

# Material Models For Thermoplastics In LS-DYNA® From Deformation To Failure

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15<sup>th</sup> German LS-DYNA® USERS CONFERENCE 2018



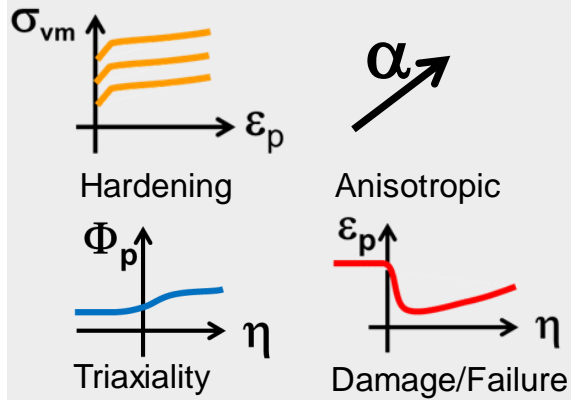
15-17<sup>th</sup> October 2018, Bamberg

# AGENDA

- introduction 4a
- motivation
- material models
- material characterization
- intermediate conclusion
- outlook IMPETUS™ - dynamic impact tensile testing

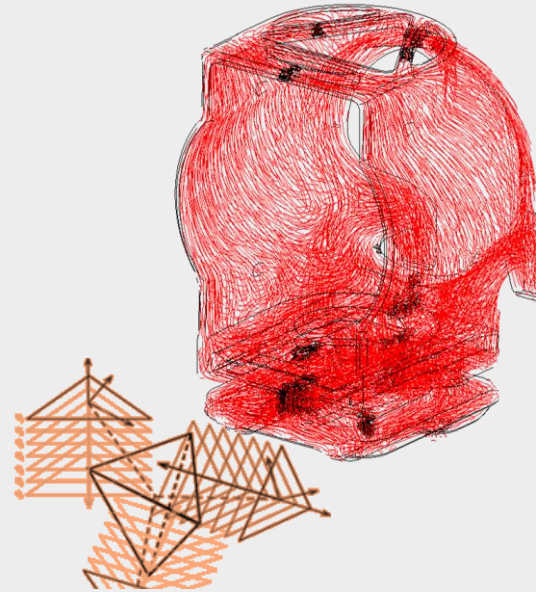
# intelligent reliable solutions for plastics, composites, metals, foams, ...

 **VALIMAT**



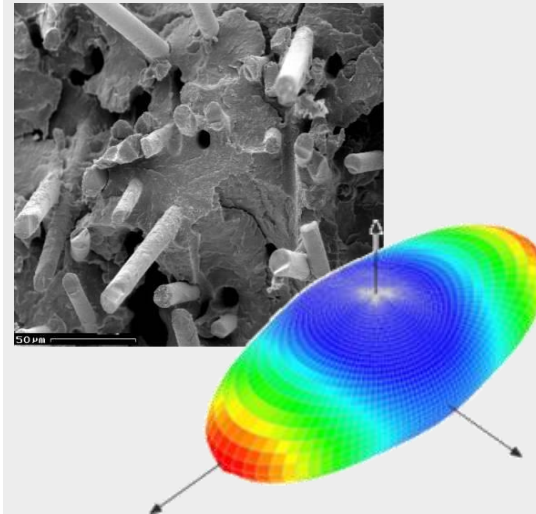
from test to validated material cards

 **FIBERMAP**



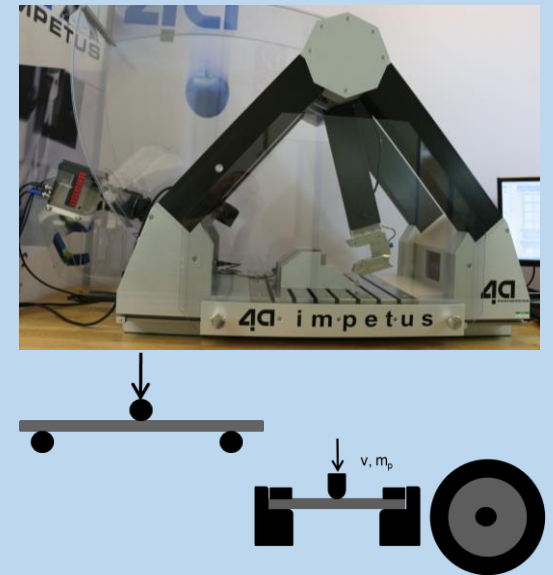
individual mapping process information

 **MICROMECC**



3D anisotropic material cards

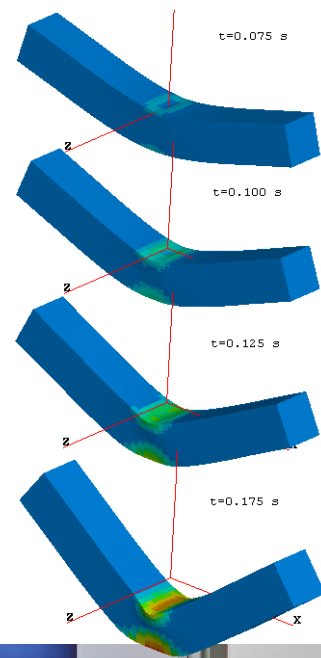
 **IMPETUS**



efficient dynamic testing

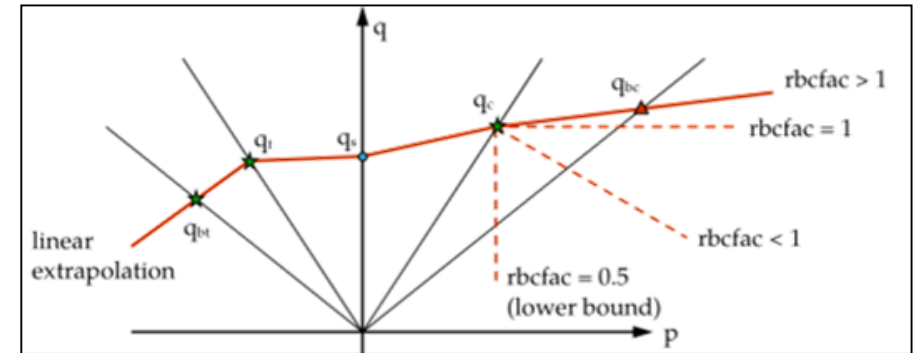
# material characterization - services

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



# Commonly Used Material Models For Plastics

- **\*MAT\_024 - The workhorse**  
(*\*MAT\_081, \*MAT\_089, \*MAT\_123, ...*)
- **\*MAT\_124 - The hidden**
- **\*MAT\_187 - The plastic expert**



[LSDYNA MANUAL]

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



# Characterizing mechanical deformation behavior of plastics

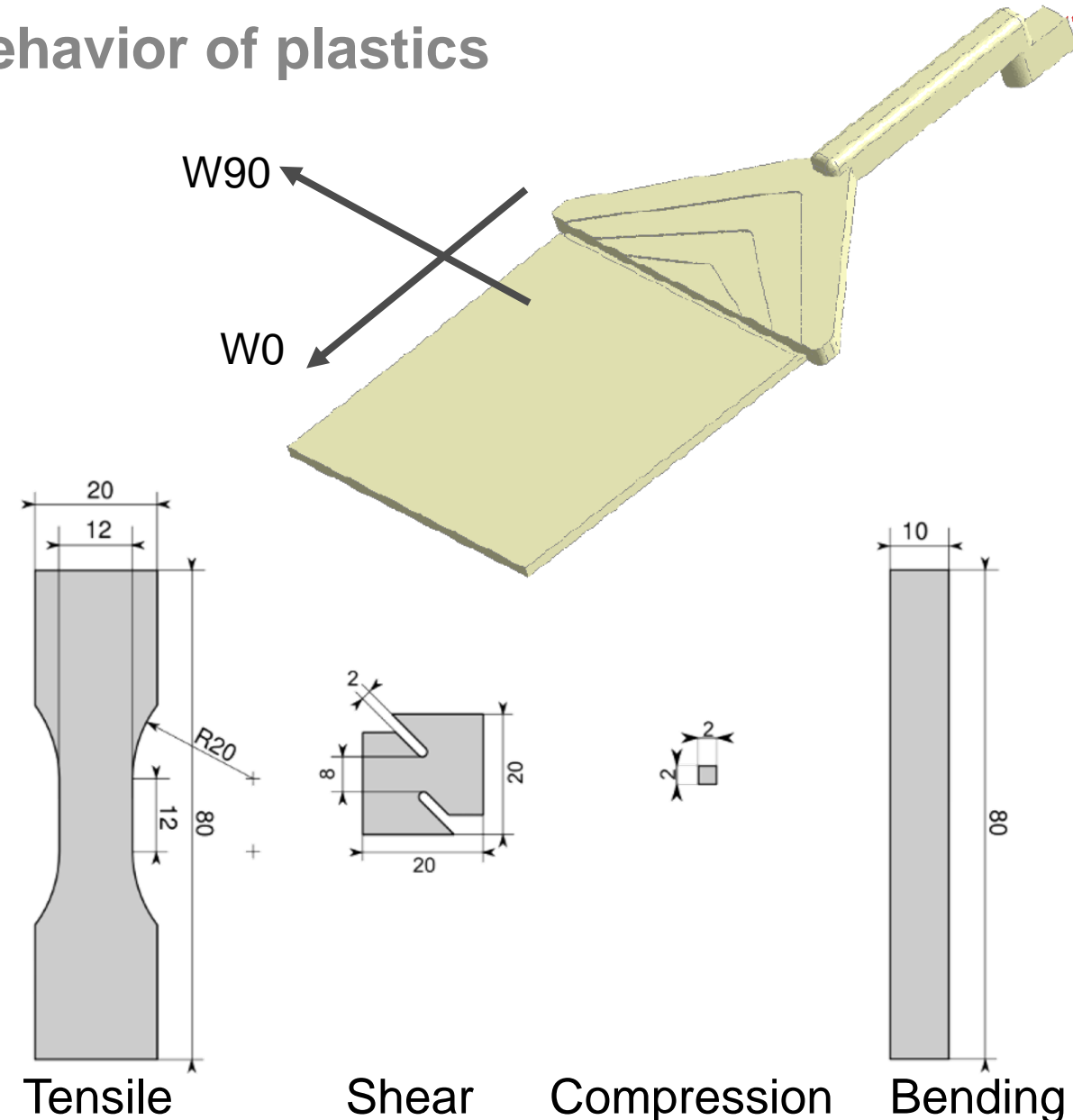
## Ph.D-thesis of F. Kunkel

- Injection molded PP T16 (Hostacom XBR 169G)
- specimen milled out in W0 and W90
- classical static and dynamic tests with **DIC**

## **The Old School** - material characterization as described in the material model

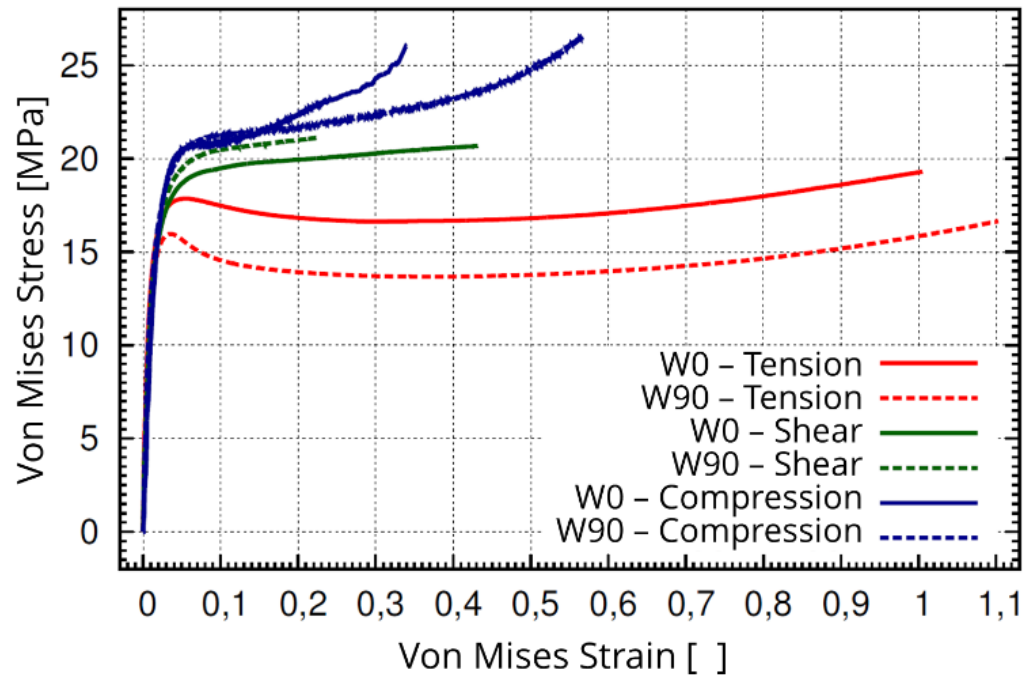
- Tensile
- Shear
- Compression

## **comparison IMPETUS™ bending**

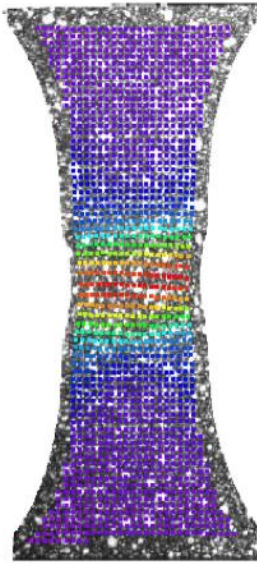
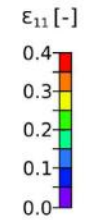
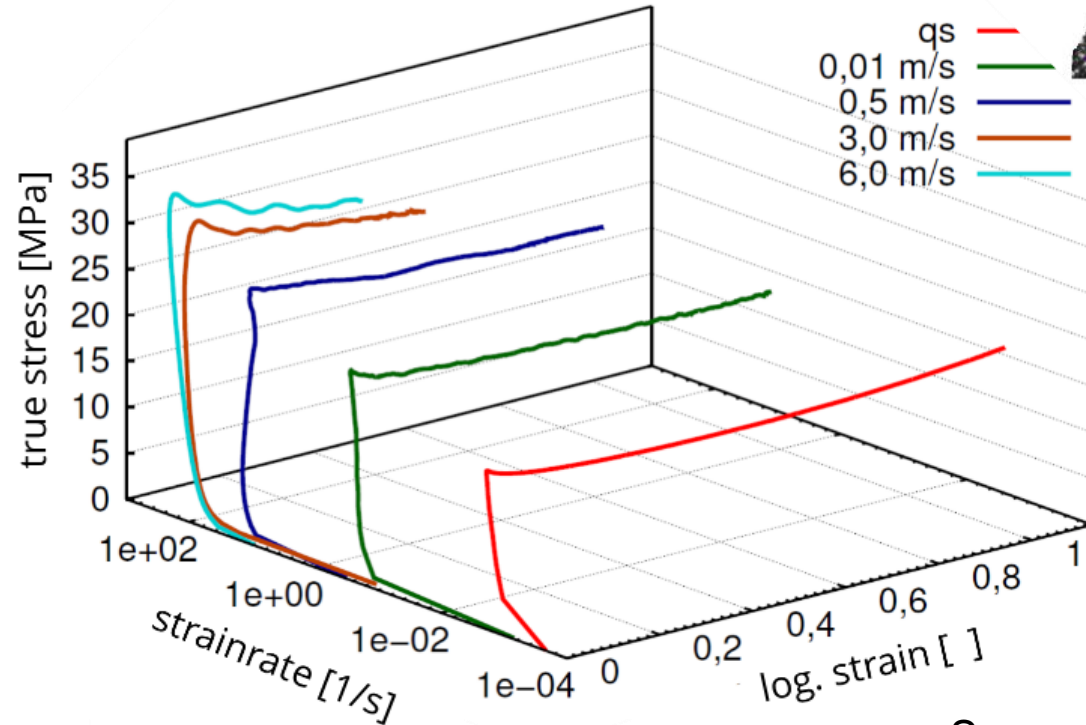


