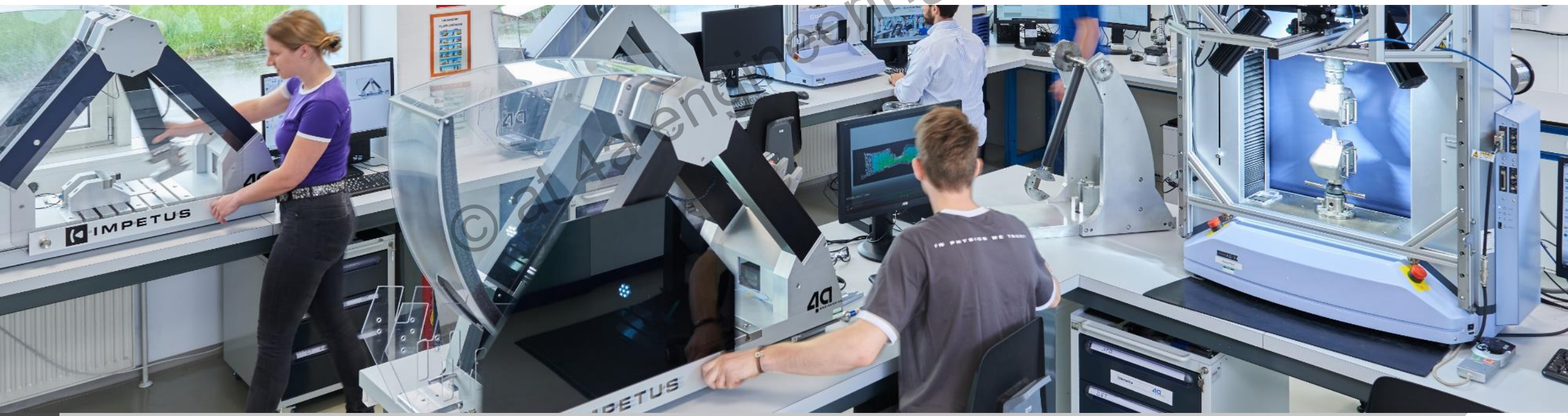
# 4a Summer School
# Introduction to VALIMAT® - from test to material card

P. Reithofer, S. Riemelmoser, Ch. Schober
Traboch, 07.07.2020





# Content

- 4a Summer School
  - Outlook on the upcoming week
  - Addtional information
- Introduction 4a engineering GmbH
- Motivation and case studies
- IMPETUS® - short introduction in efficient dynamic testing
- VALIMAT® - from test to material card – a first look
- Summary

# 4a Summer School

## 1st week - Introduction and outlook


**07. July** - Introduction to VALIMAT® from test to material card


**08. July** - Efficient dynamic testing with IMPETUS®


**09. July** - Material card generation: vonMises plasticity (**MAT_024*), simple failure, setting up our Autofit


**10. July** - Summary: Lessons learned, outlook and upcoming features

# Summer School

## 2nd week - Advanced topics

**14. July** - Evaluating and checking test data
interpretation of typical results

**15. July** - general yield surface (*MAT_187) and other material models,
failure approaches and comprehensive Autofit setup

**16. July** - Fiber reinforced plastics and their modelling approach
an extensive guide

**17. July** - Python: a powerful tool with VALIMAT®,
user defined material cards/specimen

TECHNOLOGY
GmbH

**excellence in**

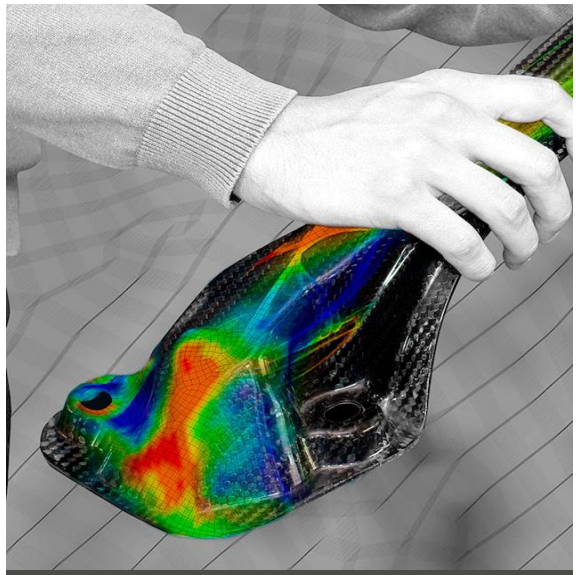
**plastics&simulation**

**testing equipment**

**lightweight products**



# 4a business units

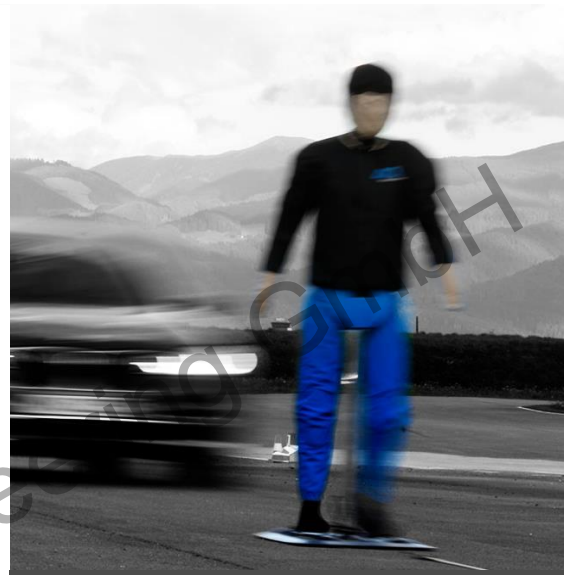


**4a engineering**

**Engineering and simulation for plastic products and composites**

**Impetus**

**Testing equipment generating material data for the dynamic simulation of plastics**



**4activeSystems**

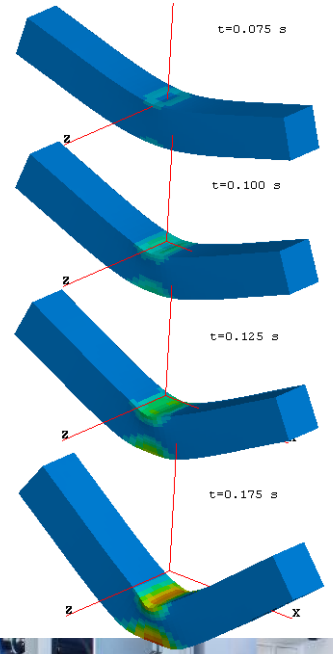
**Dummies and testing facilities for active vehicle safety**

**4a manufacturing**

**Specialized thin foams and multi layer materials**

# Material characterization - services

- efficient high-dynamic testing
- dynamic material behaviour
- plastics, foams, composites, …
- **validated material cards ready to use for your crash-simulation**




# validated material cards – packages

Comprehensive overview

- isoP - isotropic Plastic
- frP – fibre reinforced Plastic
- comP - composite
- foam

| Materialcard detail | basic | standard | prof. |
|---|---|---|---|
| strain rate/hardening | isoP & frP | | |
| compression/tension asymmetry | | isoP & frP | |
| damage/failure | | isoP & frP | |
| validation on component | | | isoP & frP |



4a test packages

thermoplastic materials

setups & measurement definition

VALIMAT

IMPETUS

excellence in ..

from test to material card

efficient dynamic testing for

plastics, foams, composites, ...

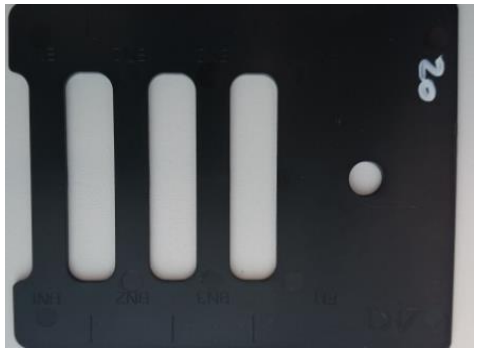


*Standard package optionally includes temperature-based measurements

# validated material cards - injection mold for plastics

Dom & Wall thickness

Melt- & Weldlines



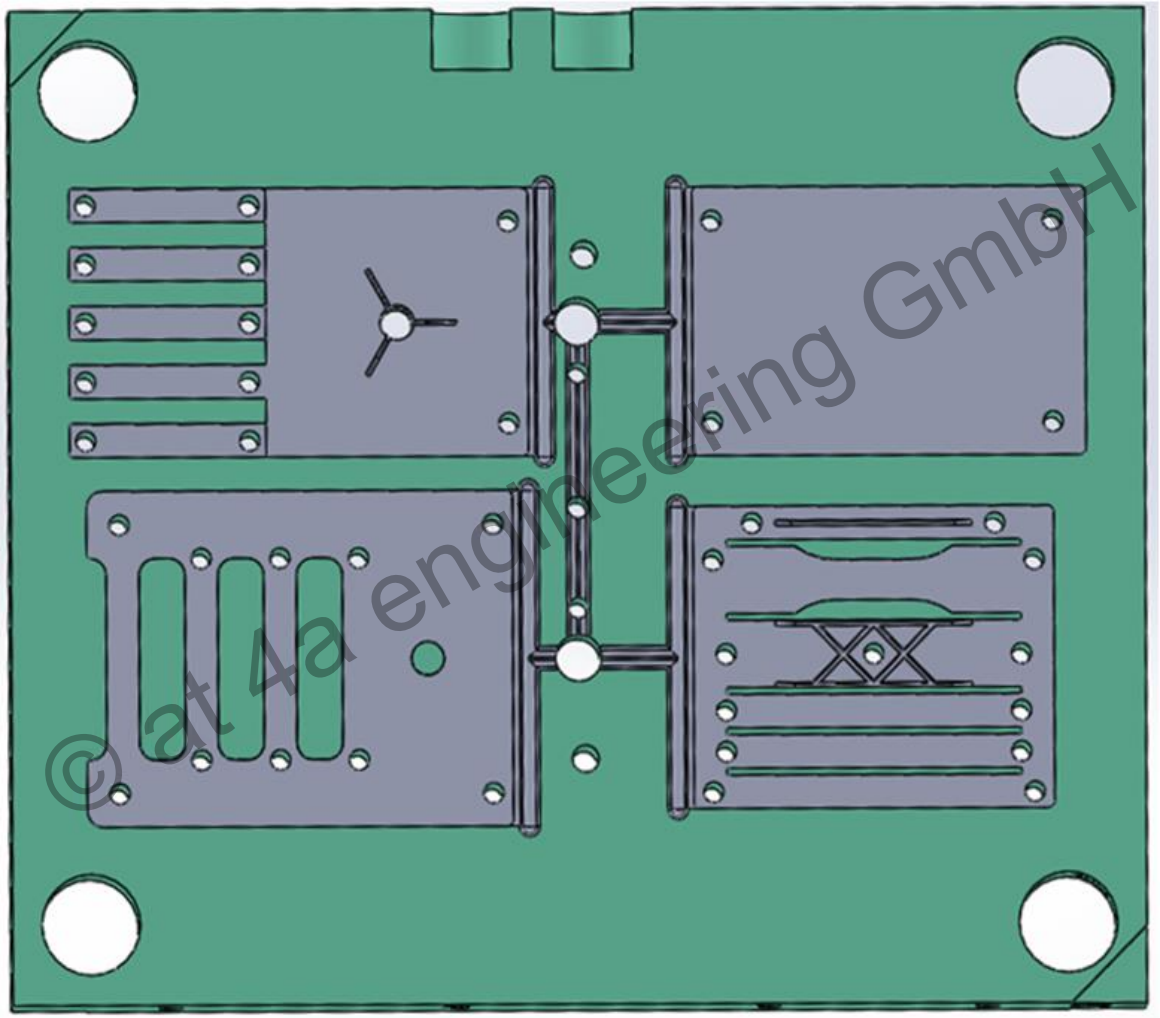


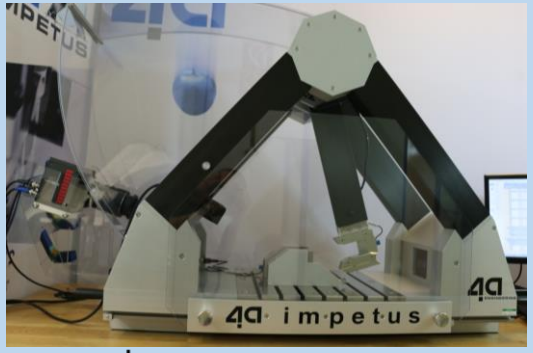


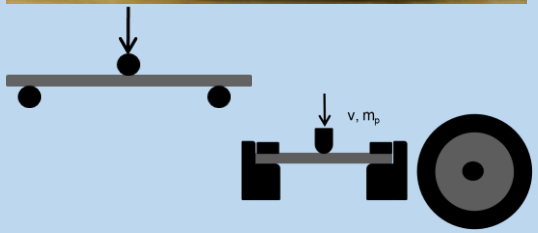
Plate 120 x 80 x 2 mm

Multi-Specimen &
XX-Rib & Component

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

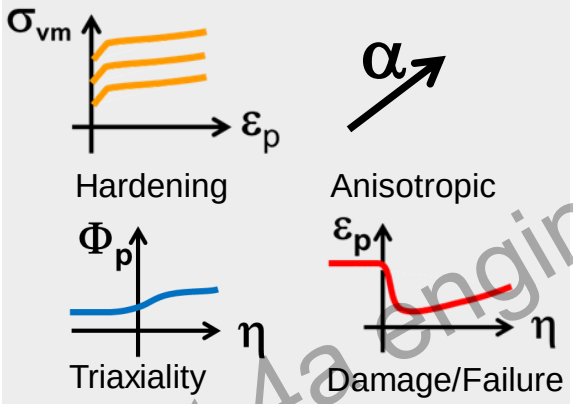
## IMPETUS



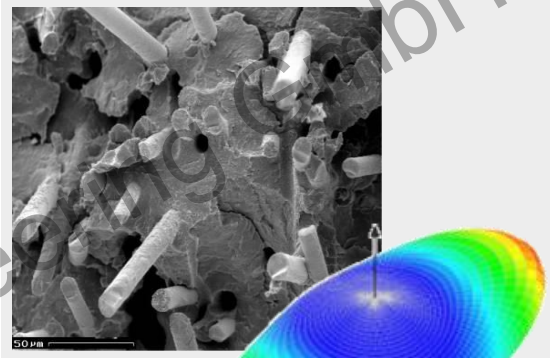

efficient
dynamic testing

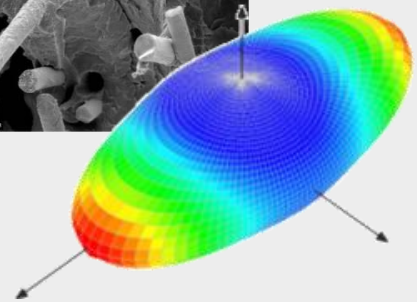
## VALIMAT




from test to validated
material cards

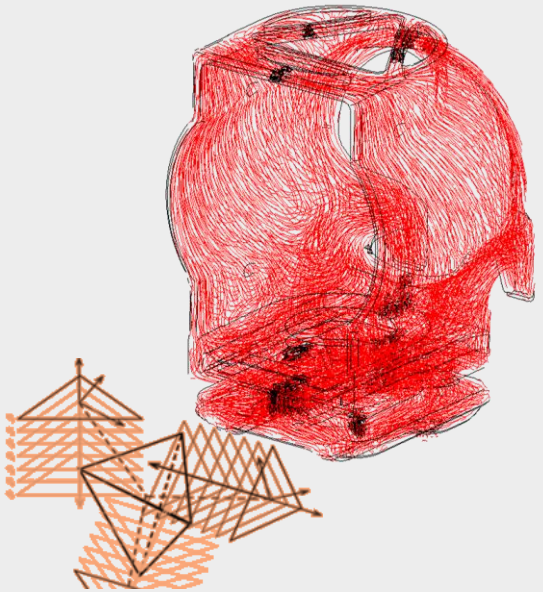
## MICROMEC





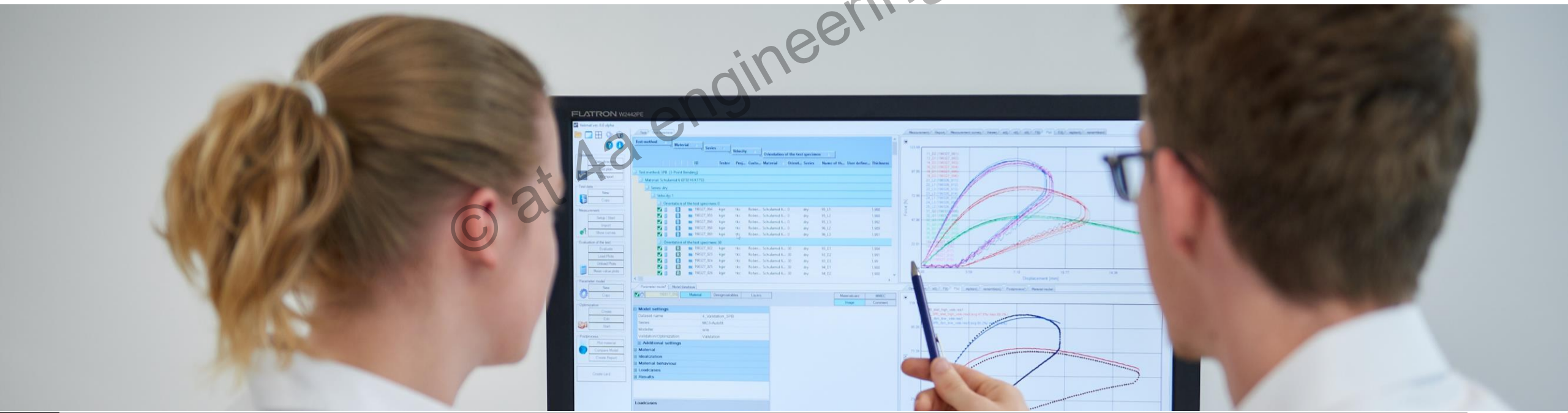
3D anisotropic
material cards

## FIBERMAP

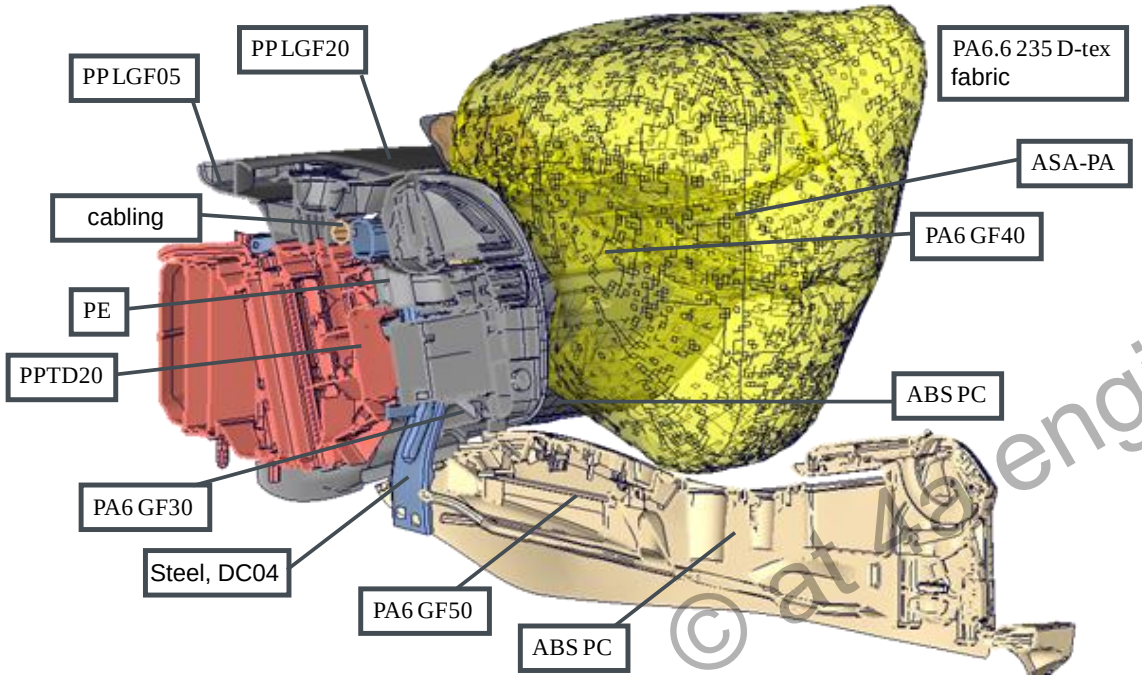


individual mapping
process information

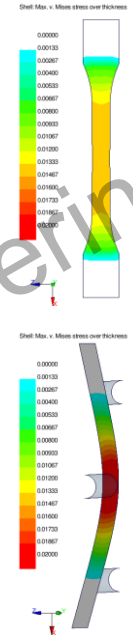
# Motivation

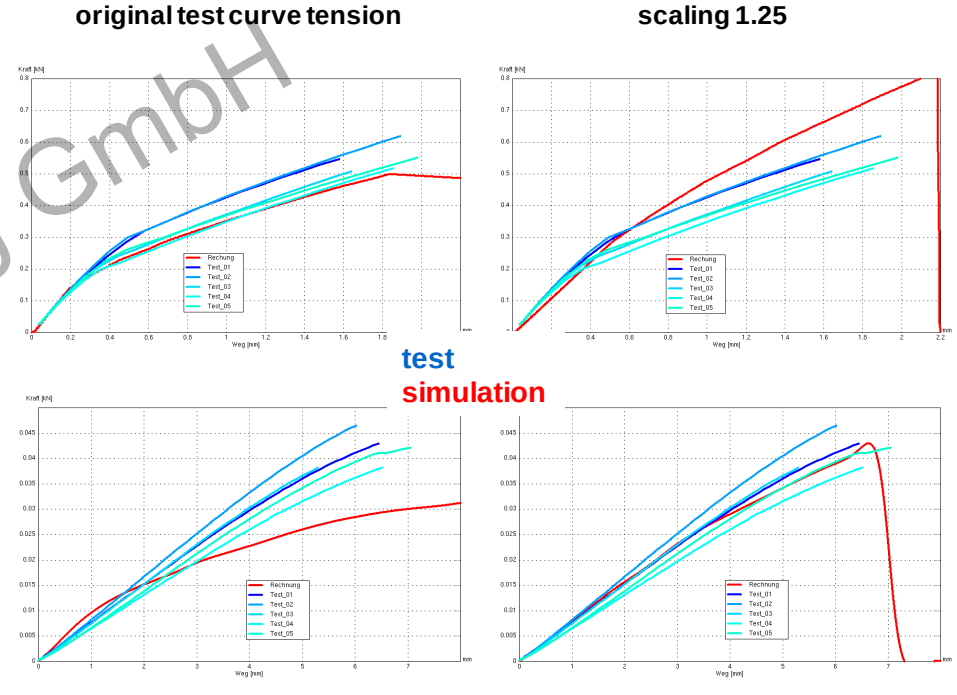


## material variety




## bending load case



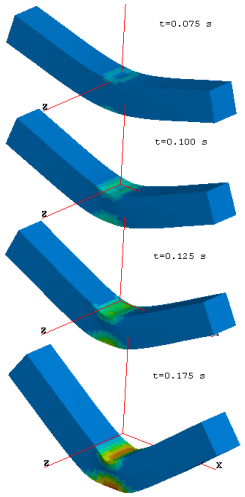




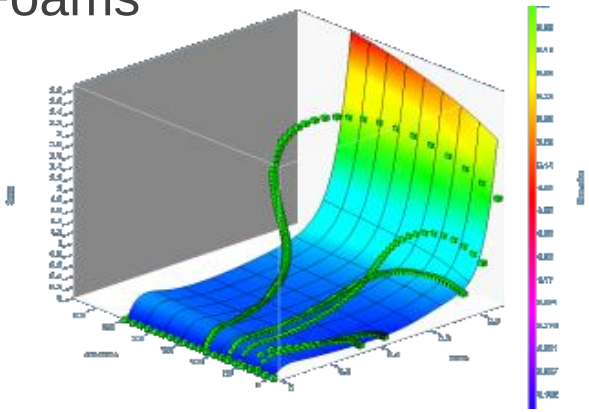

Source: R. Luijkx - *Kunststoffmaterialien in der Interieur Funktionsauslegung bei Audi AG,* 4a Technologietag 2010

