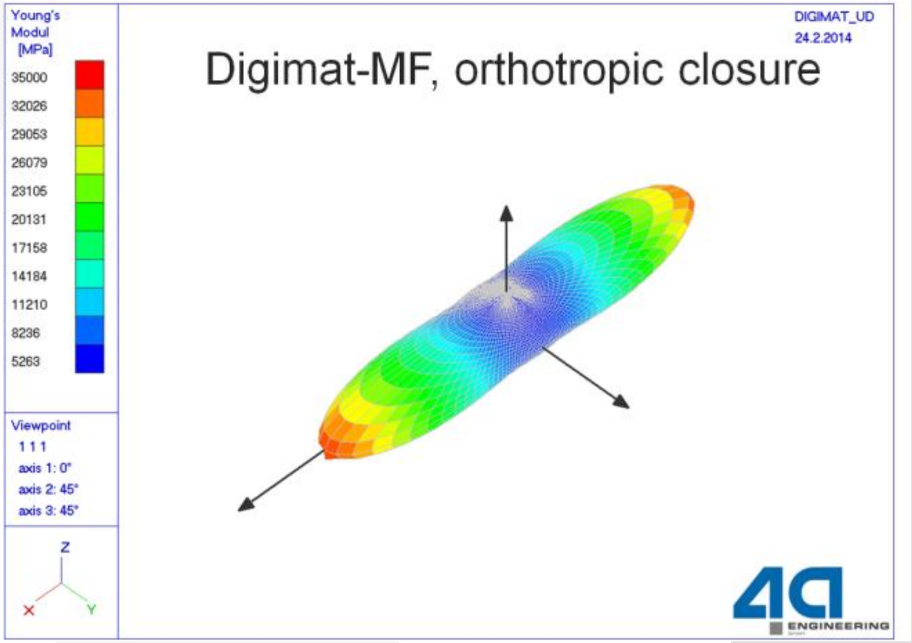
Interface to
LS-Dyna, Abaqus, MSC Nastran

- SFRT, LFRT, CFRP, GFRP, ….
- 3D thermo-elastic properties
- Further information: micromec.4a.co.at



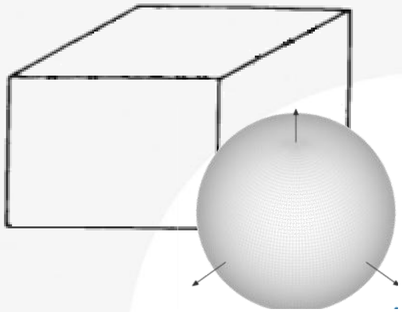
Micro mechanic based material models
4a micromec: Calculating the elastic values

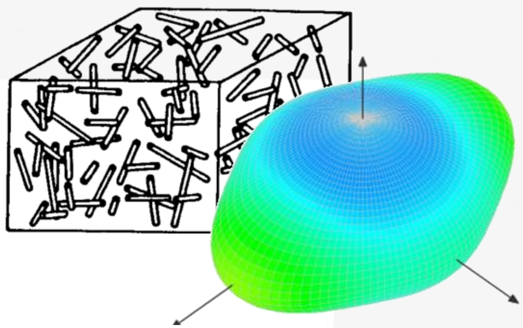




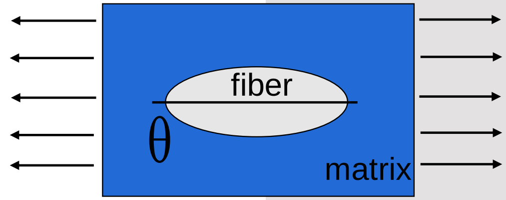
- Comparison by Montanuniversitaet Leoben between Digimat-MF and 4a micromec

Source: Bodor Ch. – Anwendung der µ-Computertomographie für die Materialmodellierung; 4a Technologietag 2014, Schladming