# Characterizing mechanical deformation behavior of plastics

## *The Old School* - material characterization as described in the material model



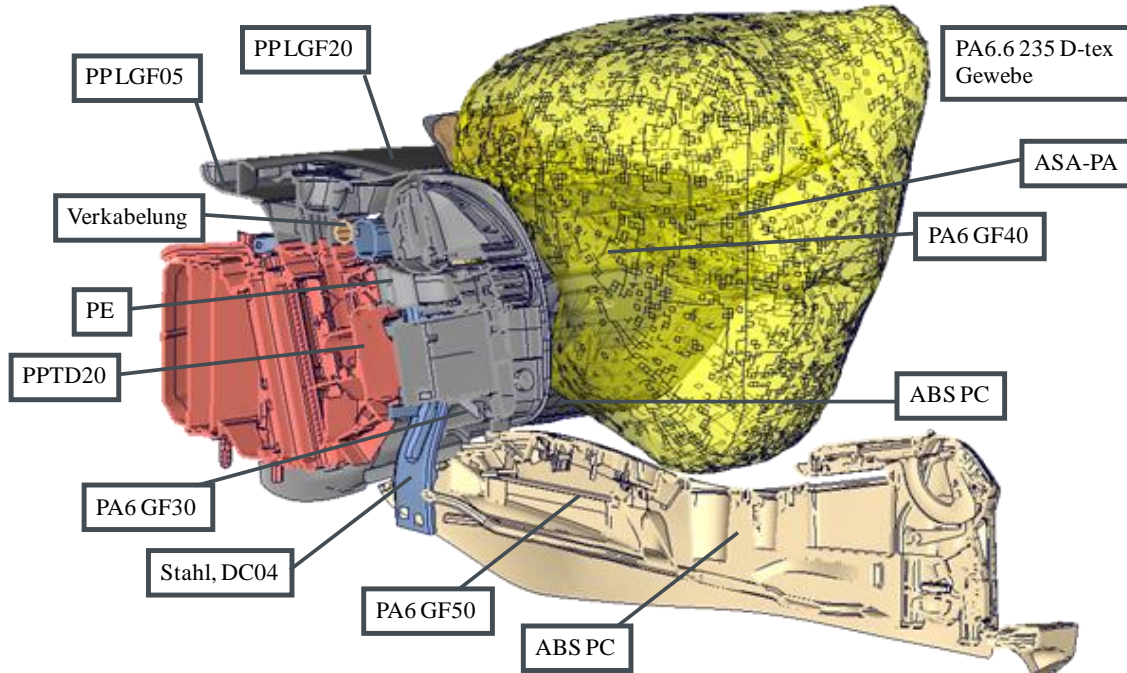
→ no constant loading (triaxiality) and strain rate



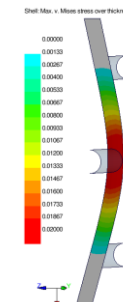
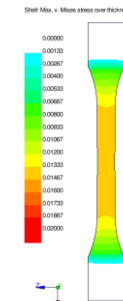
Source: F. Kunkel

# 2004 - motivation

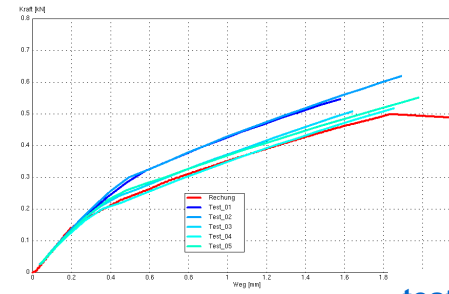
## material variety



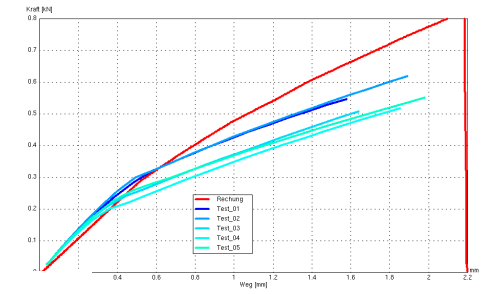
## bending load case



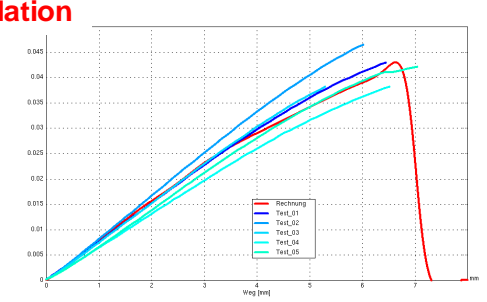
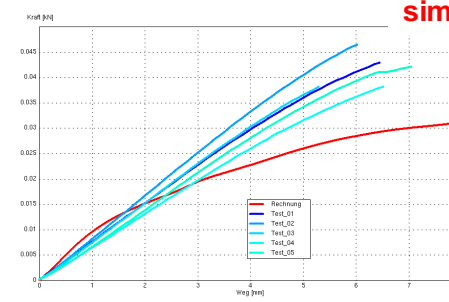
original test curve tension



scaling 1.25



test simulation

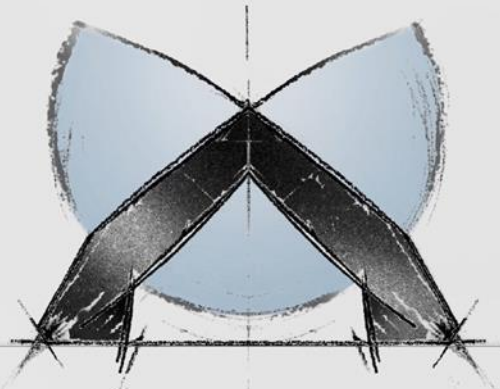
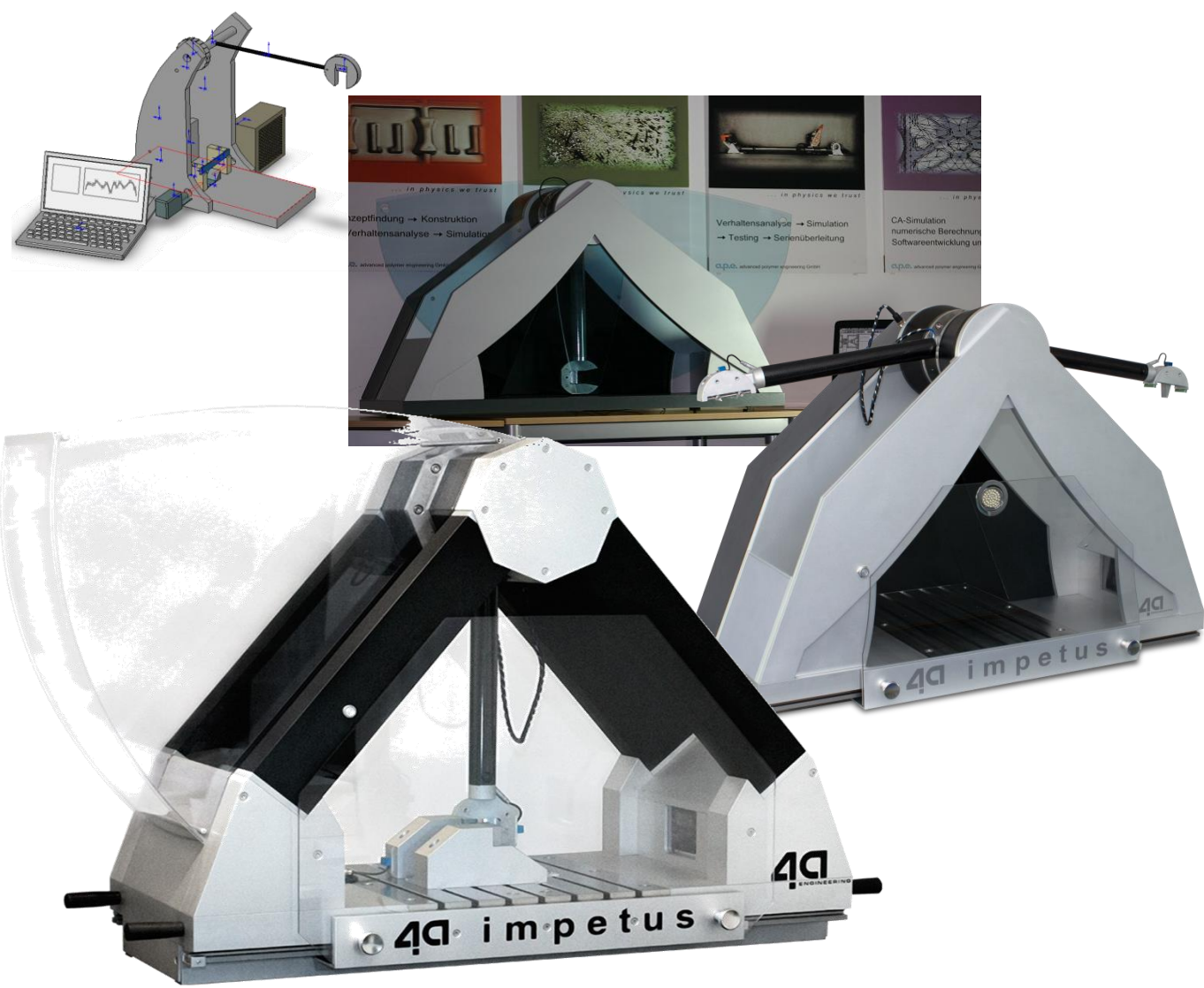


Source: R. Luijck - *Kunststoffmaterialien in der Interieur Funktionsauslegung bei Audi AG*, 4a Technologietag 2010



# efficient dynamic testing

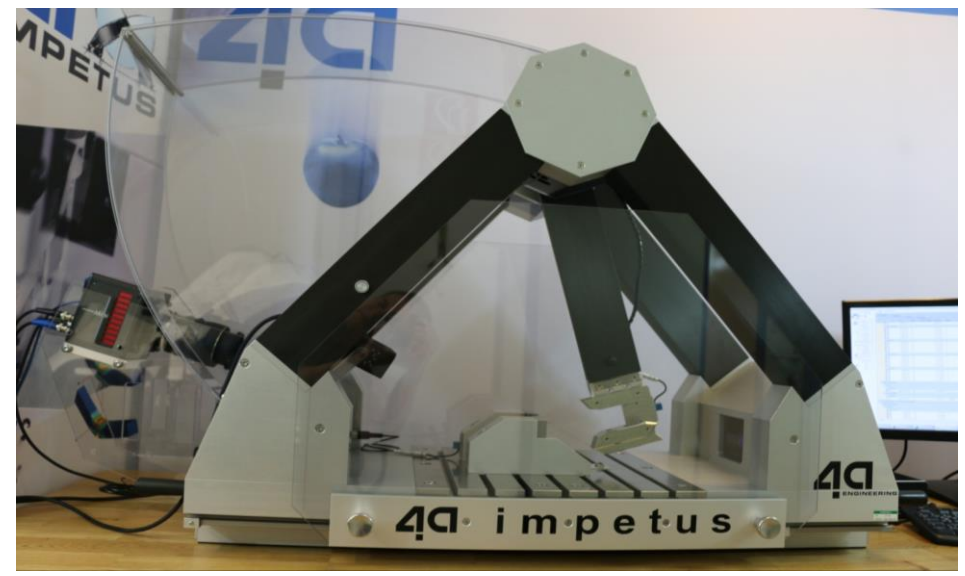
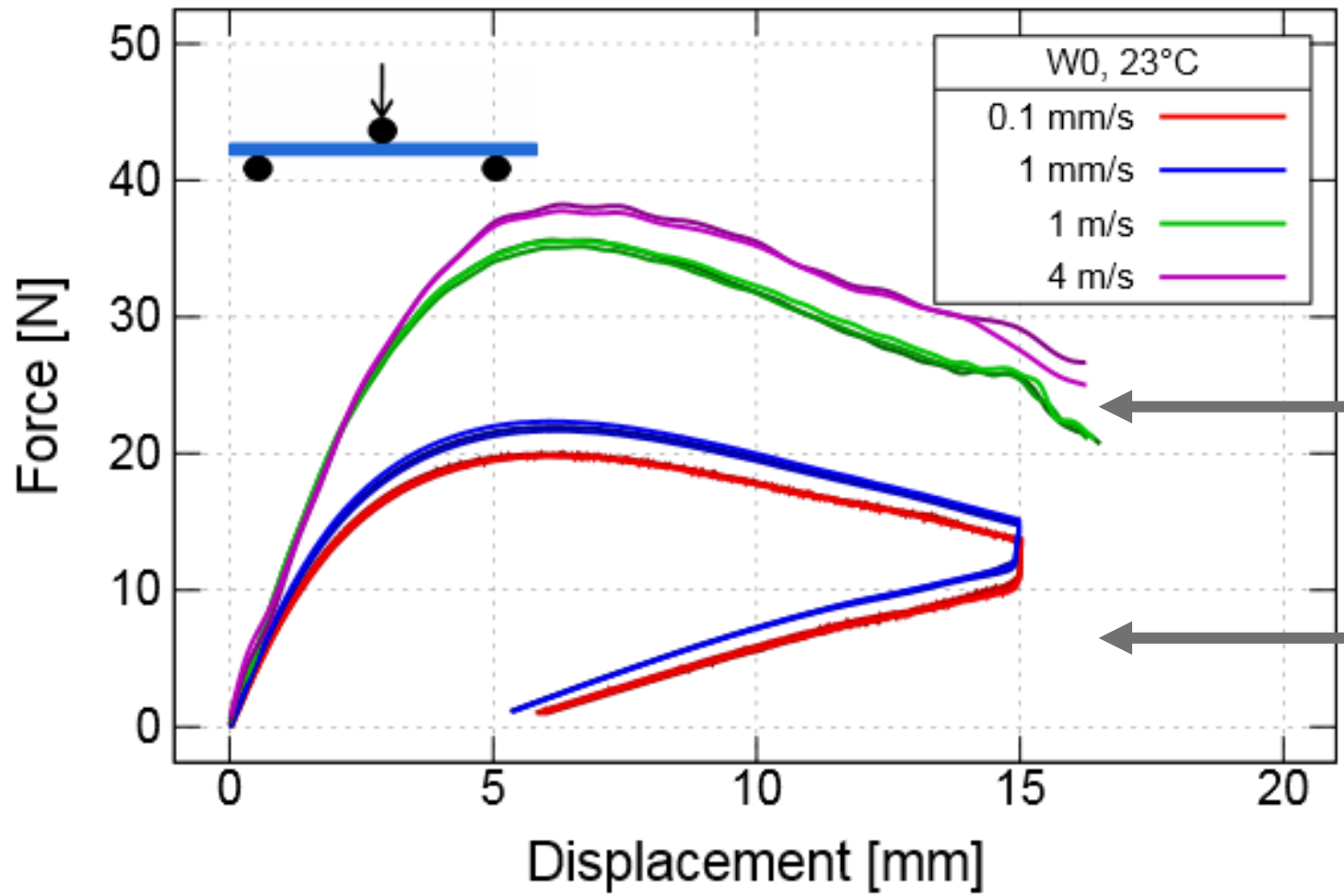
- desktop testing device
- instrumented high speed testing
  - acceleration → force / displacement
- impact velocity 0.5 – 4.5 m/s
- maximum energy 50 J



