Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS

From Strain-Rate Effects to Automated 3D-DIC Forming Limit Evaluation

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Dr. Akbar Farahani, eSavant

GREAT DESIGNS IN STEEL™

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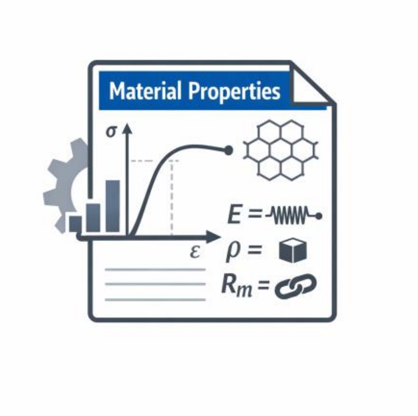

Generate datasheets according to standards

Missing link to simulation data input – datasheet is not enough

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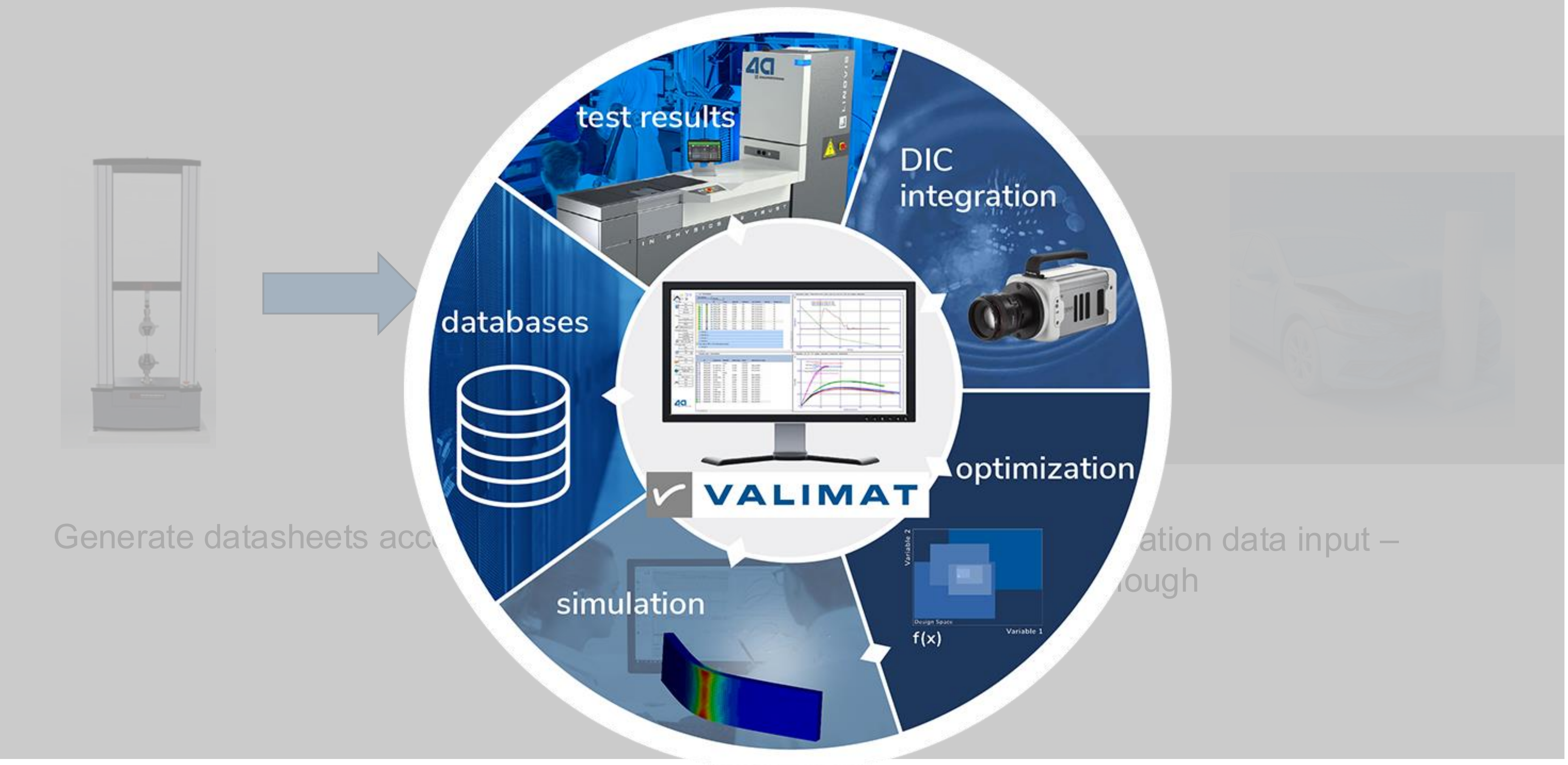

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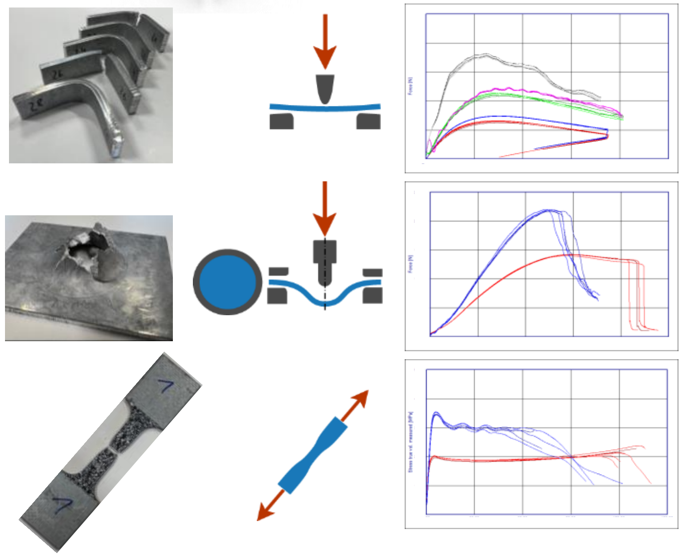
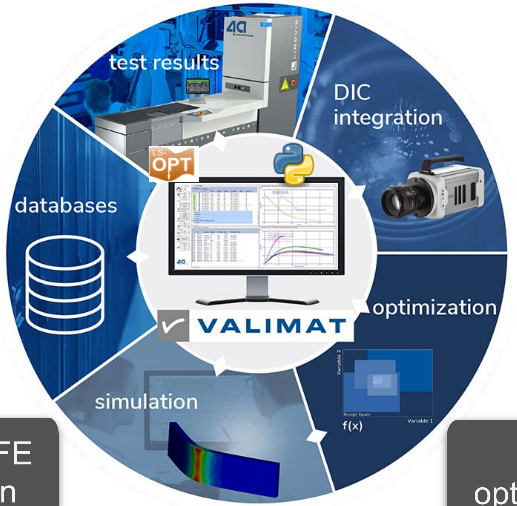
Static and dynamic mechanical characterization

LINOVIS
high performance modular testing

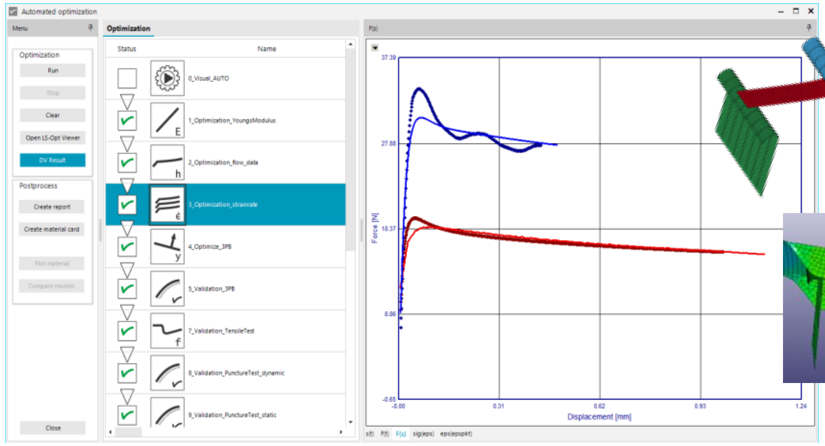


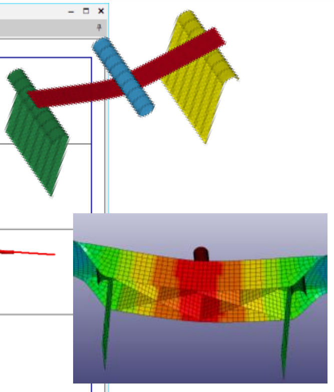
Modelling and parameter identification



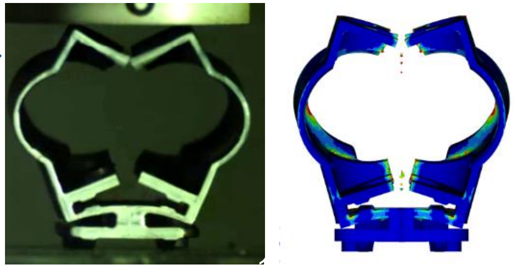
Fully automated FE model generation

Automated optimization workflows





Validation and implementation to bigger models



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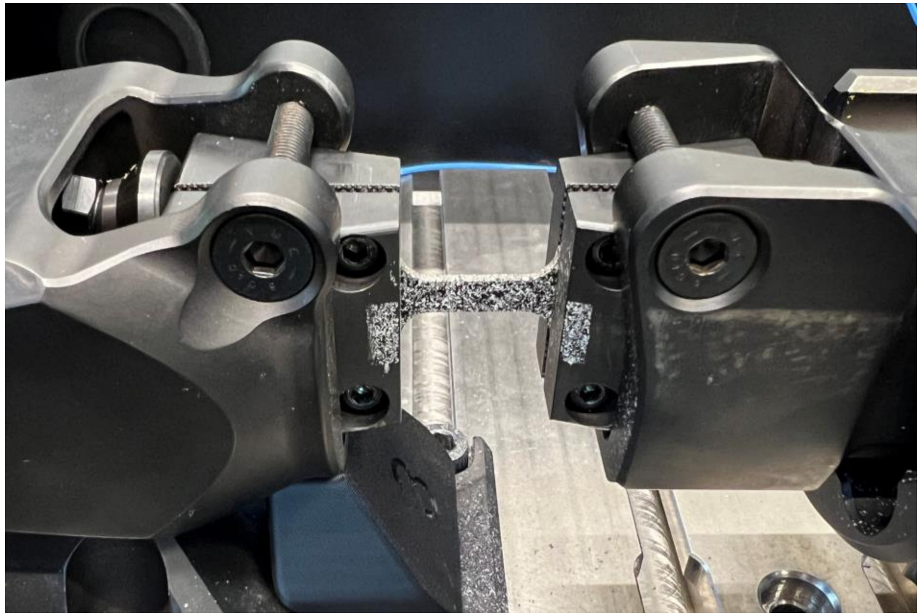
Tensile Test Setup



