

Digital Twin Material Characterization of Dual- Phase Steels using LINOVIS

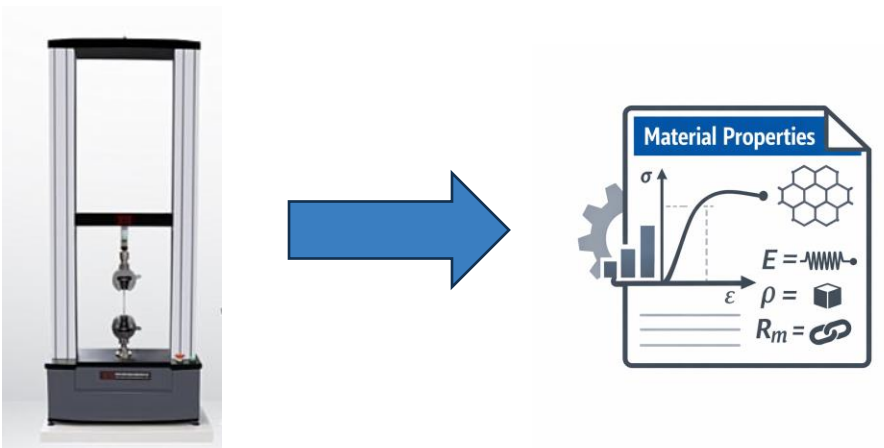
From Strain-Rate Effects to Automated
3D-DIC Forming Limit Evaluation

Dr. Martin Schwab, 4a engineering

Dr. Akbar Farahani, eSavant

GREAT DESIGNS IN
STEEL™

Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS



Generate datasheets according to standards



Missing link to simulation data input –
datasheet is not enough

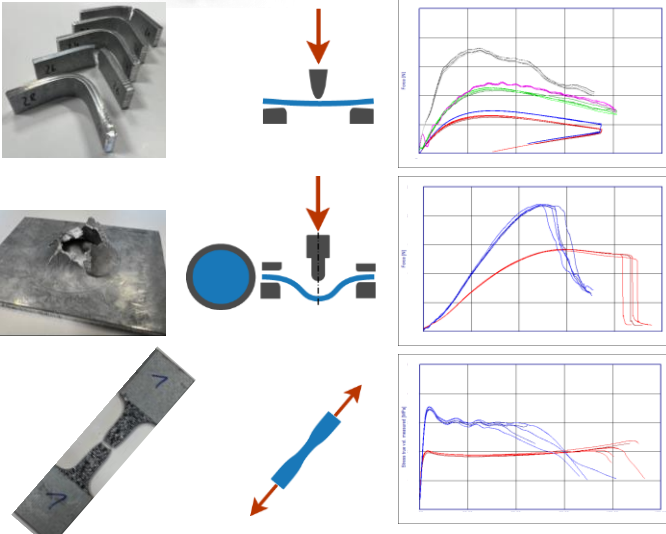
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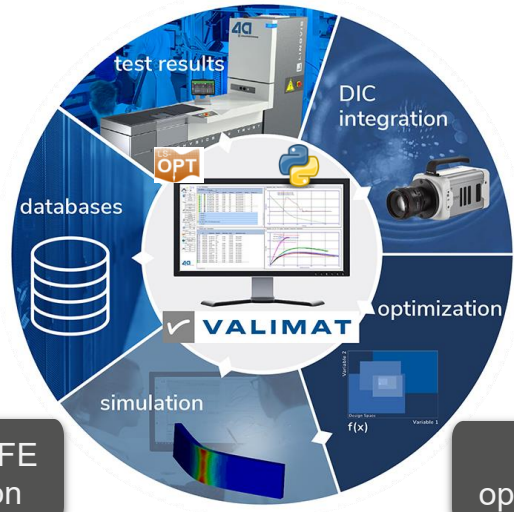
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Static and dynamic mechanical characterization