# Case study – drop test

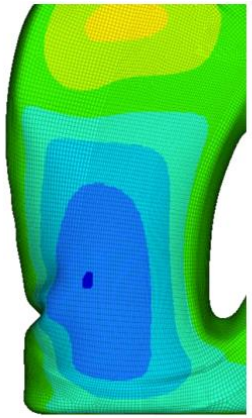
- Drop test of plastic bottle
- Easy to use material card
- **good prediction with new material card from 4a**

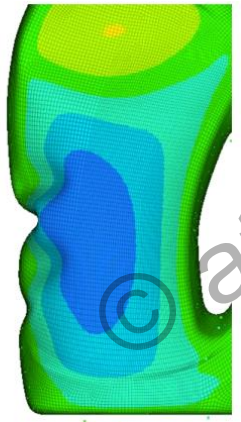



- Droptest of Beamer
- Packaging EPS/EPP Foams
- Energy absorption

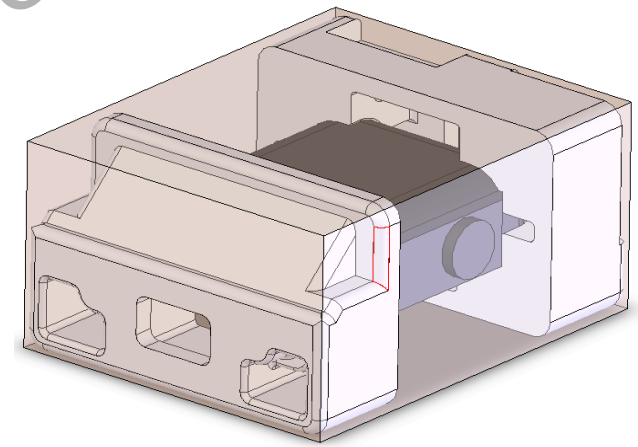


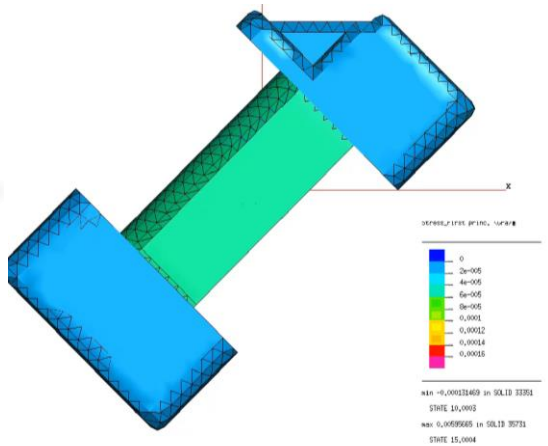

Drop test


No
rate dependency
(old)


With
rate dependency
(new)


Experiment: Drop test



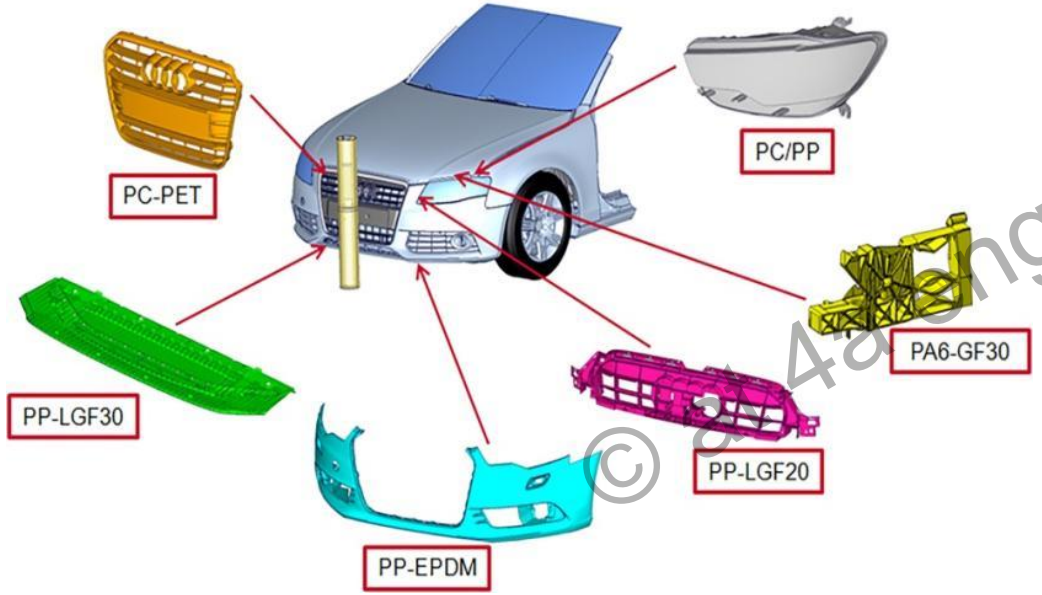


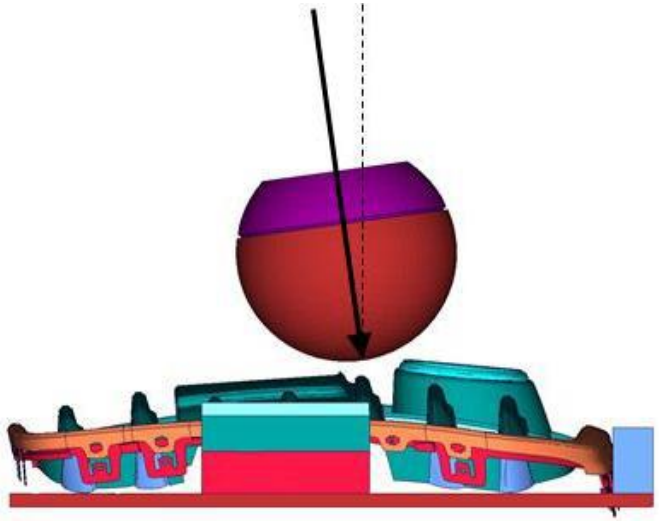


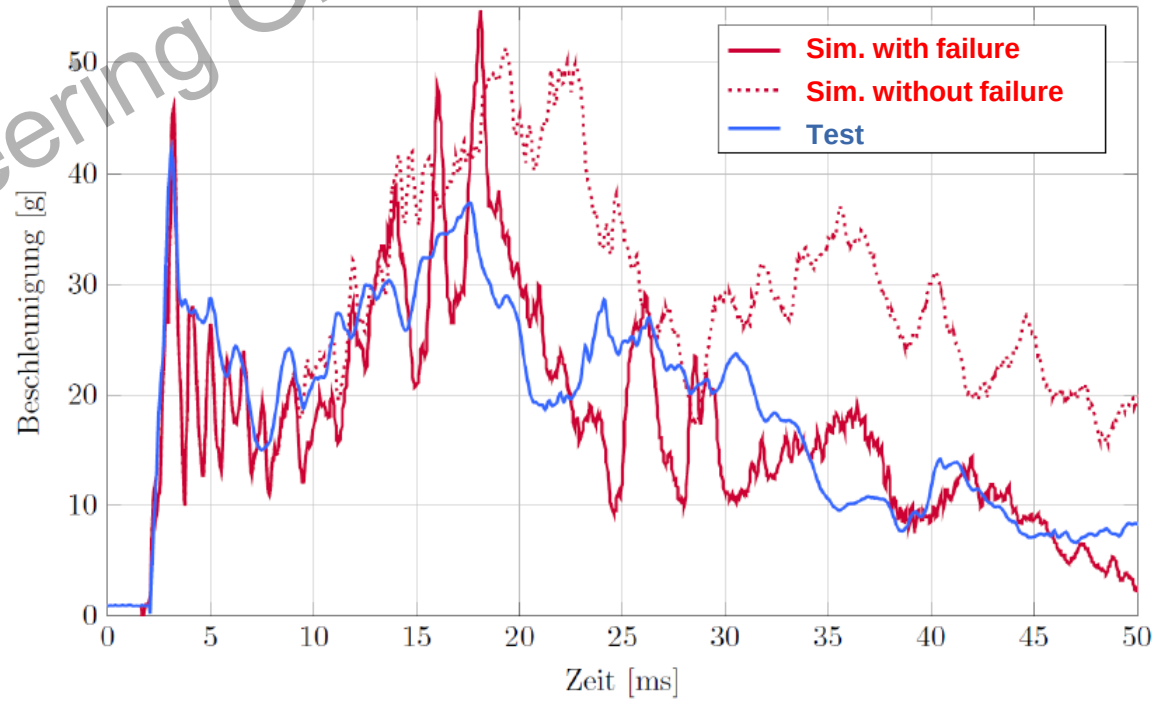
SOURCE: LINK to PAPER

# Case study - pedestrian safety

- Low Speed Impact behavior
- Plenty of different plastic grades
- Temperature influence -35°C up to 80°C

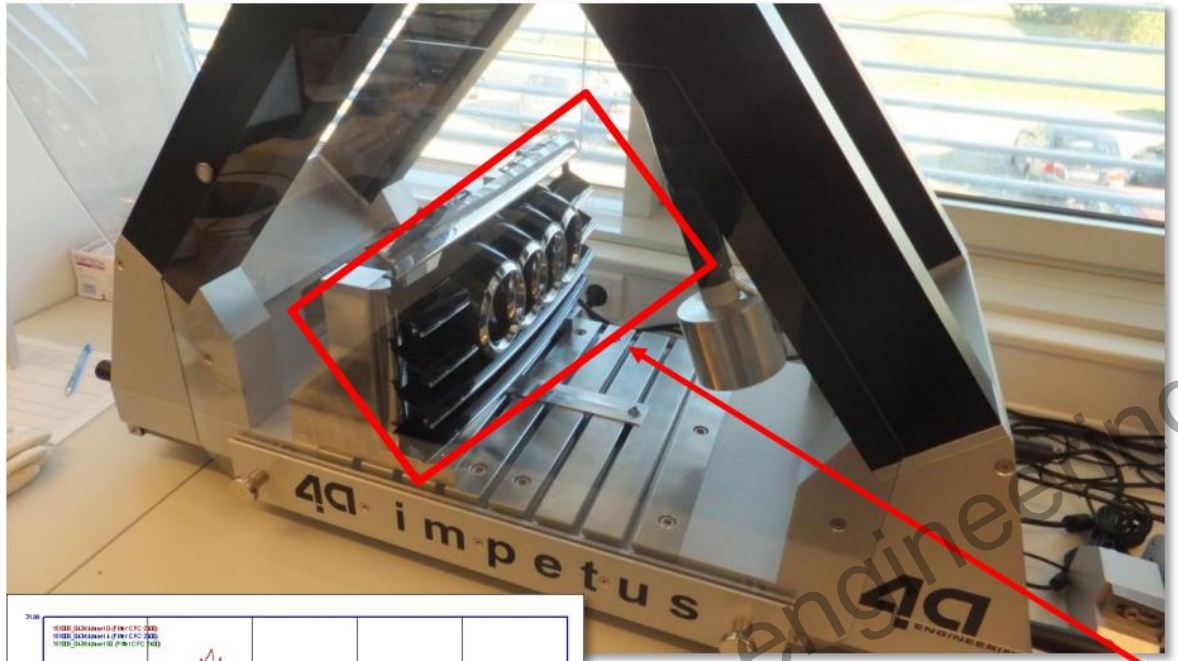


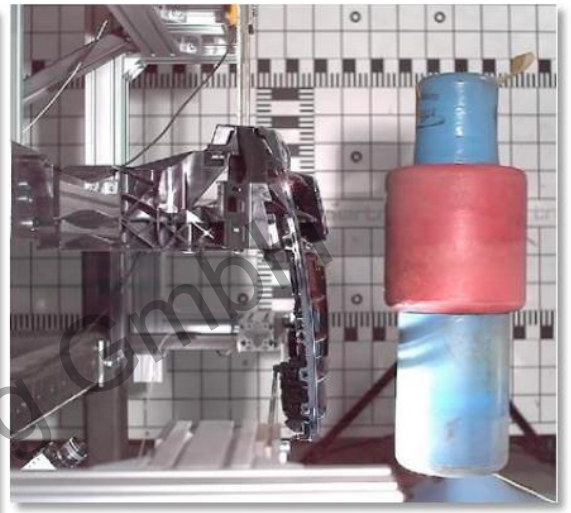



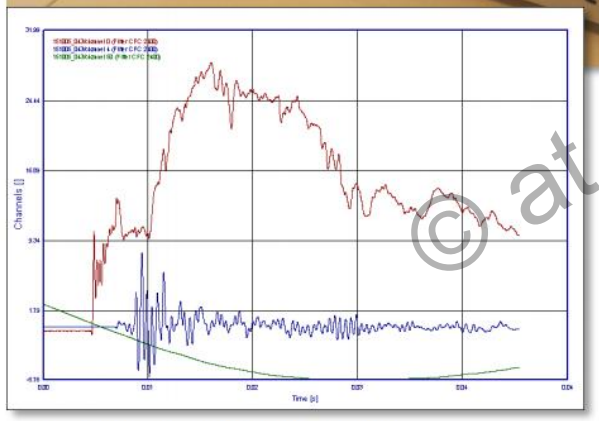


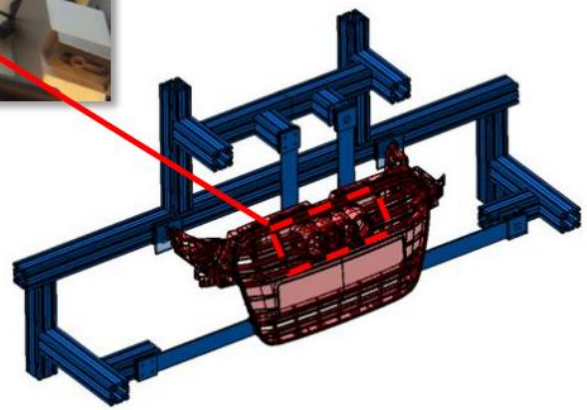

SOURCE: LINK to PAPER

# Case study - pedestrian safety  Component Testing







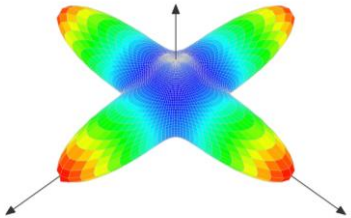
22 H. Staack/ A. Koukal, AUDI AG, Ingolstadt

Audi
Vorsprung durch Technik



SOURCE: LINK to PAPER

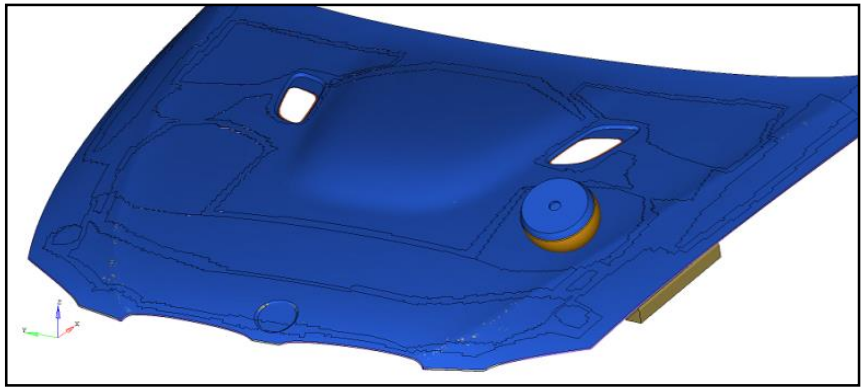
# Case study - composite



- Front hood
  - Stiffness versus pedestrian safety
- Material card
  - Composite layup with anisotropic material behavior
  - Core material – Honeycomb different compression levels





SOURCE: LINK to PAPER

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

IMPETUS

VALIMAT

MICROMEC

FIBERMAP

Foams

Thermoplastics

Fiber reinforced Plastics (SFRT & LFRT)

Composites (Carbon)

Metals

efficient
dynamic testing

from test to validated
material cards

3D anisotropic
material cards

individual mapping
process information

# efficient dynamic testing

IMPETUS

plastics

engineering

production

**excellence in testing**

concepts

simulation

lightweight

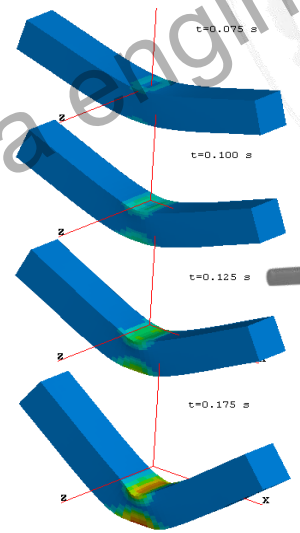
prototypes

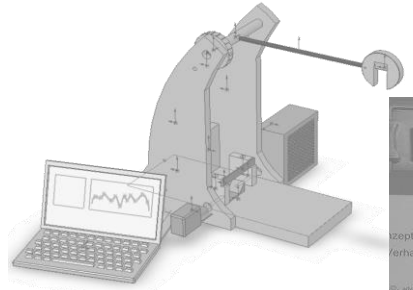


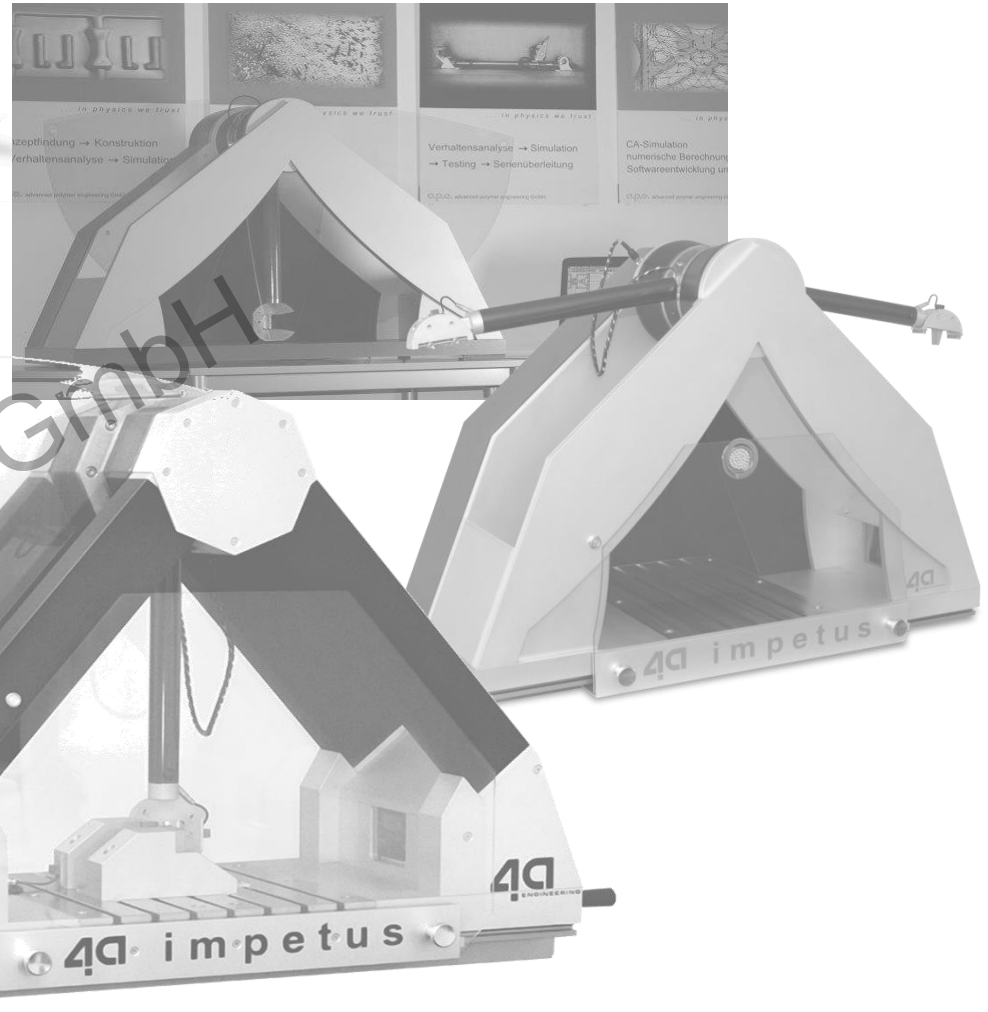
# efficient dynamic testing

- desktop testing device
- instrumented high-speed testing
  - acceleration → force / displacement
- impact velocity 0.5 – 4.5 m/s

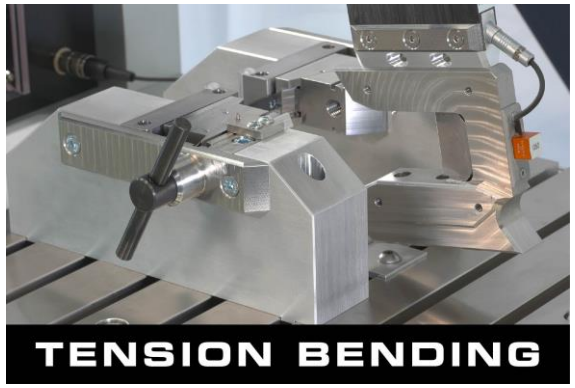
IMPETUS

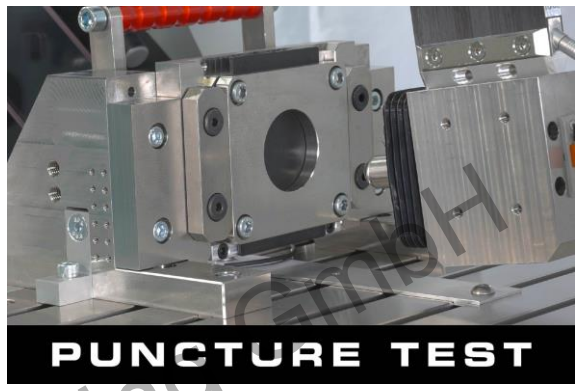



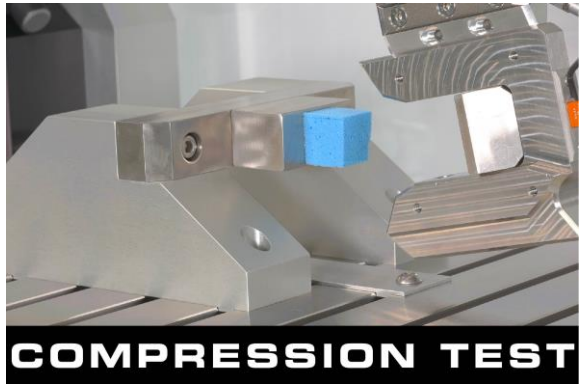


# IMPETUS® - configurations

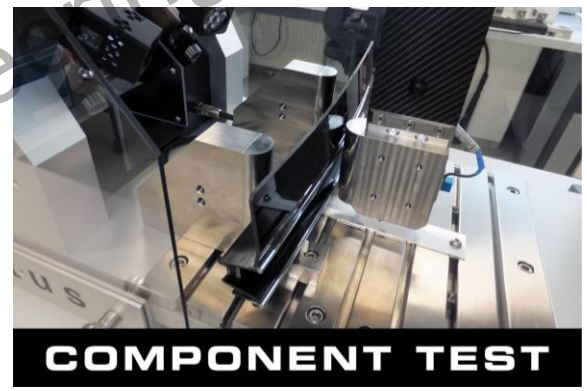











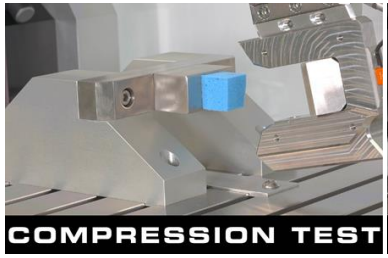
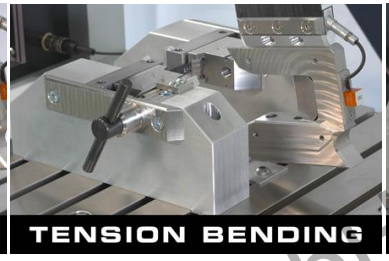
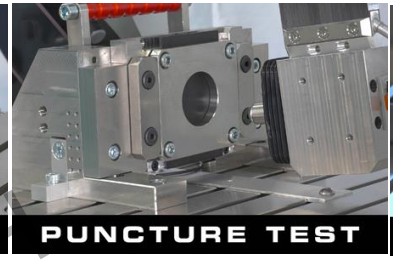