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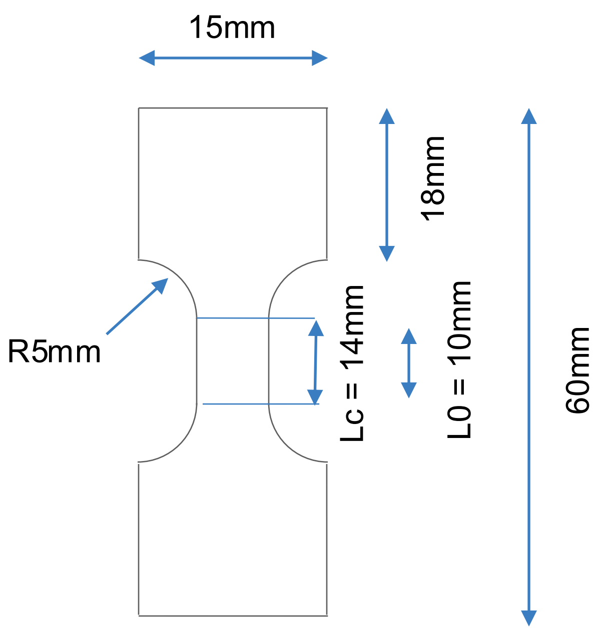
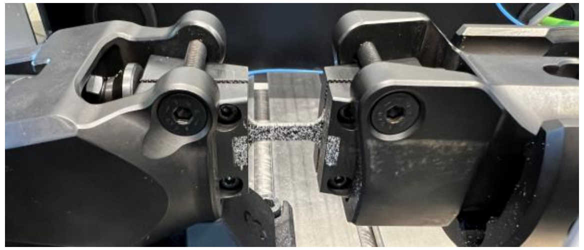
Tensile Test – Proposed Specimen Geometry for High Strain Rates



- Standard tensile test specimen for reaching high strain rates
- Max strain rate: ~200-300 1/s
  - Higher strain rates possible with smaller L0
- Full field DIC measurement
  - Gauge length can be defined based on customer requirements
- Dual phase steel grade



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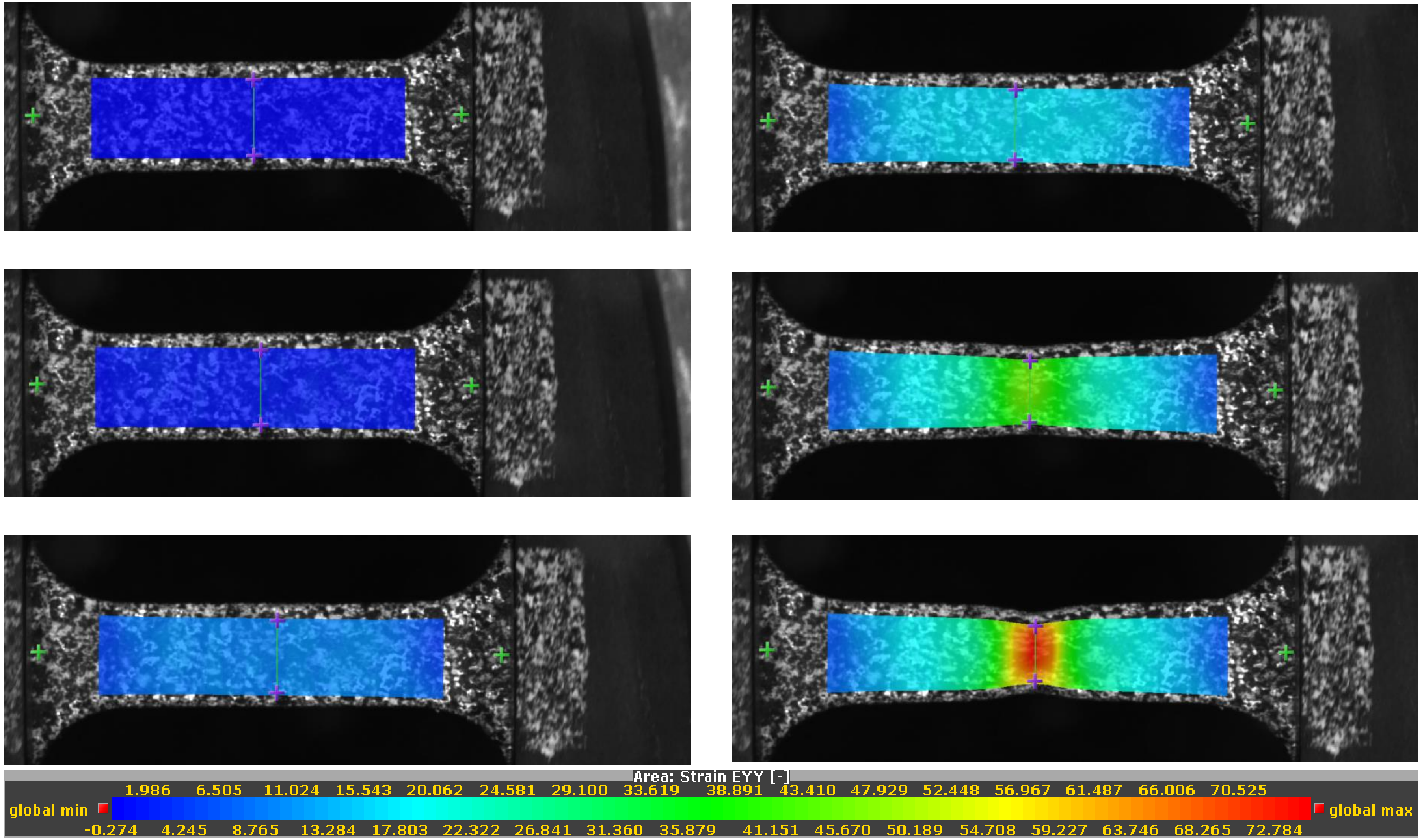

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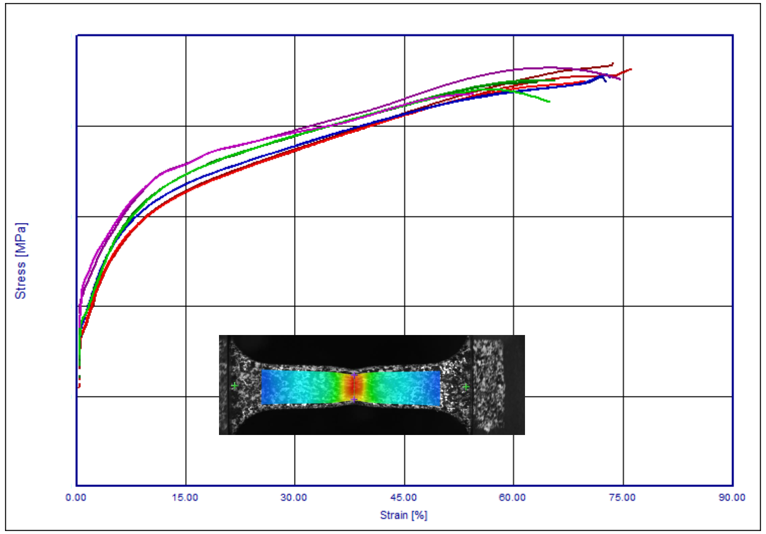
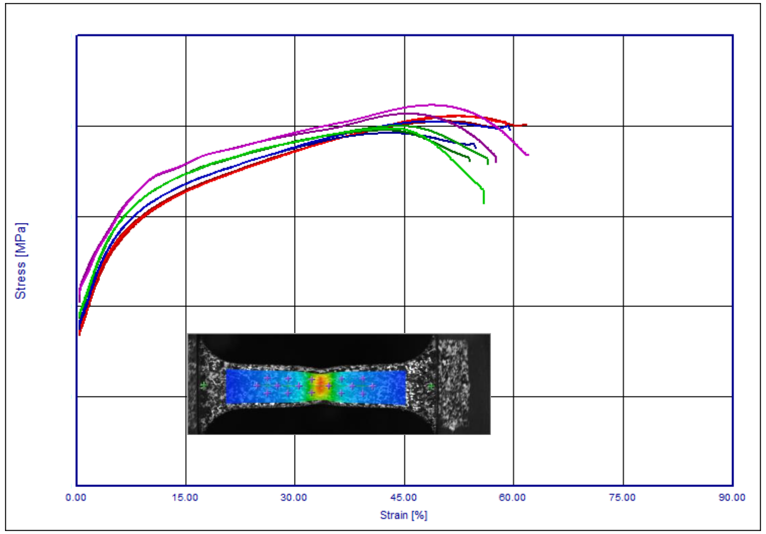
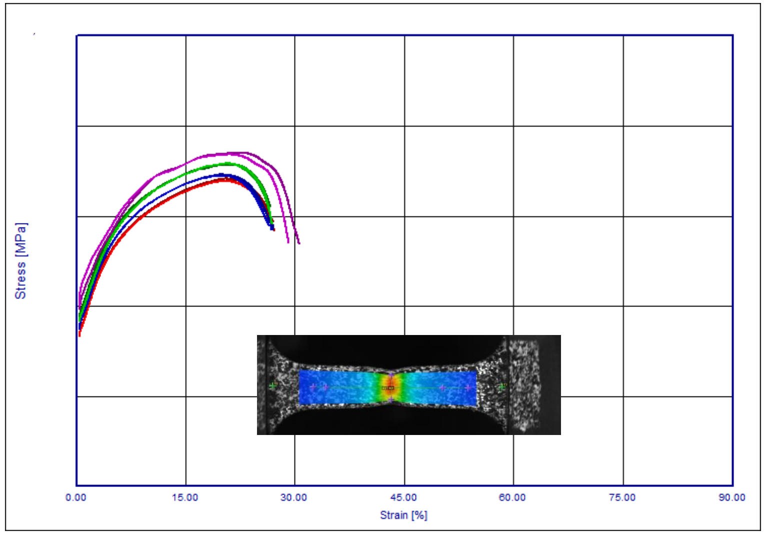
True stress-strain
L_0 = 0.47mm (DIC)



True stress-strain
L_0 = 2mm (DIC)



True stress-strain
L_0 = 14mm (DIC)



Case	samples	v_0 [m/s]	l_w [mm]	l_0 [mm]	b [mm]	t [mm]	l [mm]
TT_1mmps	**3/3**	**0.001**	**24**	**14**	**15.00**	**1.57**	**60.00**
TT_10mmps	**2/2**	**0.01**	**24**	**14**	**15.00**	**1.57**	**60.00**
TT_100mmps	**3/3**	**0.1**	**24**	**14**	**15.00**	**1.57**	**60.00**
TT_1000mmps	**2/2**	**1**	**24**	**14**	**15.00**	**1.57**	**60.00**