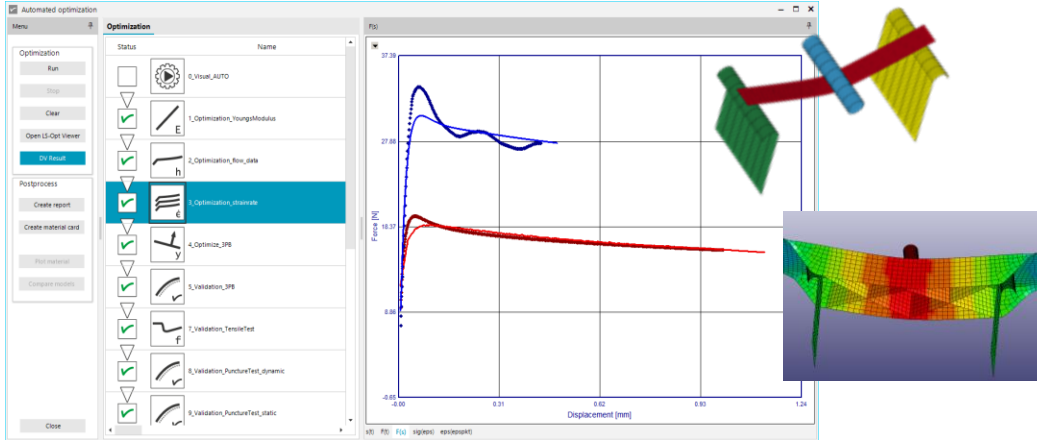


Modelling and parameter identification

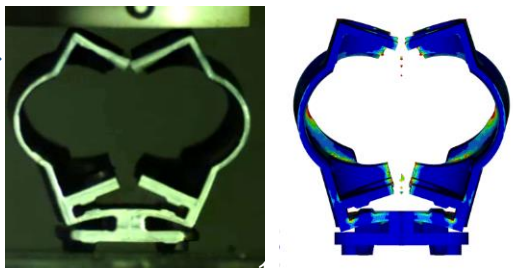


Fully automated FE model generation

Automated optimization workflows



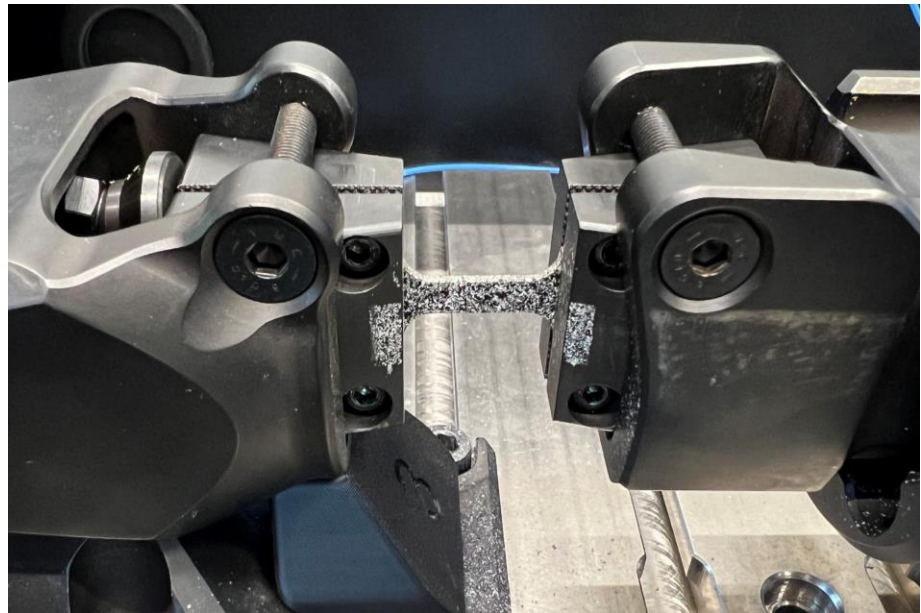
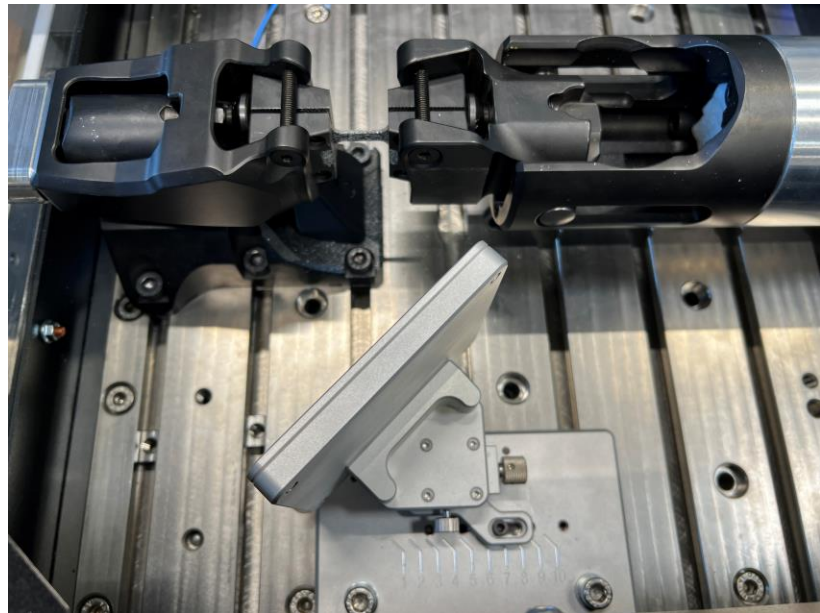
Validation and implementation to bigger models