BASIC

STANDARD

PROFESSIONAL

# efficient dynamic testing

| Material *(Typical thickness)* |  COMPRESSION TEST |  3 POINT BENDING |  TENSION BENDING |  PUNCTURE TEST |  TENSION TEST |
|---|---|---|---|---|---|
| Plastic *(1 - 4 mm)* | | ✓ | ✓ | ✓ | ✓ |
| Foam *(20 - 30 mm)* | ✓ | ~ | | | |
| Composite *(1 - 4 mm)* | | ✓ | | ✓ | |
| Aluminum *(1 – 2.5 mm)* | | ✓ | ✓ | | ✓ |
| Metals *(0.5 – 1.5 mm)* | | ✓ | | | |

# IMPETUS

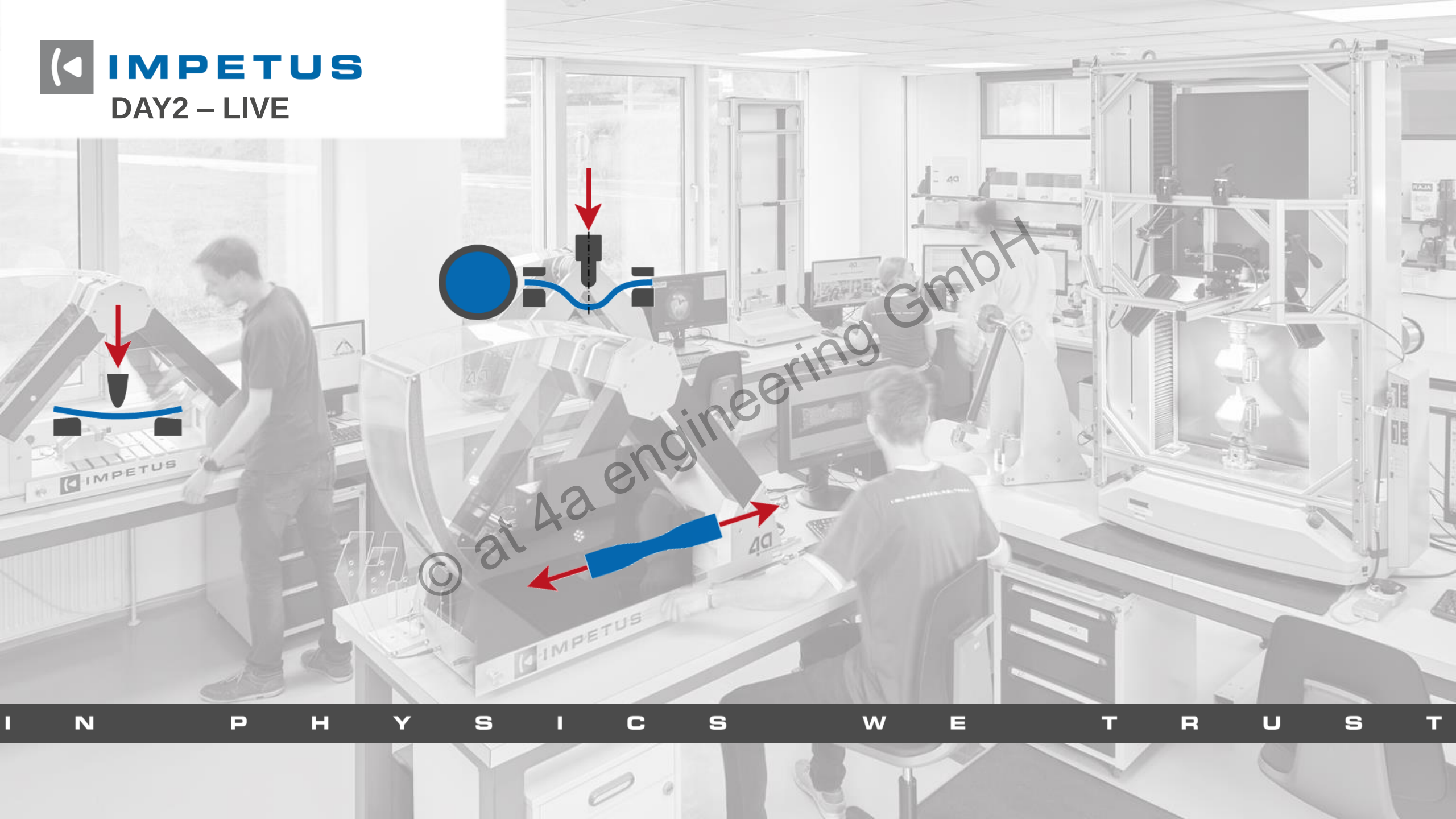
## DAY2 – LIVE




I N P H Y S I C S W E T R U S T

IMPETUS

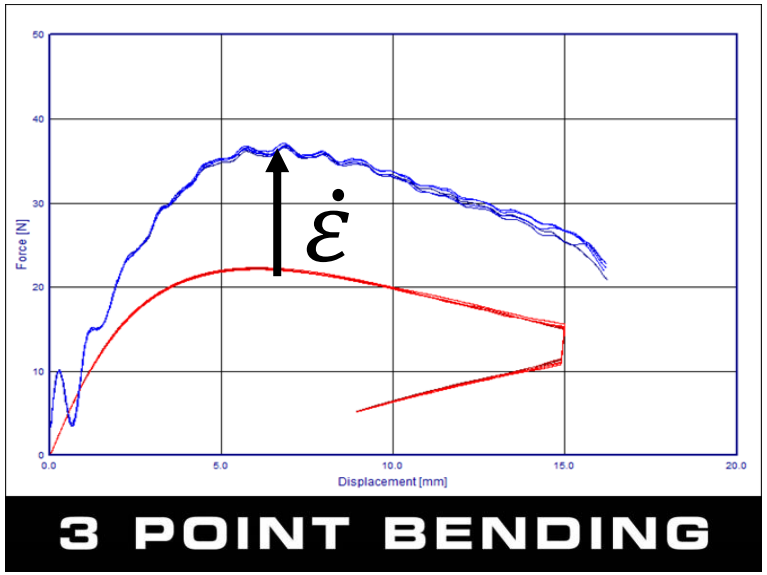
# DAY2 – LIVE



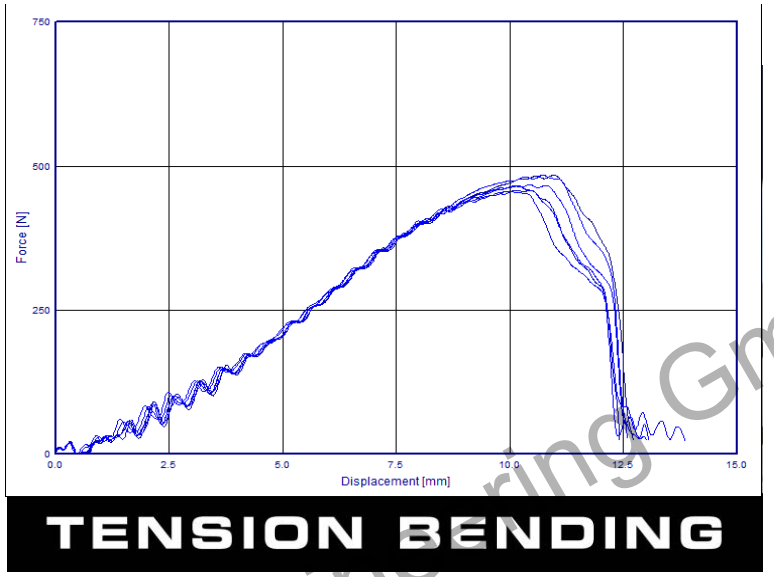



IN PHYSICS WE TRUST

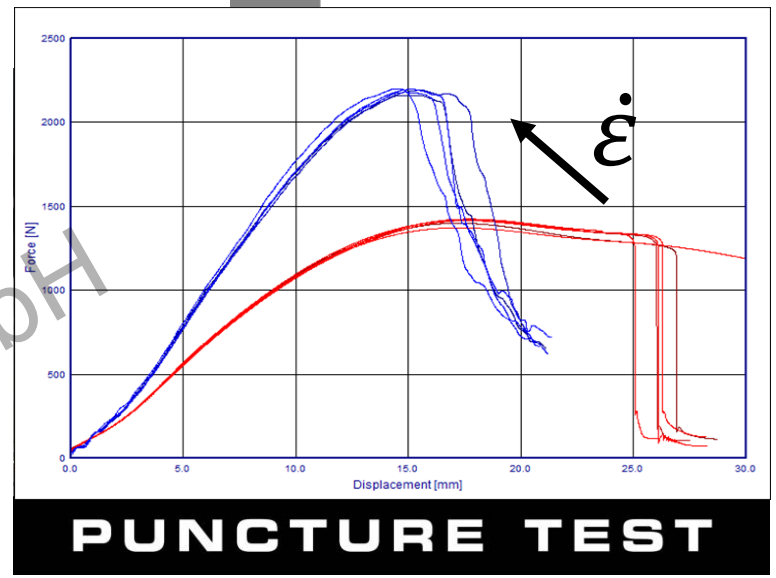
# Measurement Results



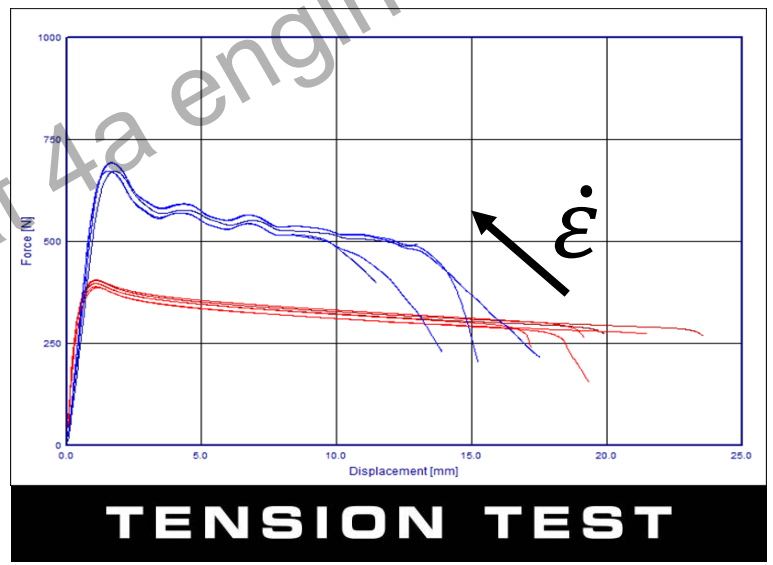

3 POINT BENDING




TENSION BENDING




PUNCTURE TEST



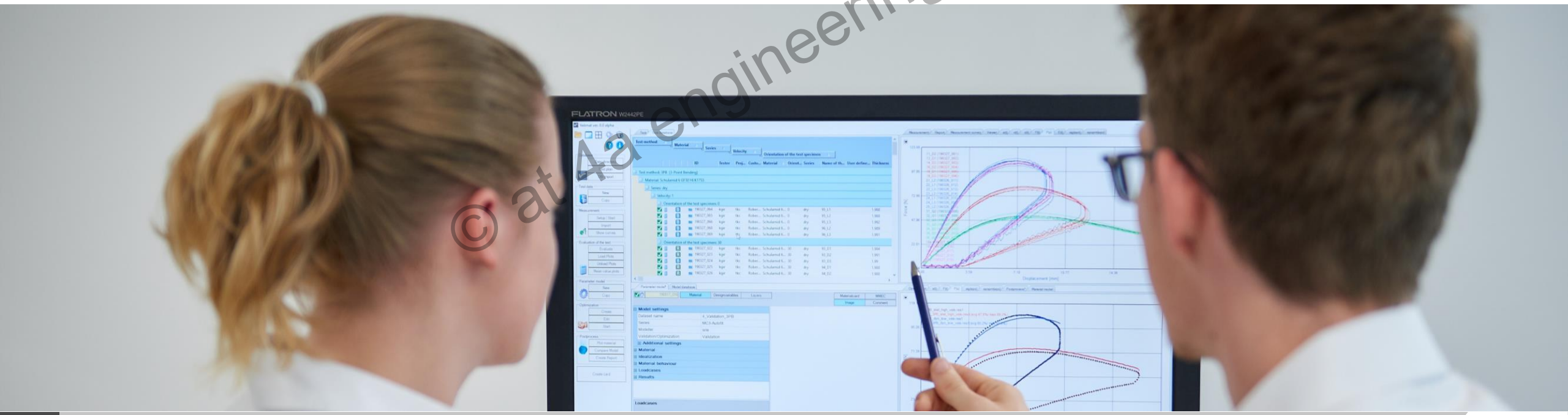

TENSION TEST

IMPETUS® ~ 3 m/s

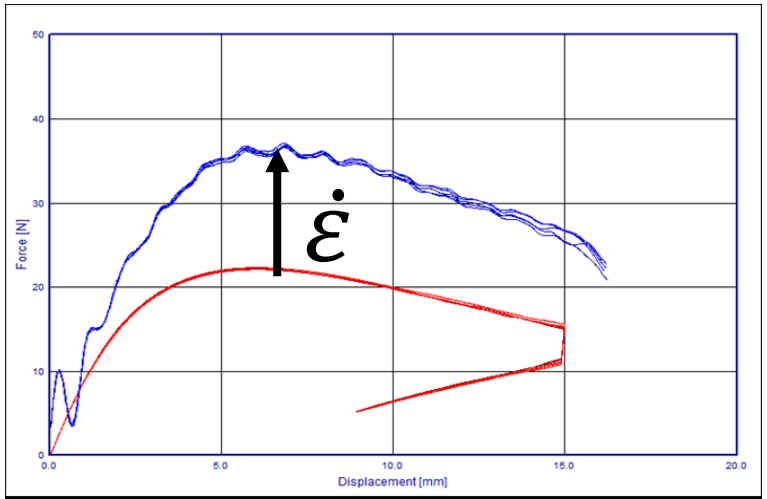
static ~ 1mm/s

VALIMAT

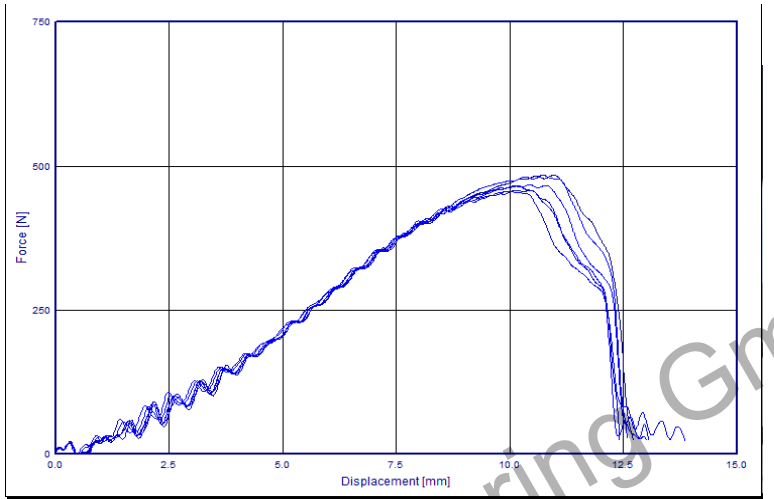
# From test to material card



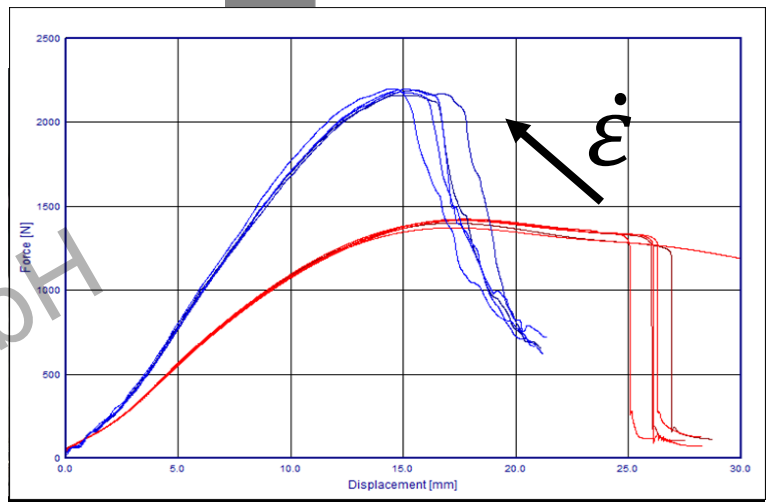
# from test to material card



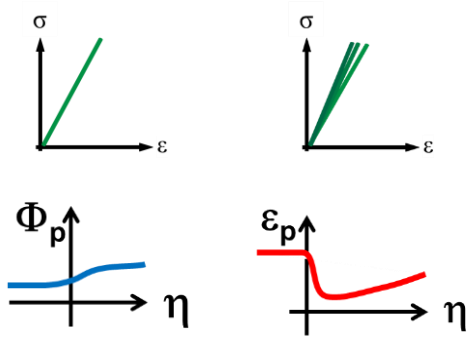

3 POINT BENDING

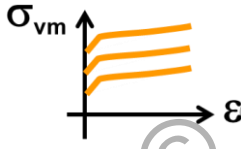


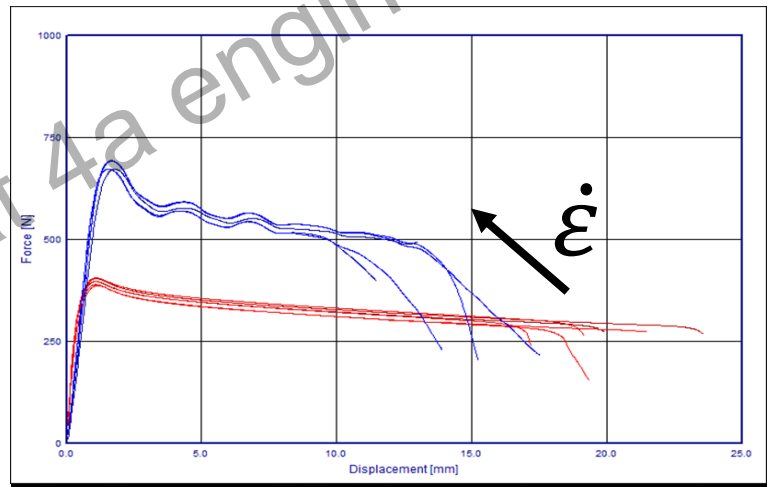

TENSION BENDING



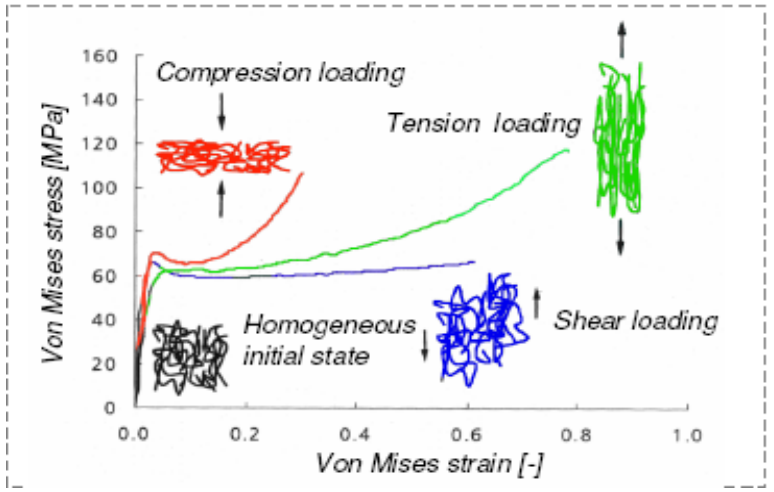

PUNCTURE TEST




TENSION TEST




Source: Mechanik der Kunststoffe *W. Retting, Hanser Verlag 1991*

# from test to material card

VALIMAT

## Current Situation

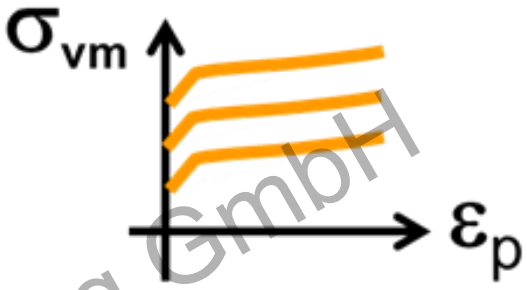
- more and more data
- Not only tension
  - Different loadcases (compression, shear, ….)
- More complex simulation models
  Investigations on failure

## NEEDED

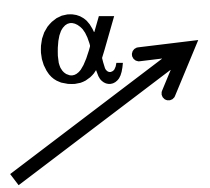
→ Smart USER INTERFACE

→ Optimization

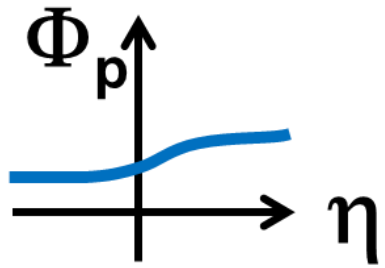
→ DATABASE handling data



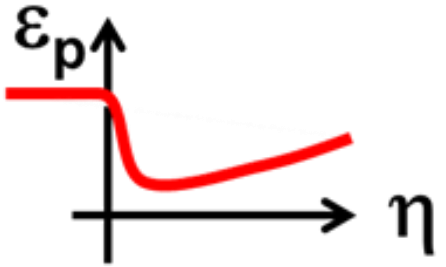

Hardening




Anisotropic




Triaxiality



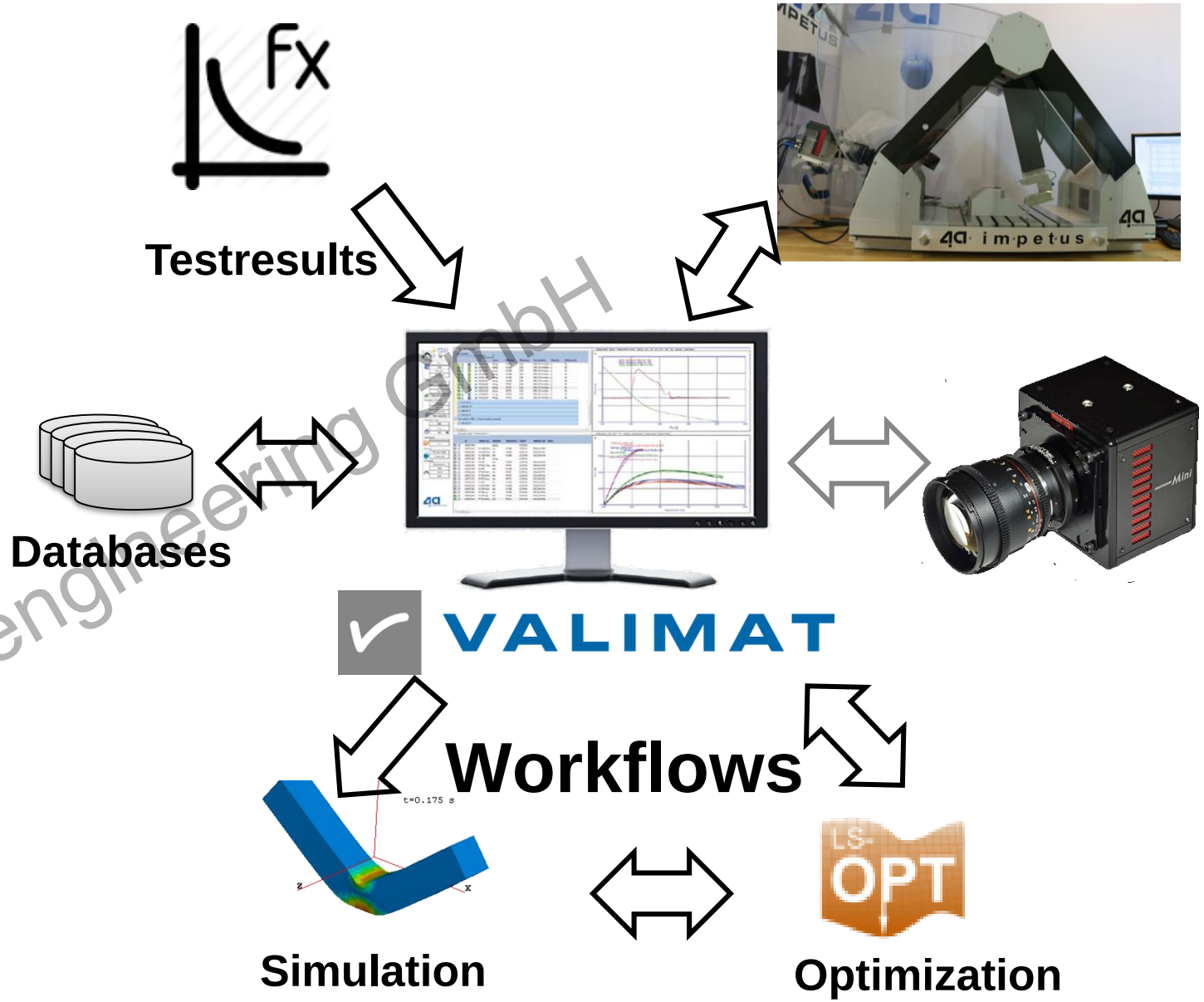

Damage/Failure

# from test to material card

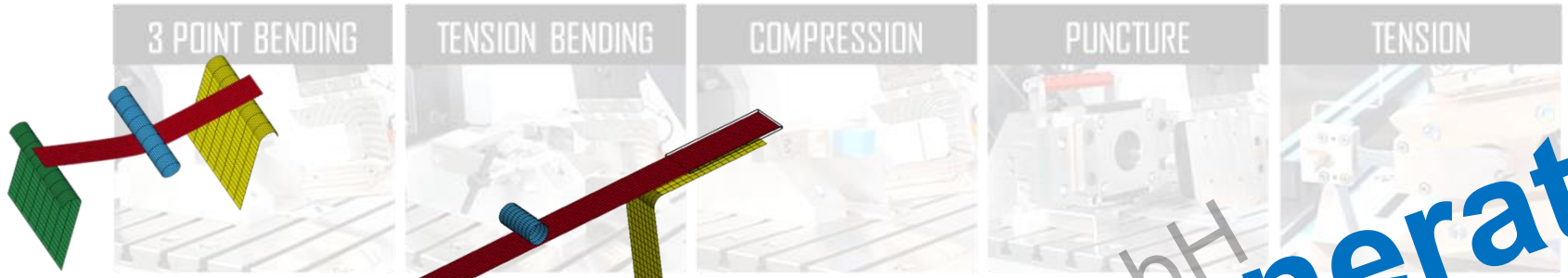
**VALIMAT®**

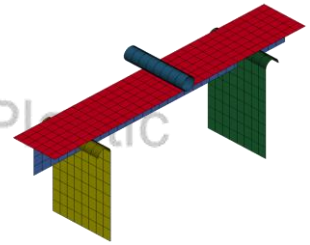
Advantage

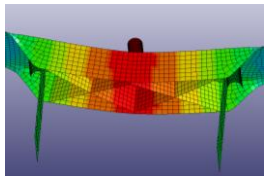
- Handling of bigdata
- Complex models
- Good correlation to simulation