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



Eshelby Tensor

macro scale

constitutiv… law → composi…

micro scale

homogenizat…

Mises plasticity

- quick & d…
- criti… …g t… …l …orientation

elastic

- orthotro…
- aniso…

elasti… …astic

- …city

α α

M… matrix

- isotropic elas… viscoplast…

F… fiber

- iso… …stic

*MAT_024

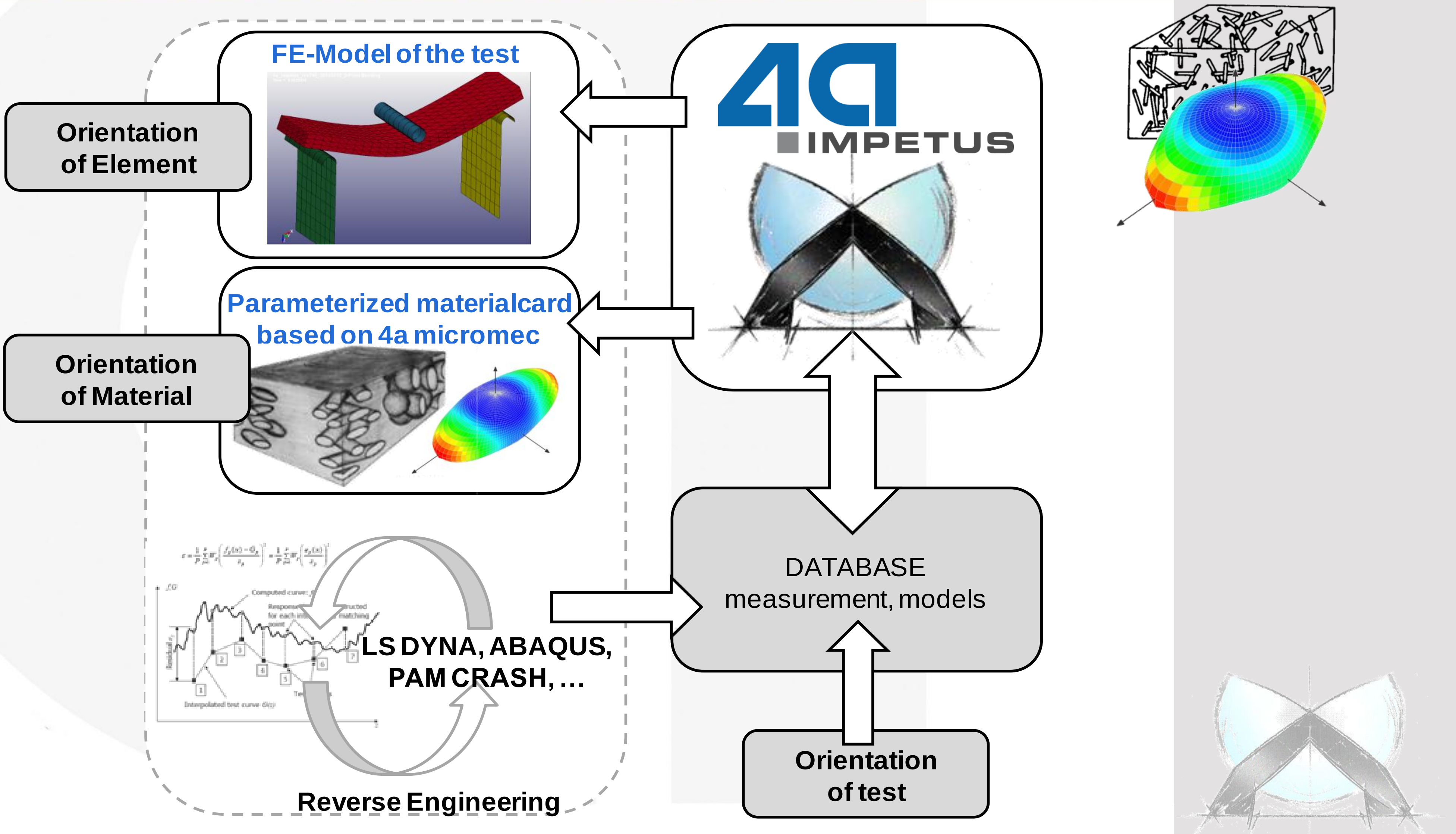
*MAT_157

*MAT_215

α – orientation dependent

4a impetus - SFRT

Workflow



Example: PPGF40 and *MAT_157
Consider each direction in one material model

- micro mechanics
  based on **fiber & matrix** properties

  Composite elasticity → orthotropic E_1, E_2, E_3, ν_{12}, ν_{13}, ν_{23}, G_{12}, G_{13}, G_{23}

  Composite plasticity → HILL coefficients F, G, H, L, M, N

- **Reverse Engineering**
  - hardening: Bilinear → **2 parameters**
  - strainrate: Johnson Cook → **1 parameter**
  - failure: DIEM → **equivalent HILL strain**

4a impetus – micro mechanical feature

Micro mechanic models as key enabler

160223_006 | Material | Designvariablen | Layers

⊟ Strain rate dependency	Table
⊞ Strain rate dependency	Johnson Cook
⊟ Micromec	User defined
⊟ Matrix	
Density of the matrix	900
E-Modulus	1500
Poisson's ratio	0.3
Yield strength	15
Strength at Break	17
Failure strain	0.05
⊟ Fiber	
Fillerlength	1000
Fillerdiameter	20
Phi or Psi	φ
Phi	12.9
Psi	30.1
Fillermaterial	E-Glas
⊟ Orientation	
⊟ Fillerorientationtype	CA lin. OF
Fillerorientationvalue 1	0.6
Fillerorientationvalue 2	0.33

matrix data

filler data

orientation data

Composite Density	1126	[g/dm³]
c_C11	6172	[MPa]
c_C12	1808	[MPa]
c_C13	1231	[MPa]
c_C14	0	[MPa]
c_C15	0	[MPa]
c_C16	0	[MPa]
c_C22	4135	[MPa]
c_C23	1181	[MPa]
c_C24	0	[MPa]
c_C25	0	[MPa]
c_C26	0	[MPa]
c_C33	2616	[MPa]
c_C34	0	[MPa]
c_C35	0	[MPa]
c_C36	0	[MPa]
c_C44	1554	[MPa]
c_C45	0	[MPa]
c_C46	0	[MPa]
c_C55	888.6	[MPa]
c_C56	0	[MPa]
c_C66	957.5	[MPa]
y_r00	1	[1]
y_r45	0.5105	[1]
y_r90	0.2665	[1]
y_scalematrix0	3.076	[1]