→ Consider FEM discretization (target element size) with regards to fracture modelling

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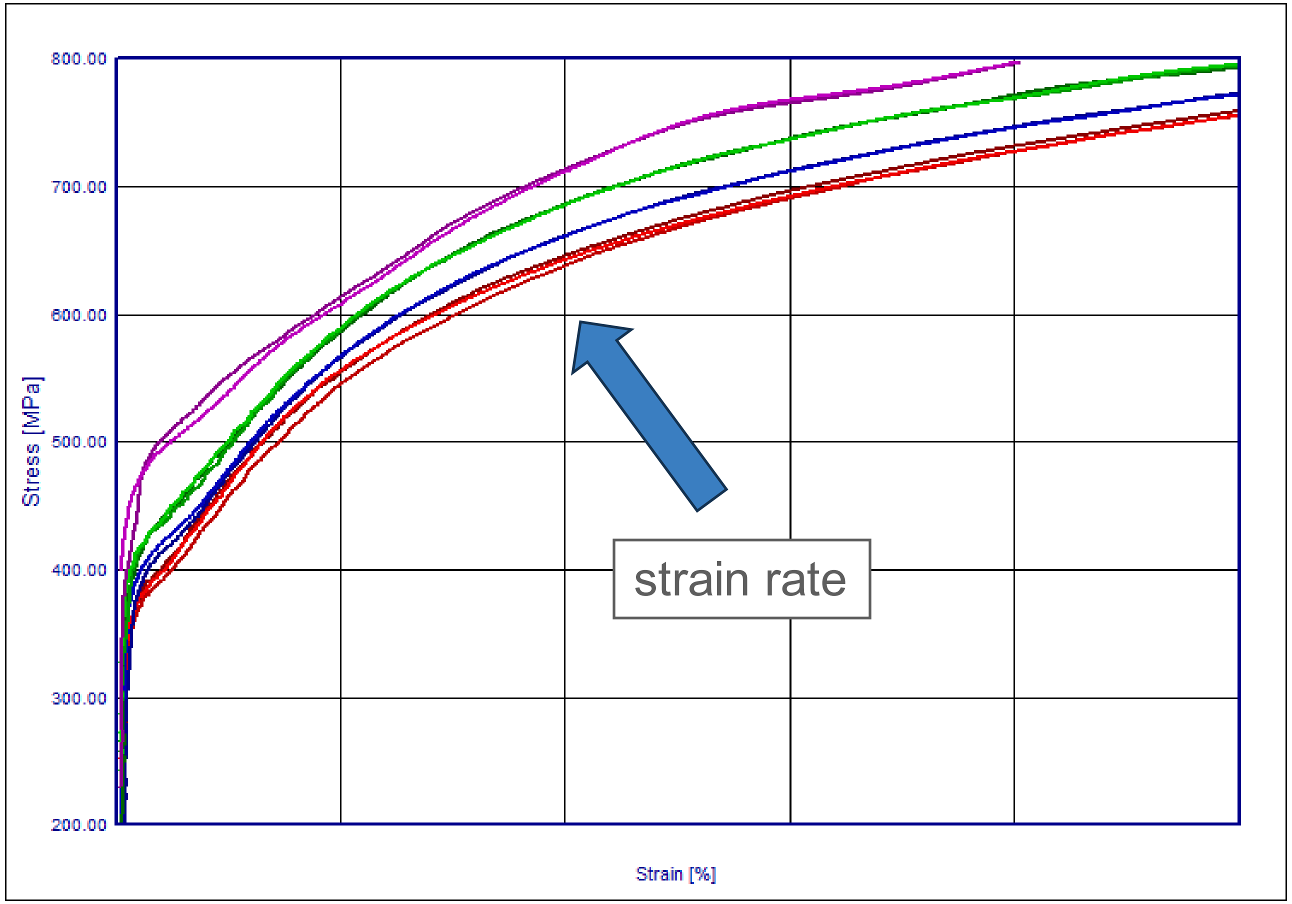
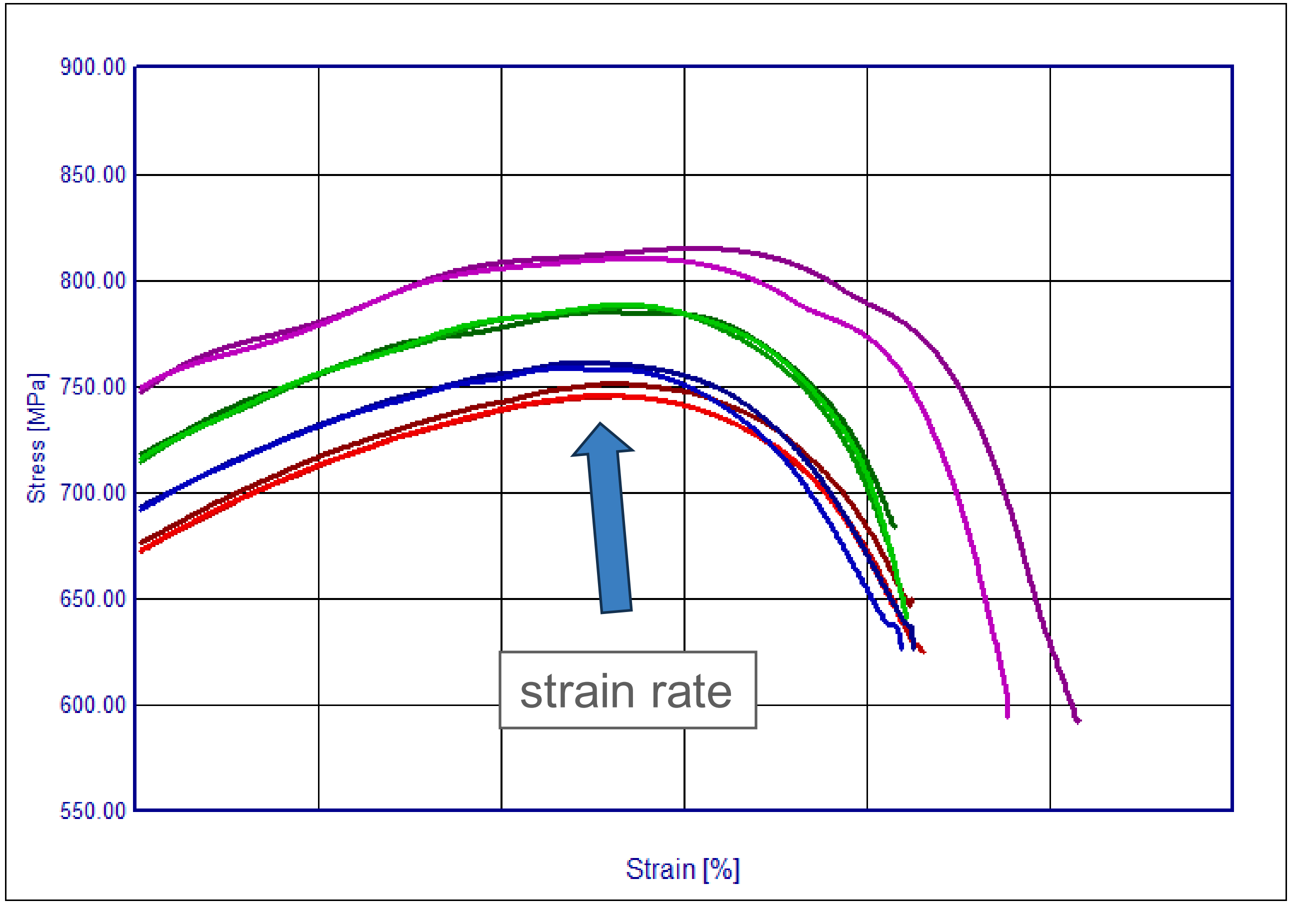


- **Increase of yield strength** by about 100 Mpa (> 20%) from quasi-static to high strain rate loading

Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS



- **Increase of yield strength** by about 100 Mpa (> 20%) from quasi-static to high strain rate loading
- **Increase of UTS** by about 60 MPa

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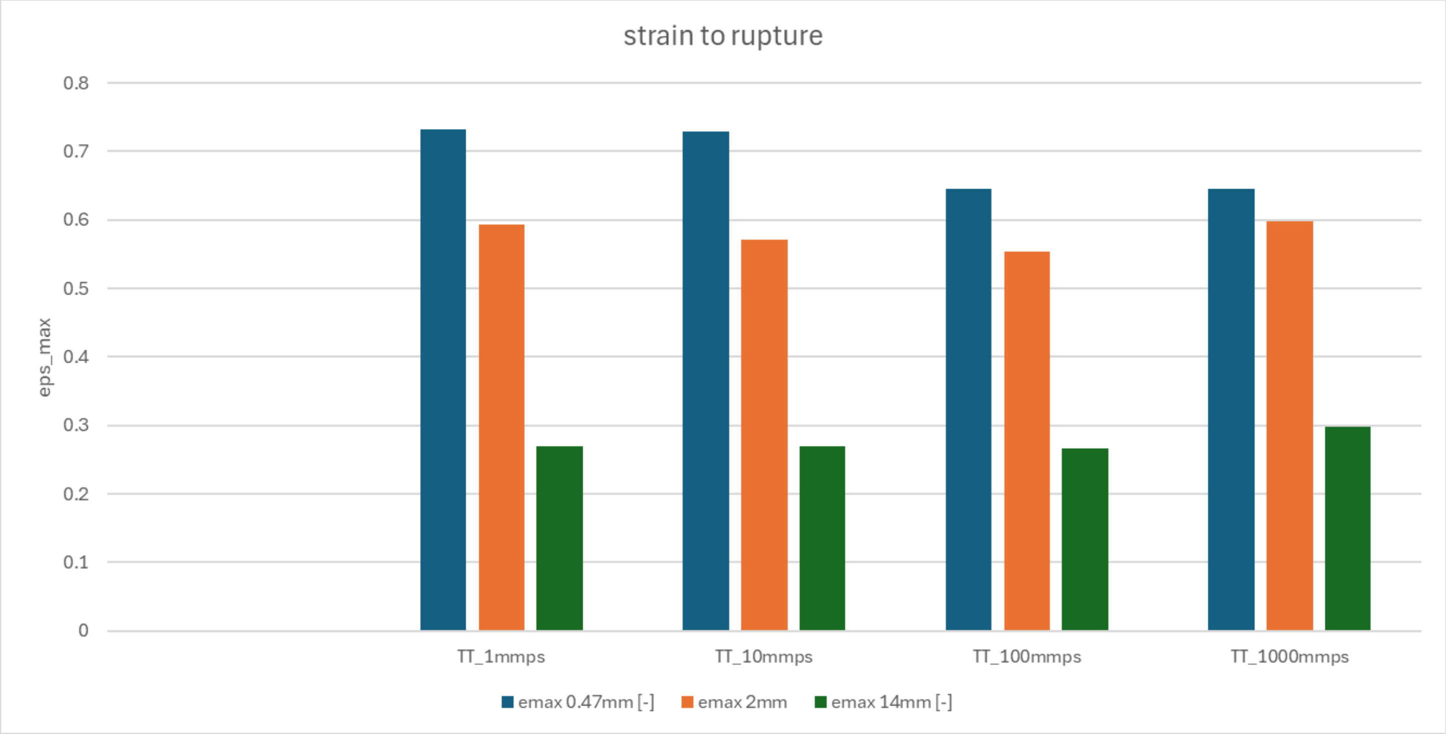