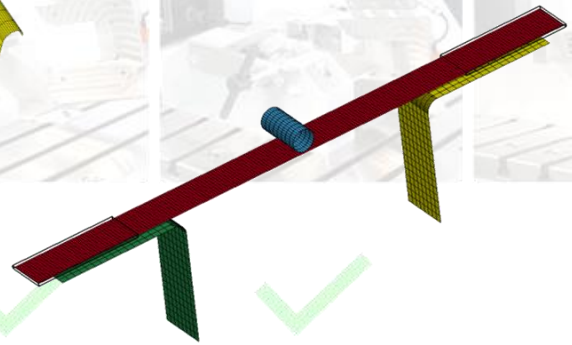


# from test to material card







Plastic

Foam

Composite

Aluminum

Metals

typical thickness

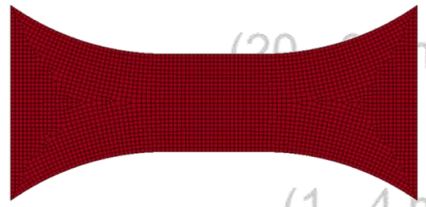
(1 - 4 mm)

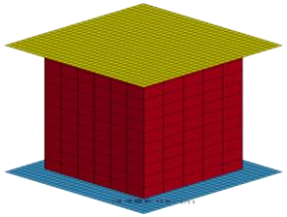
(20 - 4 mm)

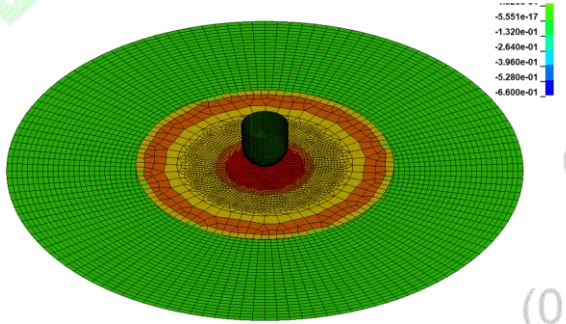
(1 - 4 mm)

(1 – 2.5 mm)

(0.5 – 1.5 mm)







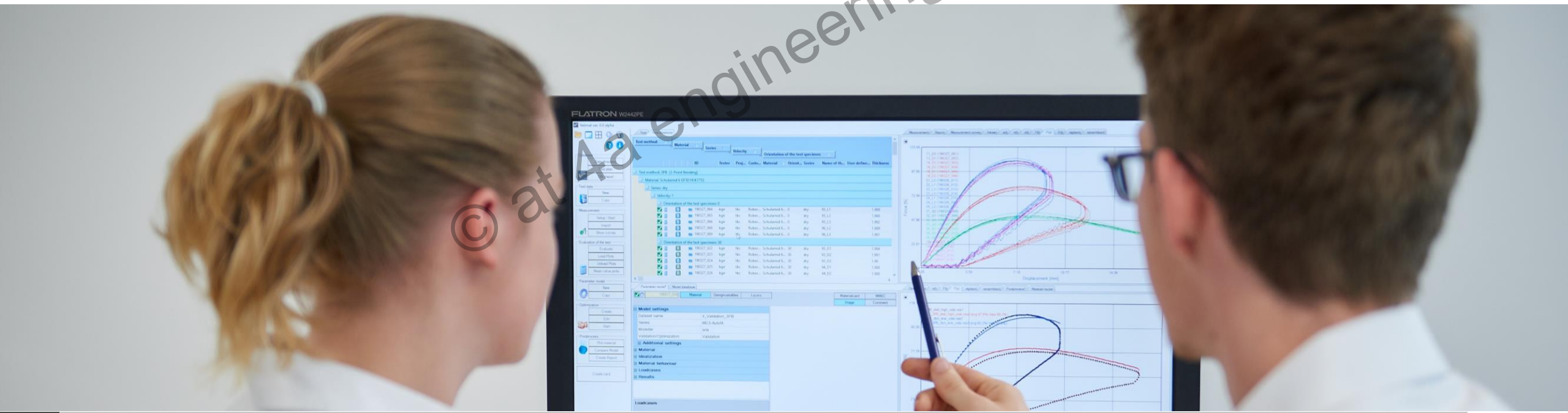

**automated FE-model generation**



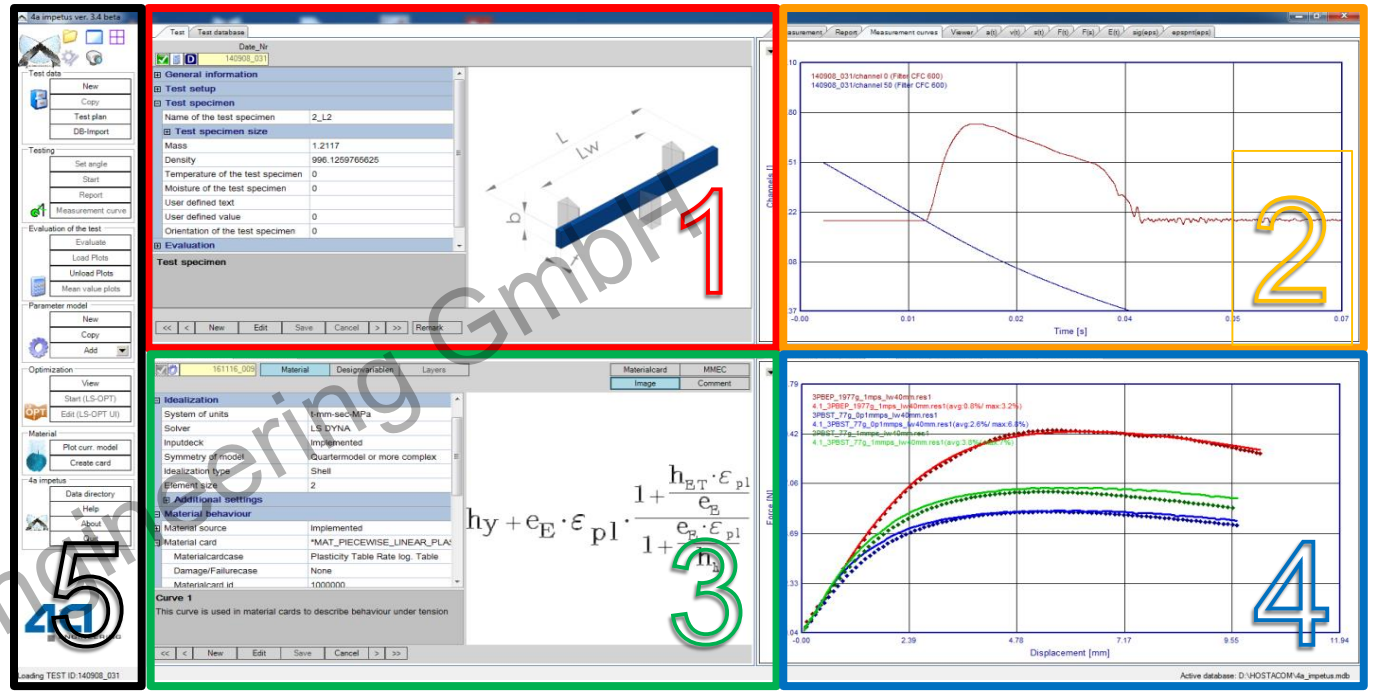
VALIMAT

VALIMAT

# FIRST LOOK



# GUI - the graphic user interface is divided into five parts

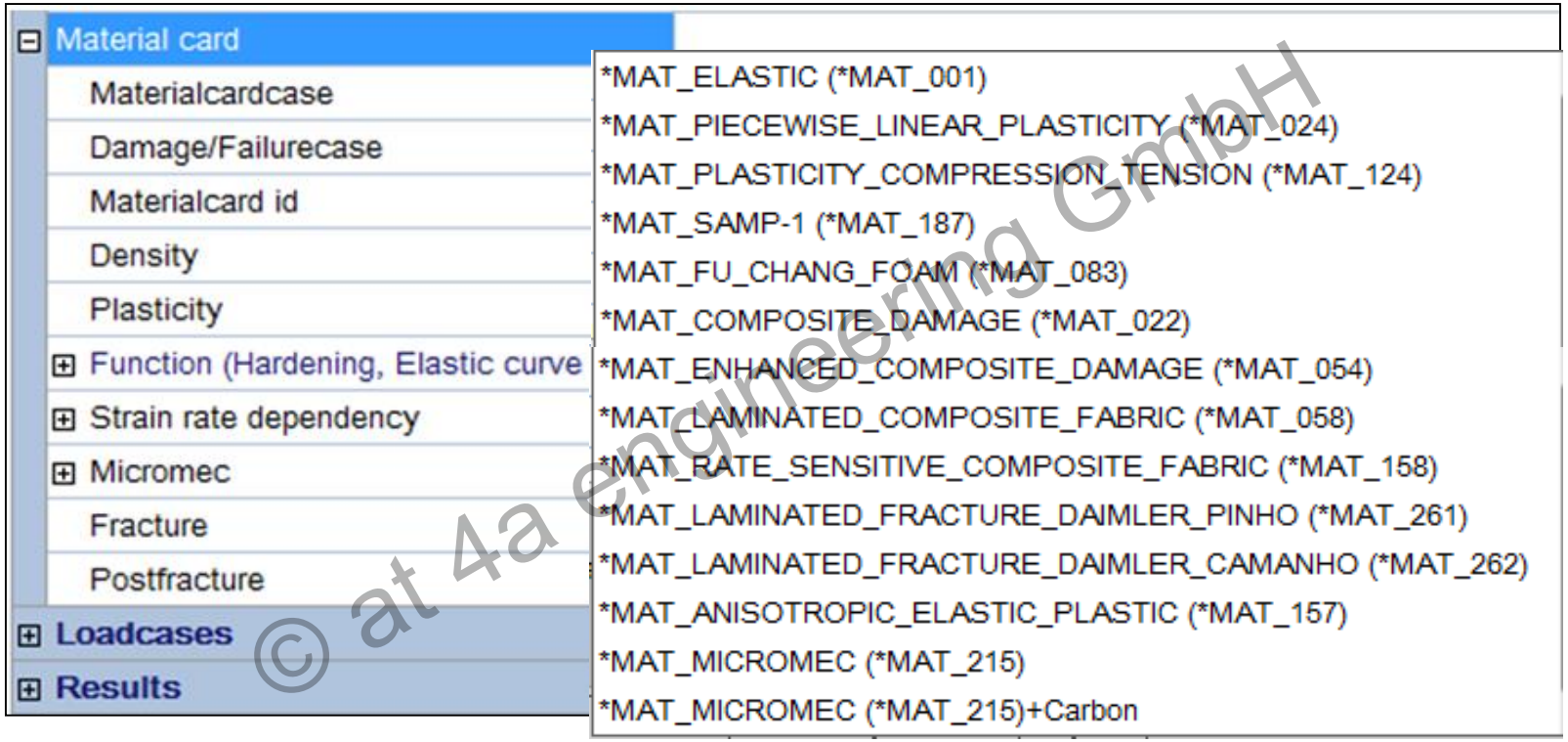



basic menu (left margin, (5))
window top left (1) → test; data base
window top right (2) → measurements; info; measurement results
window bottom left (3) → model parameter; optimization settings
window bottom right (4) → optimization; results of the optimization
the basic menu describes the principal process from the test to the completed material model and allows a simple and fast access of the most important functions.

# material models

VALIMAT

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



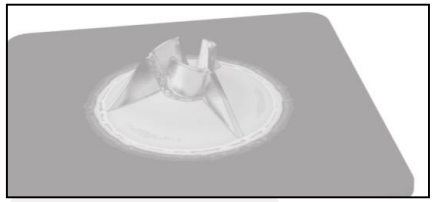


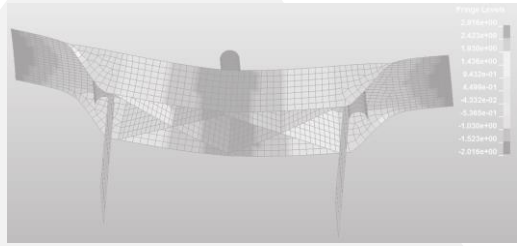

- ***Whole number*** of LS-Dyna material models is available through ***userdefined material cards***