**4Q**  
**IMPETUS**  
ADVANCED  
dynamic testing system  
validated material cards  
intelligent software solution

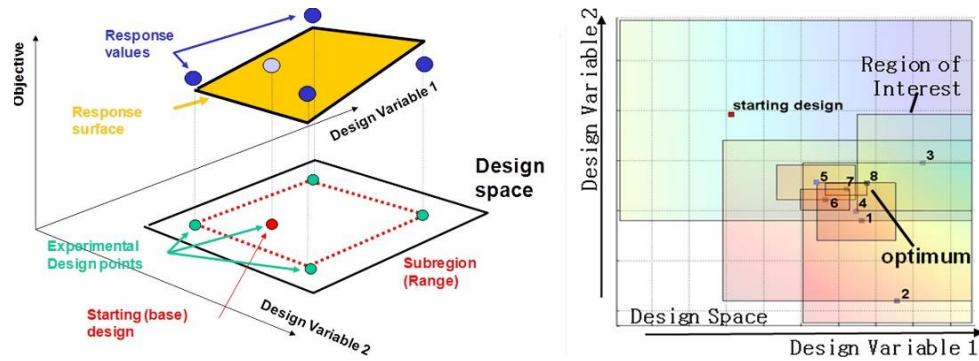
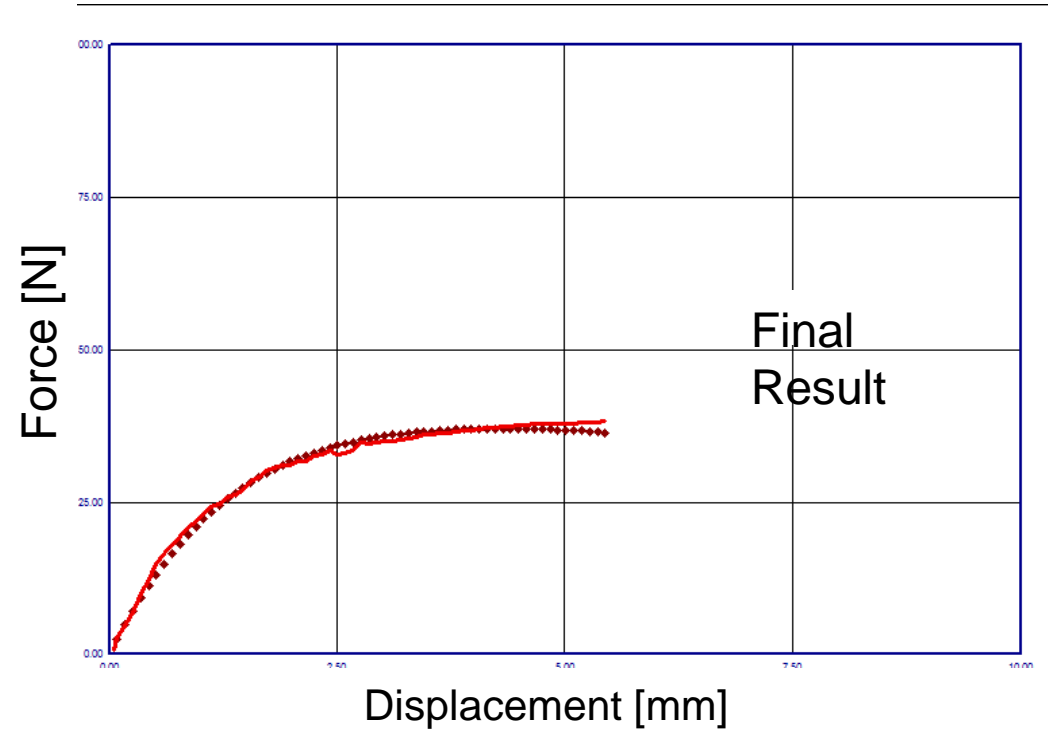
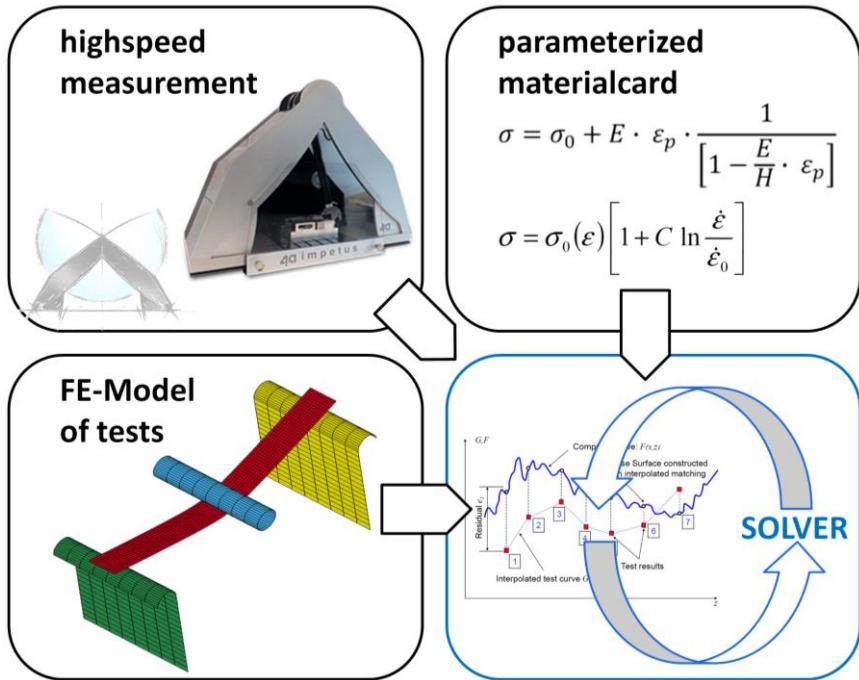
I N P H Y S I C S W E T R U S T

# efficient dynamic testing

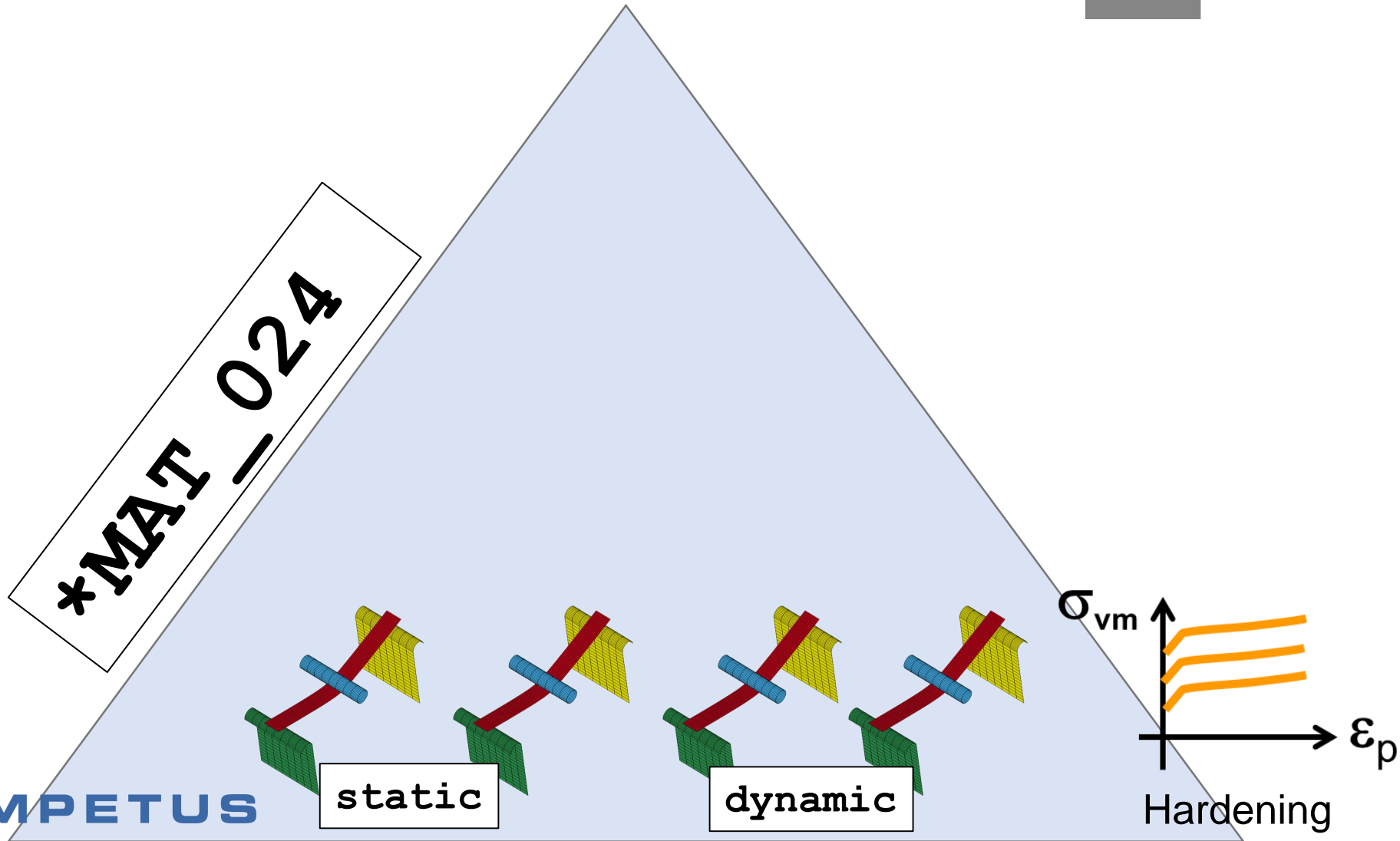


Universal static testing

# reverse engineering



Source: Dynamic Material Characterization Using 4a impetus – PPS Conference 2015, Graz



# from test to material card - Material Parameter Identification Process

Automated optimization

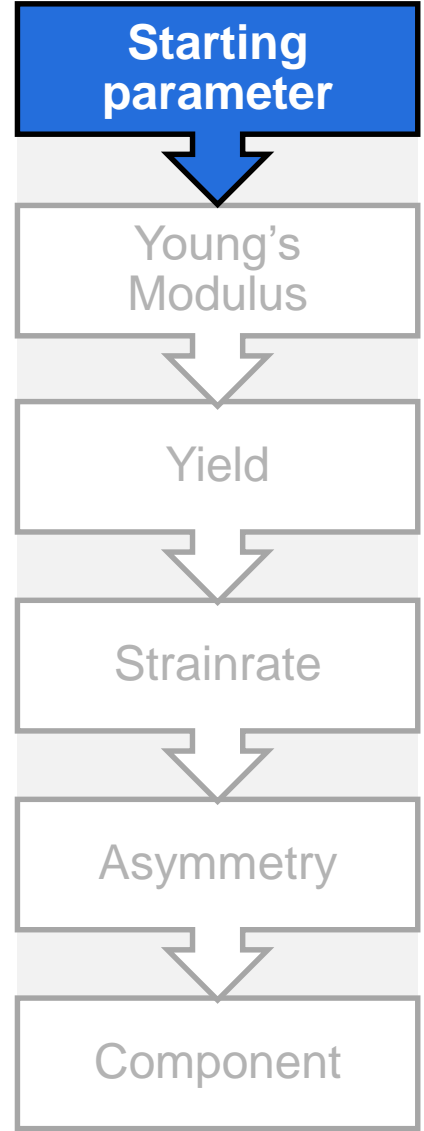
ID	Name	Optimization/Validation	Status	VP Autovalue
161124_001	Young's Modulus	Optimization	✓	□
161124_002	Plastic data	Optimization	✓	□
161124_003	Strain rate dependency	Optimization	R	✓
161124_004	Validation	Validation	✓	□

calc max strain 0.2 [1]  
 calc strainrates 0.0001 - 100 [1/s]

Init Autofit    Open LS-Opt Viewer

DV	Autovalue	161124_001	161124_002	161124_003	161124_004
e_E	2009.4	2049.762	2049.762	PRUN(c)	PRUN(c)
e_nue	n.a.	0.3	0.3	PRUN(c)	PRUN(c)
y_0	15.344	n.a.	12.2752	PRUN(c)	PRUN(c)
h_y	n.a.	n.a.	12.2752	=y_0	=y_0
h_ET	-1.4782	n.a.	1024.881	PRUN(c)	PRUN(c)
h_h	15.344	n.a.	7.672	PRUN(c)	PRUN(c)
v_p	9.5407	n.a.	9.5407	AUTO	PRUN
v_epspt	0.0001	n.a.	0.0001	AUTO(c)	PRUN(c)

Run    Stop    Exit



4a Impetus v3.00 beta

licensed for: PeterReithofer 4aengineering

Versuch/Test Database Tests

Datum\_Nr 110125\_001

**Allgemeine Informationen**

Prüfsetup

Probekörper

Auswertung

Filter 0 kein F

Geschwindigkeitsermittl 3 - Weg (stat)

Nulpunktsbestimmung 0 - manuelle

Brucherkenung 0 - manuell (G)