Strain to rupture:

- Local evaluation within necking zone: strain to rupture decreases with increasing strain rate
- Longer gauge lengths: no significant change / slight increase at highest strain rate
- → indication that necking area is increasing with strain rate

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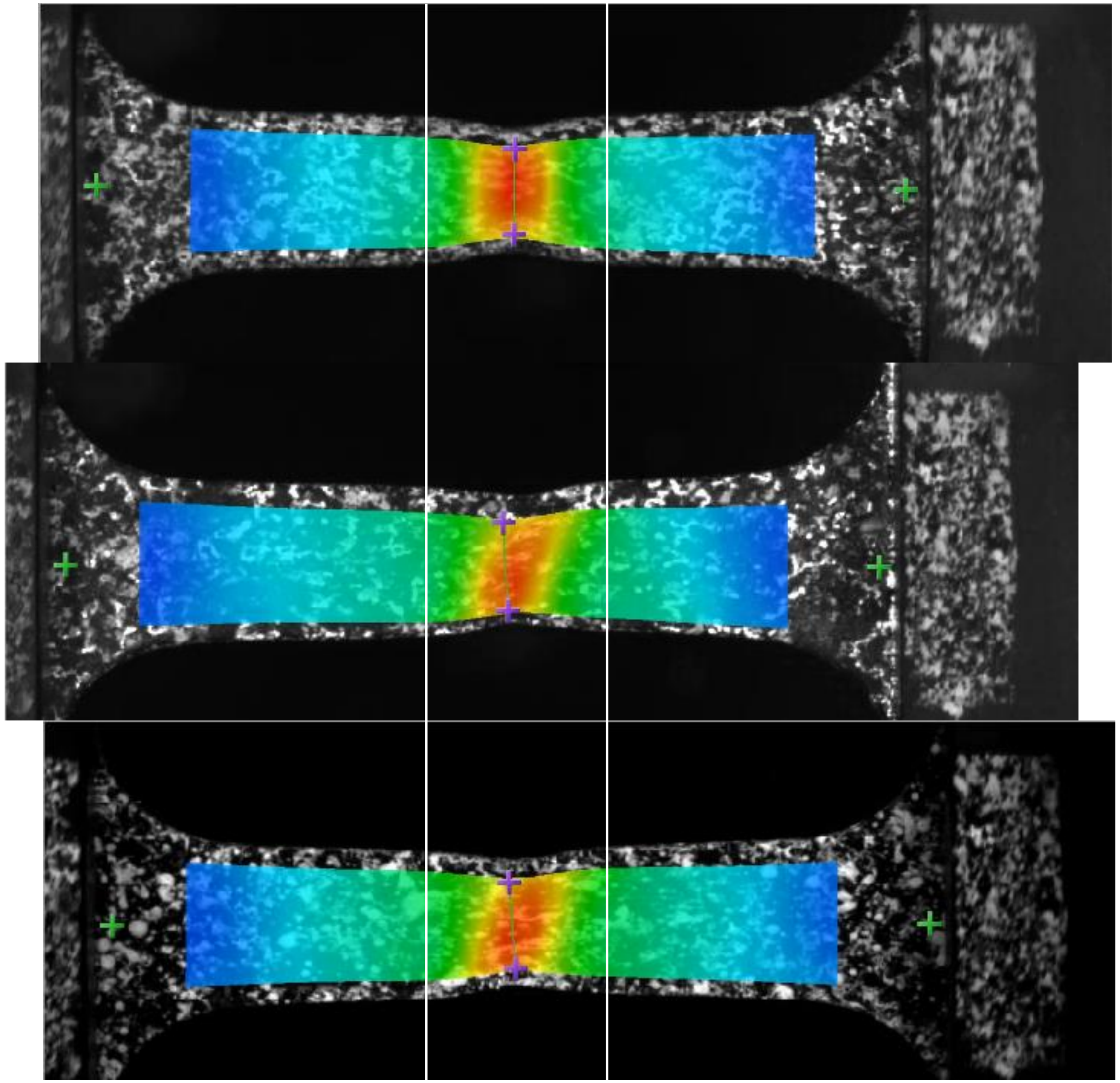
QS

0.1 m/s

1 m/s



- Surface strain field indicates increase of area with higher strains towards higher strain rates
- Shape/inclination of necking zone changes: change from normal to shear fracture

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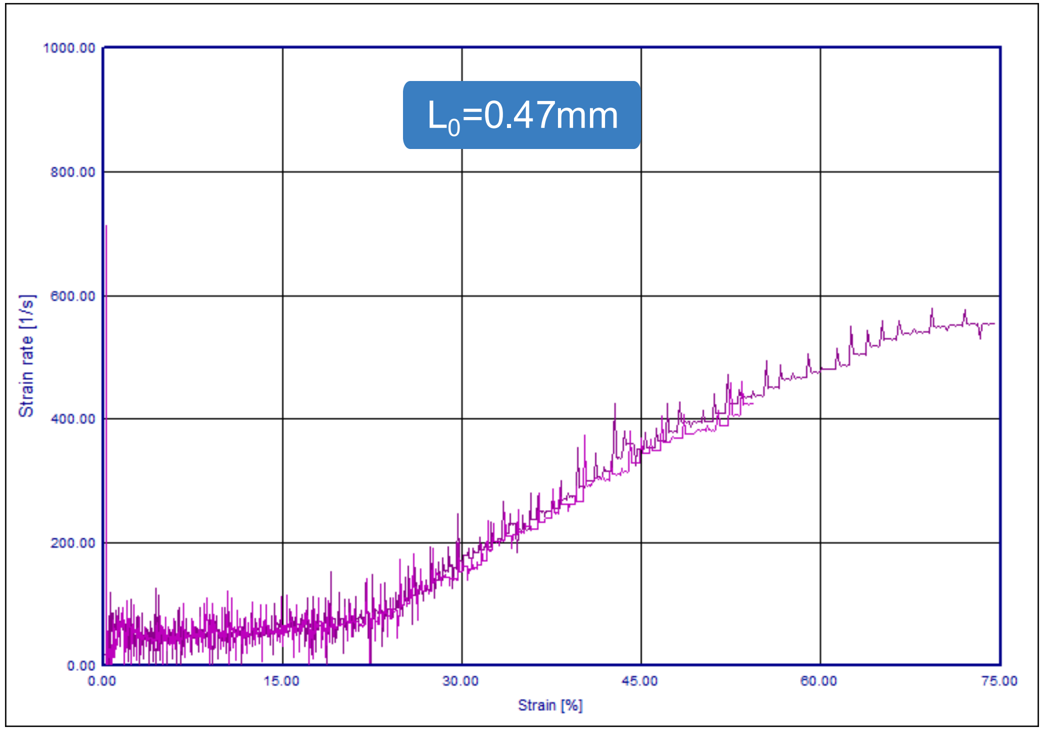

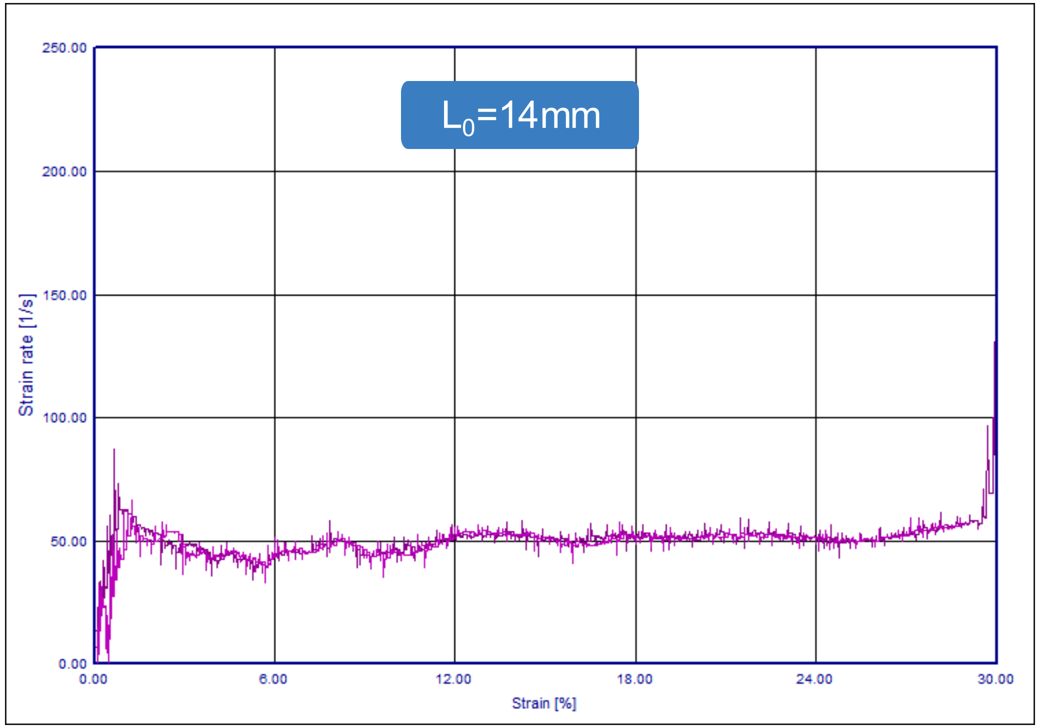

1 m/s tensile test – evaluation of strain rate:

- Significant increase of local strain rate with onset of necking
  - Max. strain rate of ~ 550 1/s observed before fracture