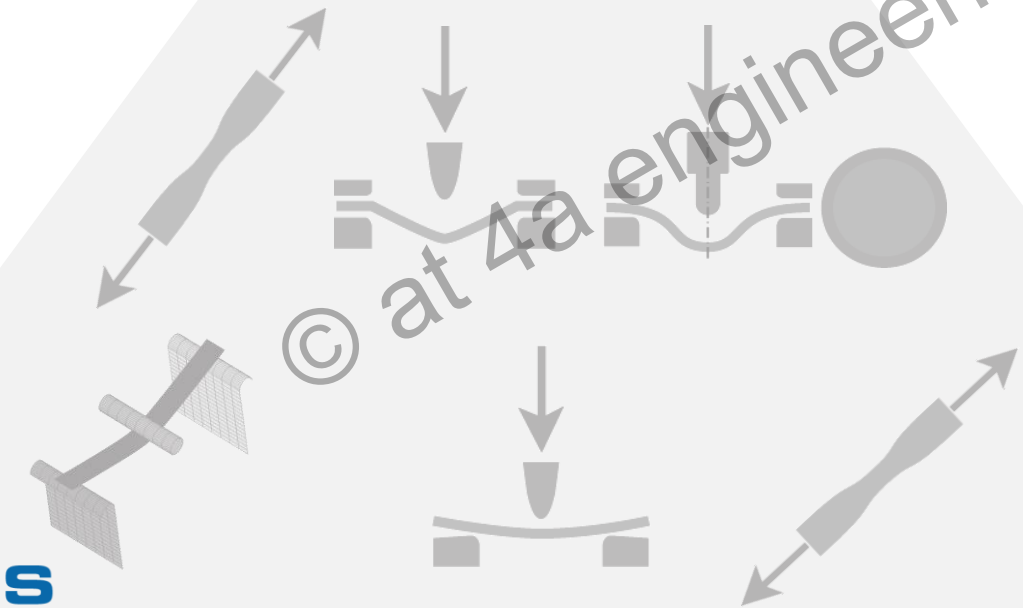
# from test to material card

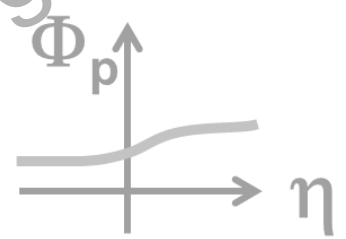
VALIMAT

Deformation → Failure
Creep → Static → Crash
ISOTROPIC → ANISOTROPIC

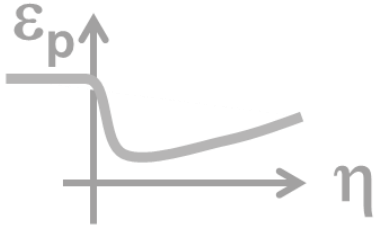




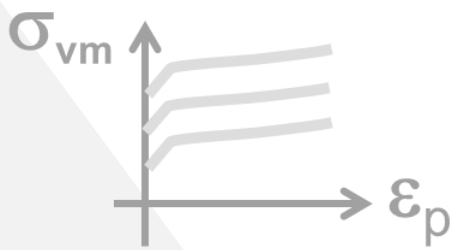





Triaxiality




Damage/Failure




Hardening

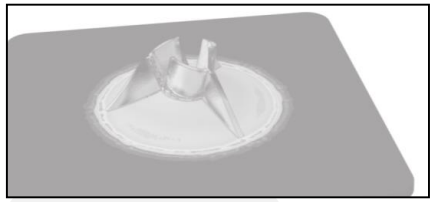

Anisotropic

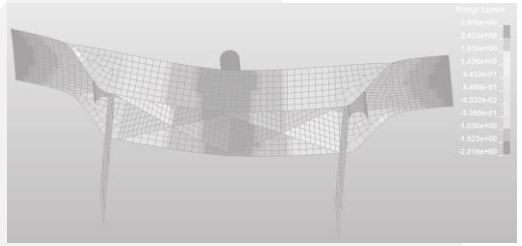


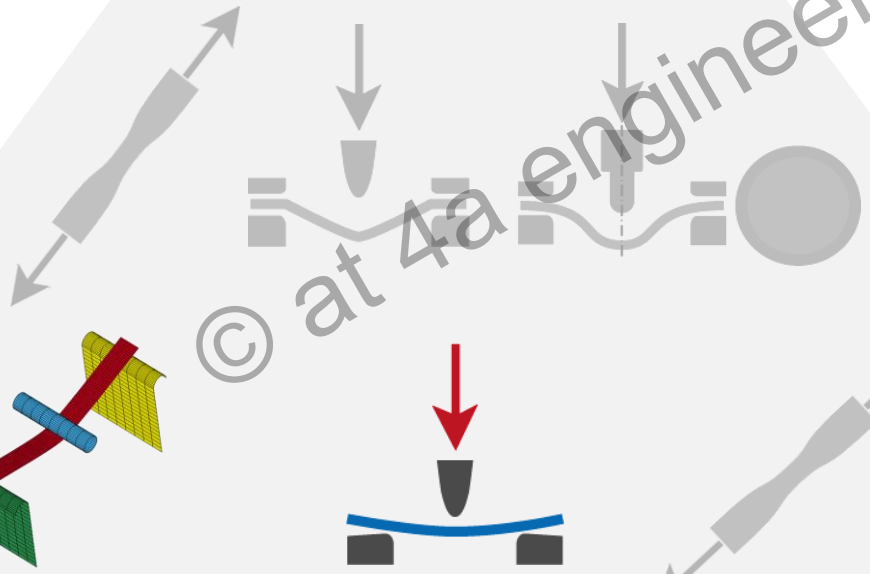
IMPETUS

# from test to material card

VALIMAT







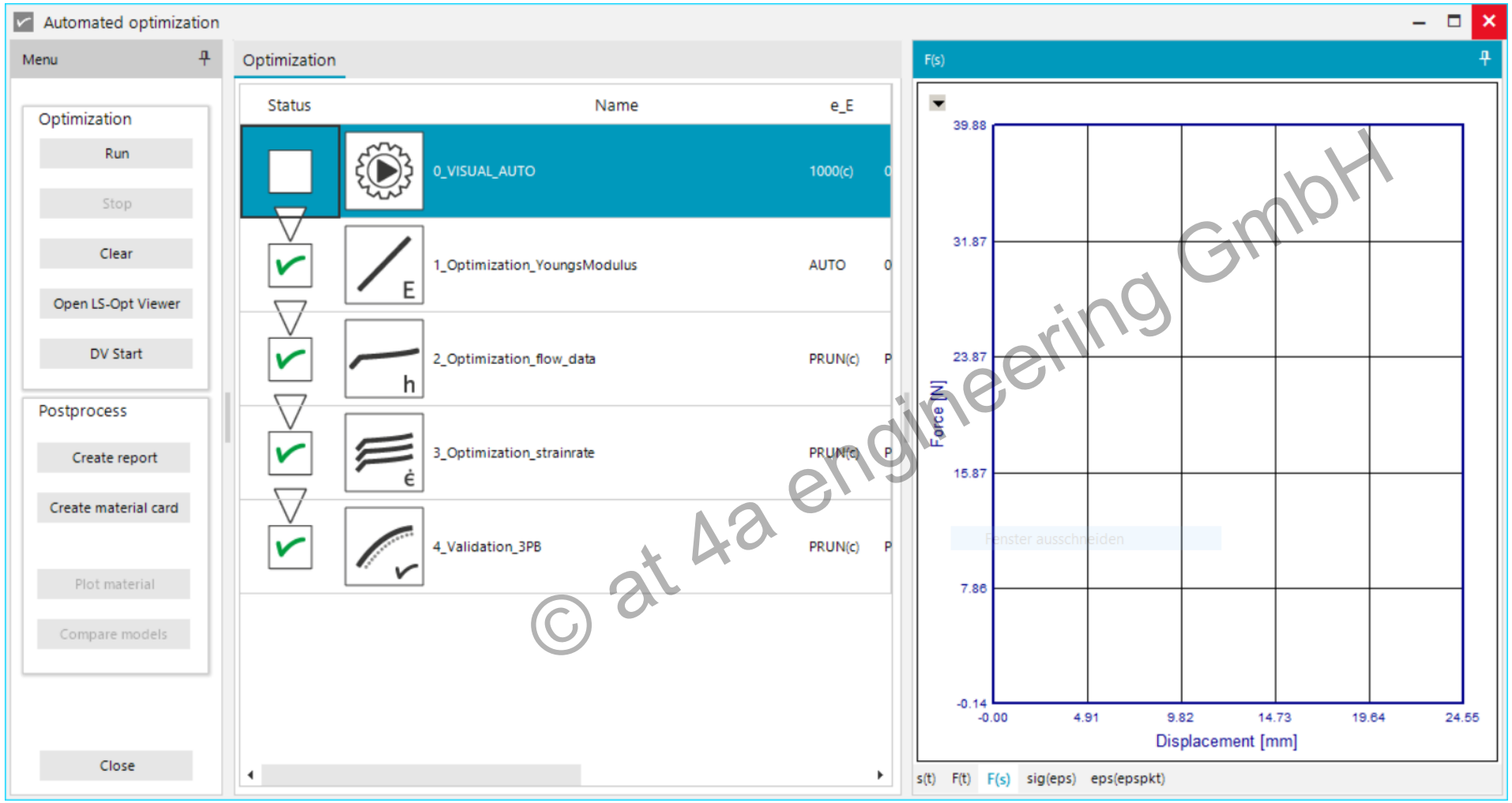




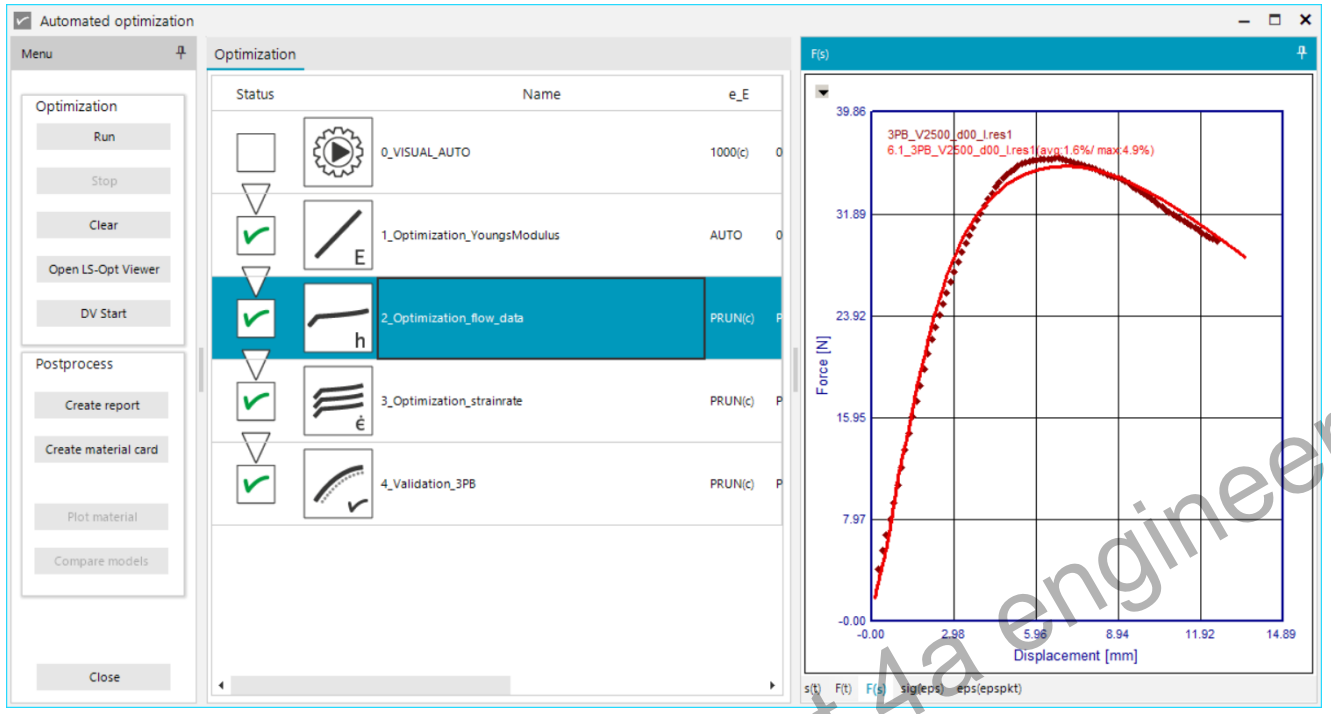
IMPETUS

# Workflow for Material Card Generation - AUTOFIT

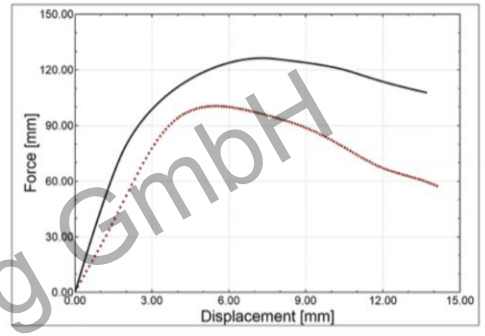
VALIMAT

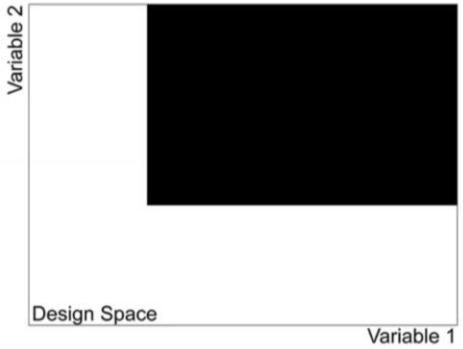


# Workflow for Material Card Generation - AUTOFIT

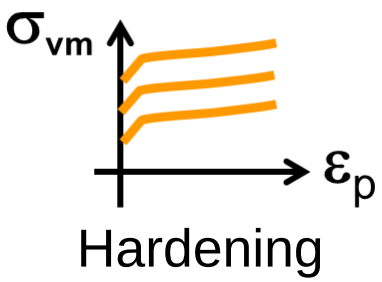


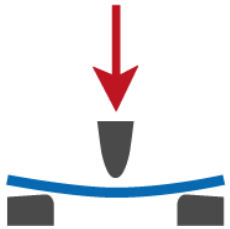

optimization – successive response surface method




$$hardening\ function = f(Variable\ 1, Variable\ 2)$$

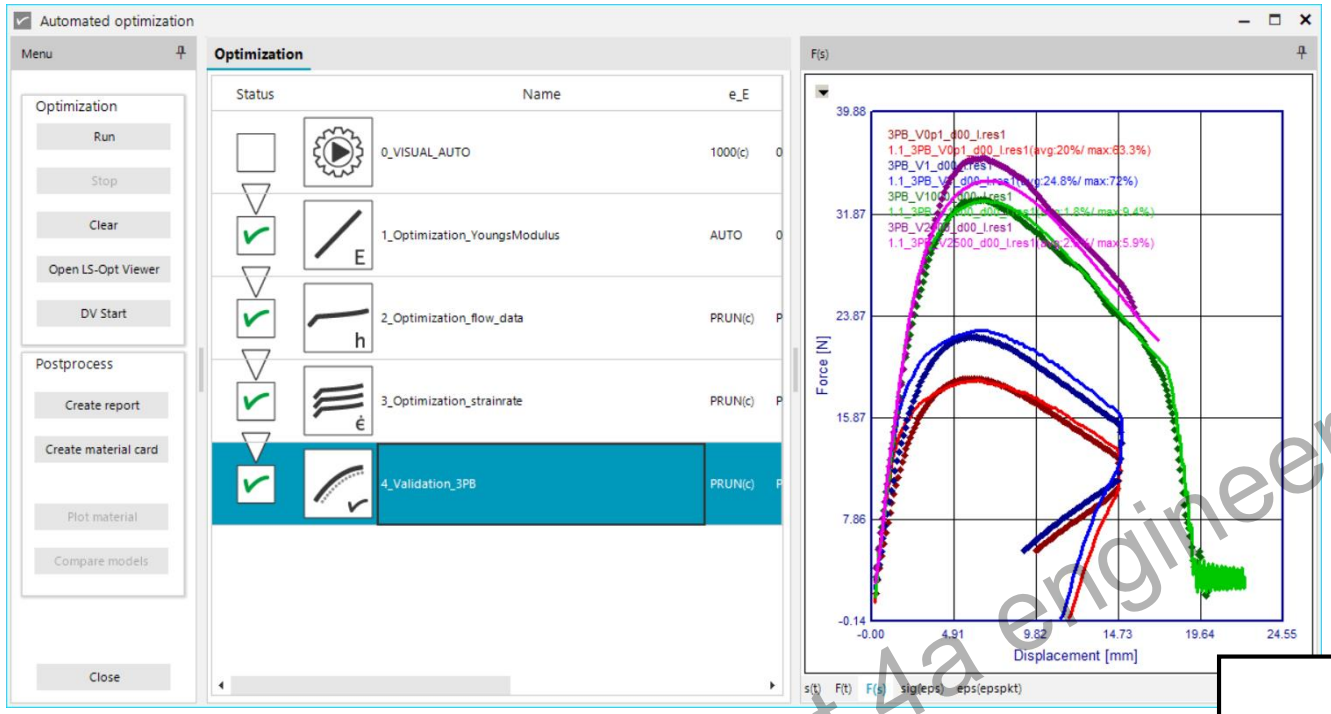


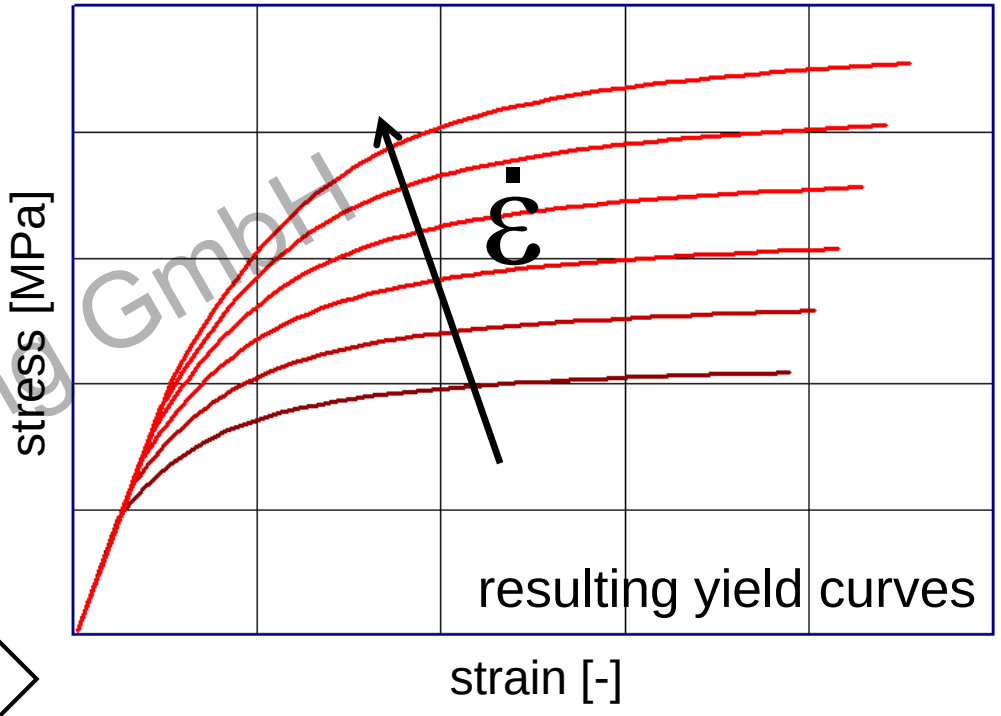



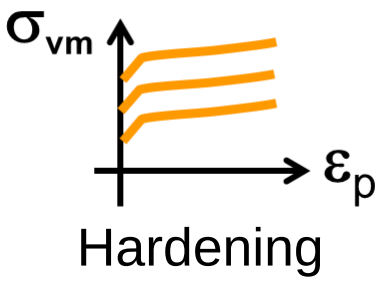
[redacted]

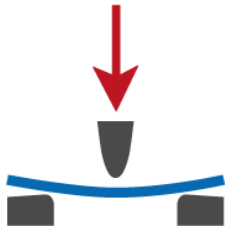
# Workflow for Material Card Generation - AUTOFIT

VALIMAT



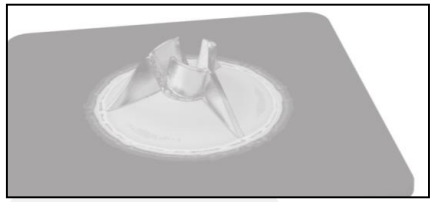



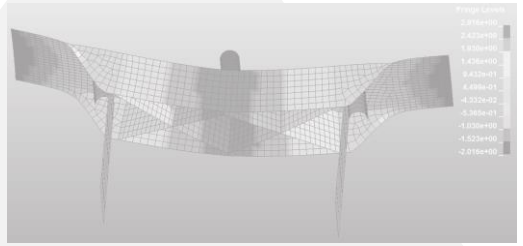



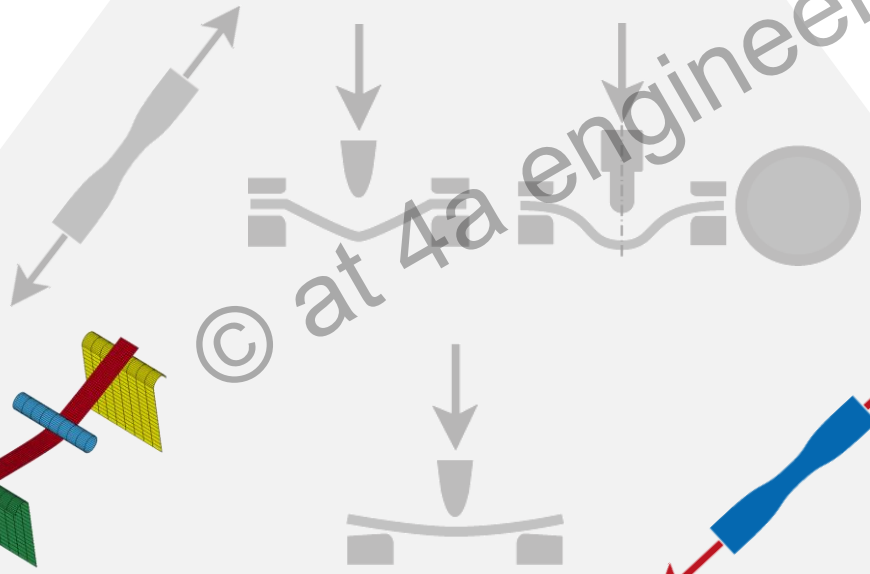
more on DAY 3

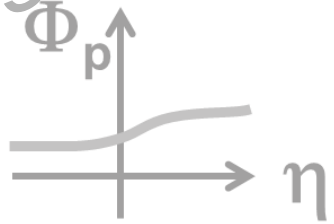
# from test to material card

VALIMAT

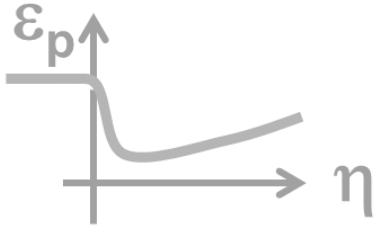




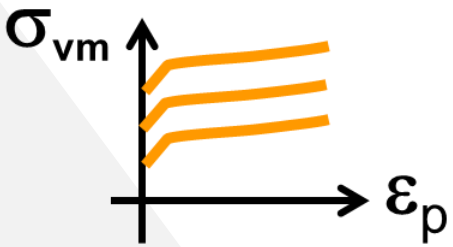





Triaxiality




Damage/Failure



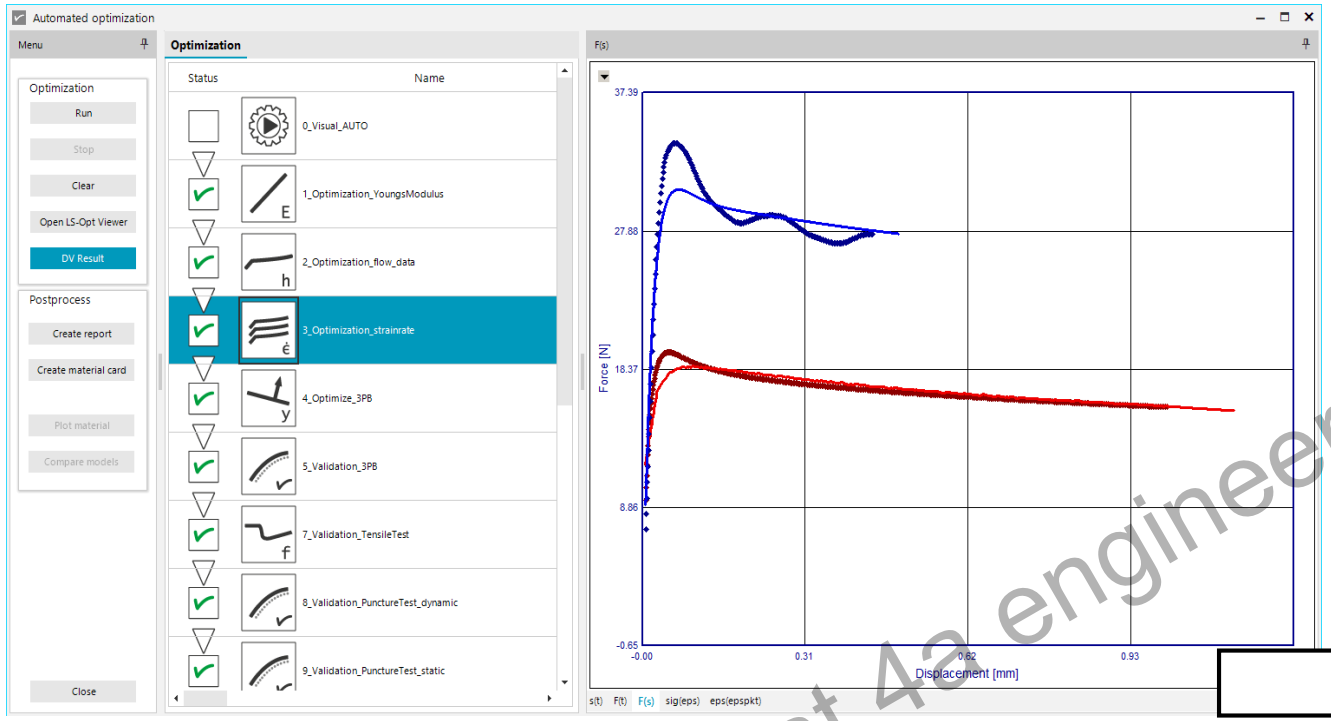

Hardening


Anisotropic

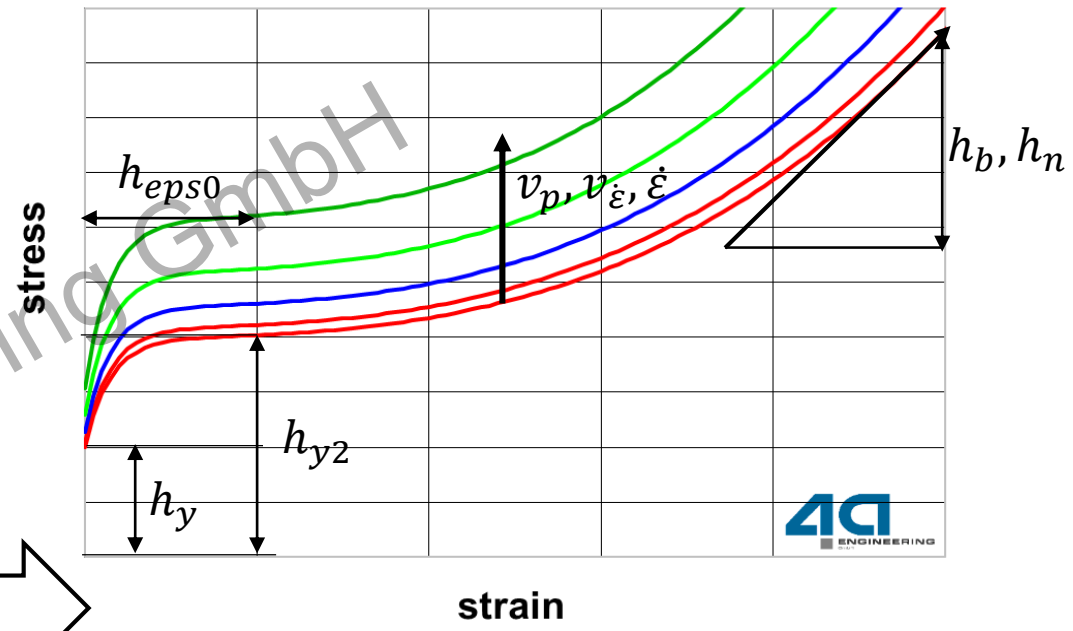


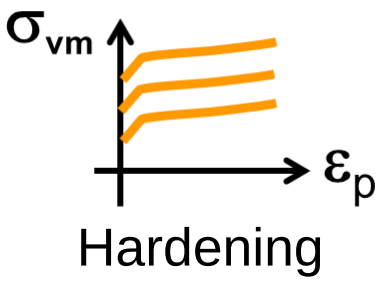
IMPETUS

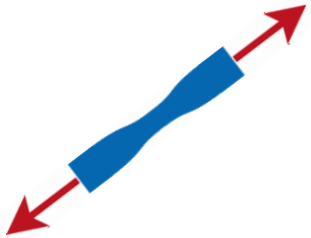
# Workflow for Material Card Generation - AUTOFIT