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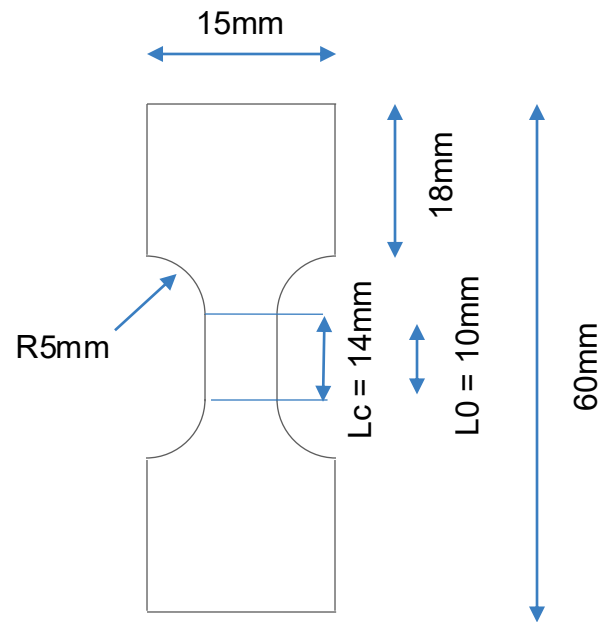


Tensile Test Setup



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