4a impetus – micro mechanical feature

Micro mechanic models as key enabler

160223_006 | Material | **Designvariablen** | Layers

Name	Start	const...	Description
GroupName: 10_elasticity			
c_C11	MMEC	✓	constitutive matrix 11
c_C12	MMEC	✓	constitutive matrix 12
c_C13	MMEC	✓	constitutive matrix 13
c_C14	MMEC	✓	constitutive matrix 14
c_C15	MMEC	✓	constitutive matrix 15
c_C16	MMEC	✓	constitutive matrix 16
c_C22	MMEC	✓	constitutive matrix 23
c_C23	MMEC	✓	constitutive matrix 23
c_C24	MMEC	✓	constitutive matrix 24
c_C25	MMEC	✓	constitutive matrix 25
c_C26	MMEC	✓	constitutive matrix 26
c_C33	MMEC	✓	constitutive matrix 33
c_C34	MMEC	✓	constitutive matrix 34
c_C35	MMEC	✓	constitutive matrix 35
c_C36	MMEC	✓	constitutive matrix 36
c_C44	MMEC	✓	constitutive matrix 44
c_C45	MMEC	✓	constitutive matrix 45
c_C46	MMEC	✓	constitutive matrix 46
c_C55	MMEC	✓	constitutive matrix 55
c_C56	MMEC	✓	constitutive matrix 56
c_C66	MMEC	✓	constitutive matrix 66

160223_006 | Material | **Designvariablen** | Layers

Name	Start	const...	Description
GroupName: 10_elasticity			
GroupName: 20_yield			
y_0	90	■ (red)	yield stress
y_scale...	MMEC	✓	yield scale 11 direction
y_r00	MMEC	✓	yield hill anisotropy ratio 0°
y_r45	MMEC	✓	yield hill anisotropy ratio 45°
y_r90	MMEC	✓	yield hill anisotropy ratio 90°
GroupName: 21_hardening			
h_ET	50	■ (red)	
h_y	90	✓	
GroupName: 31_strainrate			
v_epspkt	0.01	✓	initial strain rate threshold
v_p	15	■ (red)	strain rate scale (1/vp)
GroupName: 51_failure			
xf_NUM...	0.75	✓	Number of failed integration points prior to

MMEC – Design Variable calculated by micro mechanic model

Less free Design Variables left for material parameter identification

Example: PPGF40 and *MAT_157

Micro mechanic models as key enabler

PP GF40 from Celanese, quasi-static and dynamic tests

⊟ Material card	*MAT_COMPOSITE_DAMAGE (*MAT_022)
Deformation	7500_MAT22
Damage/Failure	None
Materialcard id	1000000
Density	-1203.270310622
Plasticity	None
⊞ Function (Hardening, Elastic curve form)	
Strain rate dependency	None
⊟ Micromec	User defined
⊟ Matrix	
Density of the matrix	900
E-Modulus	1800
Poisson's ratio	0.3
Yield strength	50
Strength at Break	70
Failure strain	0
⊟ Fiber	
Fillerlength	200
Fillerdiameter	10
Phi or Psi	ψ
Phi	18.5
Psi	40
Fillermaterial	E-Glas
⊟ Orientation	
⊟ Fillerorientationtype	CA lin. OF
Fillerorientationvalue 1	0.7
Fillerorientationvalue 2	0.28
⊞ Strength	
Fracture	None
Postfracture	None
⊟ **Loadcases**	
⊞ Casename	stat_longitudinal
⊞ Casename	stat_diagonal
⊞ Casename	stat_perpendicular
⊞ **Results**	