parametrized material card

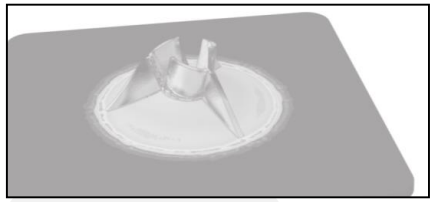


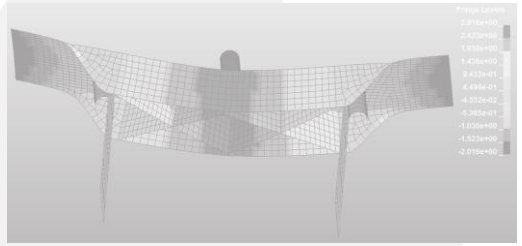



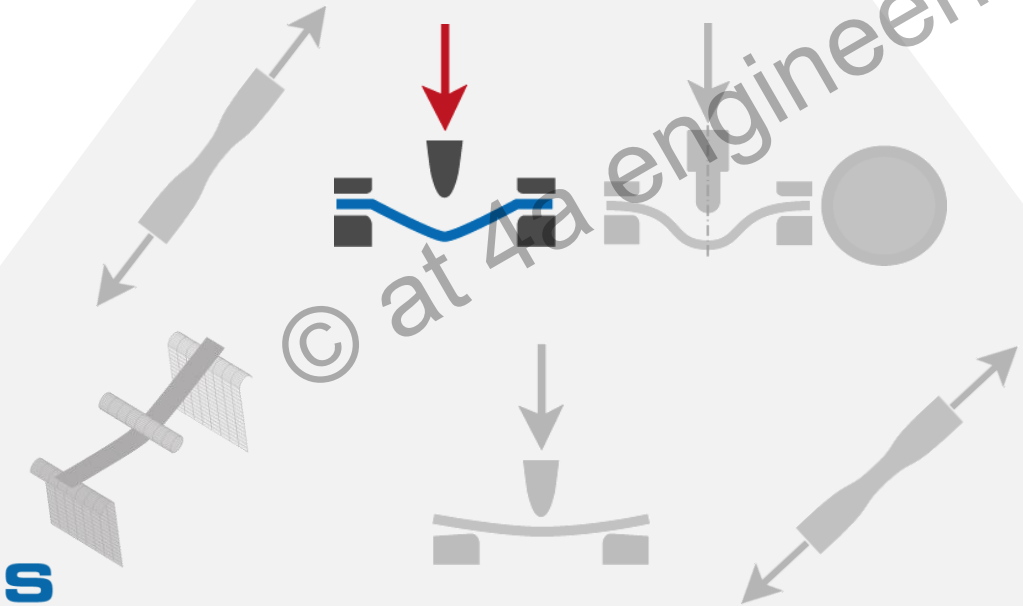



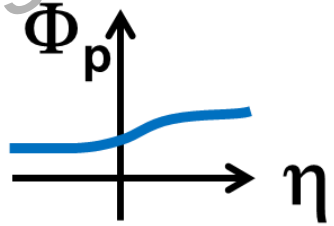
# from test to material card

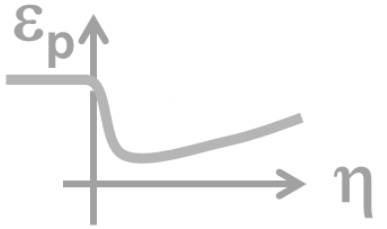
VALIMAT

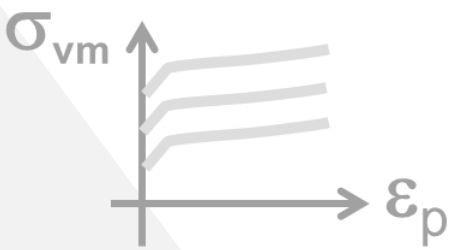








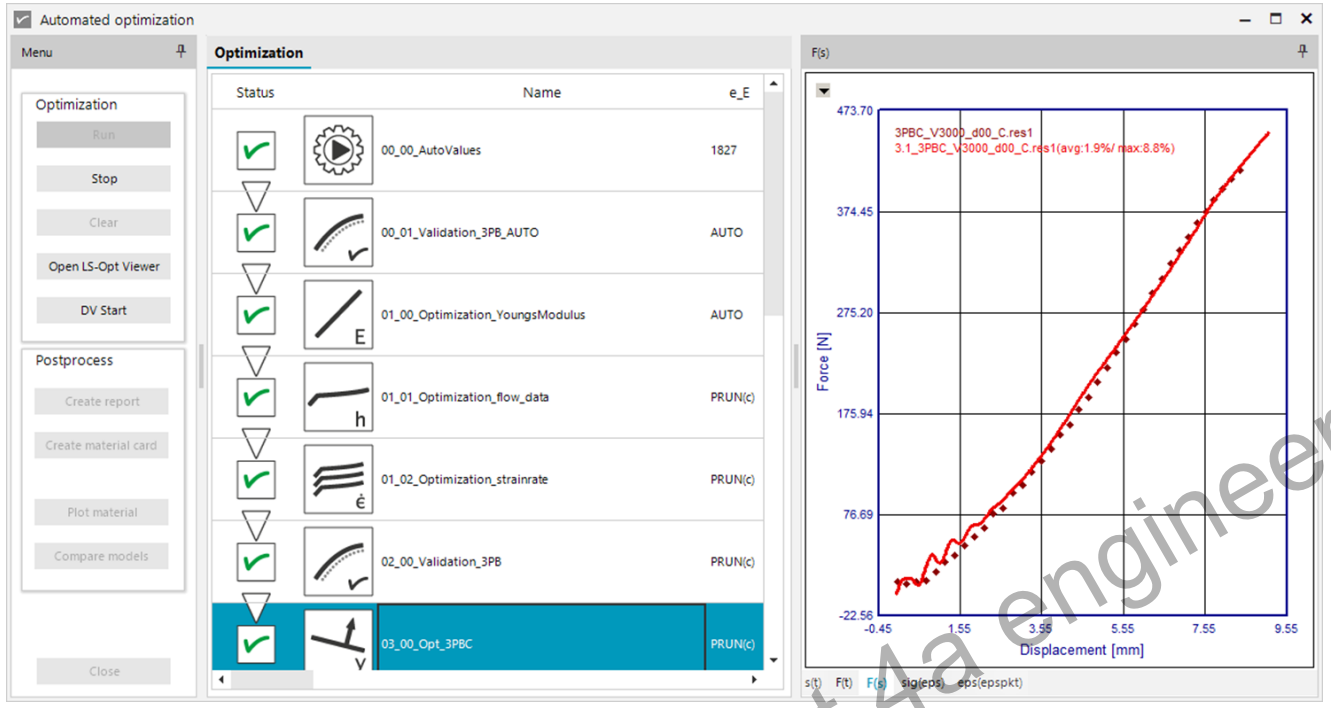



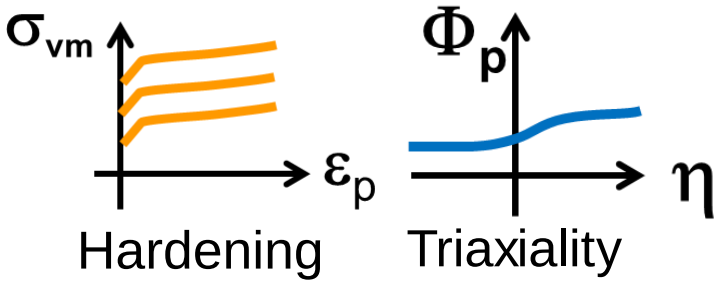


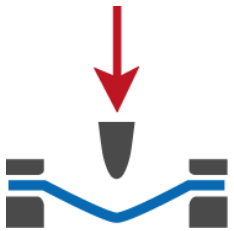


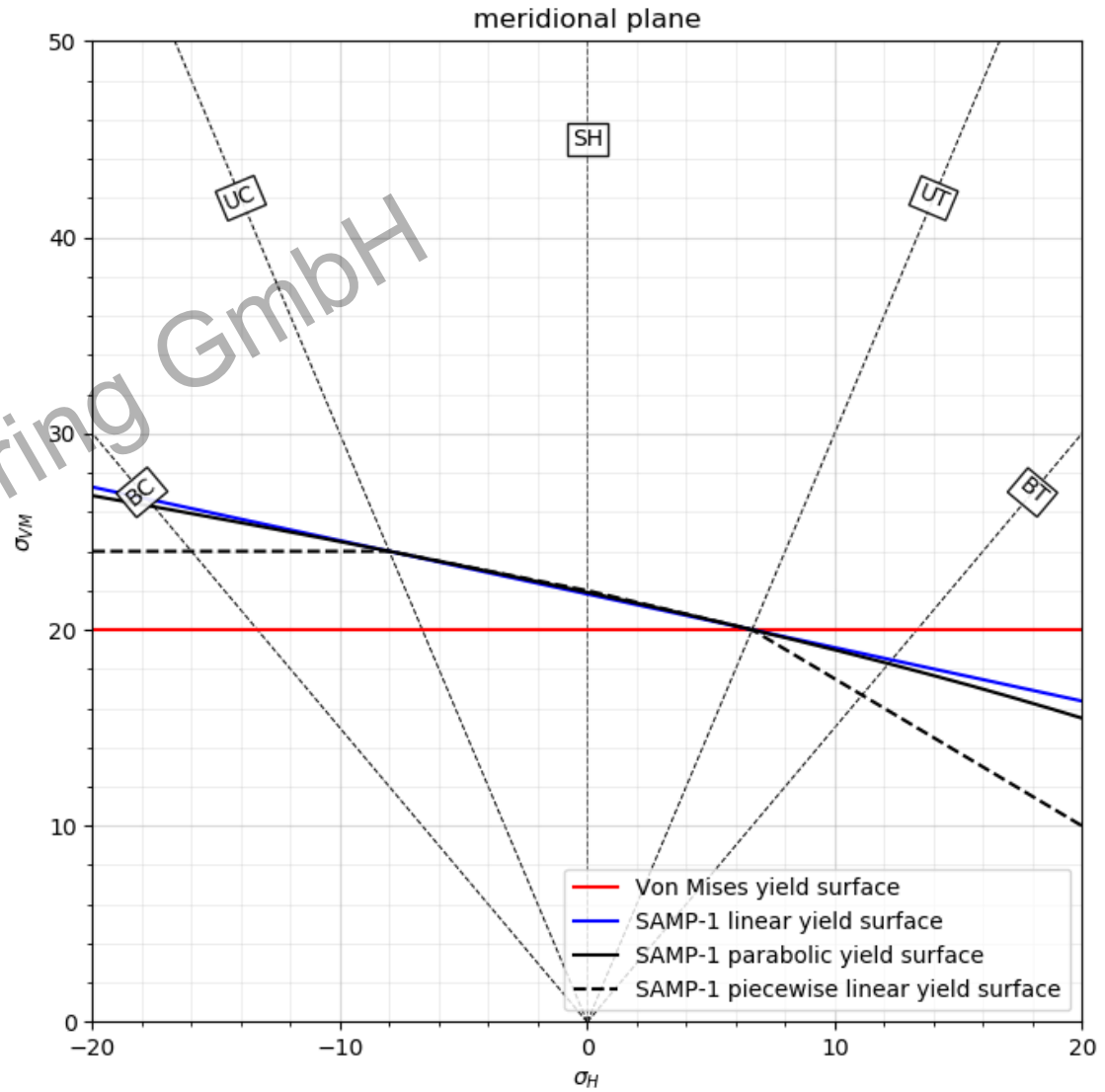
IMPETUS

# Workflow for Material Card Generation - AUTOFIT



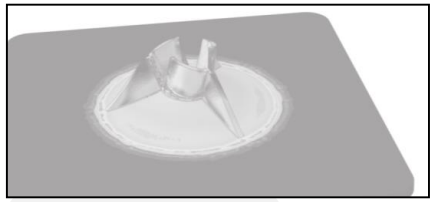



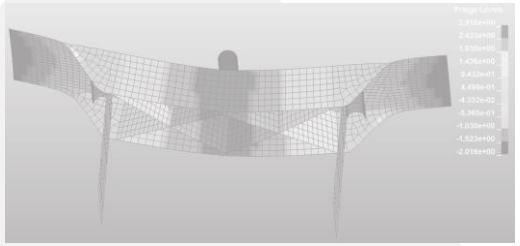



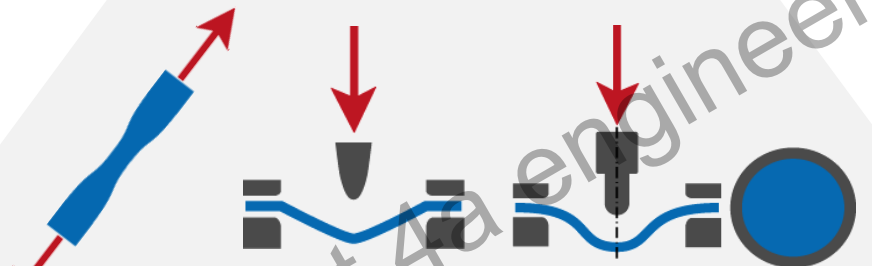


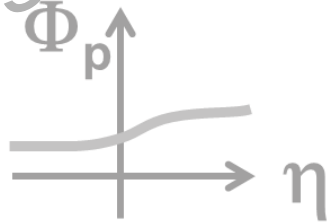
# from test to material card

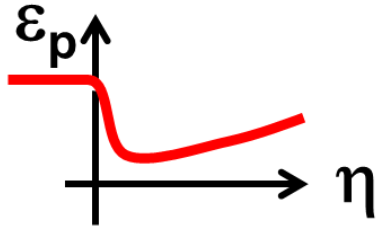
VALIMAT

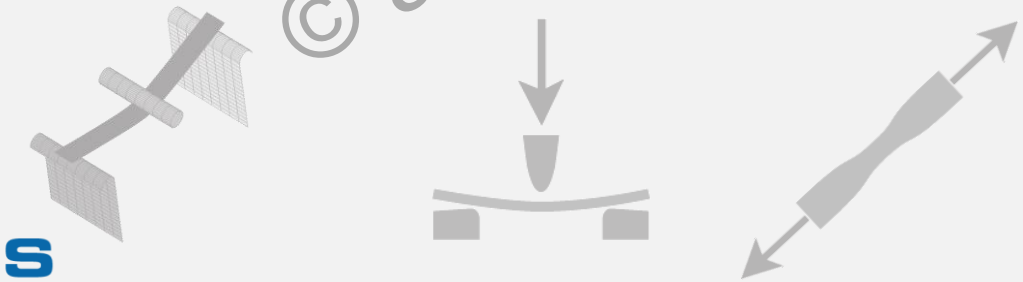


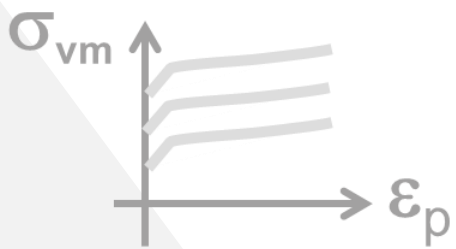








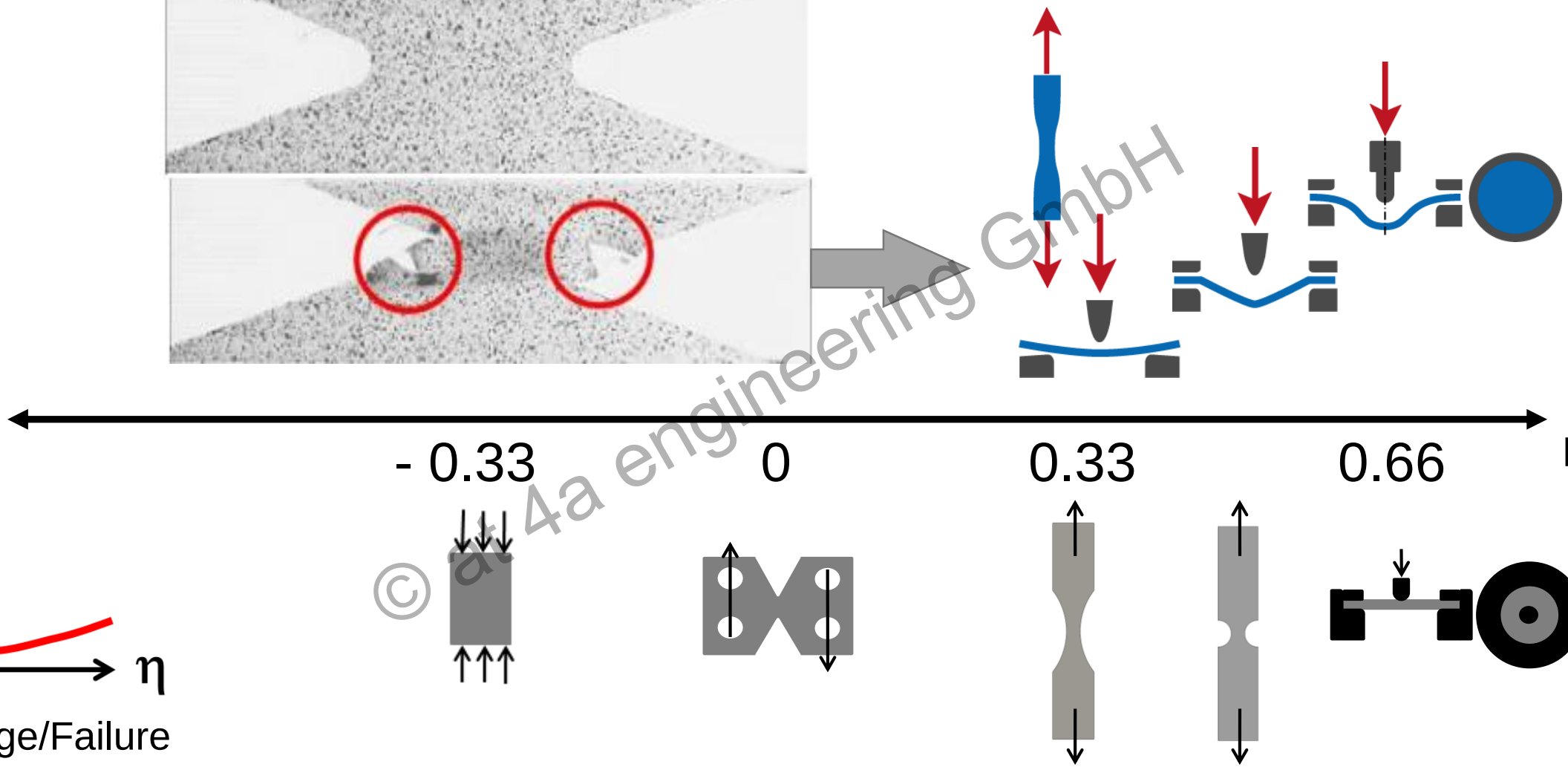




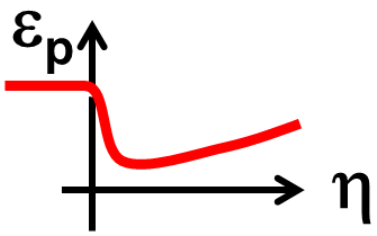
IMPETUS

# from test to material card

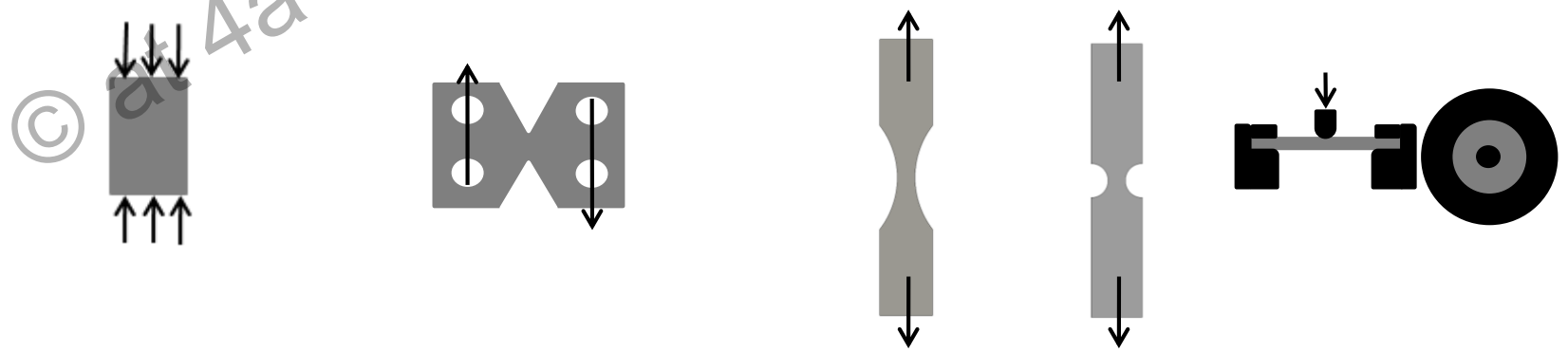




# from test to material card

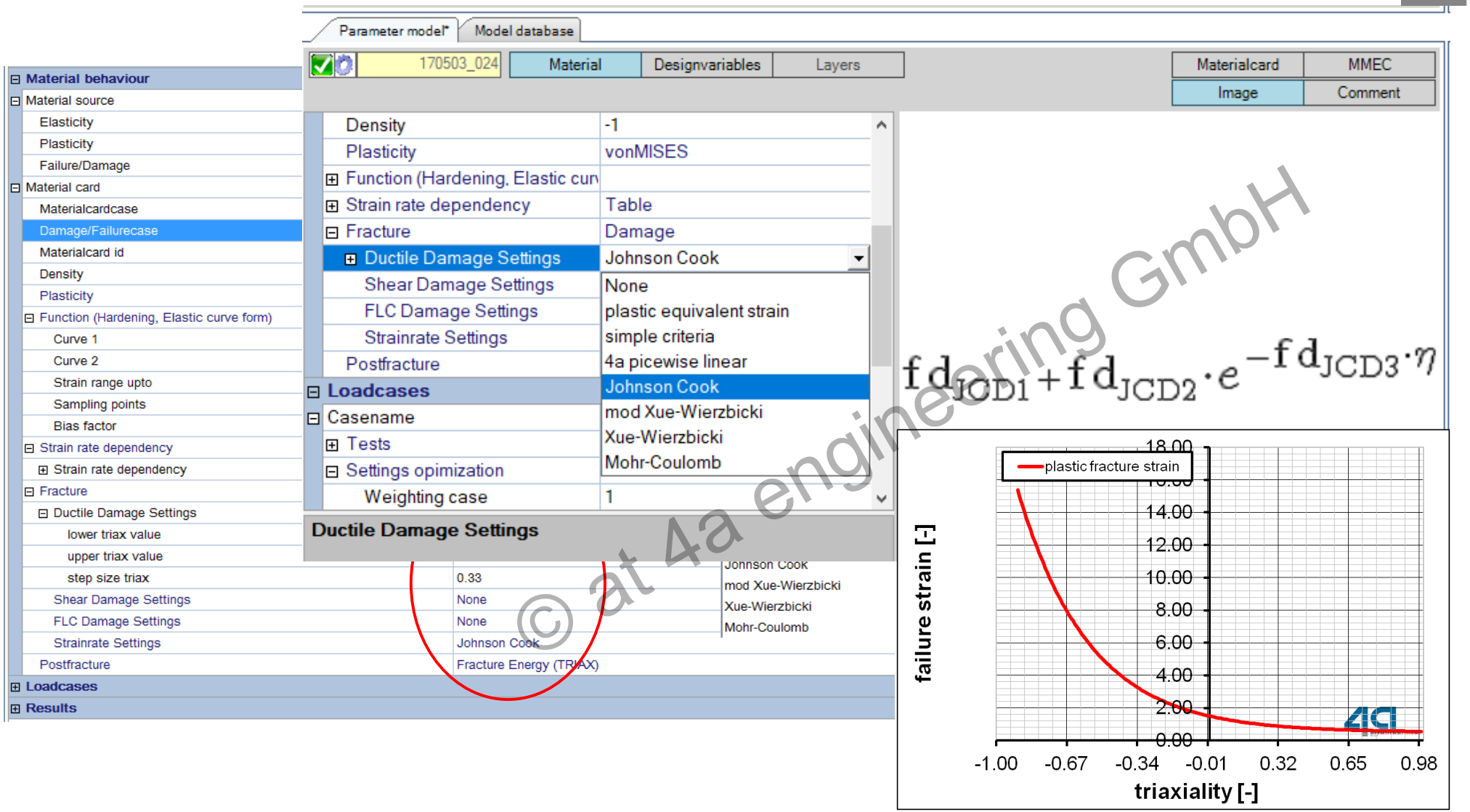




Damage/Failure



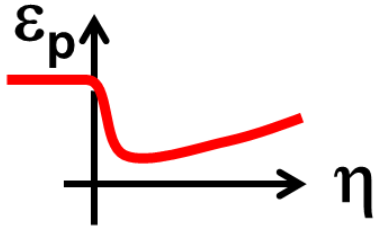
# fracture models → *MAT_ADD_EROSION

VALIMAT



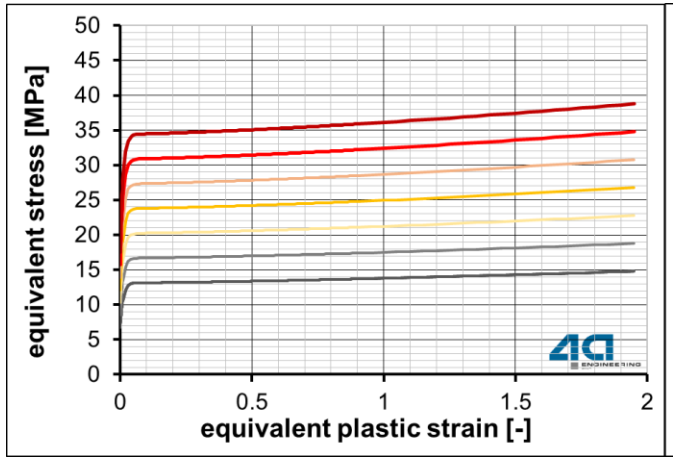

$$fd_{JCD1} + fd_{JCD2} \cdot e^{-fd_{JCD3} \cdot \eta}$$

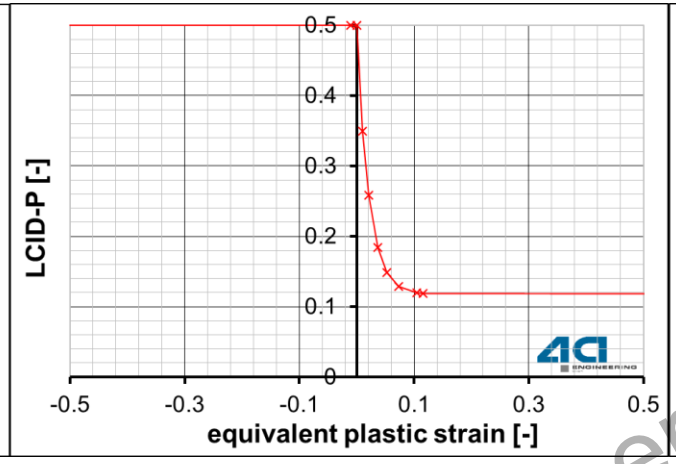


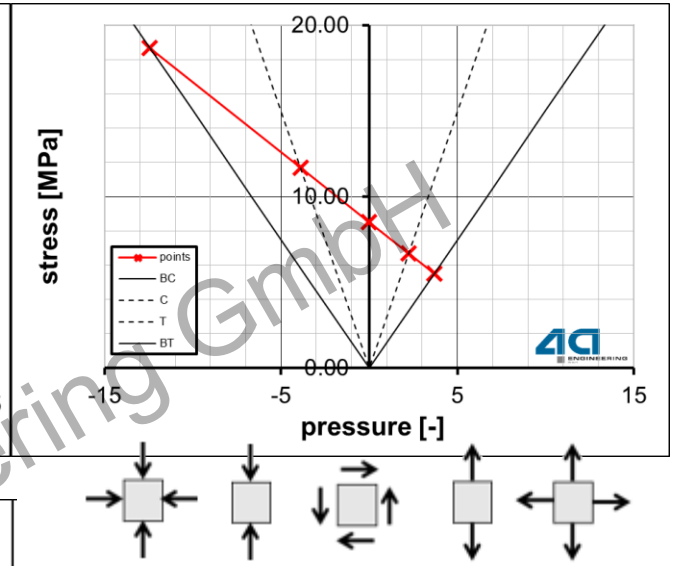



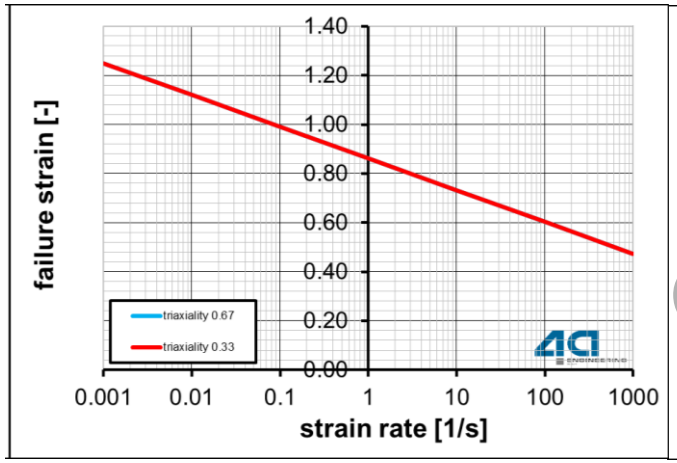

Damage/Failure

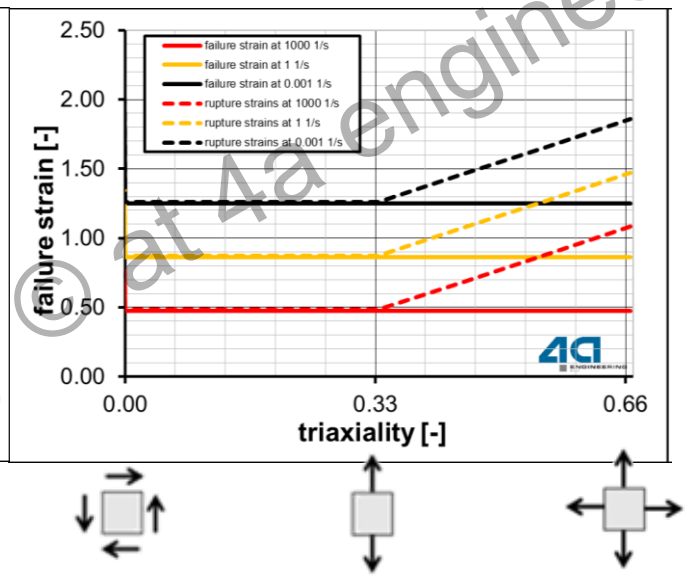
# typical result - *MAT_SAMP-1 with failure