Spannungsauswertung

Steifigkeitsauswertung

Ergebnisse

Parametermodell

Neu

Kopieren

Hinzufügen

Optimierung

View

Start

Material

akt. Modell plotten

Karte erstellen

4a Impetus

Datenverzeichnis

Hilfe

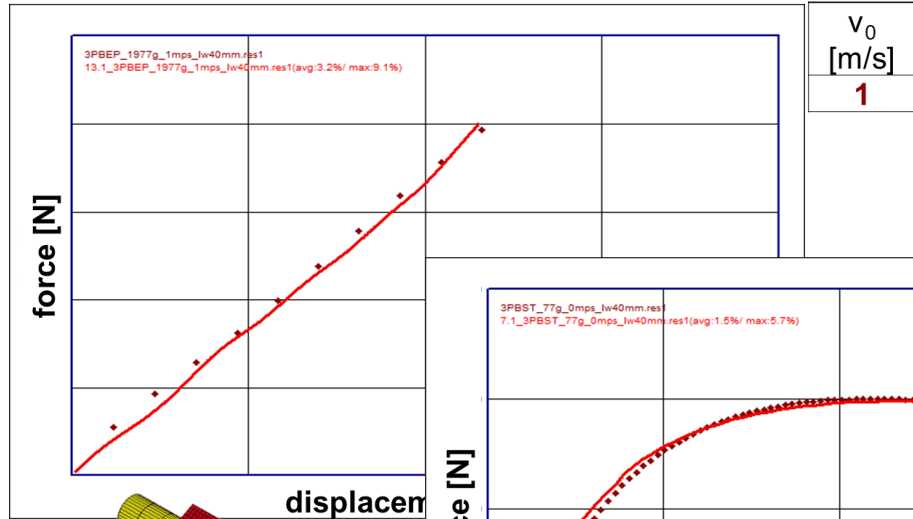
Beenden

4a ENGINEERING

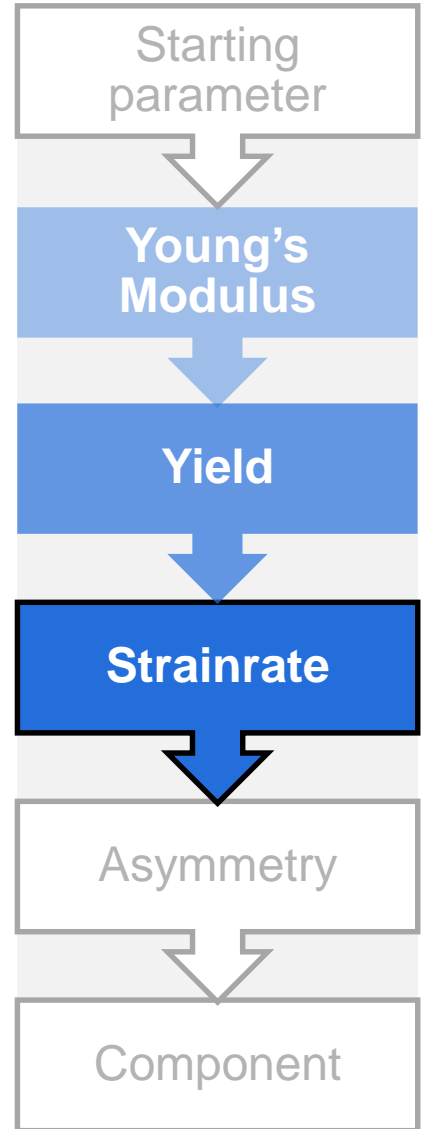
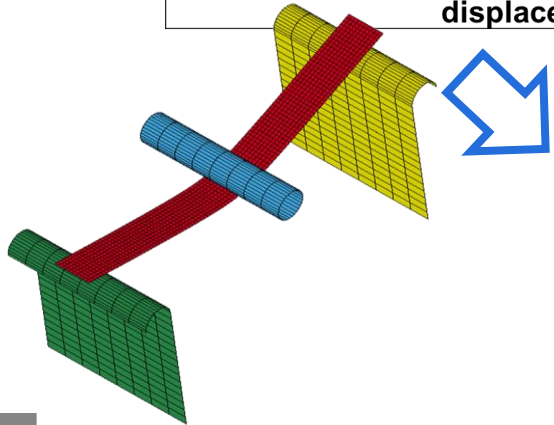
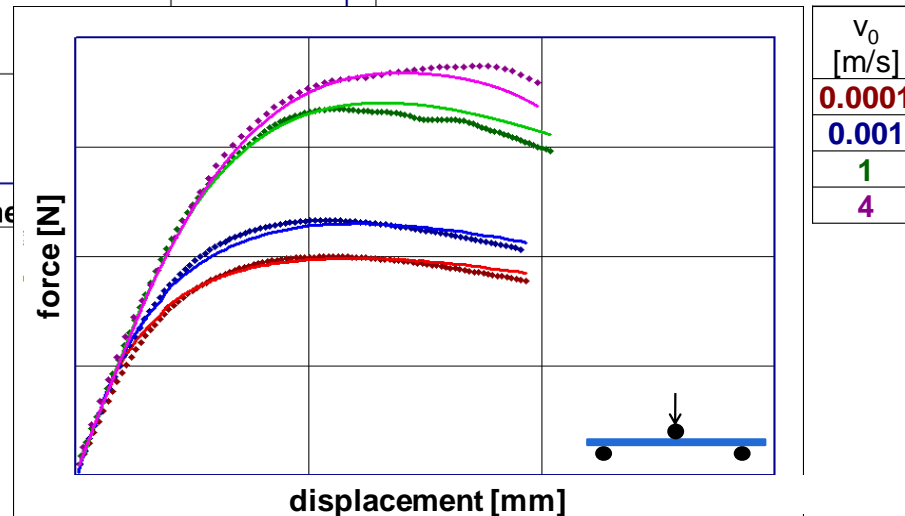
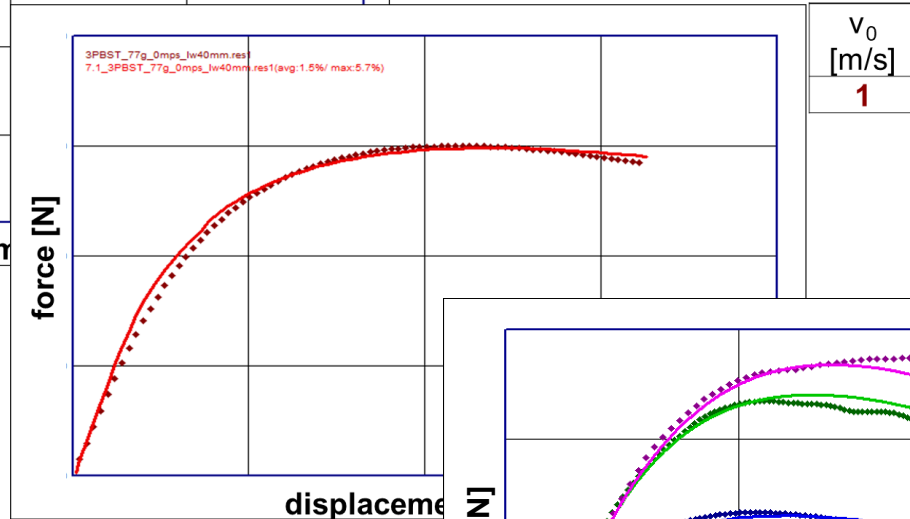
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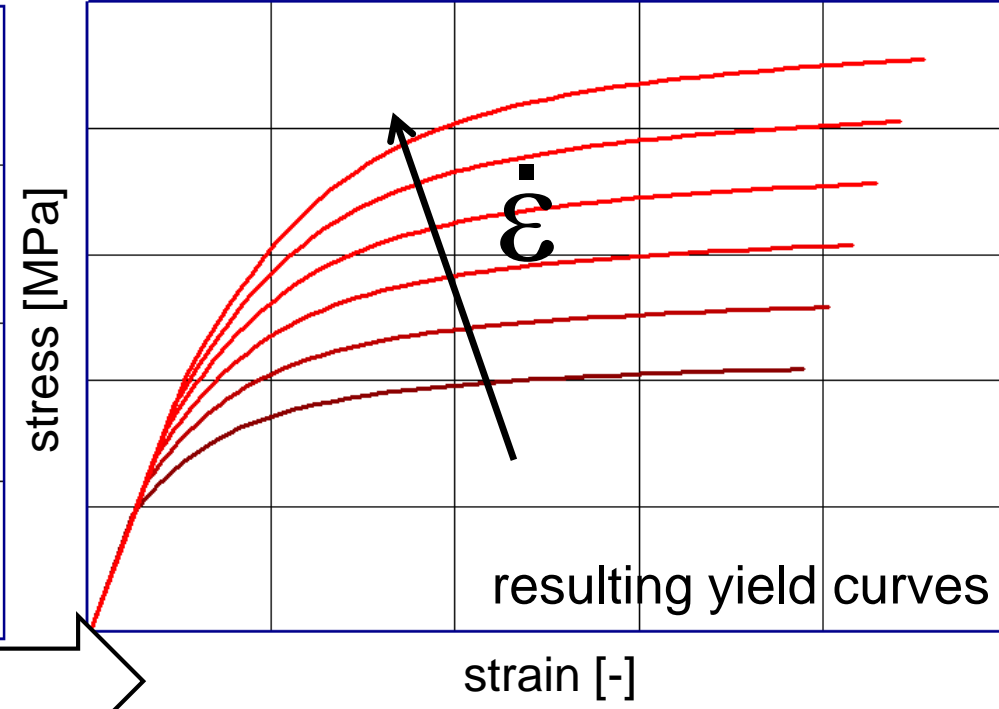
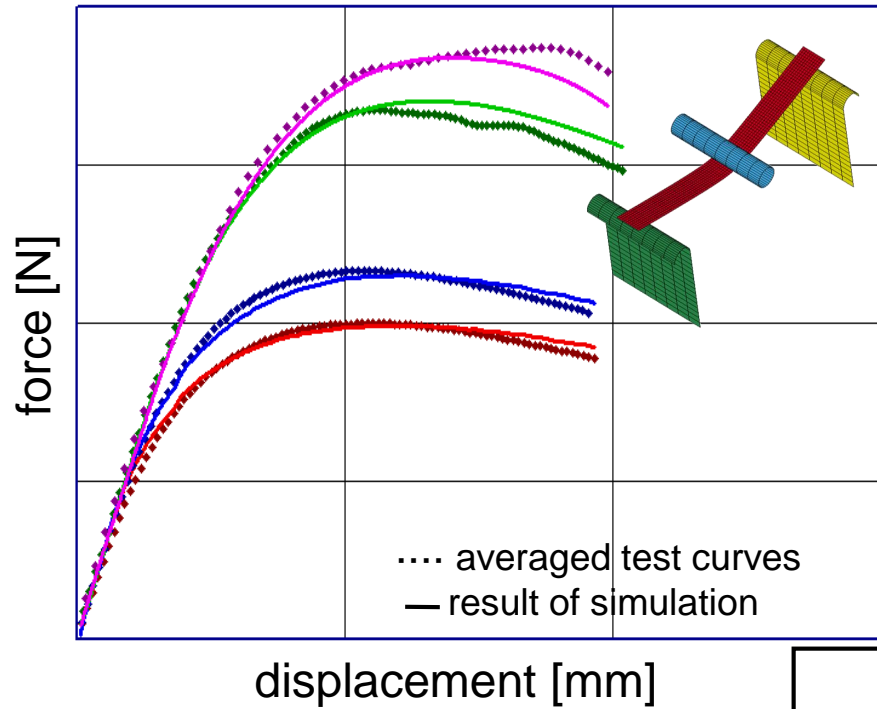
from bending → \*MAT\_024



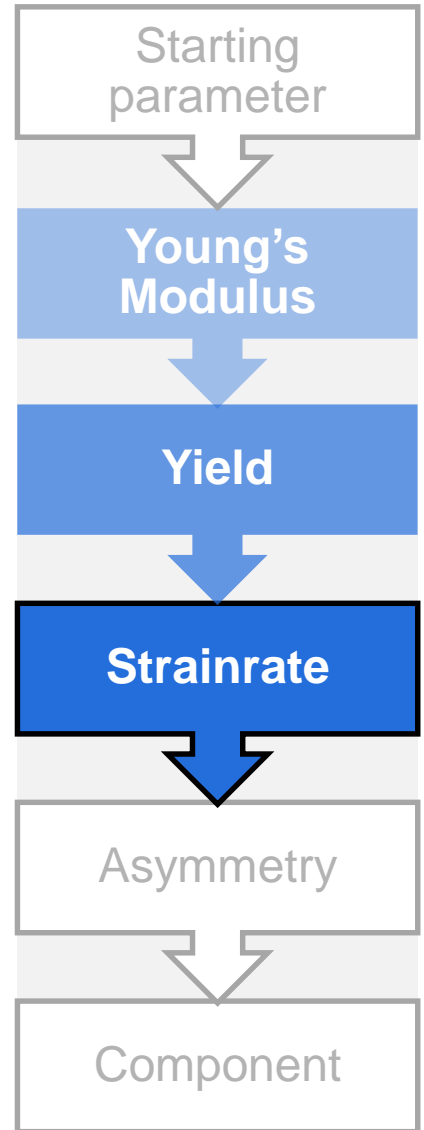
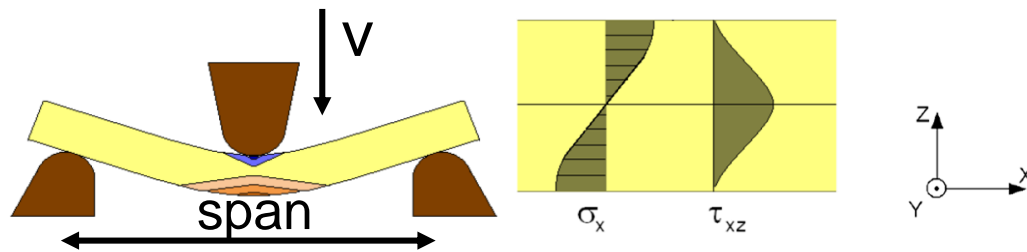
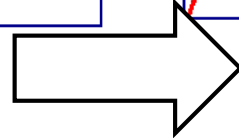
..... averaged test curves  
 — result of simulation



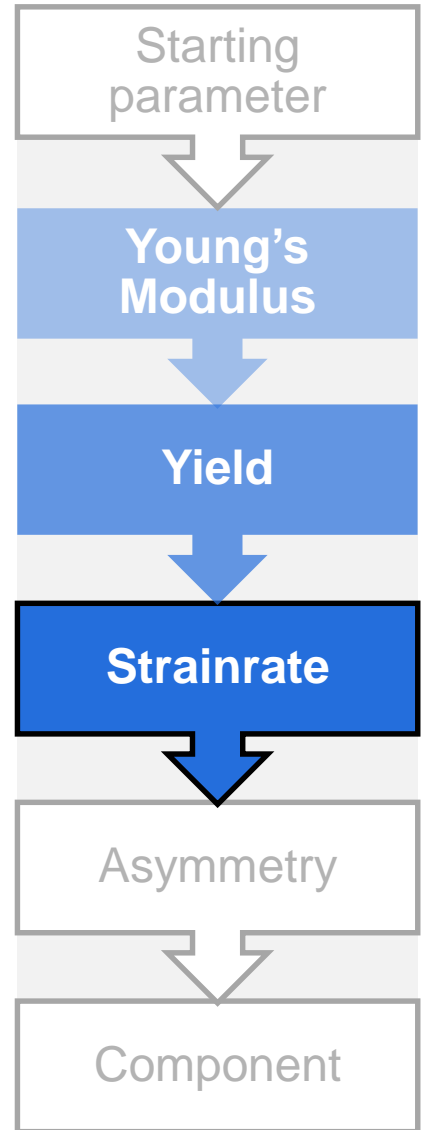
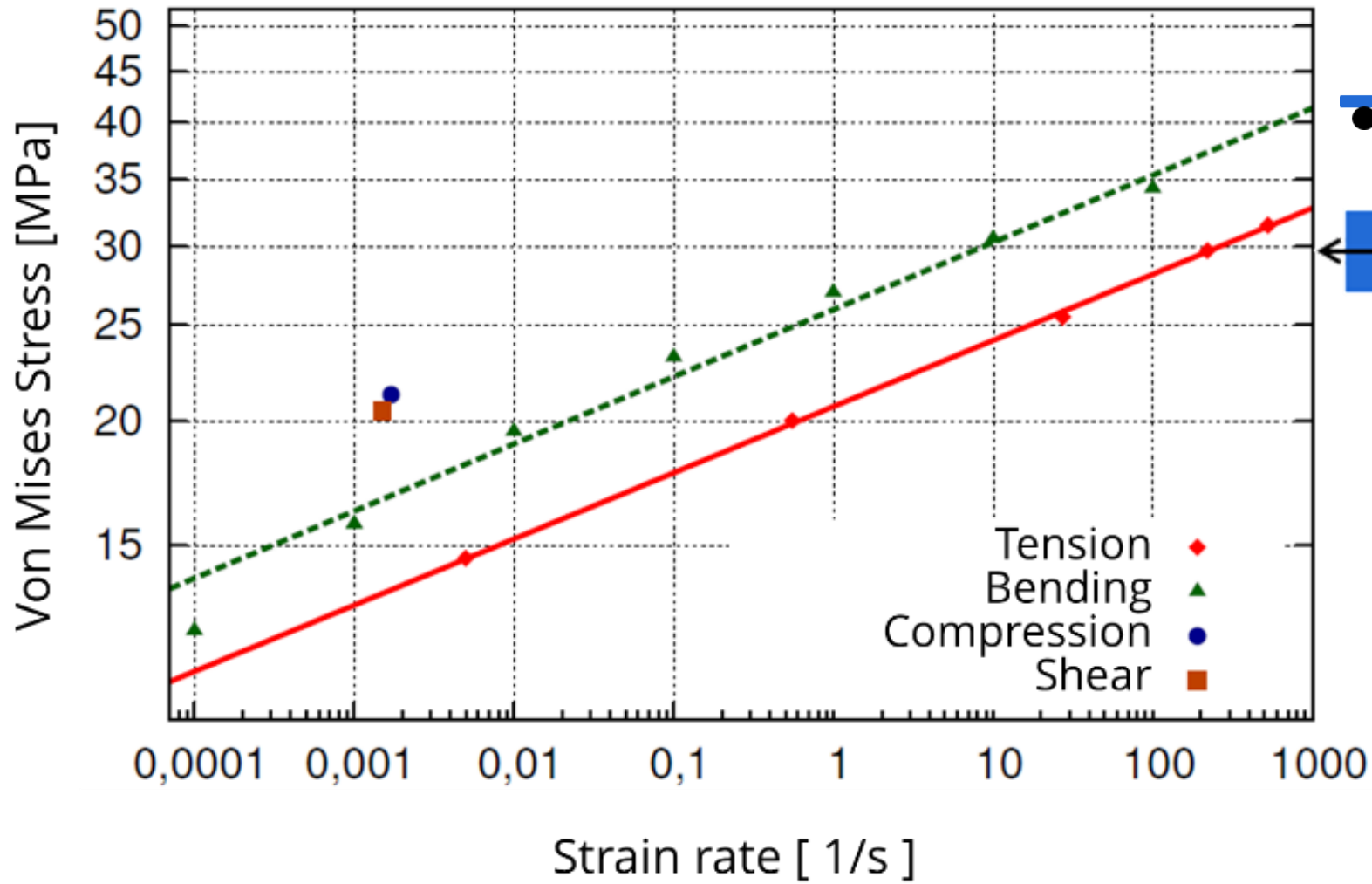
from bending → \*MAT\_024