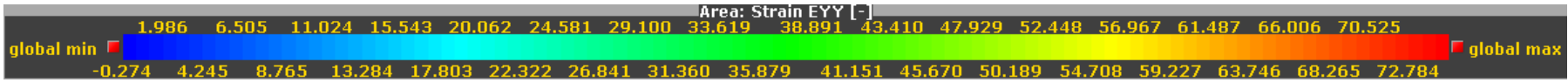
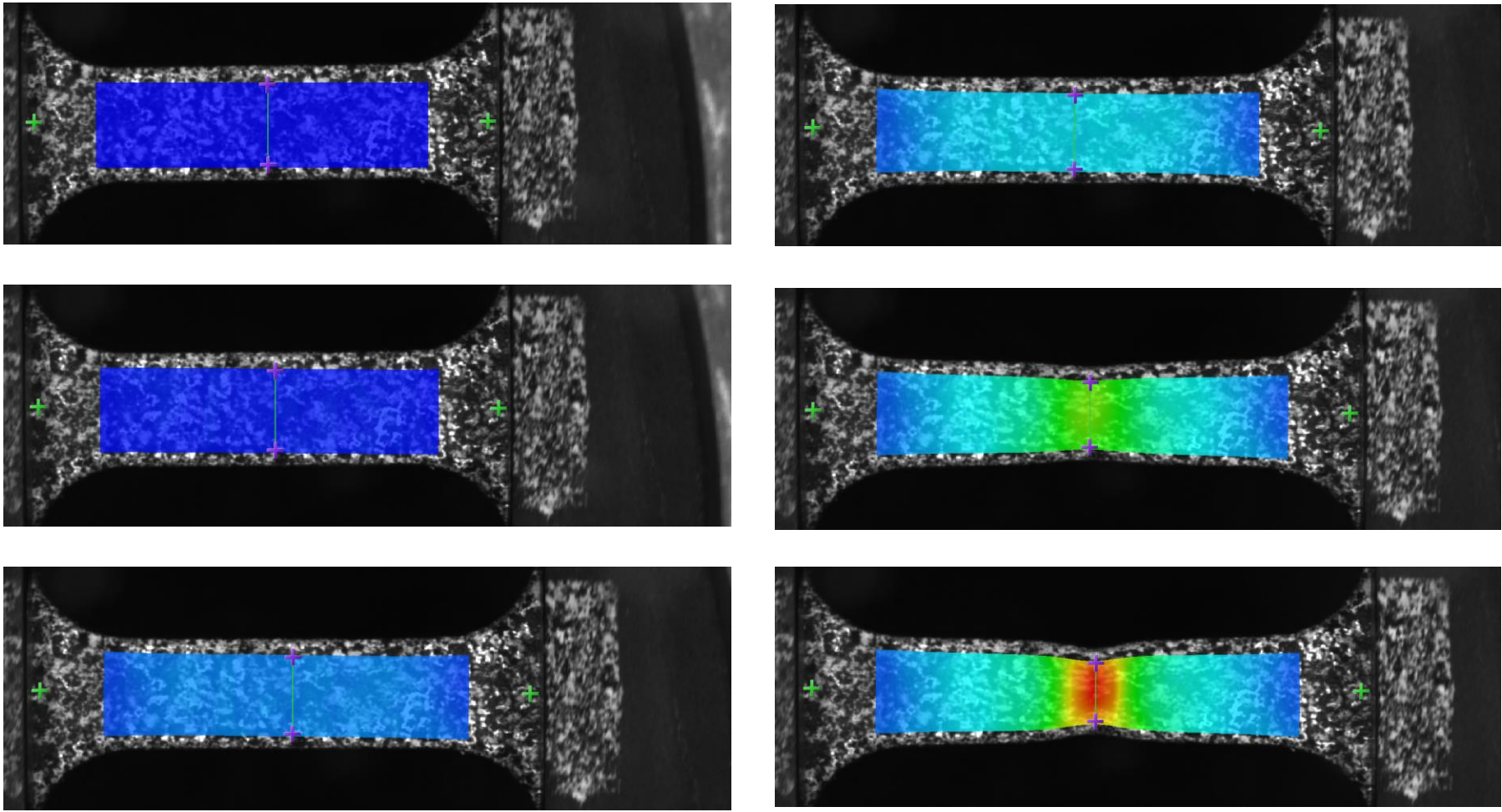
Tensile Test – Proposed Specimen Geometry for High Strain Rates