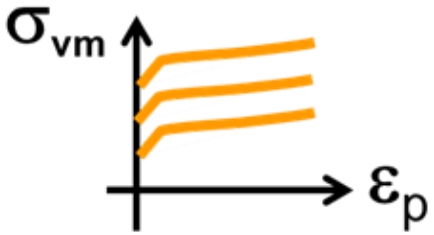


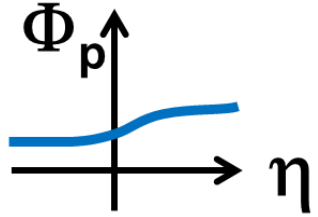



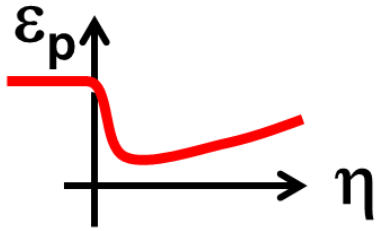




Hardening




Triaxiality

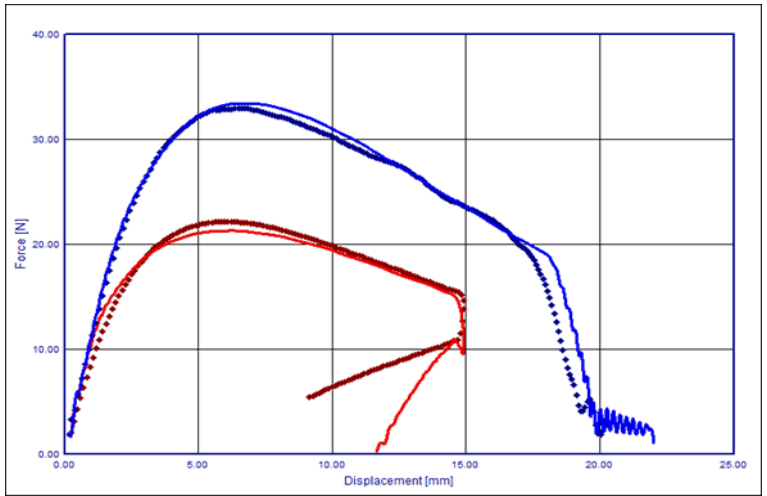



Damage/Failure

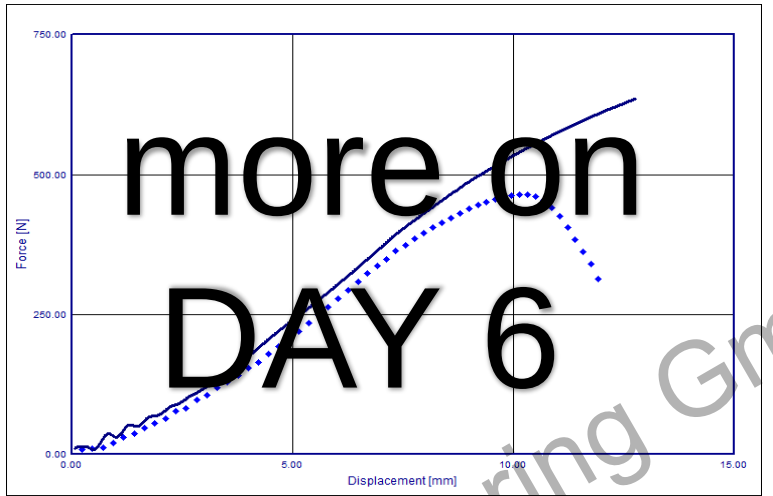
***source:*** Benjamin Hirschmann, master thesis

# typical result - *MAT_SAMP-1 with failure

VALIMAT

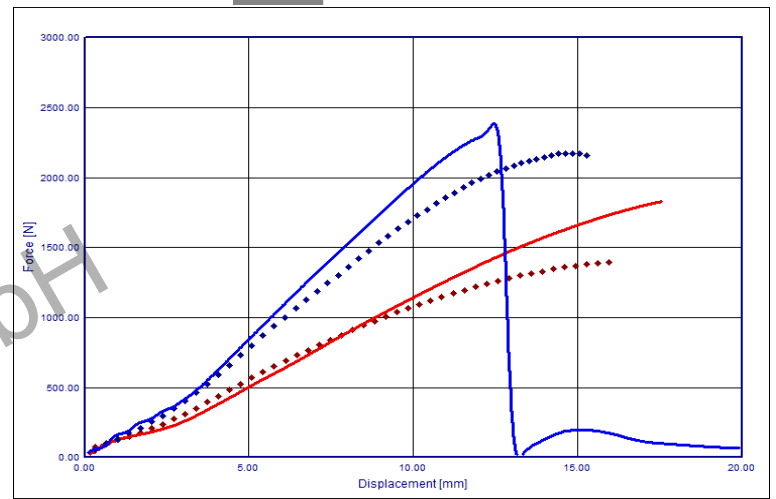



3 POINT BENDING

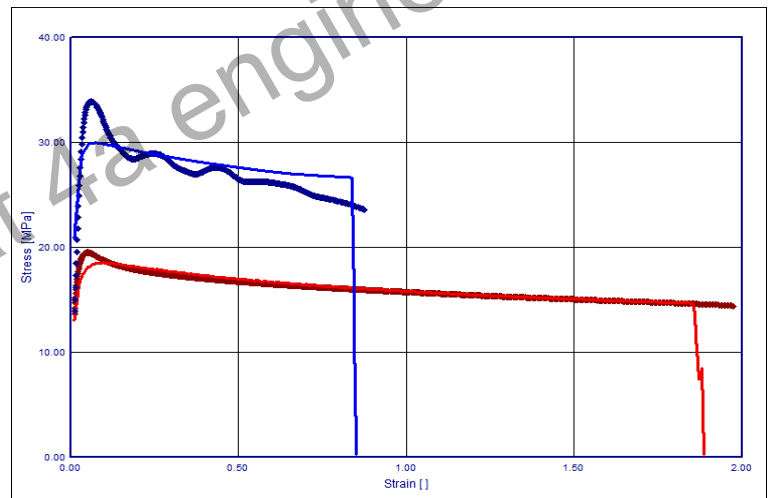



TENSION BENDING

more on DAY 6




PUNCTURE TEST

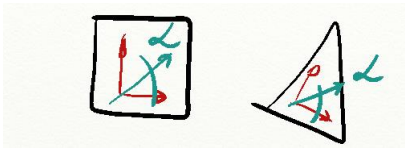



TENSION TEST



IMPETUS® ~ 3 m/s

static ~ 1mm/s



···· averaged test curves

— result of simulation

***source:*** Benjamin Hirschmann, master thesis

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

## Fiber reinforced Plastics (SFRT & LFRT)



### IMPETUS

efficient
dynamic testing

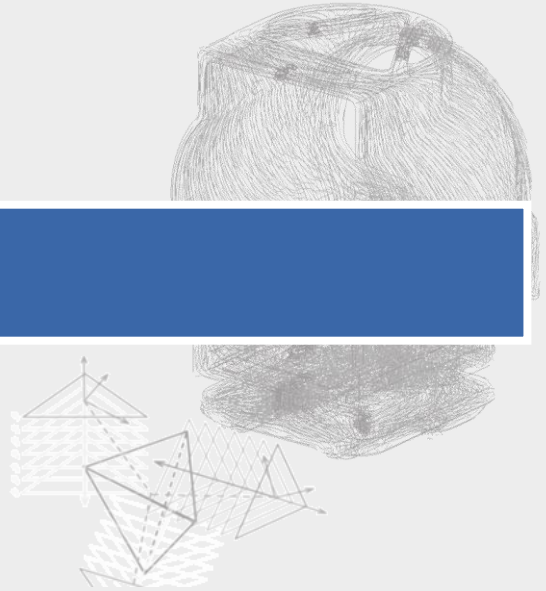
### VALIMAT


from test to validated
material cards

### MICROMEC

3D anisotropic
material cards

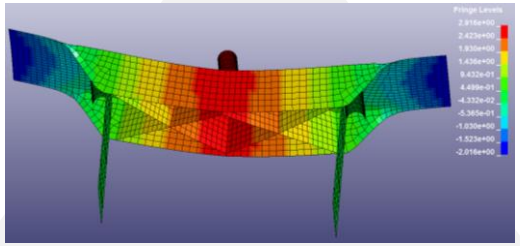
### FIBERMAP

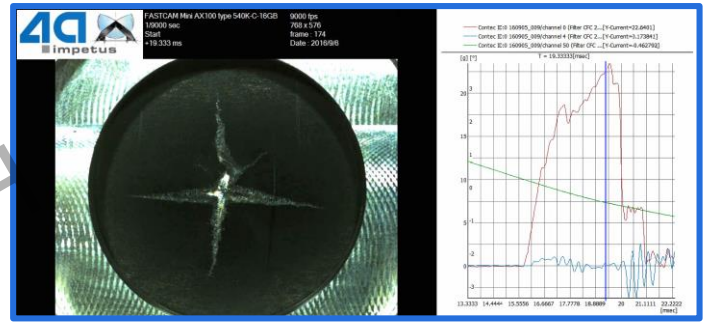


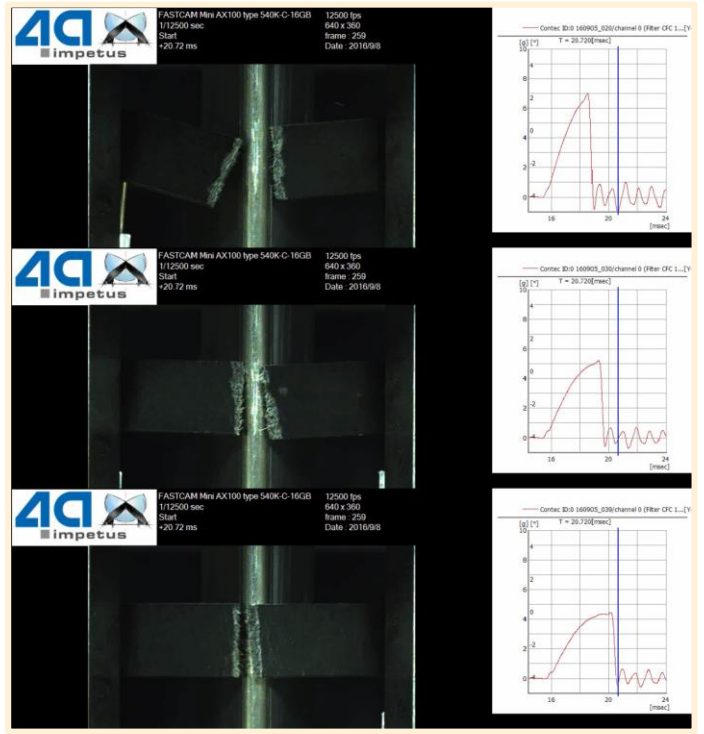
individual mapping
process information

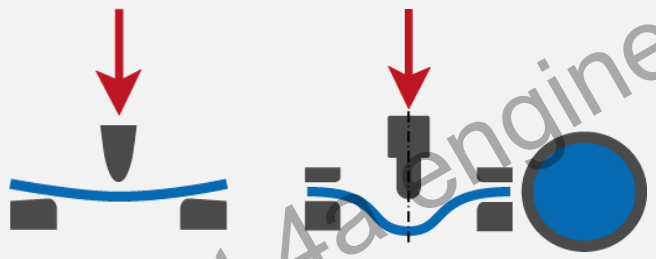
# from test to material card

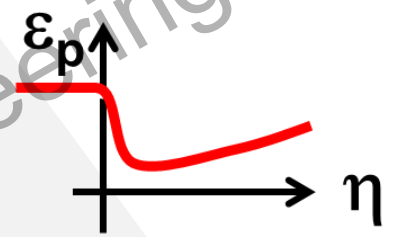
VALIMAT



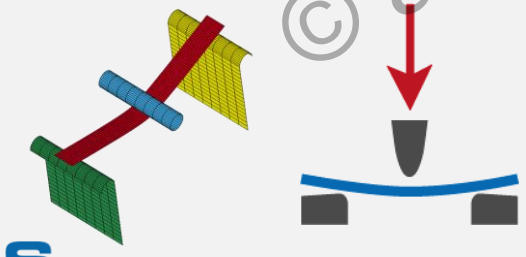




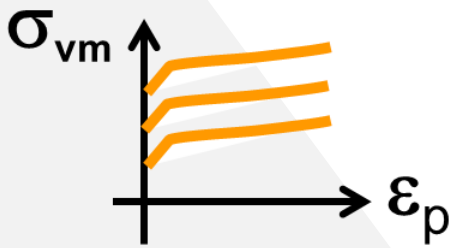





Damage/Failure




Anisotropic

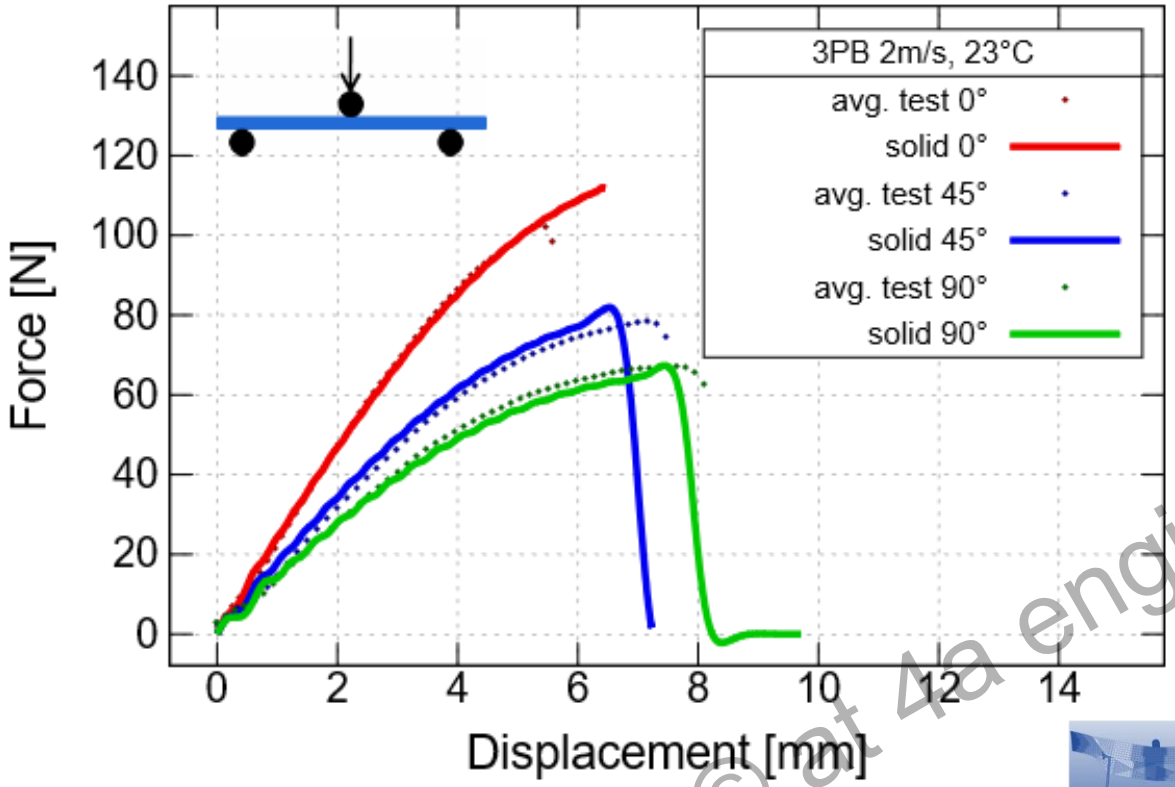


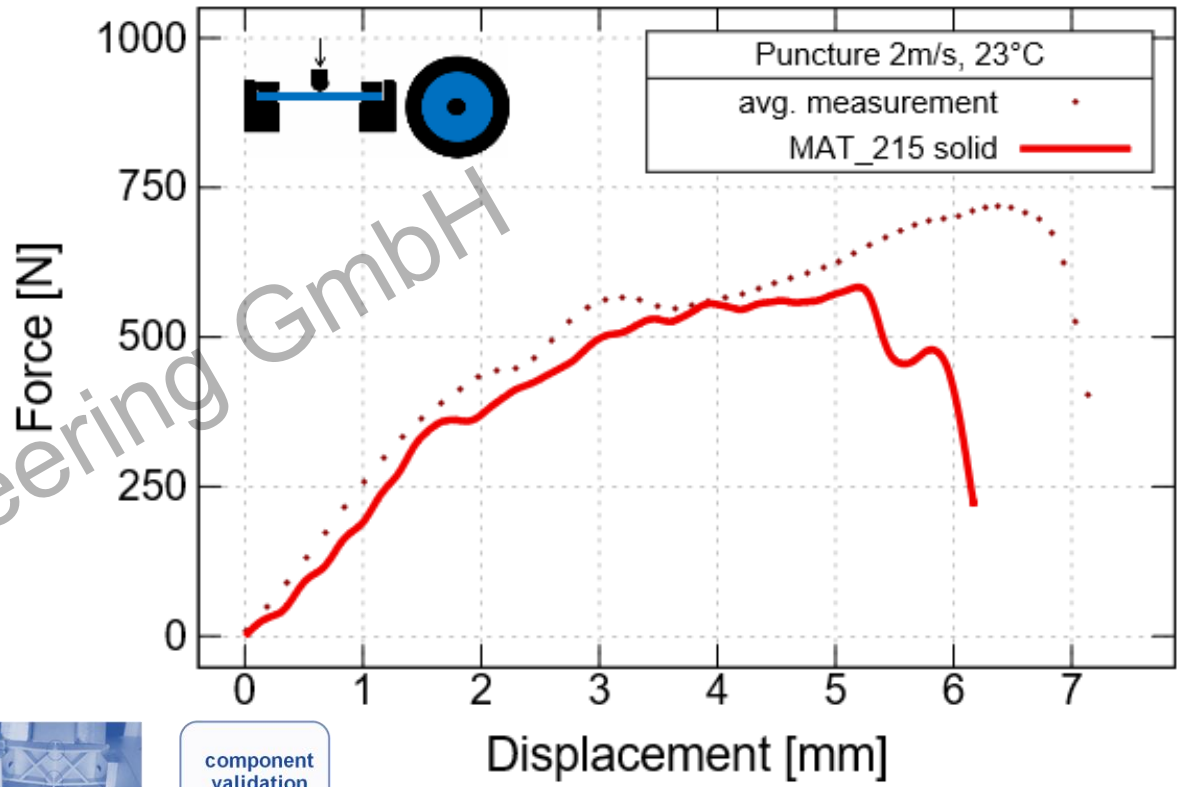

Hardening



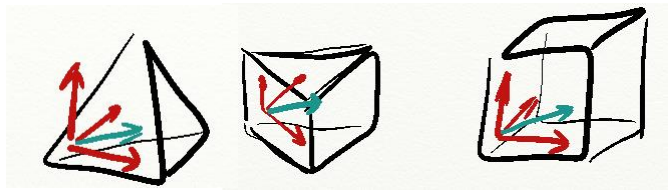
IMPETUS

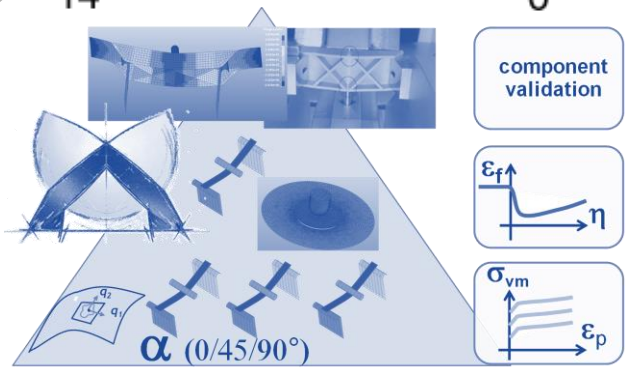
# From test to material card – PP LGF30 *MAT_215