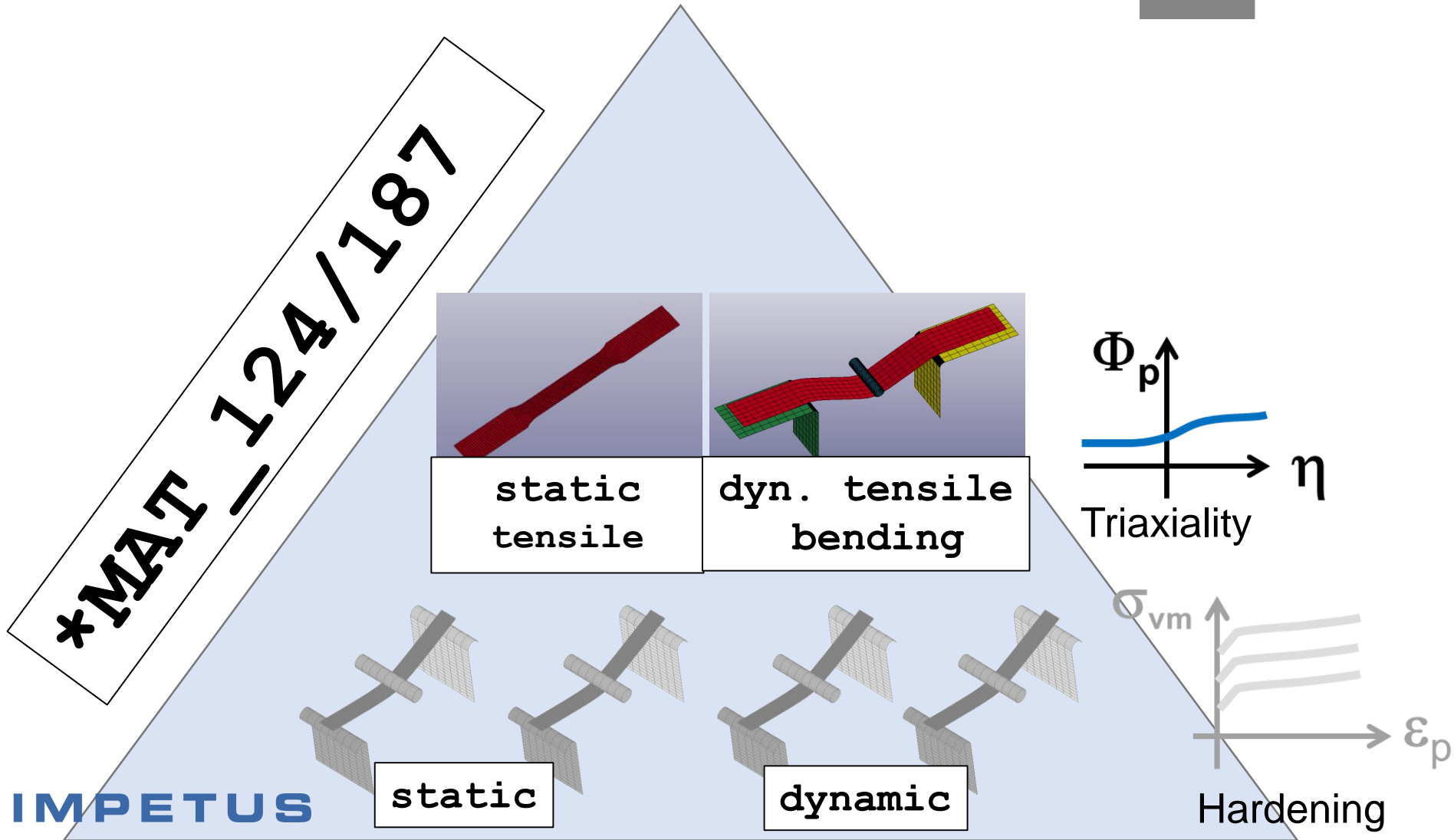


v [m/s]	span [mm]
<b>0.0001</b>	<b>40</b>
<b>0.001</b>	<b>40</b>
<b>1</b>	<b>40</b>
<b>4</b>	<b>40</b>

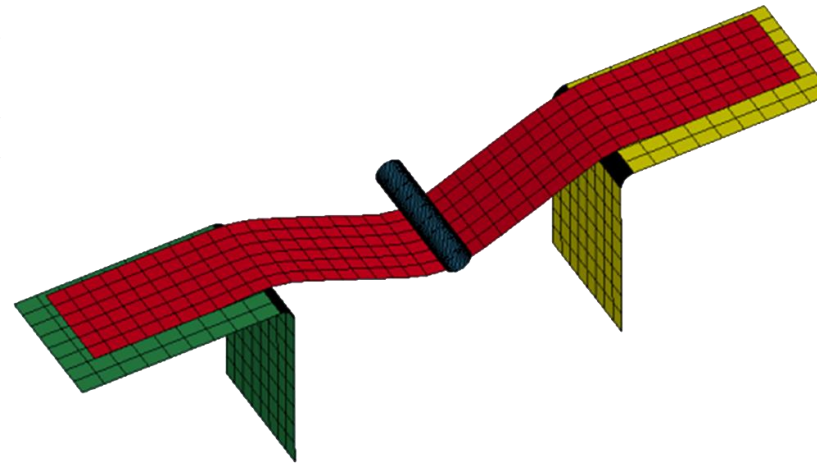
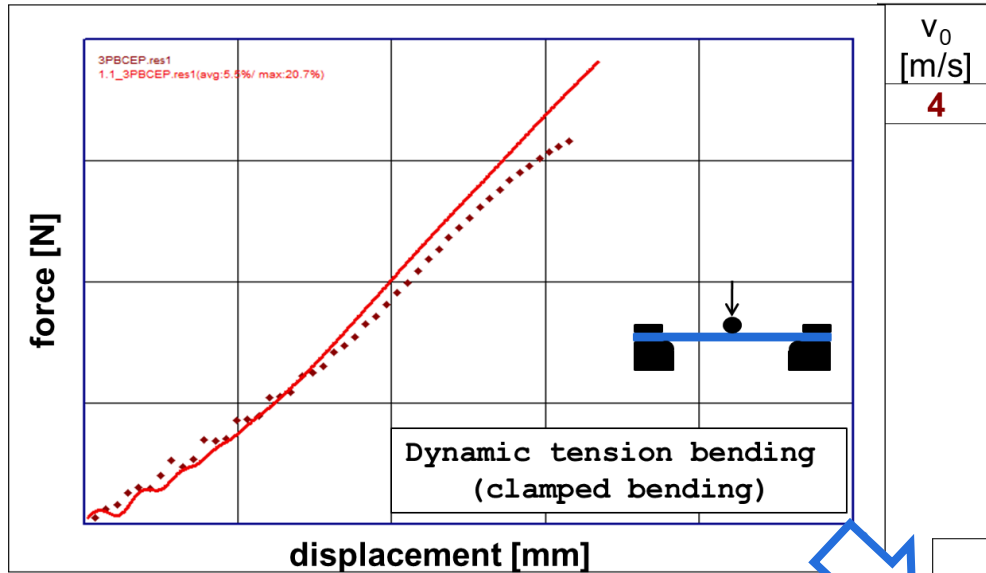


from bending → \*MAT\_024

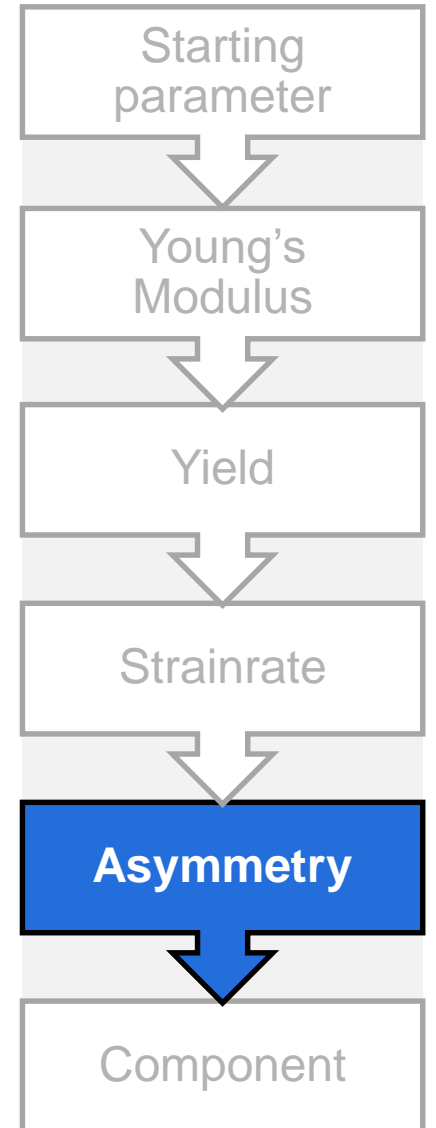
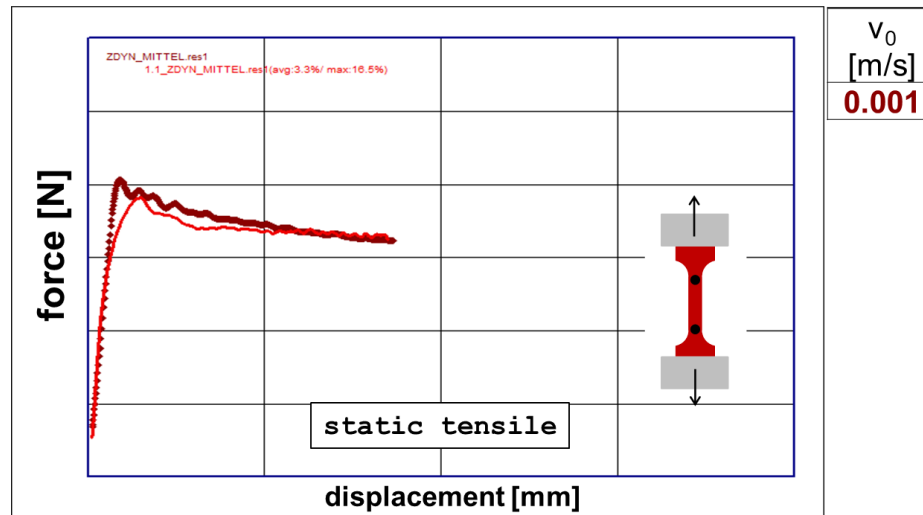




from tension bending → \*MAT\_124/187

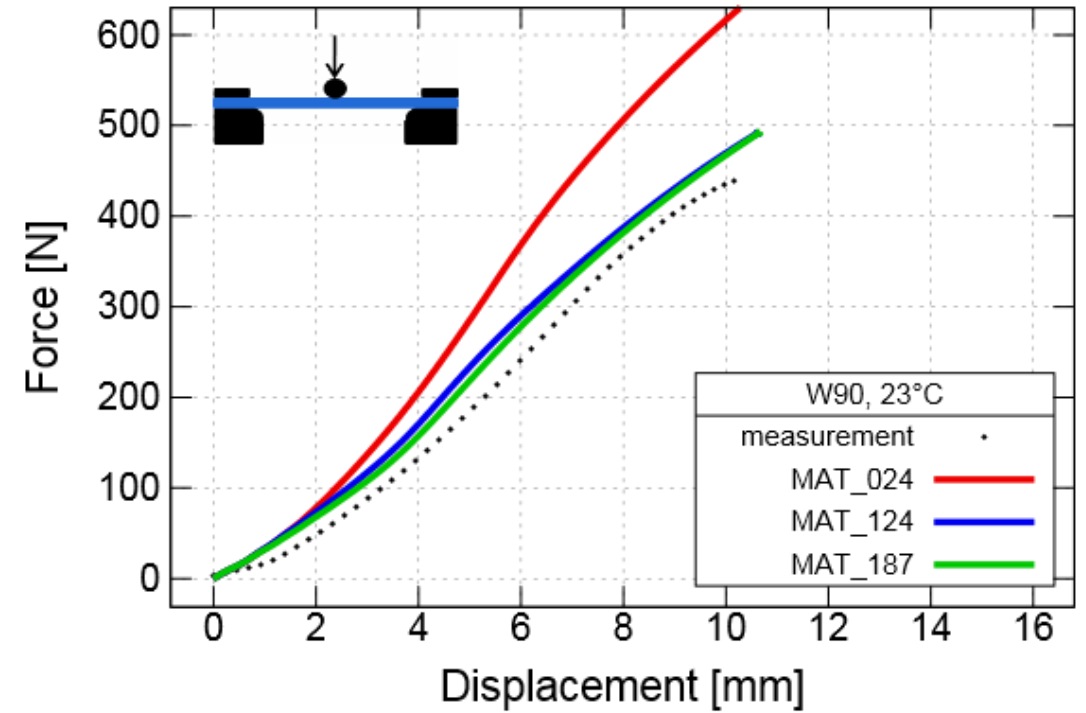
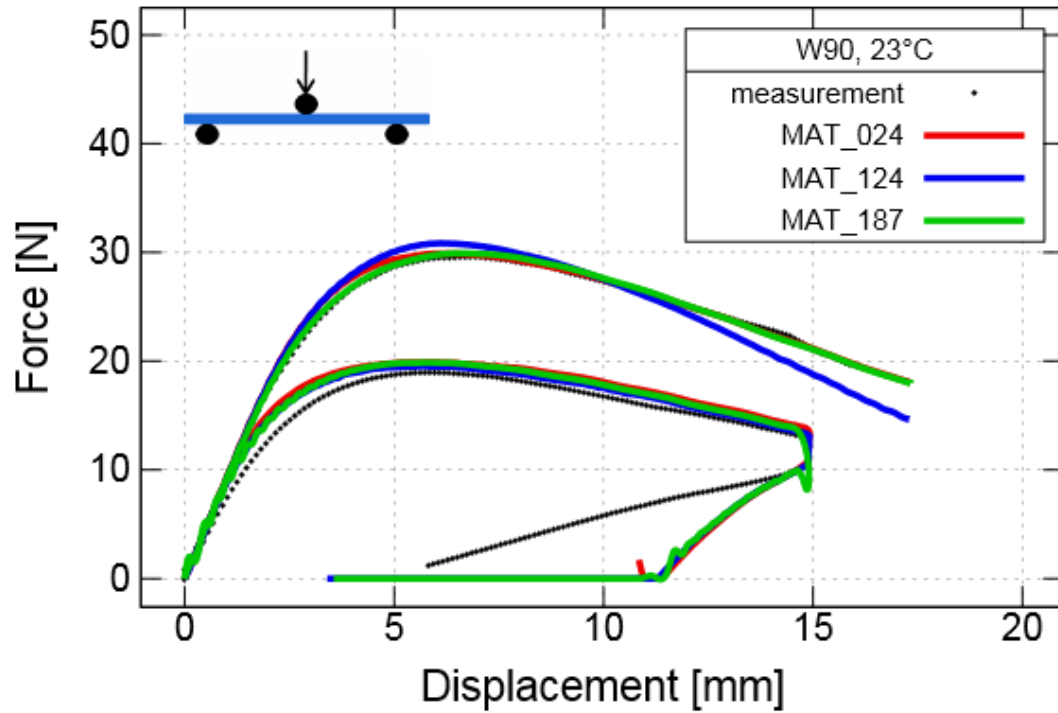