- 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

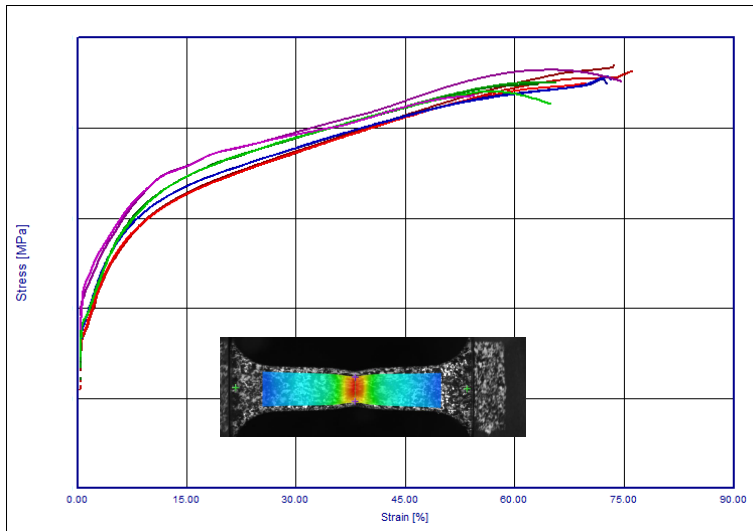


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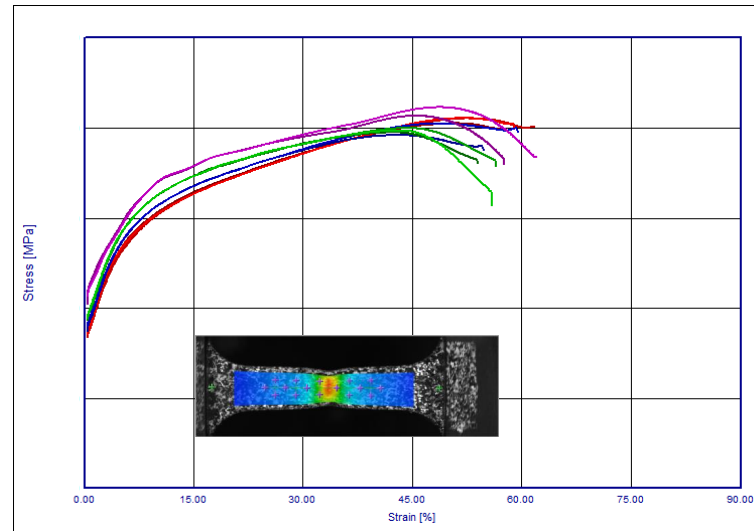


Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS

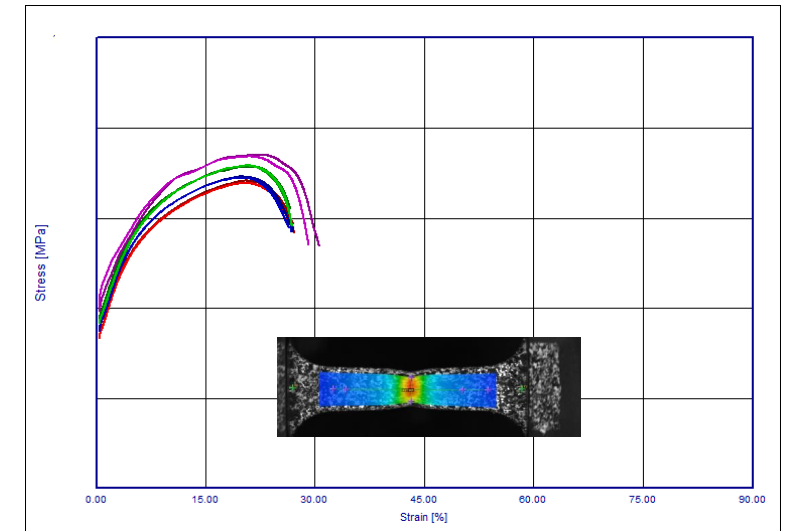
True stress-strain
 $L_0 = 0.47\text{mm}$ (DIC)



True stress-strain
 $L_0 = 2\text{mm}$ (DIC)