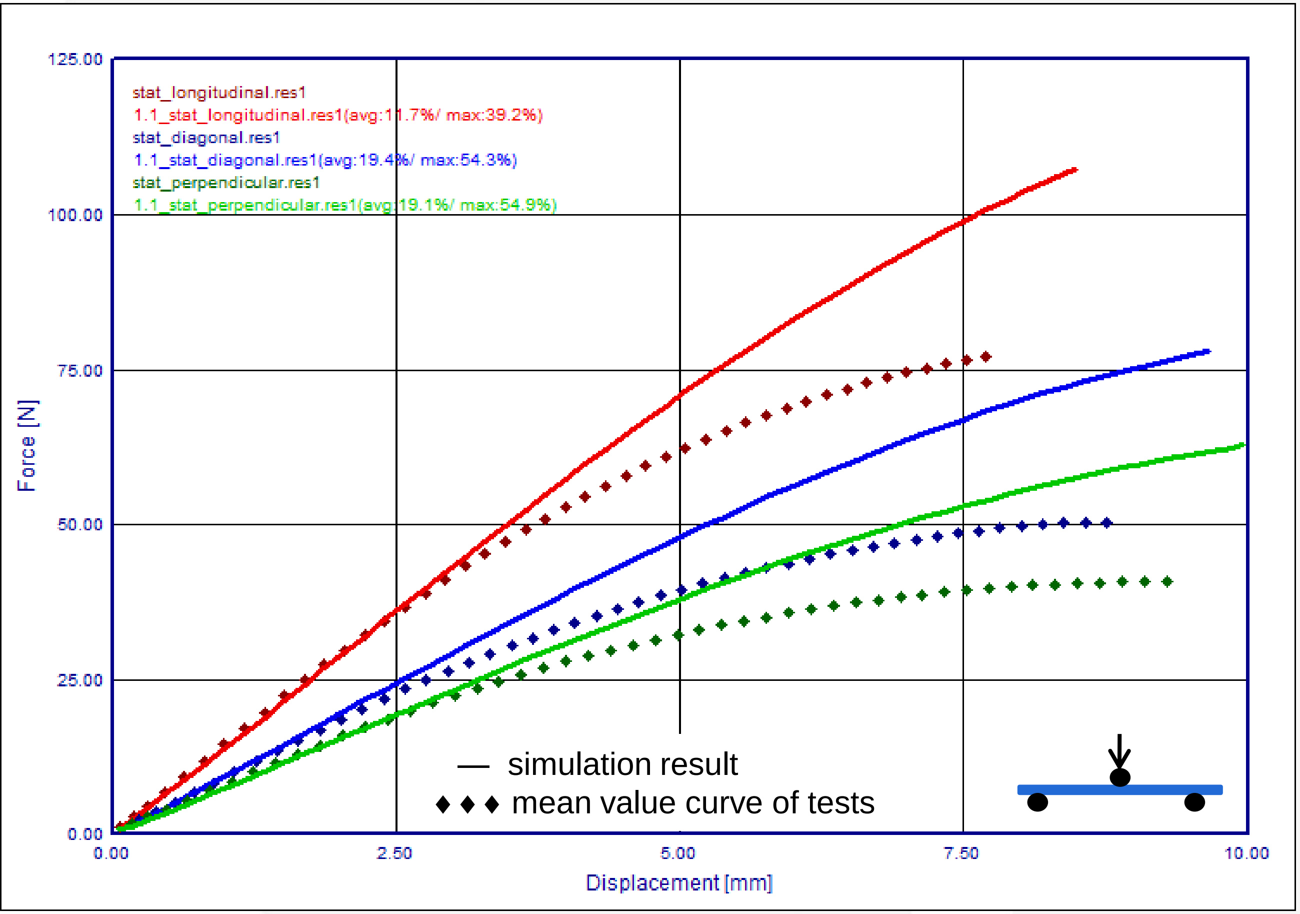
Composite Density	1224	[g/dm³]
c_E11	6941	[MPa]
c_E22	3810	[MPa]
c_E33	2689	[MPa]
c_G12	1840	[MPa]
c_G23	1055	[MPa]
c_G31	1038	[MPa]
c_nue21	0.2029	[1]
c_nue31	0.1103	[1]
c_nue32	0.2432	[1]

1st step:
calculating elastic properties on quasi-static tests
→ *MAT_022

Example: PPGF40 and *MAT_157

Micro mechanic models as key enabler

1st step: result → elastic material behavior



Model170503_032
Solver: LS DYNA, Metamodel: *MAT_COMPOSITE_DAMAGE (*MAT_022),
Element size: 2mm,
Element type:16: Fully integrated shell element (very fast), Number of integration points: 5
Assumption: Poisson's number 0.3, Friction coeff. 0.1