.... averaged test curves  
 — result of simulation

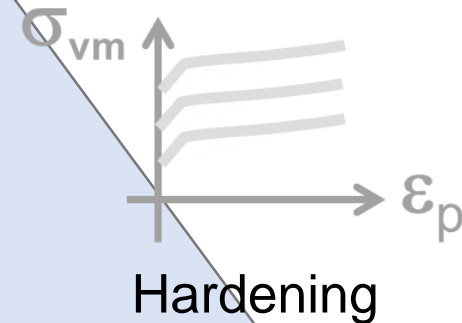
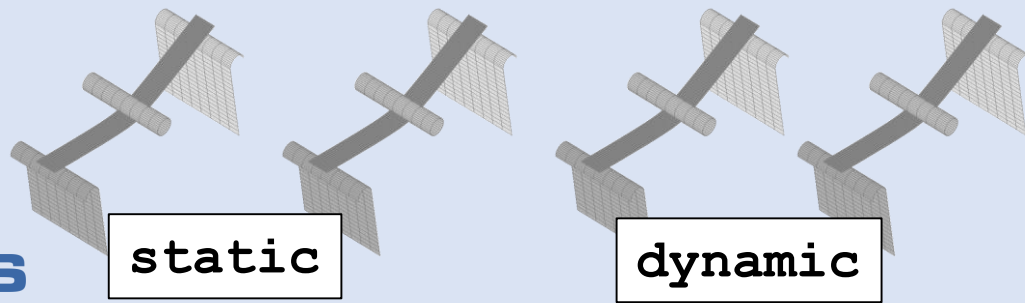
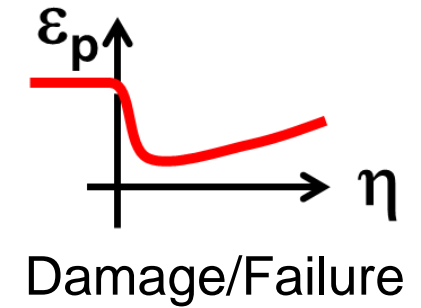
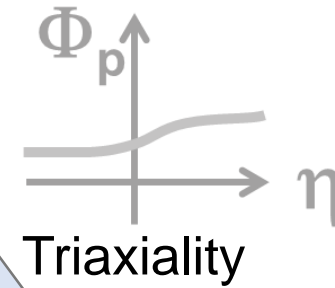
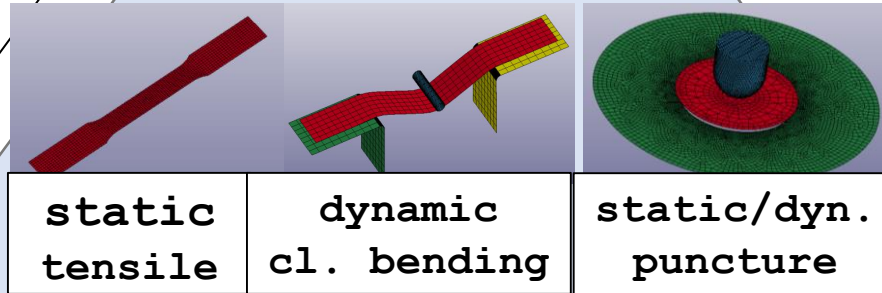




# comparison of results

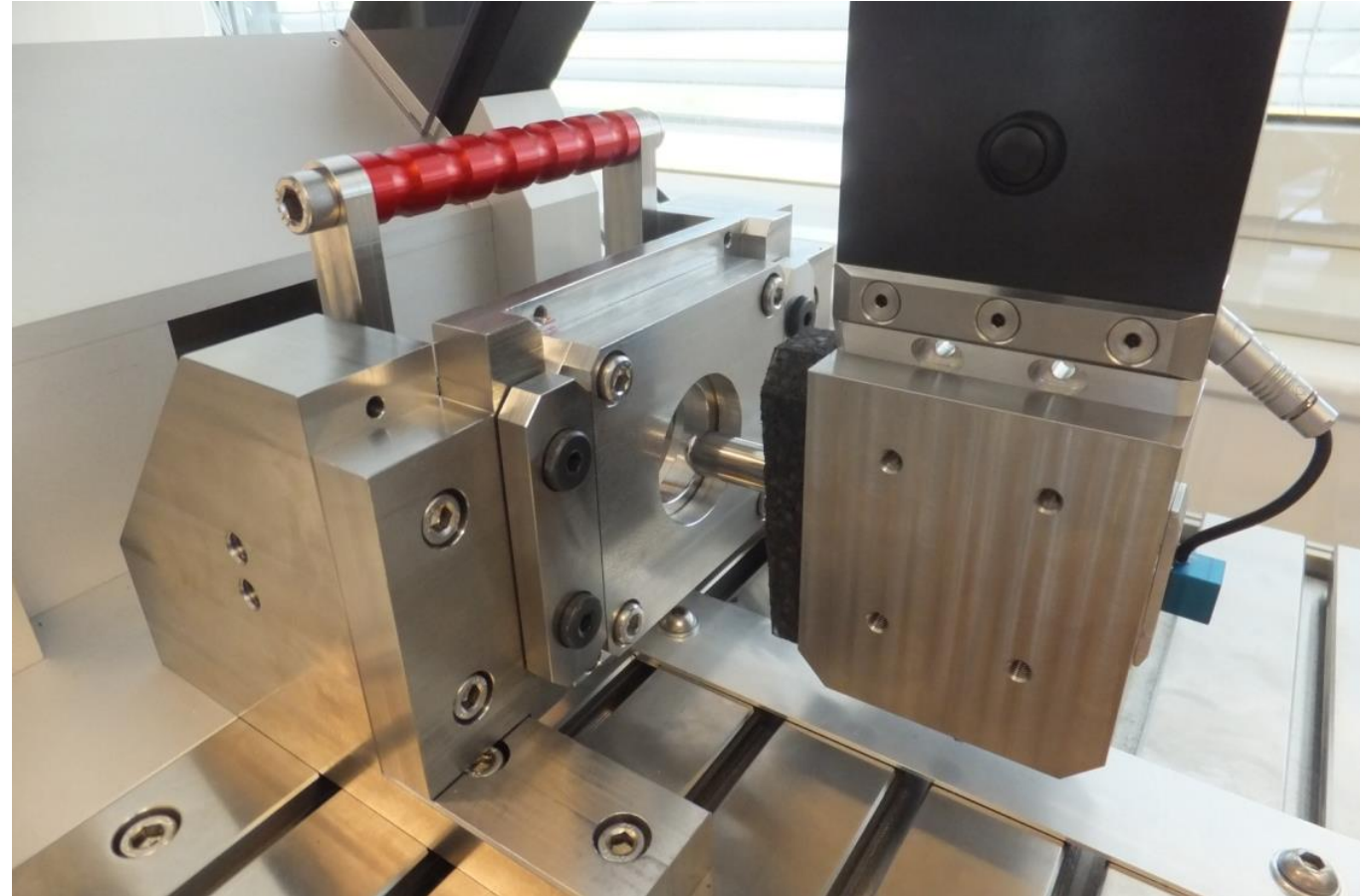


**\*MAT\_ADD\_ERROSION**

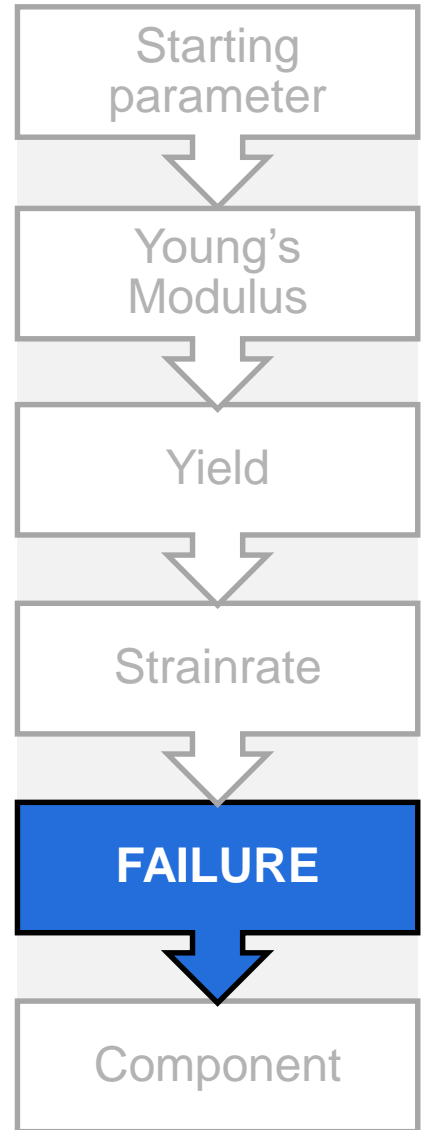
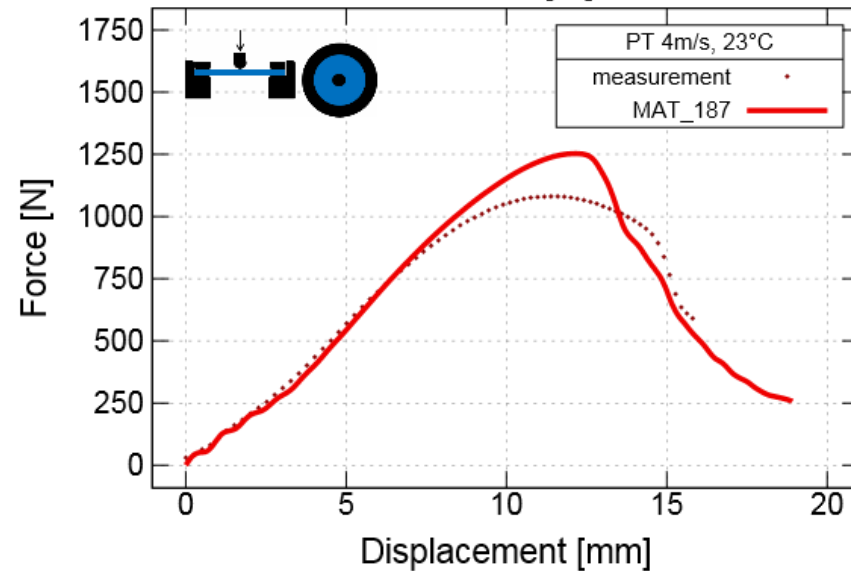
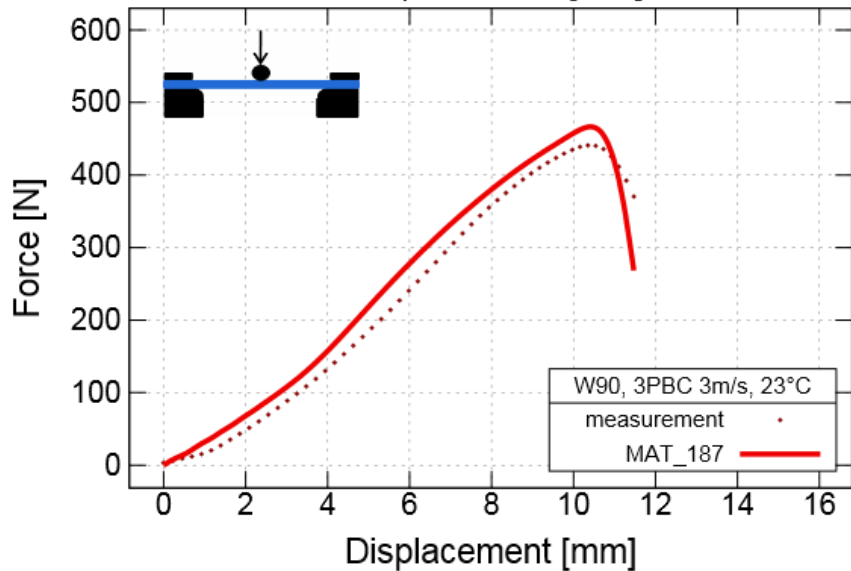
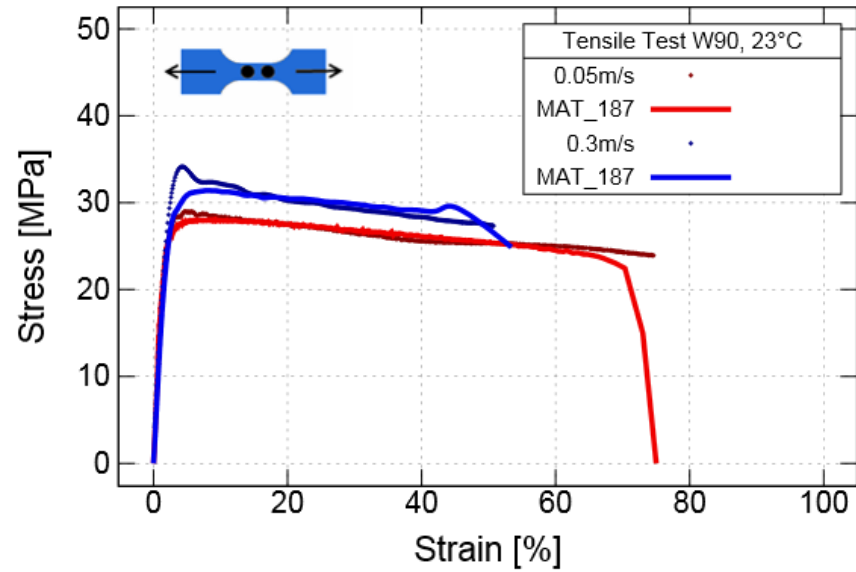
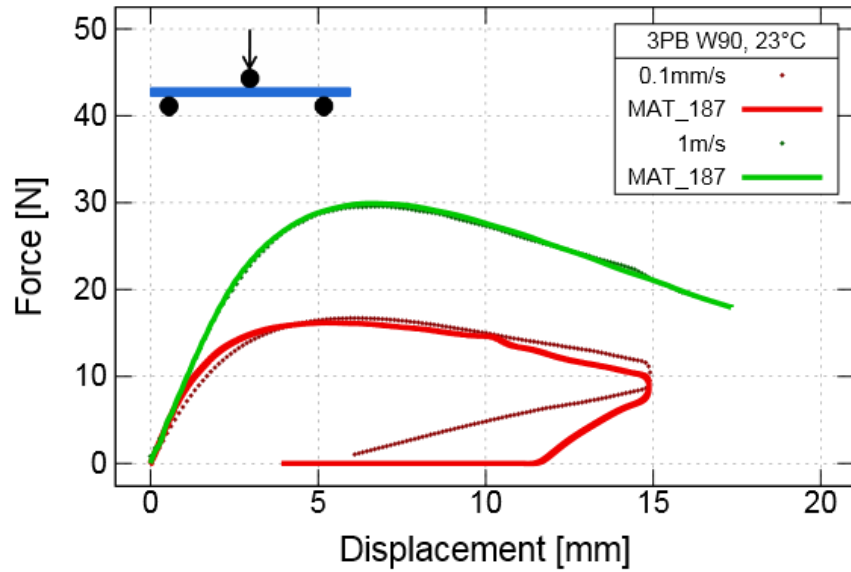


# efficient dynamic testing

- Different load cases
  - Bending
  - Tension Bending
  - Compression
  - Puncture
  - Component
  - ...
- High speed camera
  - Sync. recording
- Maximum energy 50 J
- Material Card  
Deformation → Failure