- „global“ strain rate remains constant throughout whole test

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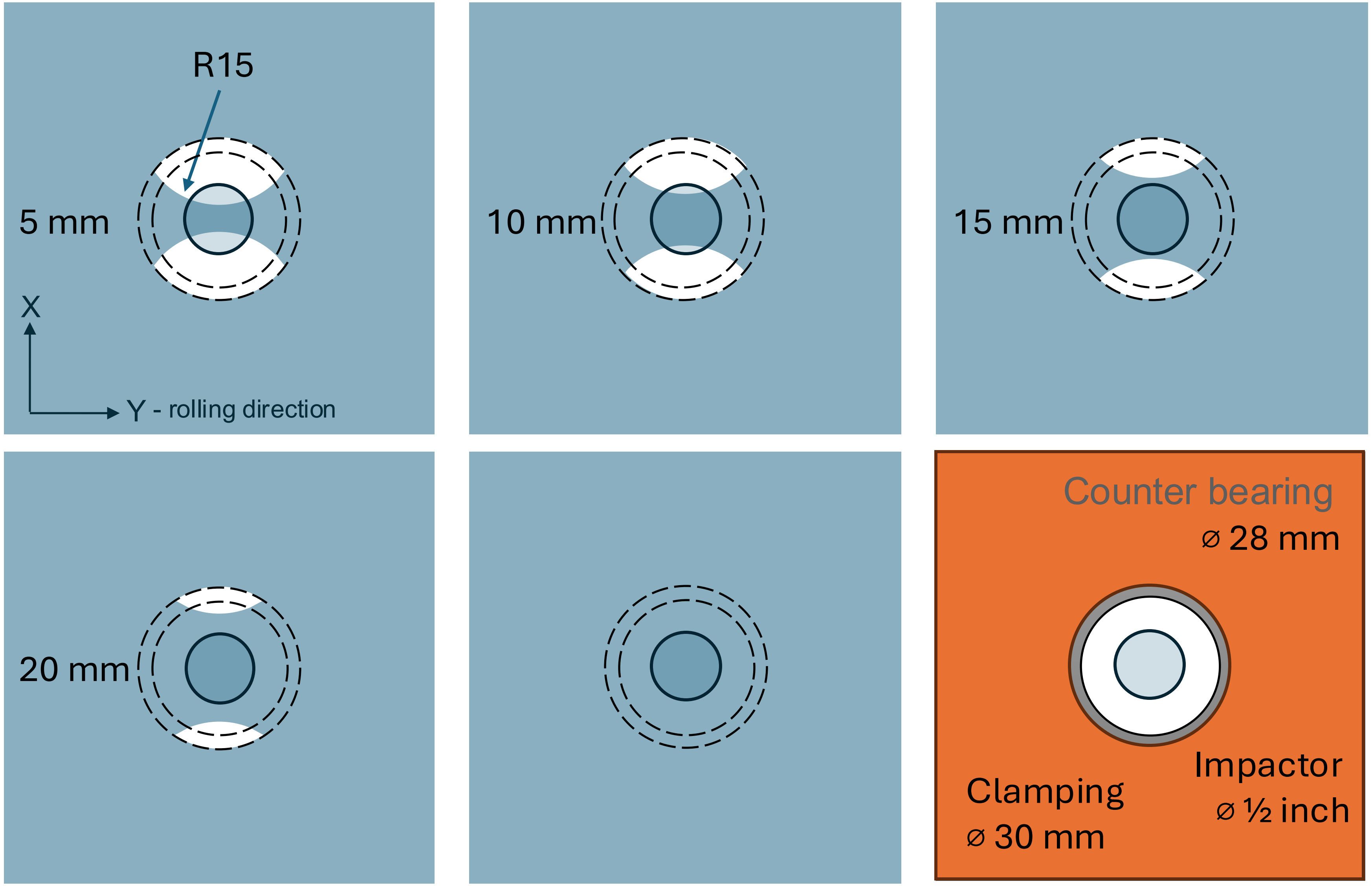

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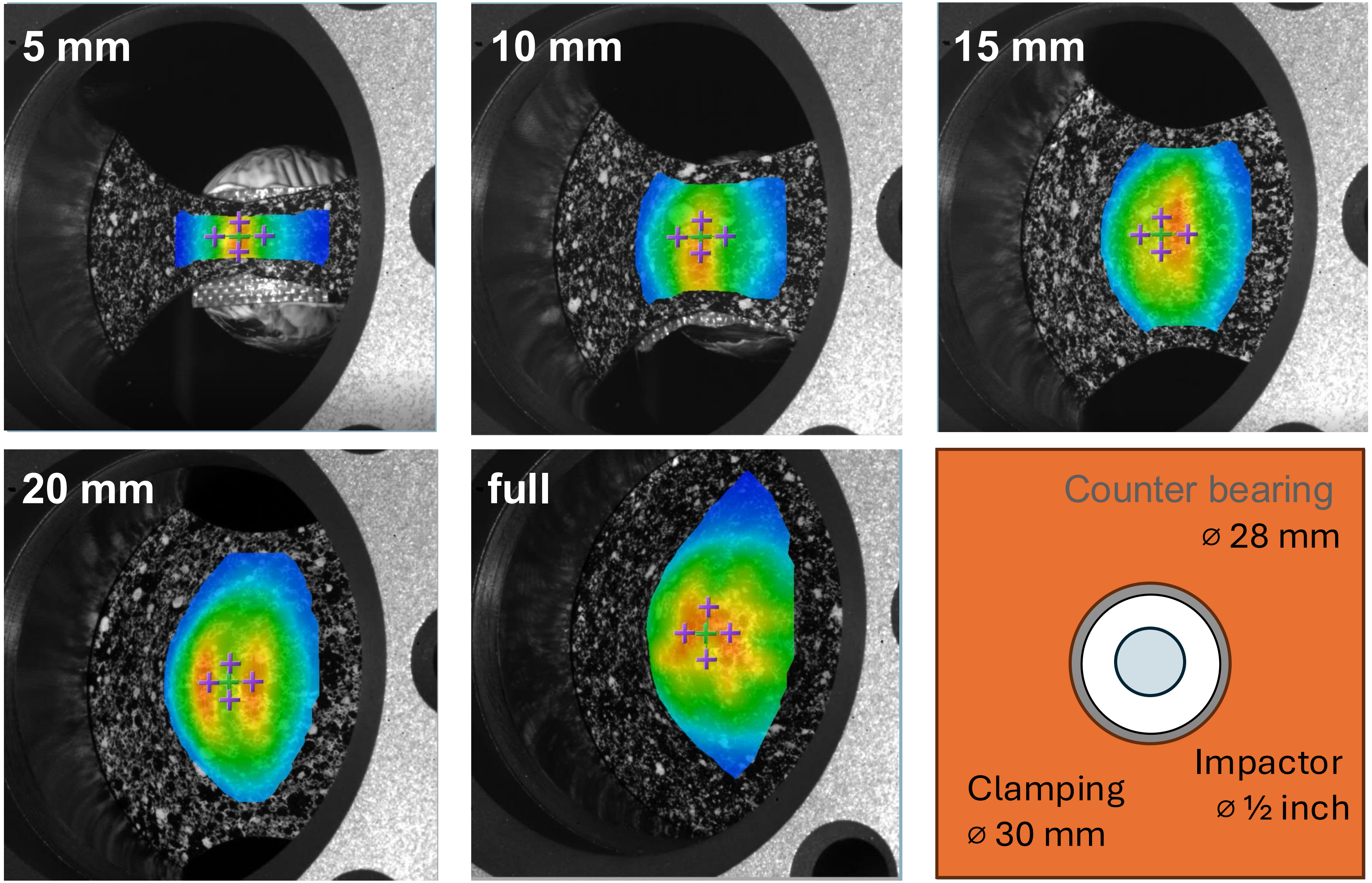

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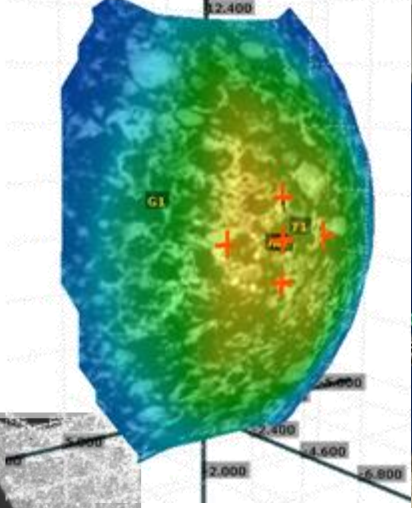
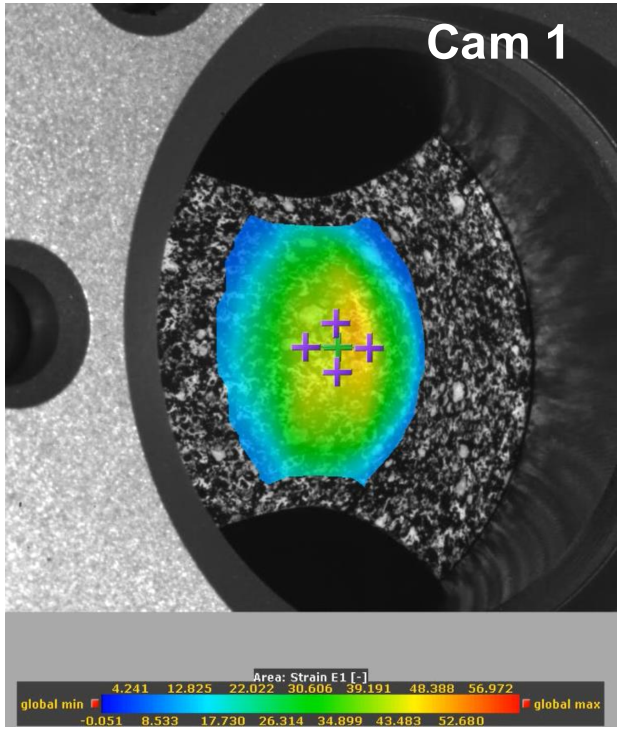
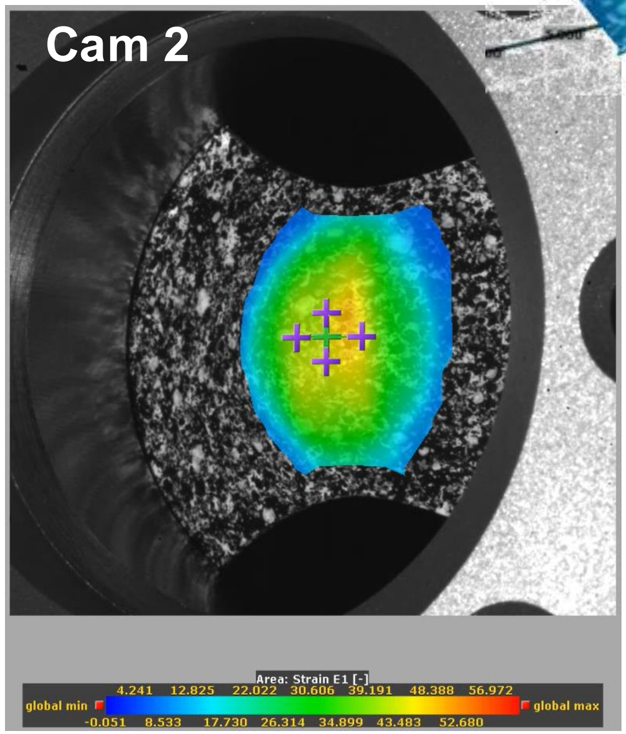
Local strain measurement: 3D DIC
- Gauge length L_0: 2 mm
- Frame rate: 15.000 fps
- Resolution: 768x768 px