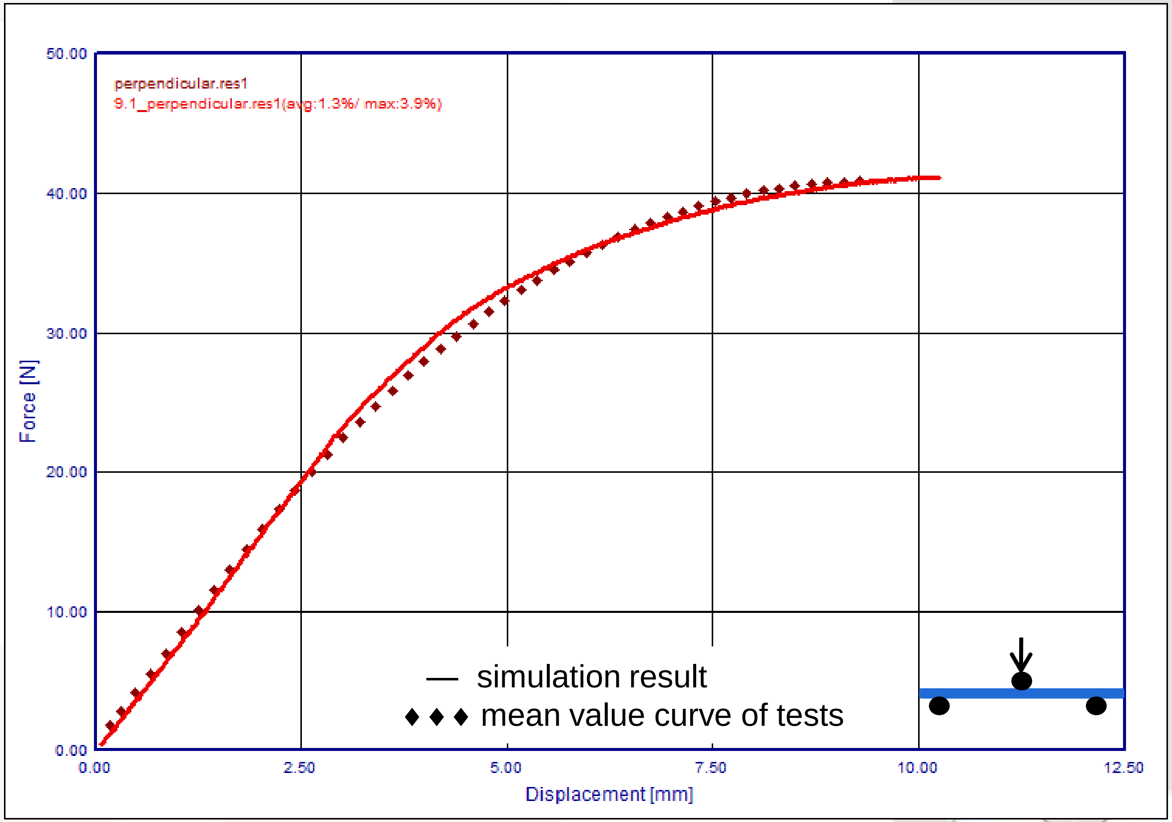
longitudinal
diagonal
perpendicular

Example: PPGF40 and *MAT_157

Micro mechanic models as key enabler

2nd step: Optimizing the hardening parameters using the perpendicular test

	Name	Start	const...	from	to	Variance	Condi...
	c_C45	MMEC	✓	(NULL)	(NULL)	(NULL)	
	c_C46	MMEC	✓	(NULL)	(NULL)	(NULL)	
	c_C55	MMEC	✓	(NULL)	(NULL)	(NULL)	
	c_C56	MMEC	✓	(NULL)	(NULL)	(NULL)	
	c_C66	MMEC	✓	(NULL)	(NULL)	(NULL)	
^	GroupName: 20_yield						
	y_0	[redacted]		15	50	(NULL)	
	y_r00	MMEC	✓	(NULL)	(NULL)	(NULL)	
	y_r45	MMEC	✓	(NULL)	(NULL)	(NULL)	
	y_r90	MMEC	✓	(NULL)	(NULL)	(NULL)	
	y_scale...	MMEC	✓	(NULL)	(NULL)	(NULL)	
^	GroupName: 21_hardening						
	h_y	[redacted]	✓	5	150	50	=y_0
	h_ET	[redacted]		500	1500	(NULL)	