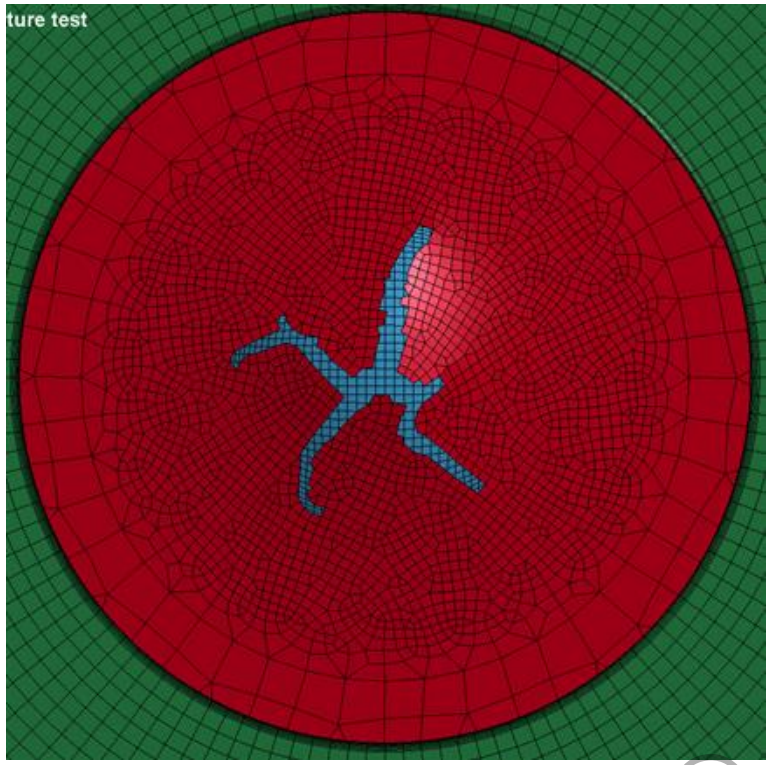



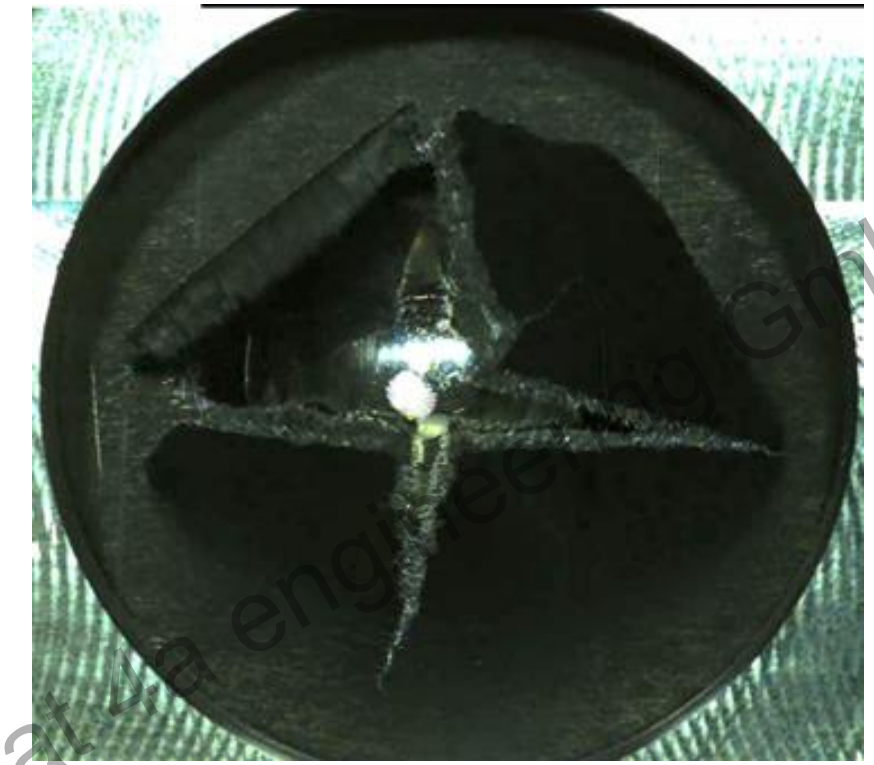


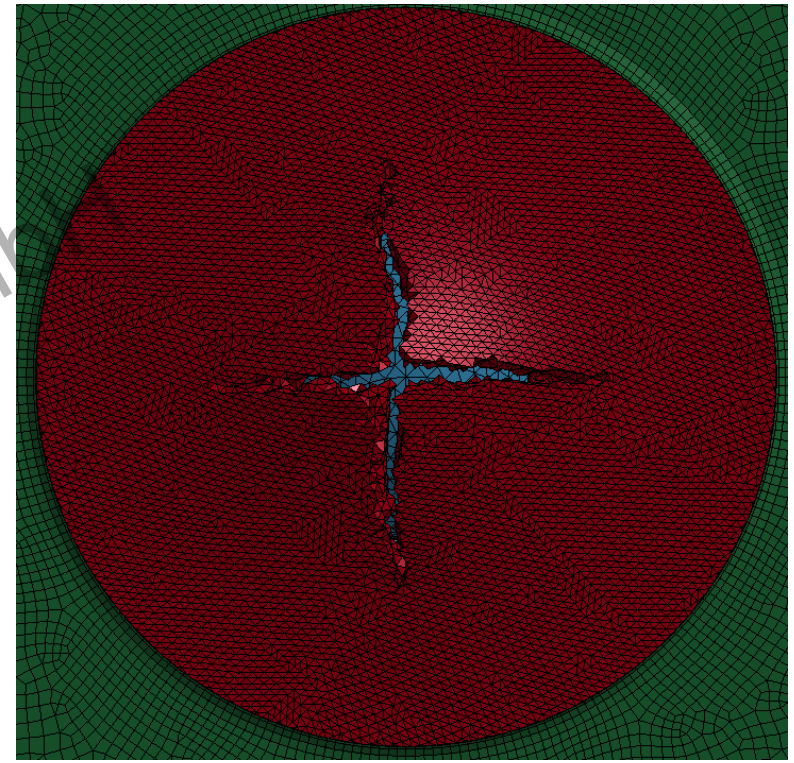

···· averaged test curves
— result of simulation

Source: P Reithofer, failure criteria SFRT and LFRT

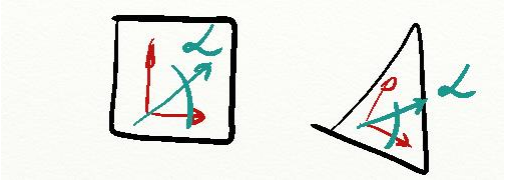
# From test to material card – PP LGF30 *MAT_215

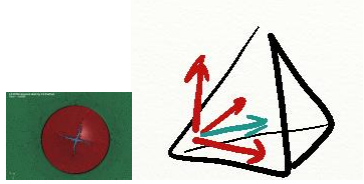




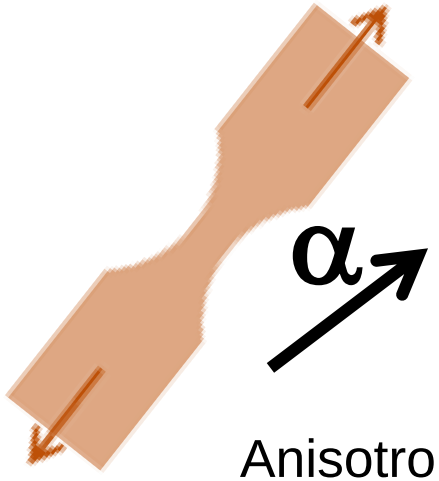






Source: P Reithofer, failure criteria SFRT and LFRT

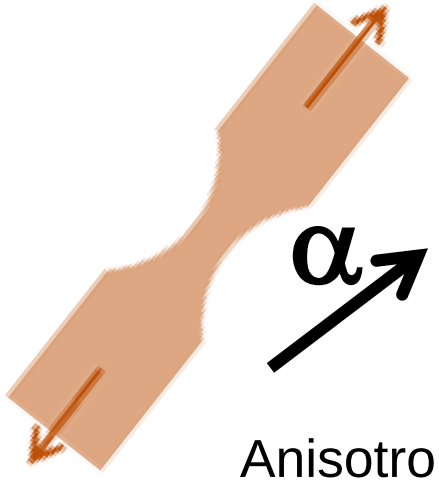
# From test to material card




Anisotropic

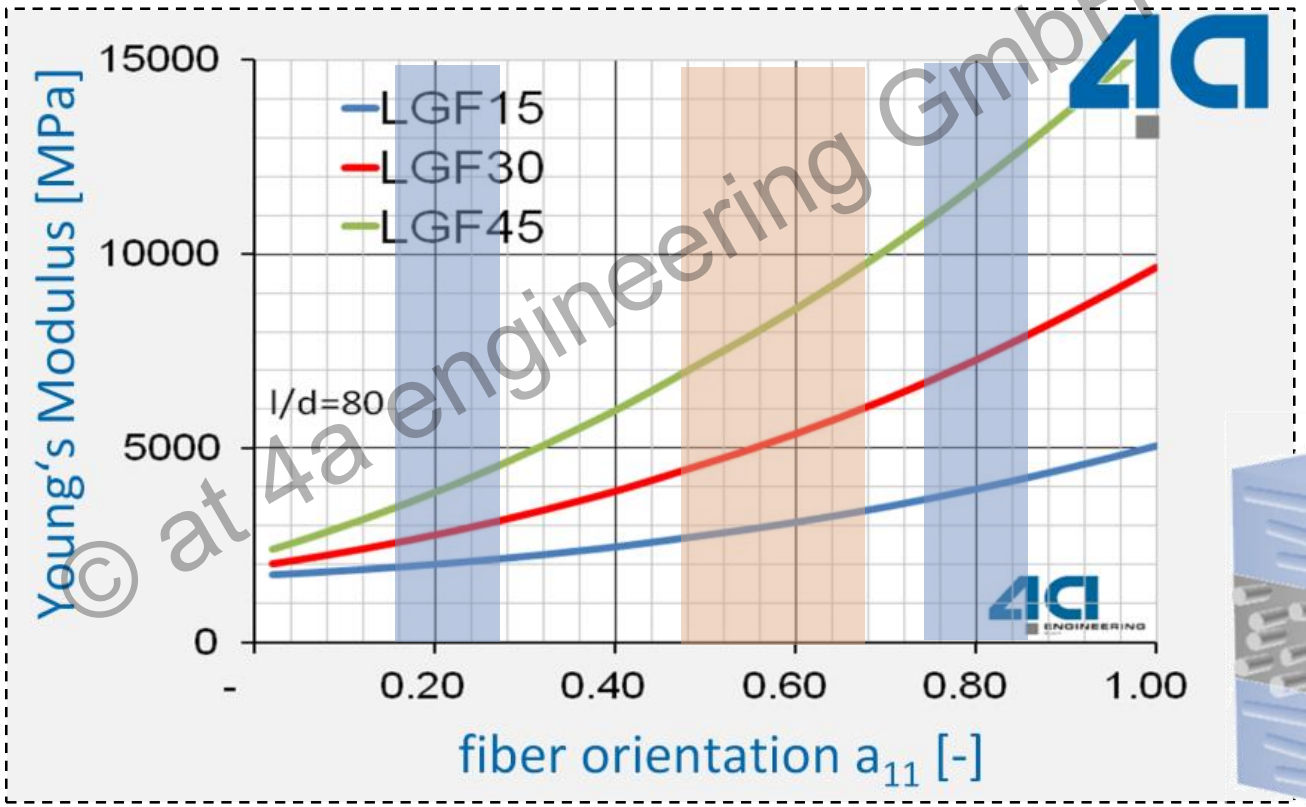
## Why not tension (only)?

# more on DAY 7

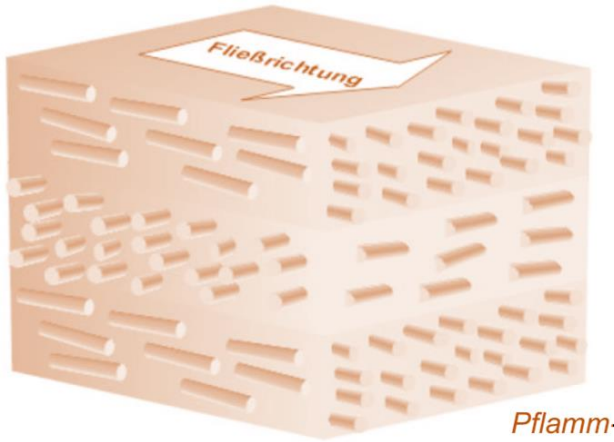



Anisotropic

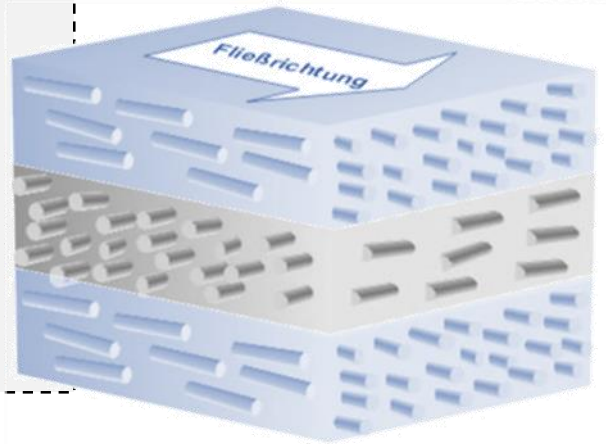
## Why not tension (only)?





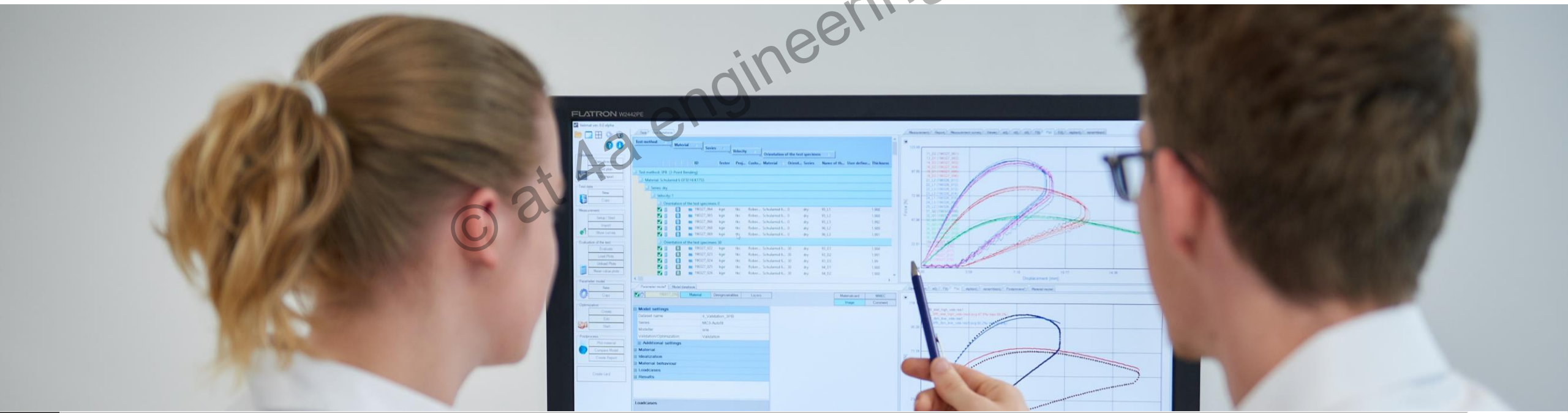




*Pflamm-Jonas 2001*



VALIMAT

# What else ?



# DAY 4 – 10th July 2020





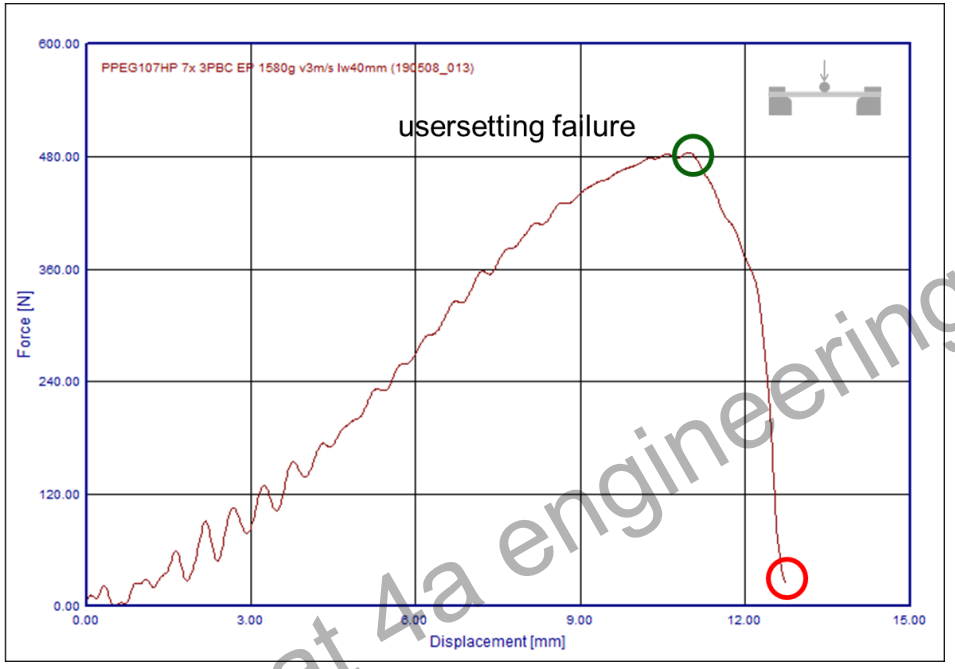
Summary

Lessons learned

Upcoming features in VALIMAT® 3.8

# DAY 5 – 14th July 2020

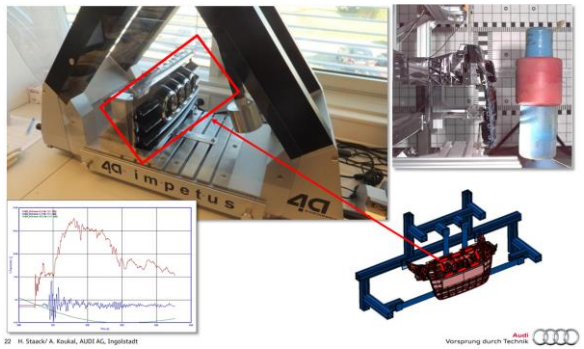
| 190508_013 | |
|---|---|
| **General information** | |
| **Test setup** | |
| Test method | 3PBC (3-Point Bending clamped) |
| Mass of the fin | 104-SP16 3PB R2 steel |
| Mass of the pendulum head | 128-EP16 |
| Mass of the pendulum | 1580 |
| Velocity | 3 |
| Contact angle | 0.59 |
| Radius of the fin | 2 |
| Support radius | 1 |
| Distance of support/gauge length | 40.02 |
| Sensor SP | ASC 4211LN-400-0HB76 17-33677 |
| Sensor Sup | ASC 4211LN-005-0HB76 15-17565 |
| **Test specimen** | |
| **Evaluation** | |
| Filter | 5 CFC SAE velocity optimum |
| Evaluation of displacement | Angle |
| Evaluation of the velocity | 1 - Angle sensor |
| Zero-point evaluation | 5 - Accelerationsignal (without filter) |
| Identification of failure | 1 - automatic |
| tend | 0.011793 |
| tfail | 0.011793 |
| alphamax_ep | -5 |
| alphamax_dp | -5 |
| Ffail | 0.05 |
| tfailfac | 10 |
| Fperc | 0.8 |
| trecovfac | 20 |
| b_criterium | 0 |
| Stress evaluation | |
| Evaluation bending | No evaluation |
| Stiffness evaluation | |
| fperc_lo | 0.1 |
| fperc_up | 0.3 |
| Results | |



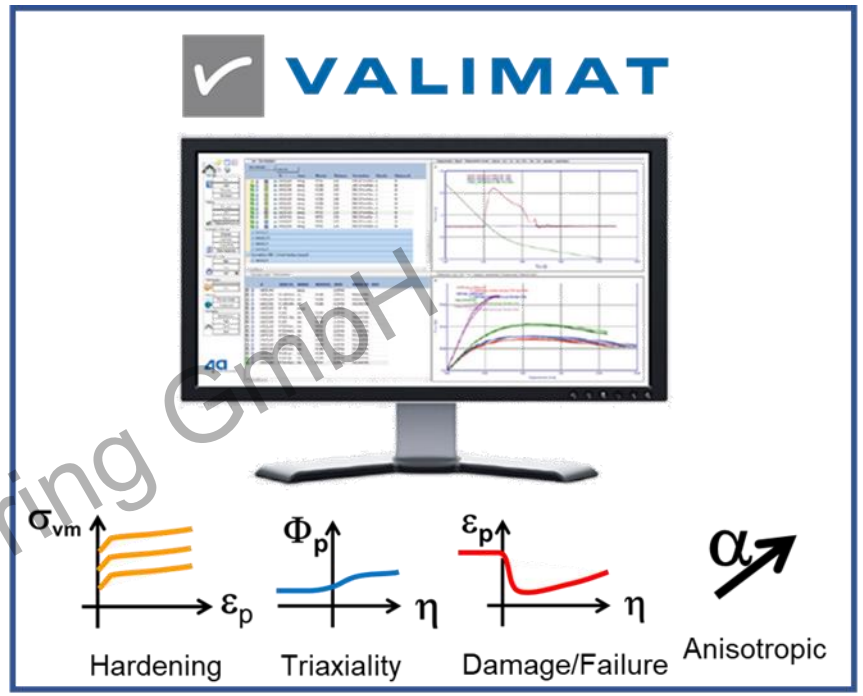



Interpretation of typical test results

# DAY 8 – 17th July 2020



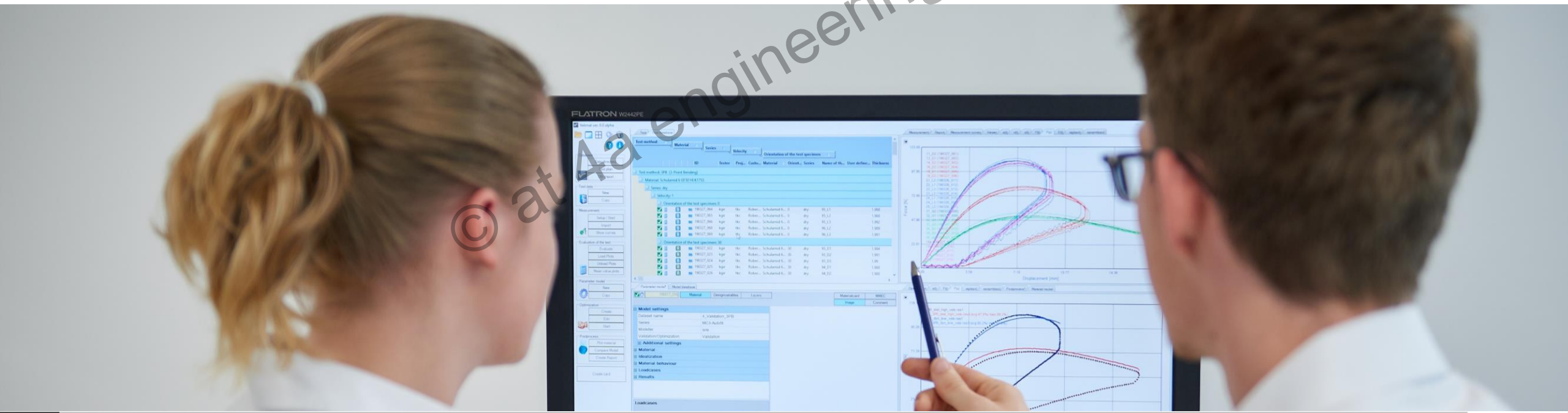
User-defined specimen/input decks
User-defined material cards




Possibilities in VALIMAT® with Python

VALIMAT

# Summary



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

## VALIMAT

- manage test results
  (import, export, filter, evaluation)
- statistics
- automatic report
- material card generation
- material card validation

**for all material types**

from test to validated material cards

## IMPETUS

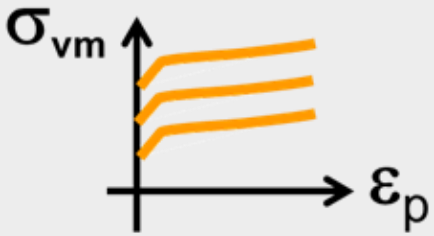
- single pendulum up to 4.5 m/s
- double pendulum up to 8 m/s
- standard test methods
- specialized test methods
- component testing
- advanced measurement

efficient dynamic testing

**plastics and composites**

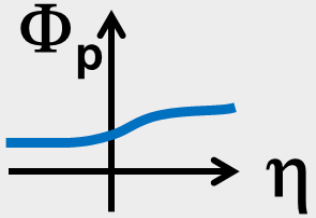
# Intelligent reliable solutions for plastics, composites, metals, foams, ...

## VALIMAT

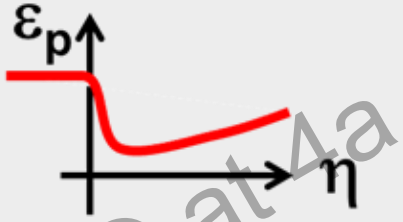



Hardening


Anisotropic




Triaxiality




Damage/Failure

**for all material types**

from test to validated material cards

## IMPETUS


efficient dynamic testing

**plastics and composites**

# Thank you for your Attention!

4a summer-school - webinar and training
Material characterization with VALIMAT® and IMPETUS®

SAVE THE DATE
**08. July - Efficient dynamic testing with IMPETUS®**



VALIMAT


IMPETUS