3D Graph







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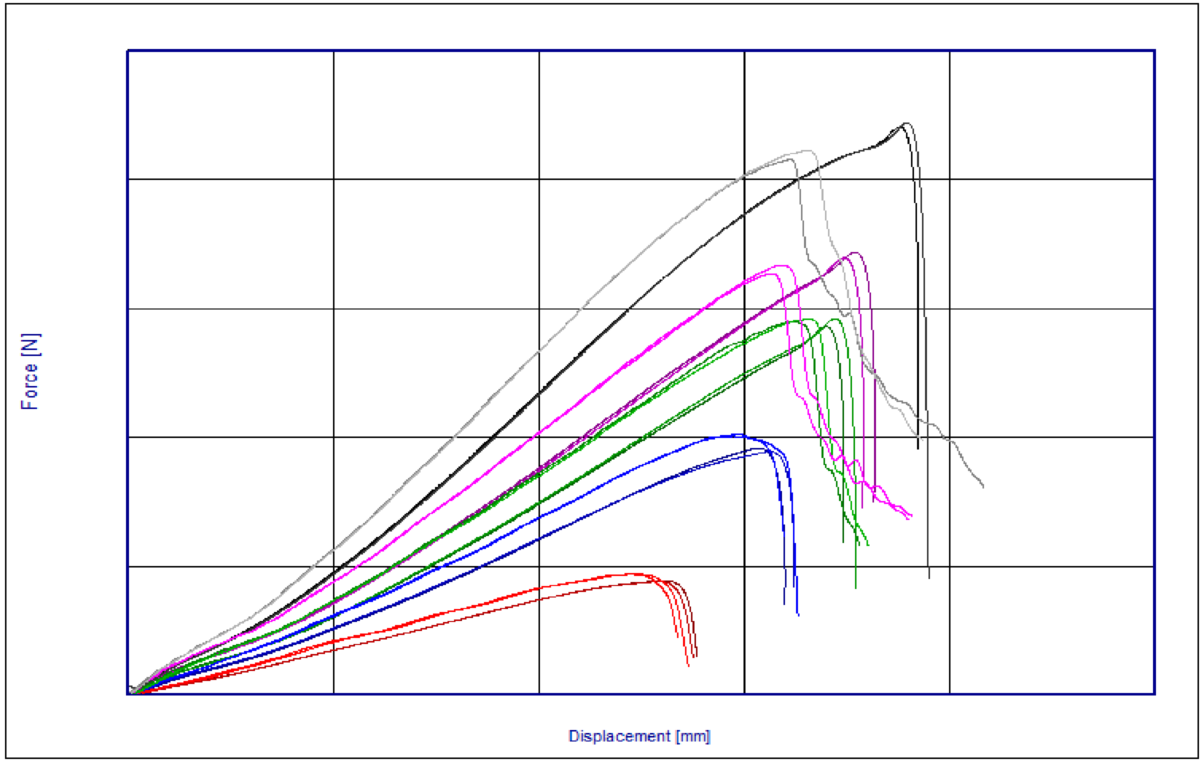

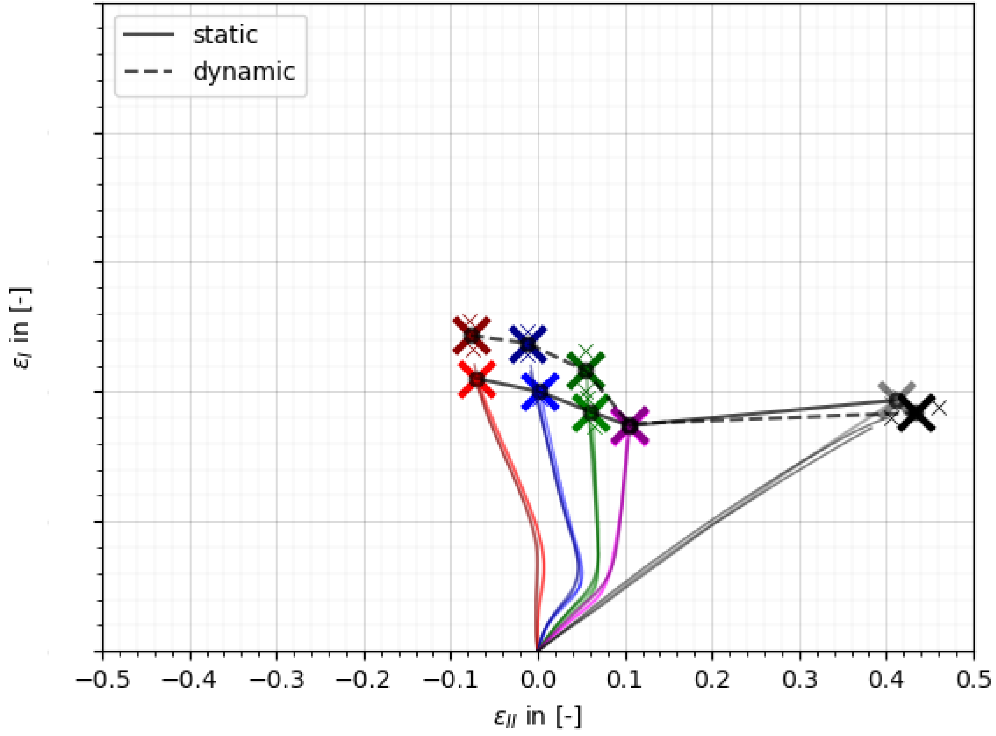

Case	v_0 [m/s]	$l_{w⌀}$ [mm]	b [mm]	t [mm]	Impactor ⌀ [mm]
Nakajima-5mm	**0.001**	**26**	**5.14**	**0.79**	**12.7**
Nakajima-10mm	**0.001**	**26**	**10.14**	**0.79**	**12.7**
Nakajima-15mm	**0.001**	**26**	**15.14**	**0.79**	**12.7**
Nakajima-20mm	**0.001**	**26**	**20.12**	**0.79**	**12.7**
Nakajima-full	**0.001**	**26**	**20.12**	**0.79**	**12.7**

Case	v_0 [m/s]	$l_{w⌀}$ [mm]	b [mm]	t [mm]	Impactor ⌀ [mm]
Nakajima-5mm	**1**	**26**	**5.14**	**0.79**	**12.7**
Nakajima-10mm	**1**	**26**	**10.14**	**0.79**	**12.7**
Nakajima-15mm	**1**	**26**	**15.14**	**0.79**	**12.7**
Nakajima-20mm	**1**	**26**	**20.12**	**0.79**	**12.7**
Nakajima-full	**1**	**26**	**20.12**	**0.79**	**12.7**

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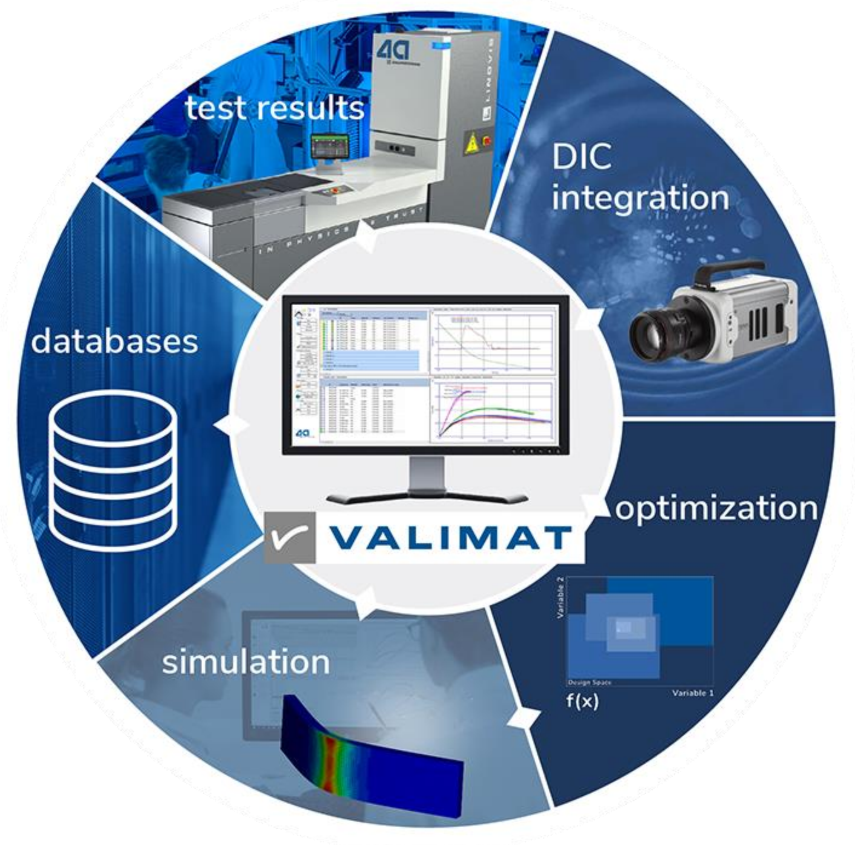
Advantages

- manage test results (import, export, filter, evaluation)
- statistics
- material card generation
  - automated parameter identification
  - complex models
- validation of material card
- database of test results and simulation data
  - direct link between test and simulation



https://www.4a-engineering.at/4a-valimat

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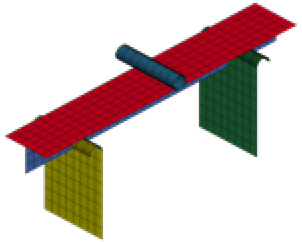
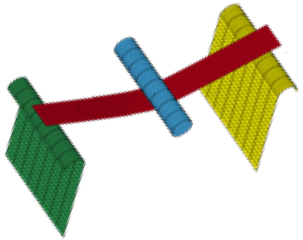
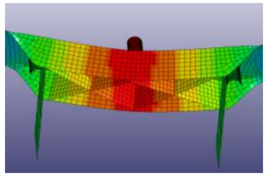
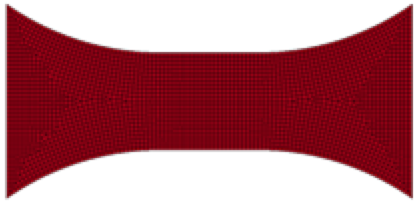