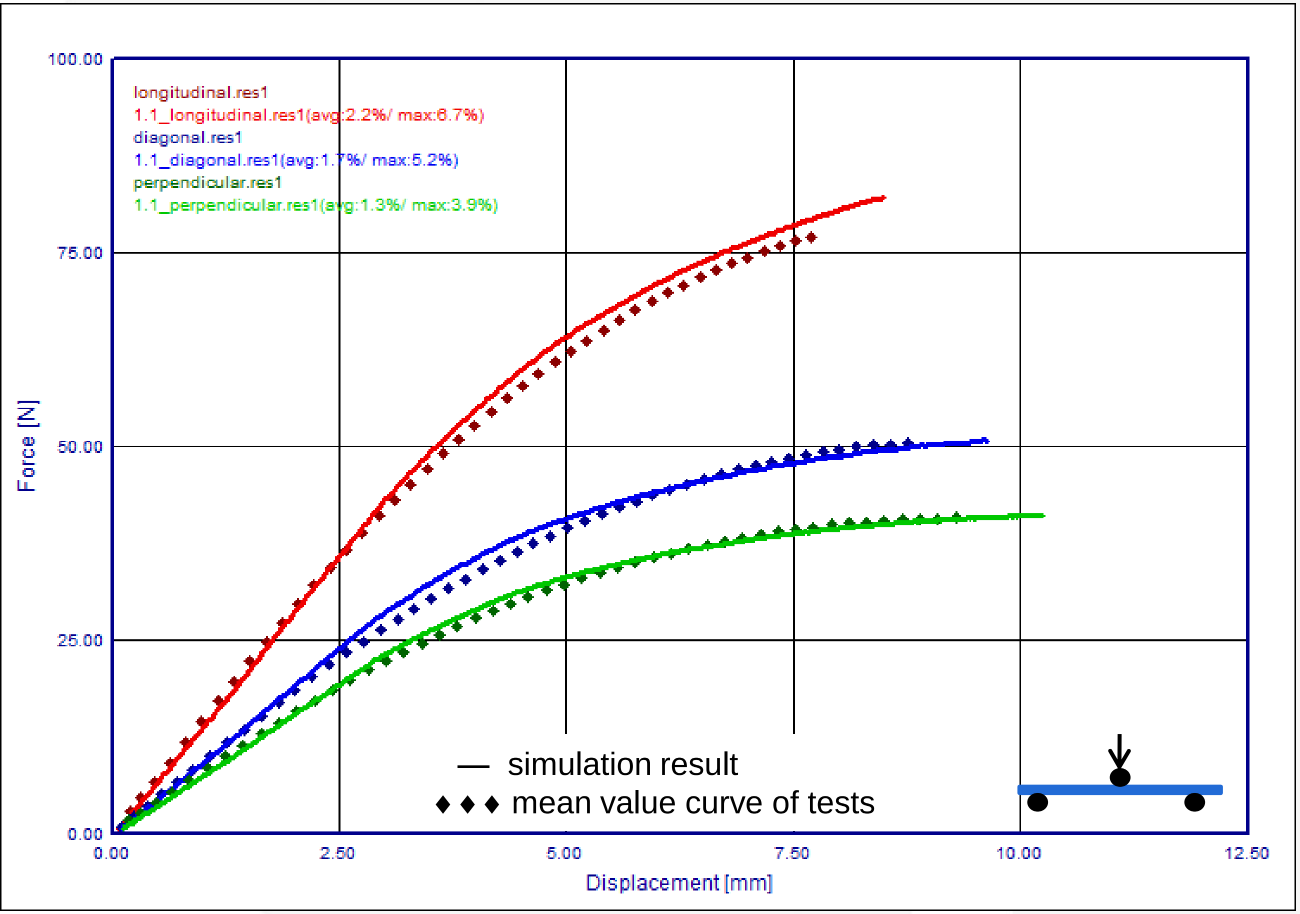


Model170503_035
Solver: LS DYNA, Metamodel: *MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157), Element size: 2mm,
Element type:16: Fully integrated shell element (very fast), Number of integration points: 5
Assumption: Poisson's number 0.3, Friction coeff. 0.1

Example: PPGF40 and *MAT_157

Micro mechanic models as key enabler

3rd step: Validating on all tests



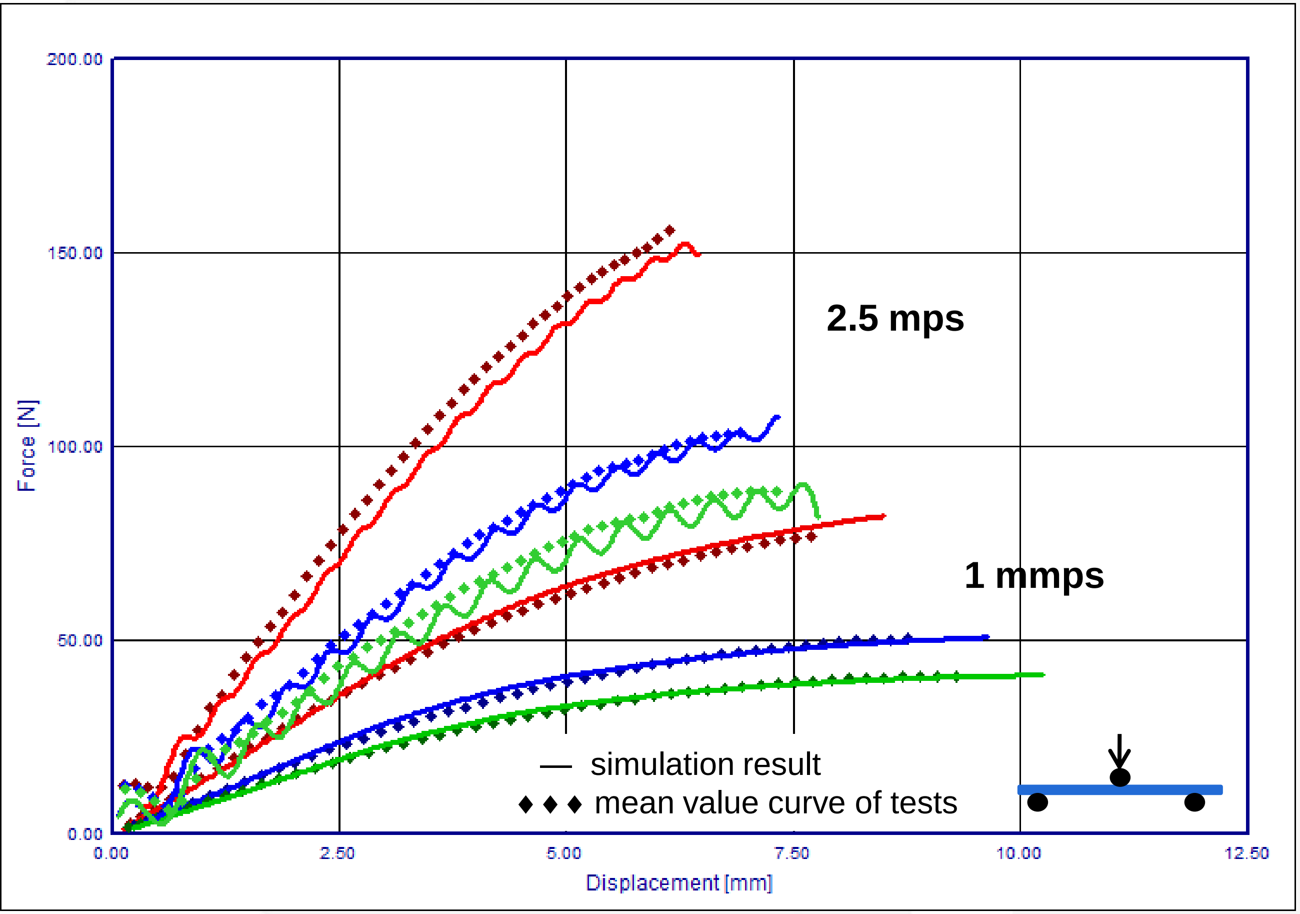
Model170503_033
Solver: LS DYNA, Metamodel: *MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157), Element size: 2mm,
Element type:16: Fully integrated shell element (very fast), Number of integration points: 5
Assumption: Poisson's number 0.3, Friction coeff. 0.1