# from failure → \*MAT\_ADD\_EROSION



# from test to material card

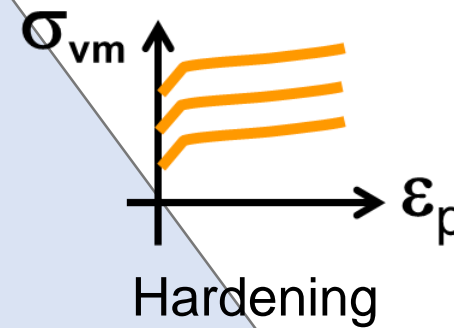
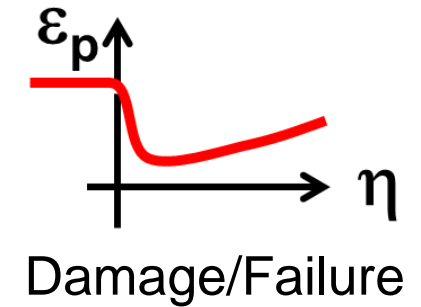
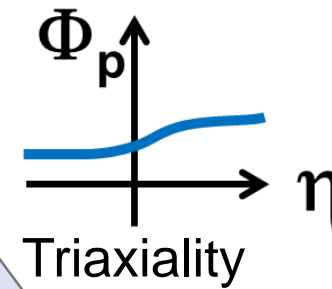
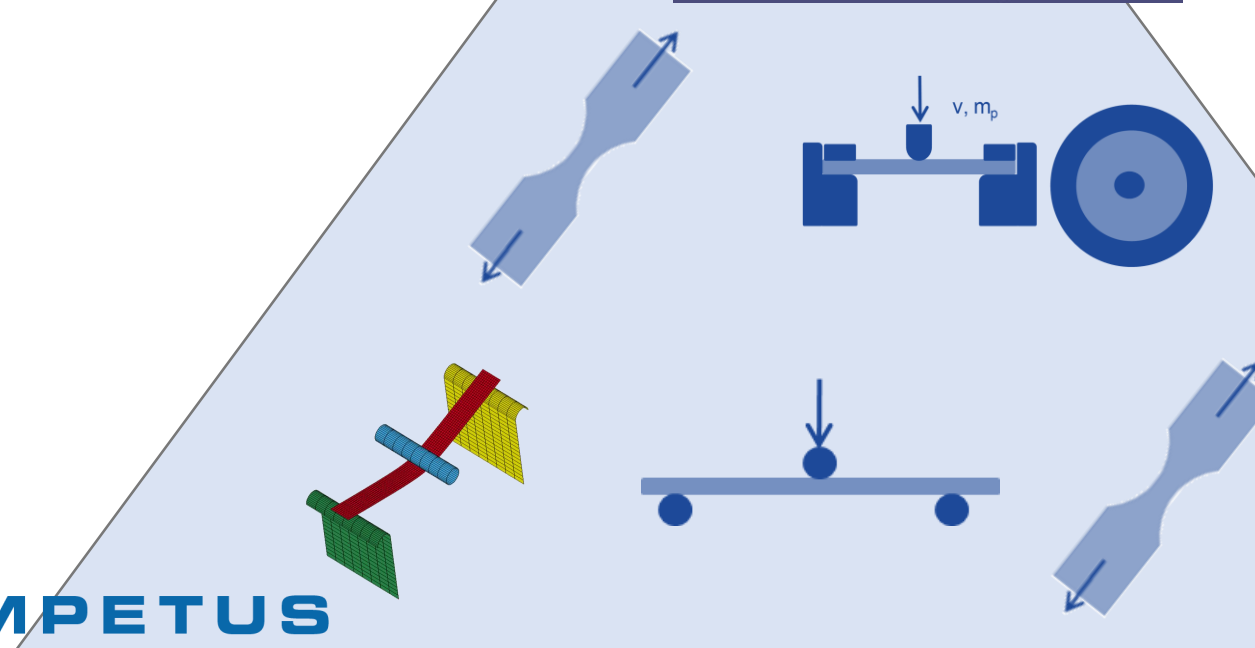
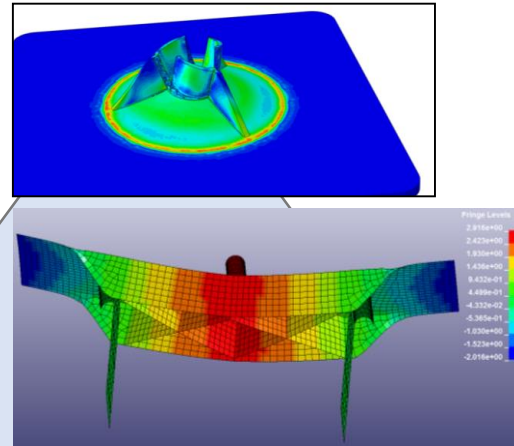


# VALIMAT

Deformation → Failure

Creep → Static → Crash

ISOTROPIC → ANISOTROPIC

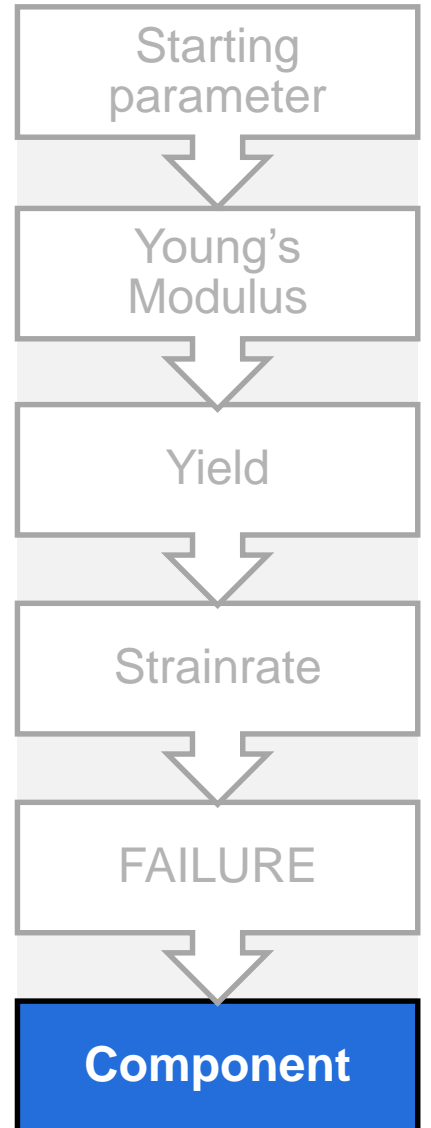
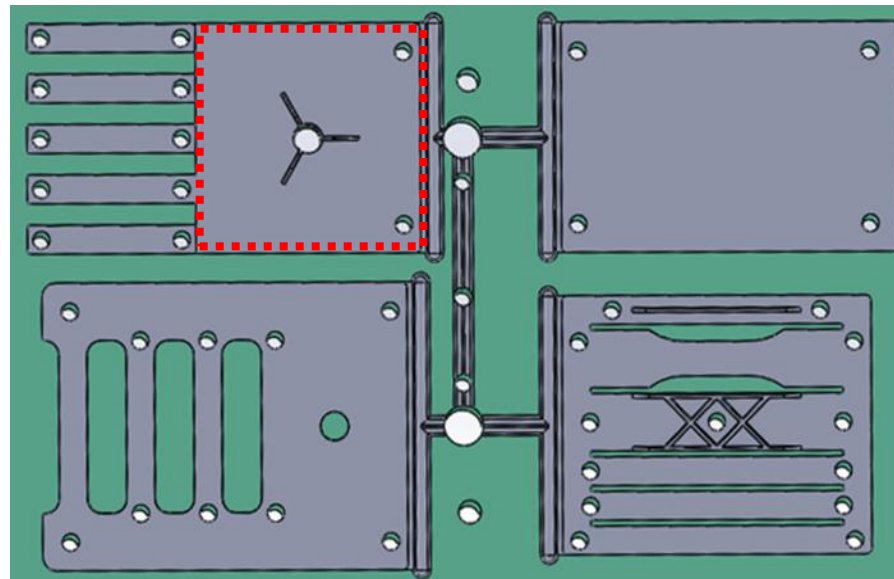
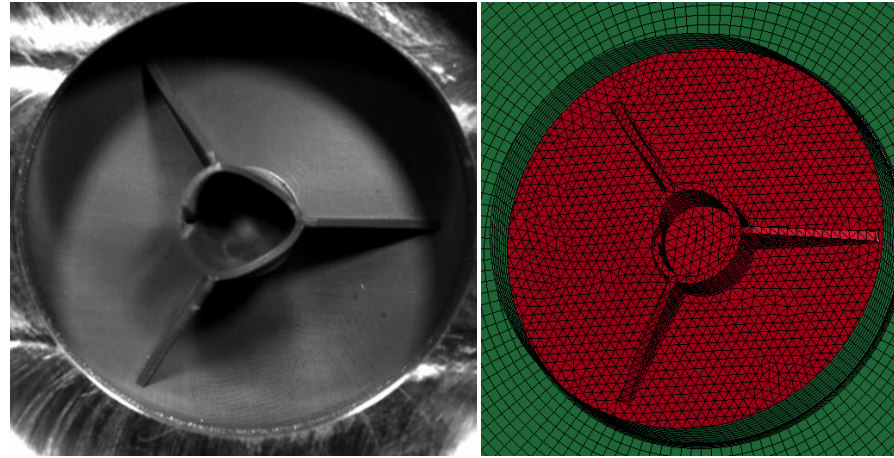
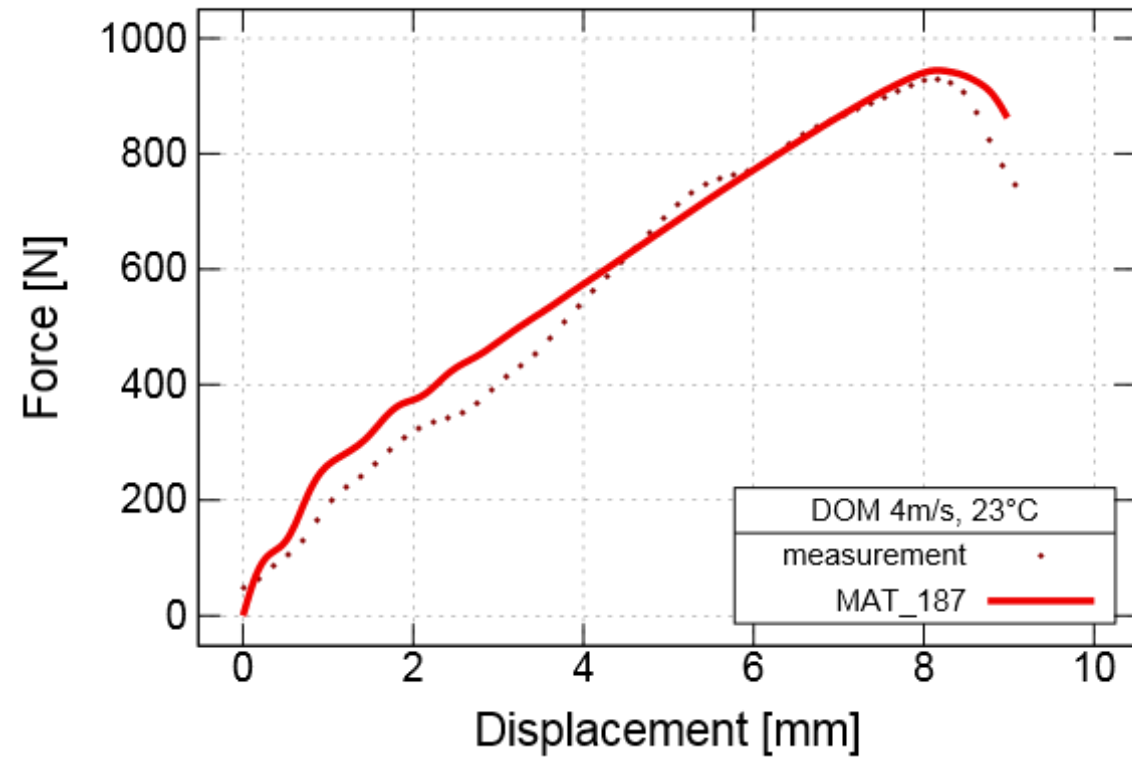


## IMPETUS





# Puncture Test → Validation on component

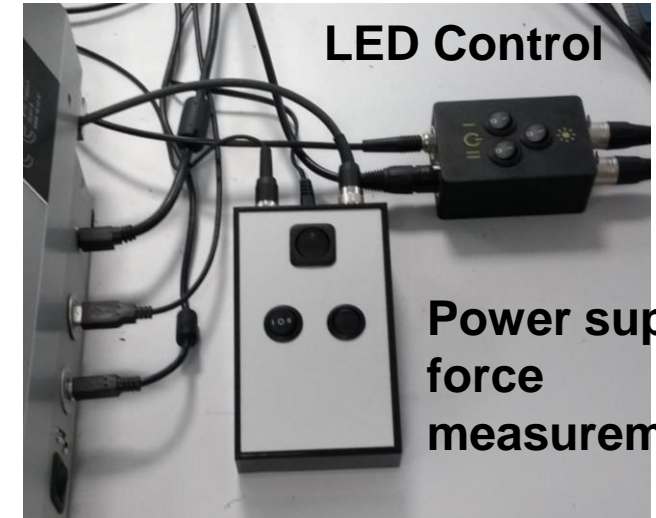
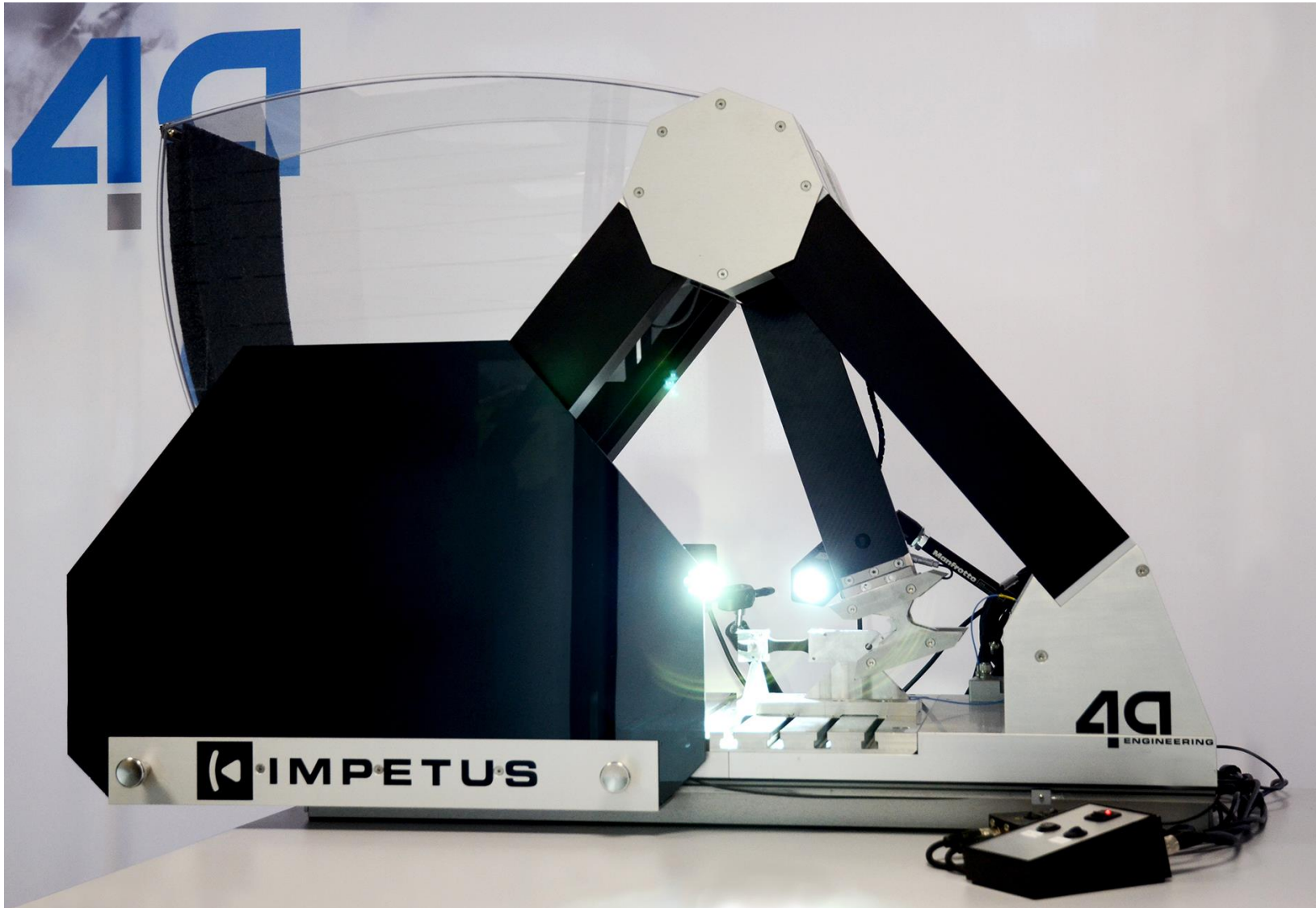