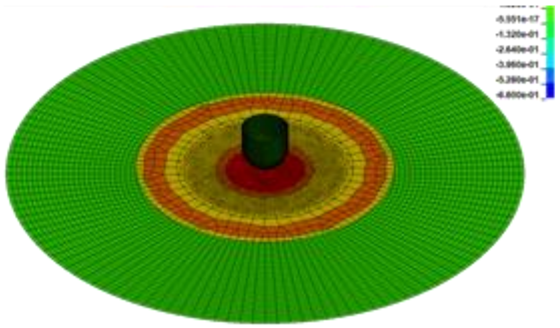


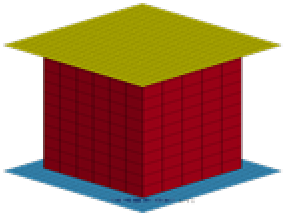


automated FE-model generation

VALIMAT







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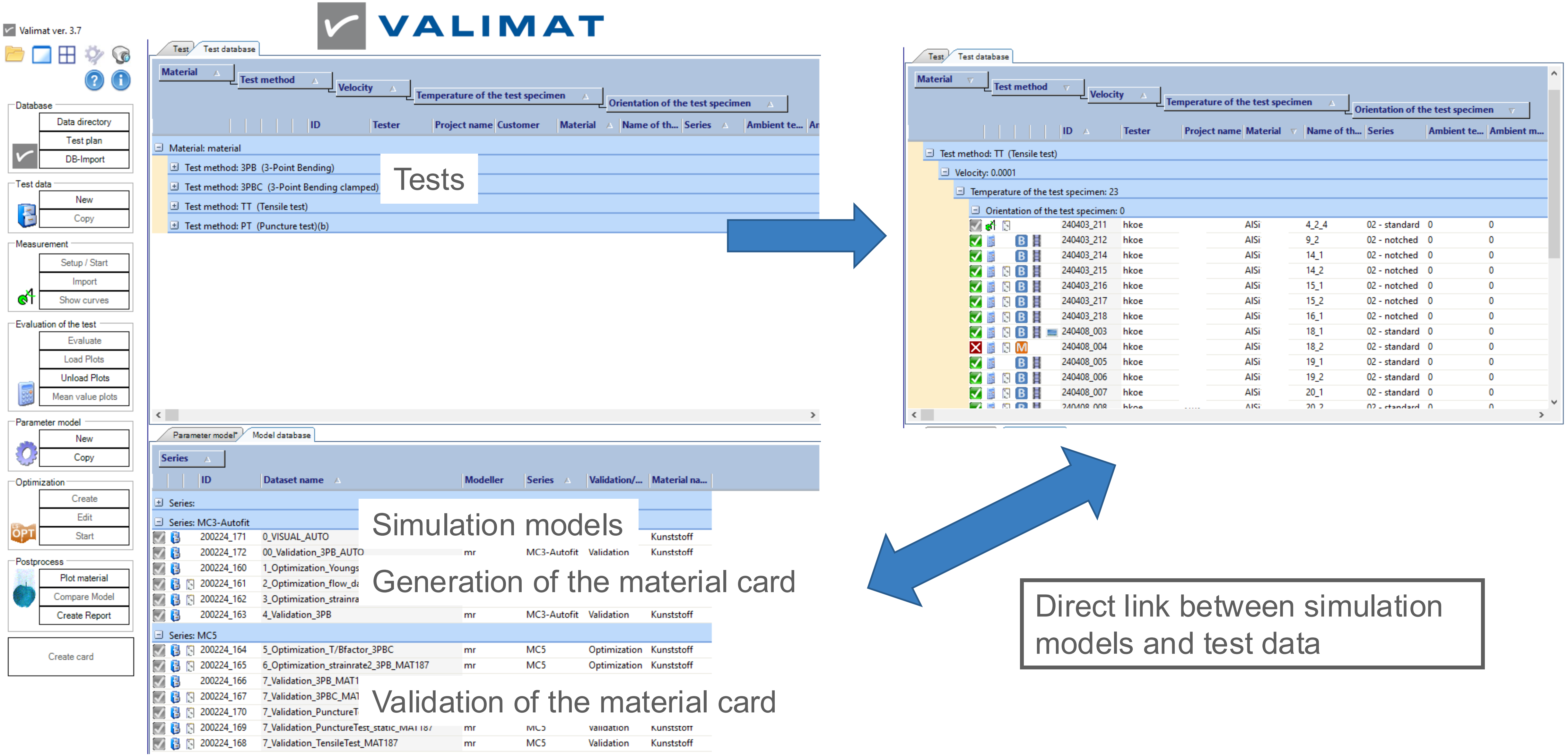

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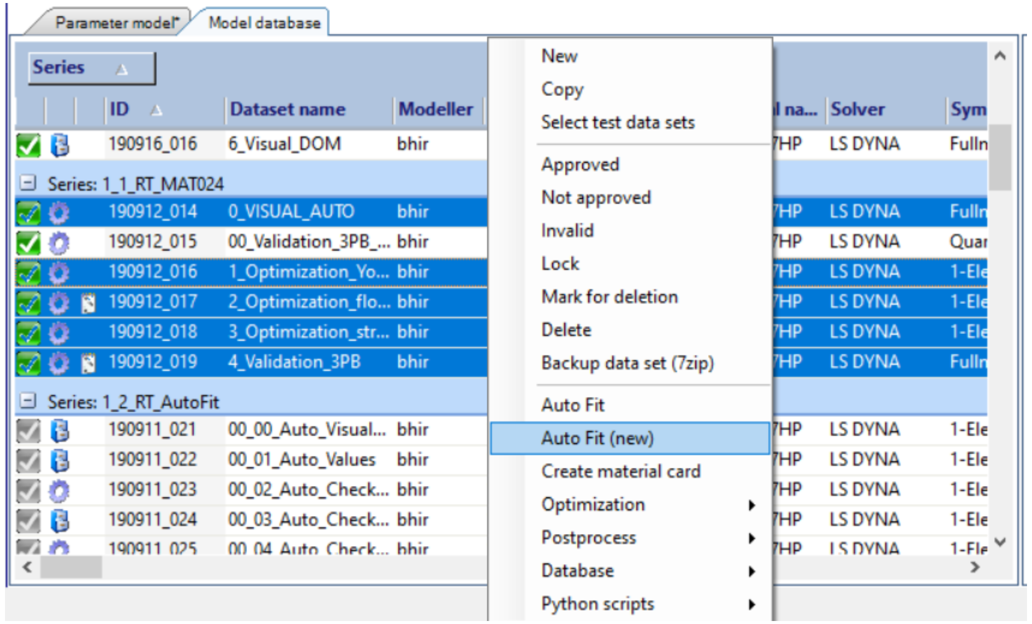