longitudinal
diagonal
perpendicular

Example: PPGF40 and *MAT_157

Micro mechanic models as key enabler

4th step: Add the strain rate dependency



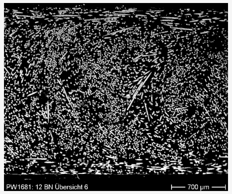
Model170503_036
Solver: LS DYNA, Metamodel: *MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157), Element size: 2mm,
Element type:16: Fully integrated shell element (very fast), Number of integration points: 5
Assumption: Poisson's number 0.3, Friction coeff. 0.1

longitudinal
diagonal
perpendicular

Outlook

Simulation process chain for injection molded parts

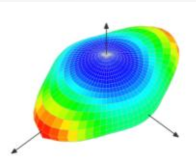
Injection molding (Moldflow, Moldex, …)



$$a_{ij} = \begin{bmatrix} 0{,}66 & 0 & 0 \\ 0 & 0{,}32 & 0 \\ 0 & 0 & 0{,}02 \end{bmatrix}$$

fiber orientation

micromechanic modeling (4a micromec, …)



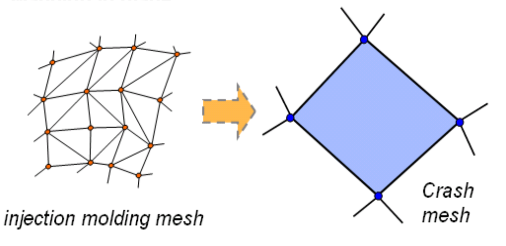
$$C = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\ & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} \\ & & C_{33} & C_{34} & C_{35} & C_{36} \\ & & & C_{44} & C_{45} & C_{46} \\ & & & & C_{55} & C_{56} \\ & & & & & C_{66} \end{bmatrix}$$

anisotropy

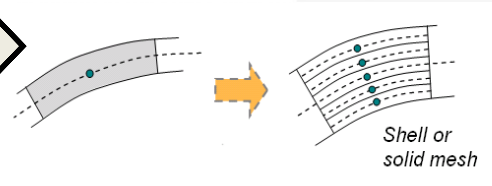
4a MICROMEC

Mapping (4a fibermap, …)

In plane mapping



Mapping in thickness direction



4a FIBERMAP

Material Model

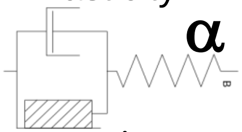
Mean Field homogenization

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

***MAT_215**

Standard Material Model

Hill Plasticity



***MAT_157**

LSTC Livermore Software Technology Corp.

LS-DYNA®

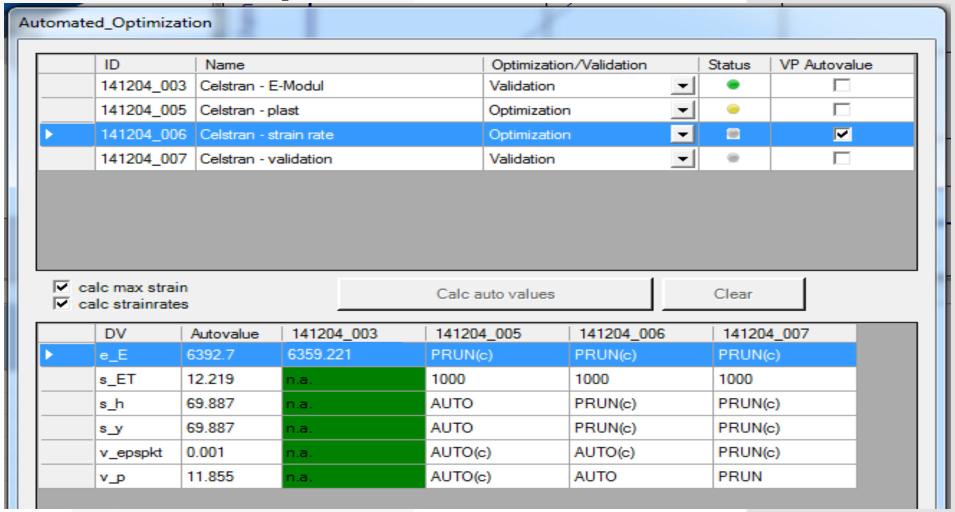
Structural Simulation

Current topics

4a impetus Hardware

Spezifikationen	
Pendelarmlänge	500 mm
mögliche Prüfgeschwindigkeiten	0,5-4,4 m/s
maximal zulässige Zusatzmassen	4000 g
maximal zulässige Prüfenergie	50J