## intermediate conclusion

- IMPETUS™
    - efficient reliable possibility for characterizing materials
    - for unreinforced as well as fiber reinforced thermoplastics
    - different testing methods for capturing  
***visco-elasticity, hardening & visco-plasticity, triaxiality, damage & failure***
  - VALIMAT™
    - for generating material cards reasonable and quickly
    - ***\*MAT\_024, \*MAT\_124, \*MAT\_187, \*MAT\_ADD\_EROSION, ...***
    - MPIP → workflow for automation of the process
    - PP T16 (Hostacom XBR169): Prove of the workflow
- **Easy and accurate material modeling**

see more: [paper Int. LS Dyna Conference Detroit 2018](#)

# Outlook - dynamic tensile test setup

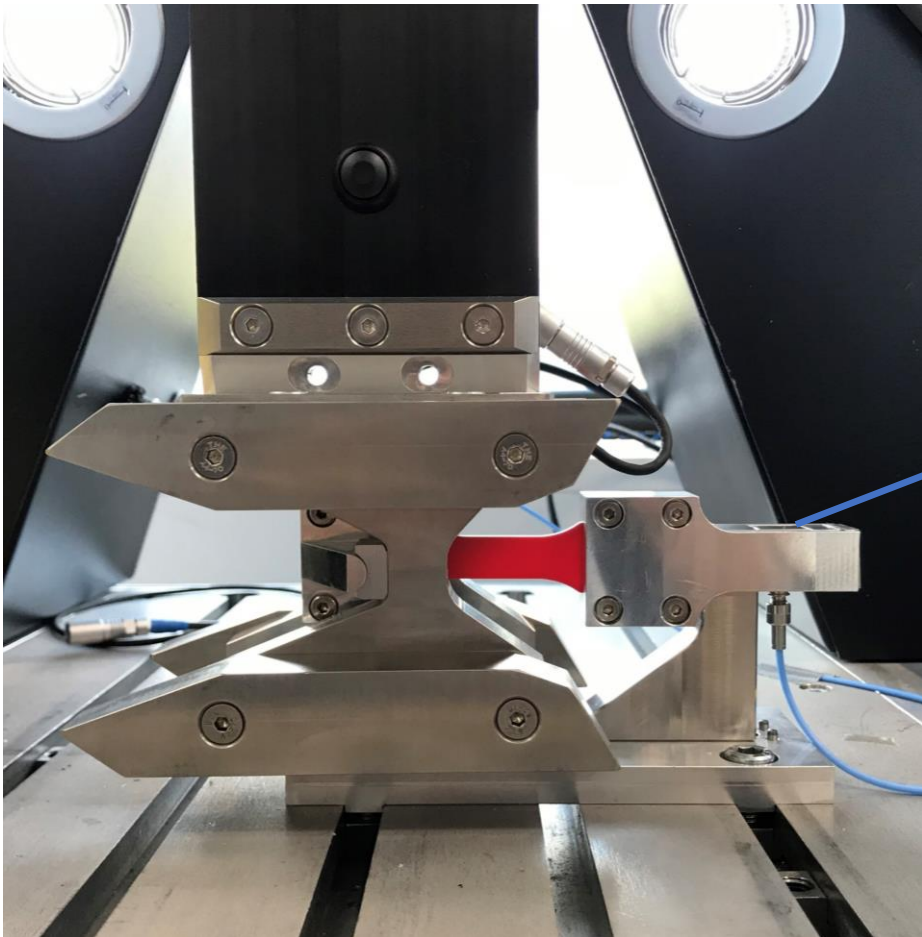


LED Control

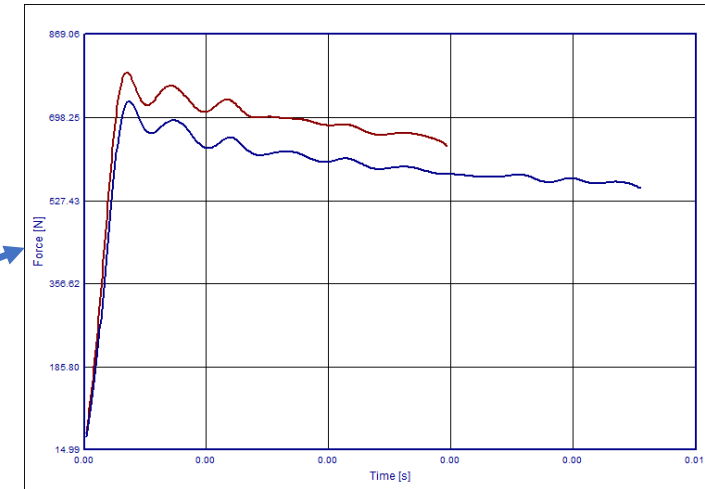
Power supply  
force  
measurement



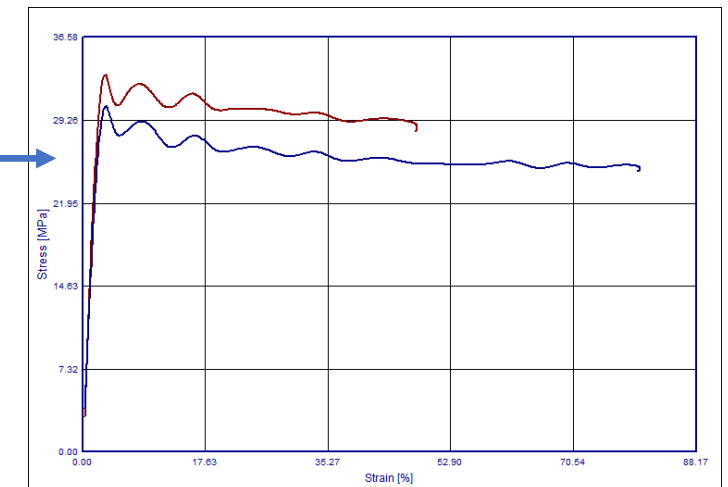
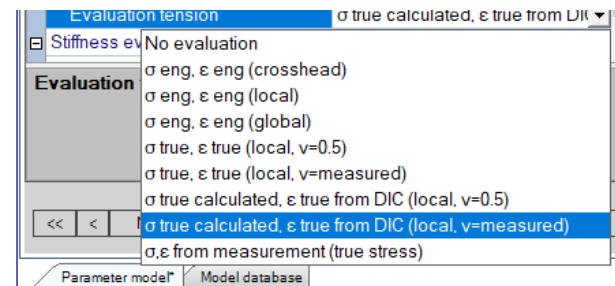
Used highspeed camera



## Force measurement



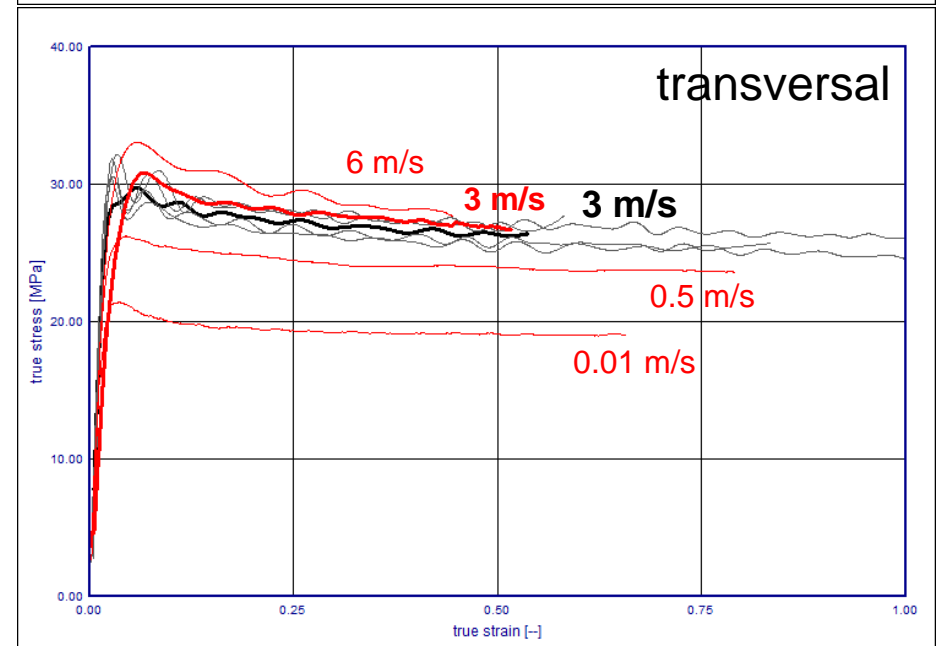
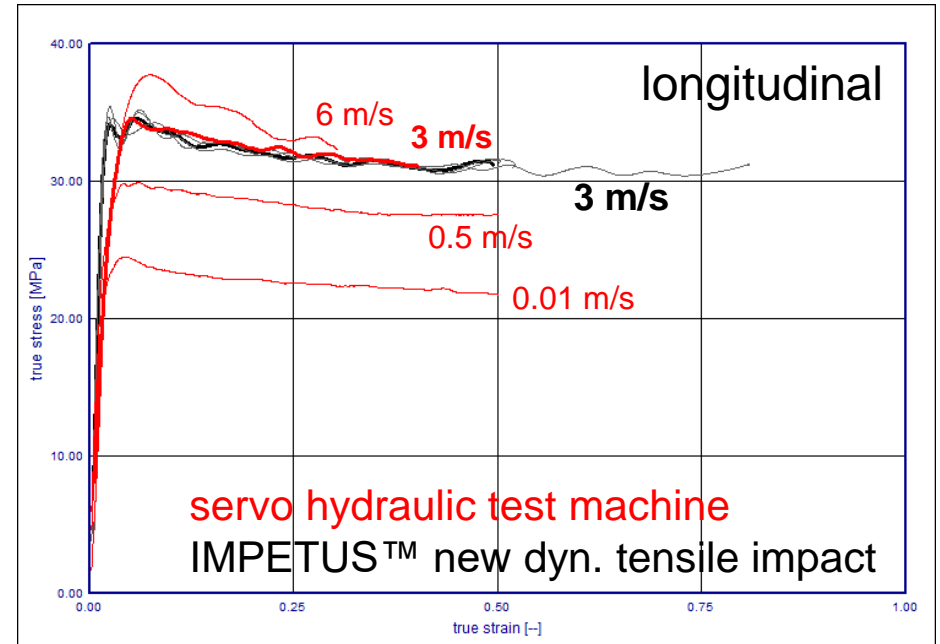
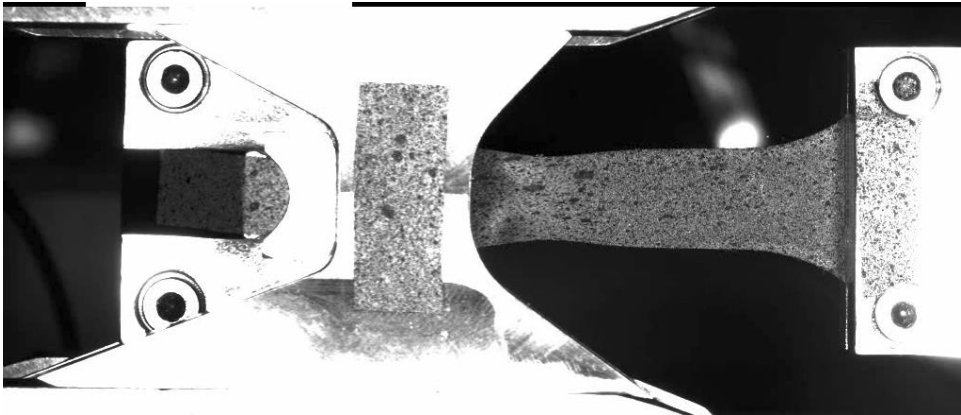
## New stress evaluation methods (support of DIC Data)





# Outlook - dynamic tensile test setup

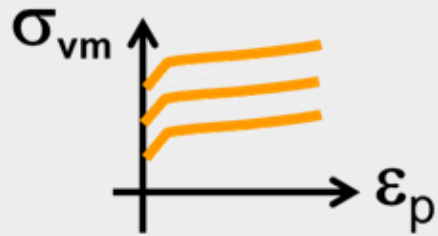
- **Comparison** on Hostacom XBR 169G (PPT16)
  - Results Ph.D Thesis F. Kunkel – **0.01, 0.5, 3, 6 m/s**
  - Current investigations – 3 m/s
  - Becker 2.5 mm thick samples
- Quite good matching between both test methods !



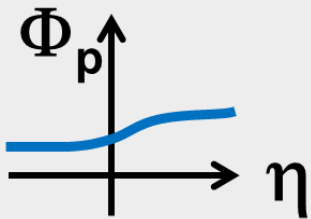


intelligent reliable solutions for plastics, composites, metals, foams, ...

# ✓ VALIMAT



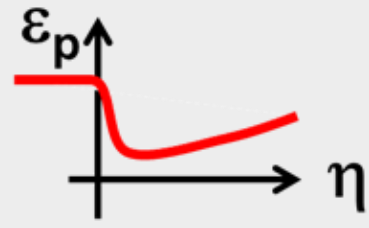
Hardening



Triaxiality



Anisotropic

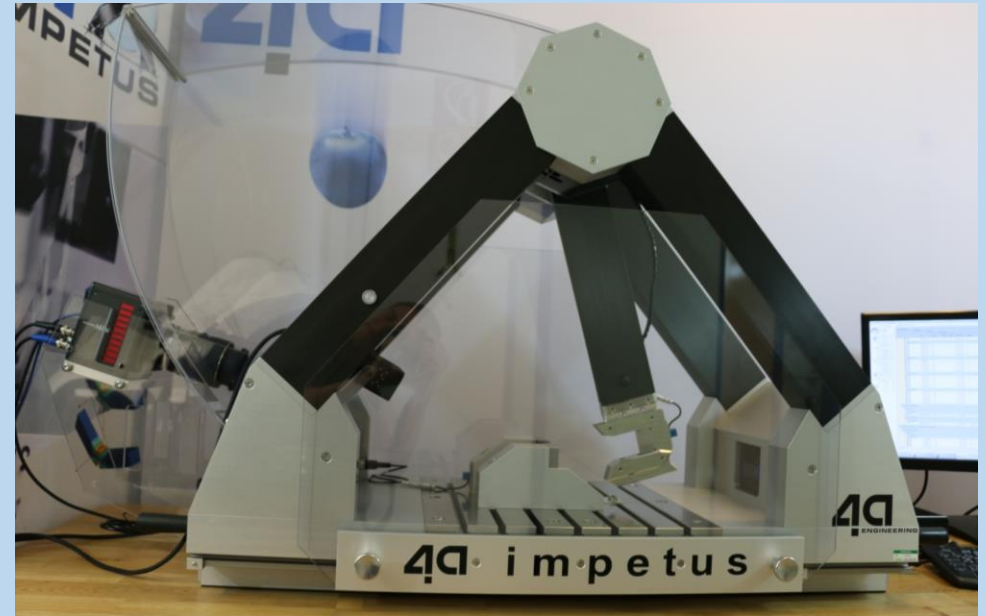


Damage/Failure

**for all material types**

from test to validated material cards

# ◀ IMPETUS



efficient dynamic testing

**plastics and composites**