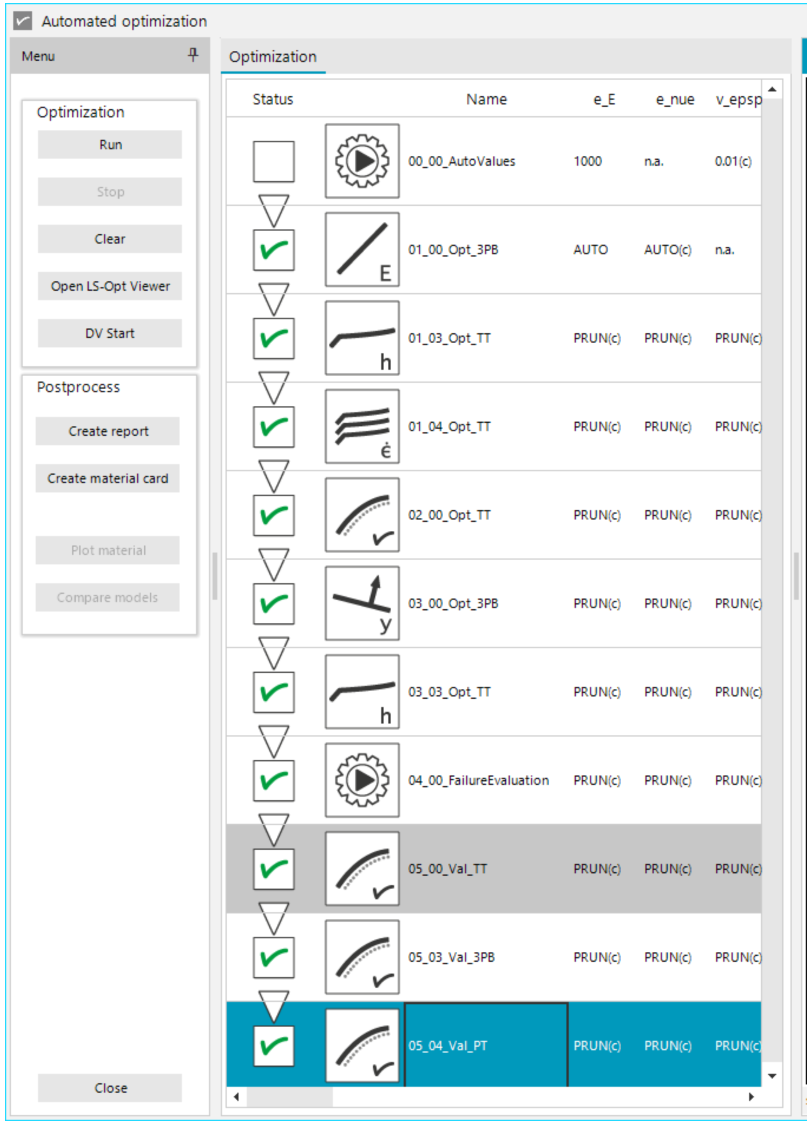

AutoFit workflow for automated parameter identification

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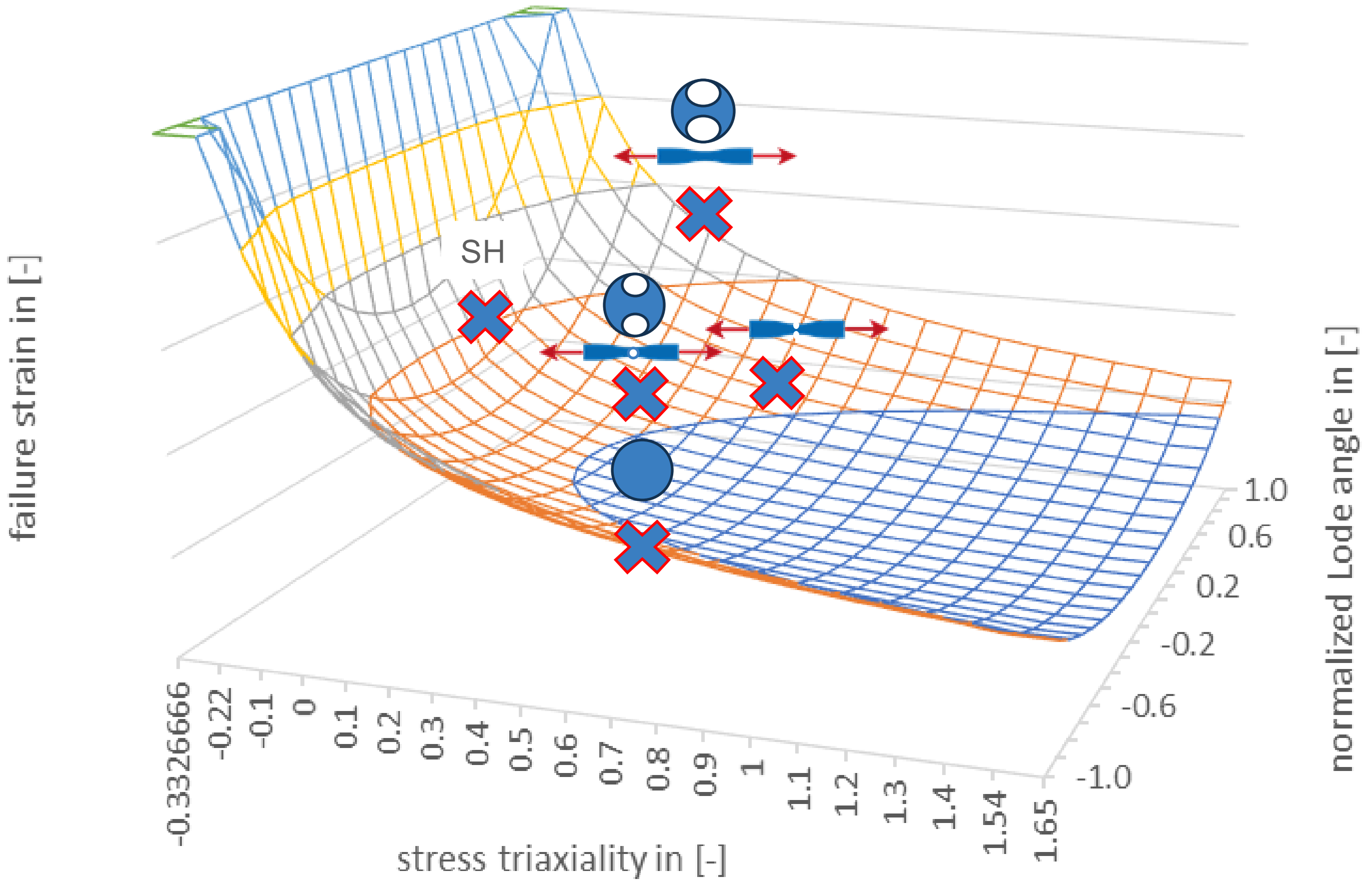
Generalized failure surface



- Failure surface also depends on stress state: 3D solid elements vs. Shell elements (plane stress)

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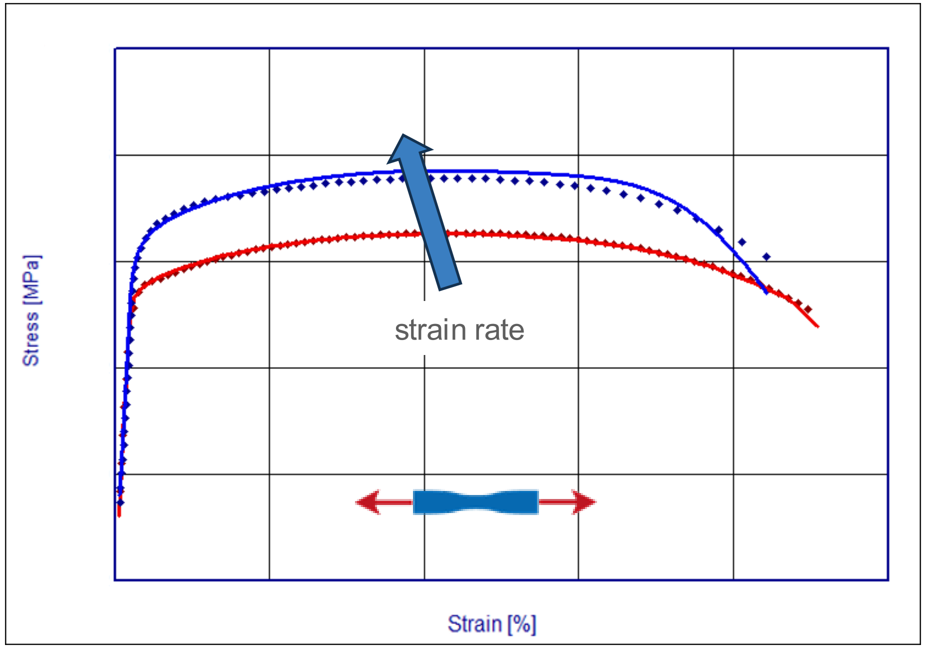
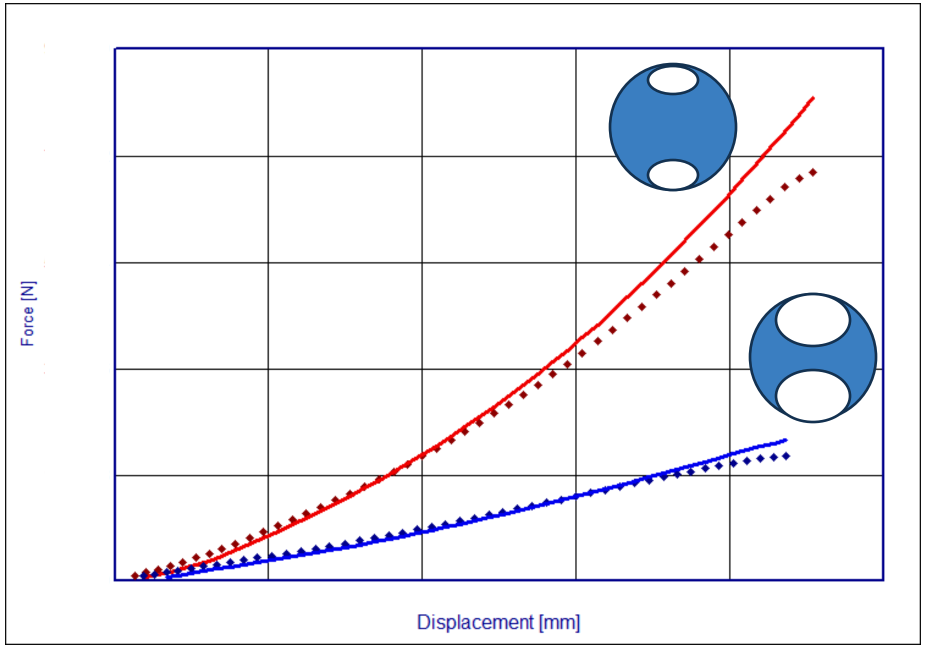
Correlation between simulation and test





— simulation result

♦ ♦ ♦ average curve of test results

Thank you!

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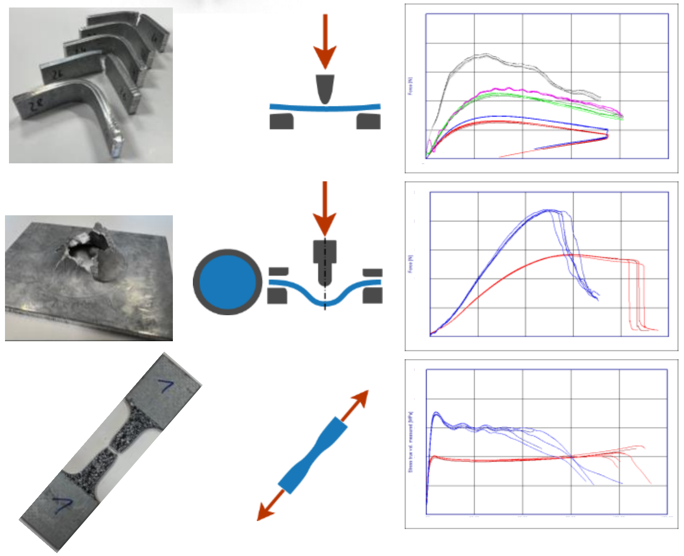

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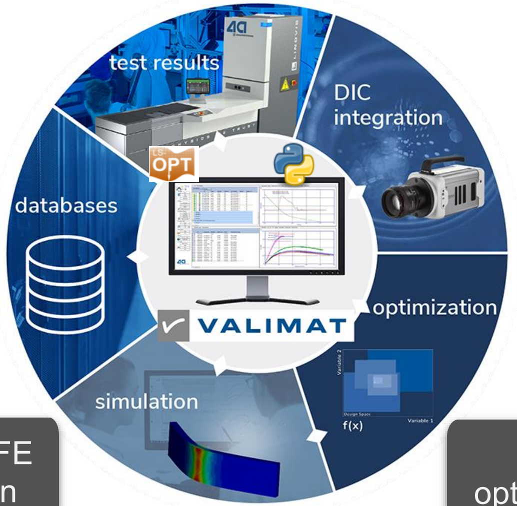

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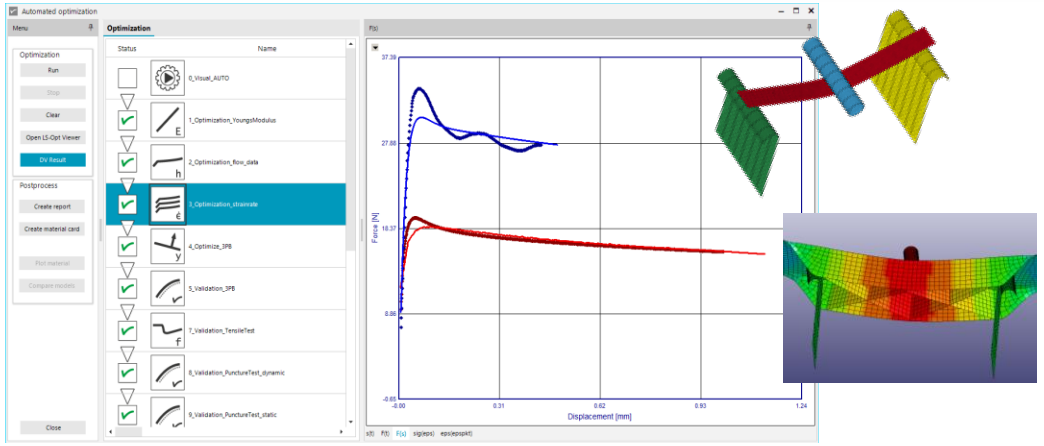

Validation and implementation to bigger models