Workflow - process automation



Automated_Optimization

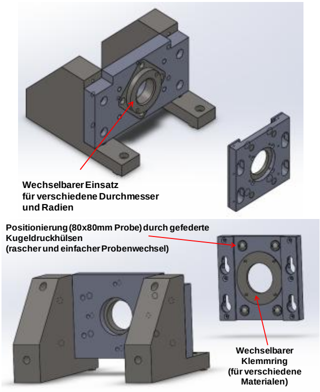
ID	Name	Optimization/Validation	Status	VP Autovalue
141204_003	Celstran - E-Modul	Validation		
141204_005	Celstran - plast	Optimization		
141204_006	Celstran - strain rate	Optimization		☑
141204_007	Celstran - validation	Validation		

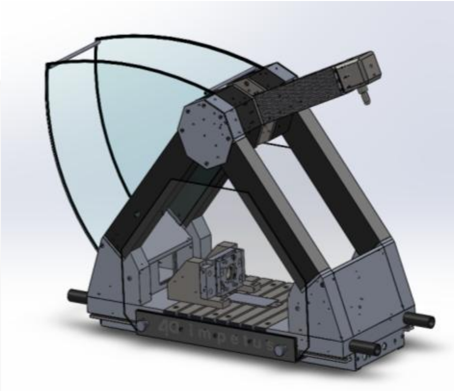
☑ calc max strain
☑ calc strainrates
Calc auto values
Clear

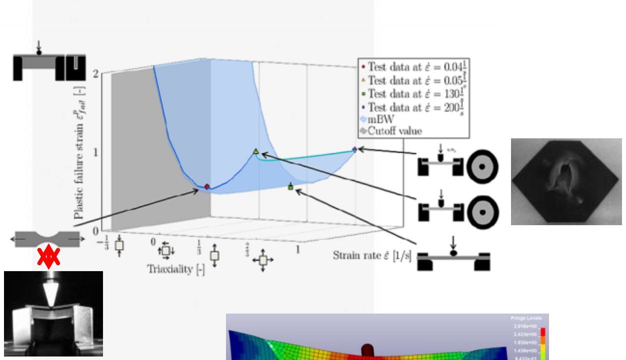
DV	Autovalue	141204_003	141204_005	141204_006	141204_007
e_E	6392.7	6359.221	PRUN(c)	PRUN(c)	PRUN(c)
s_ET	12.219	n.a.	1000	1000	1000
s_h	69.887	n.a.	AUTO	PRUN(c)	PRUN(c)
s_y	69.887	n.a.	AUTO	PRUN(c)	PRUN(c)
v_epspkt	0.001	n.a.	AUTO(c)	AUTO(c)	PRUN(c)
v_p	11.855	n.a.	AUTO(c)	AUTO	PRUN

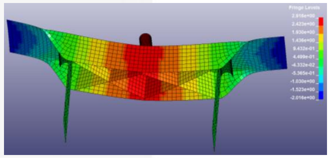
Composites
Puncture test
Component testing

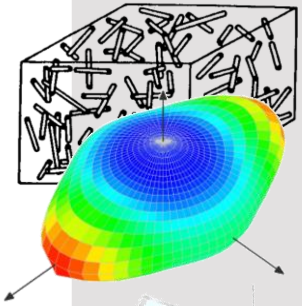
4a impetus Hardware











Failure
Anisotropy
Validation

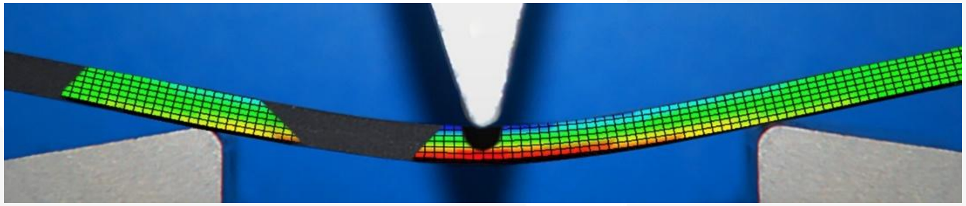
Thank you for your attention!

Thursday, 8:55: *MAT_4A_MICROMEC – Theory and Application Notes (4a engineering GmbH)

9:20: High dynamic drop test simulation for fiber reinforced plastics in automotive electronic control units (Bosch Automotive Products)

9:45: Considering the local anisotropy of short fiber reinforced plastics: validation on specimen and component (Hirtenberger Automotive Group)

11:30: Biotex BigBag Simulation – LS-Dyna Airbag Tool – Unusual Application (4a engineering GmbH)



15th 4a TECHNOLOGIETAG

28th February – 1st March 2018
in Schladming, Austria

„Plastics – Testing and Simulation"
further information: *http://technologietag.4a.co.at/*