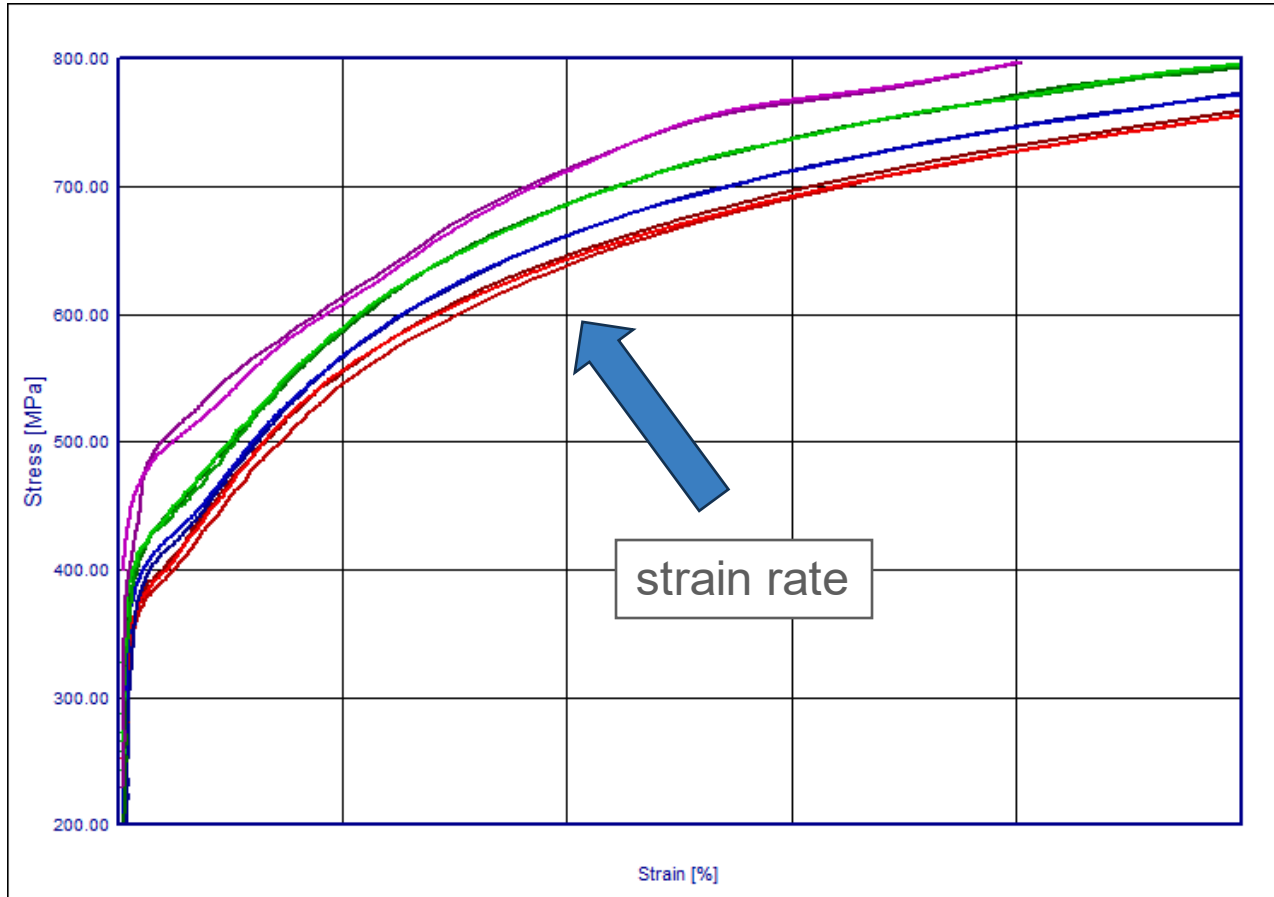
True stress-strain
 $L_0 = 14\text{mm}$ (DIC)



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

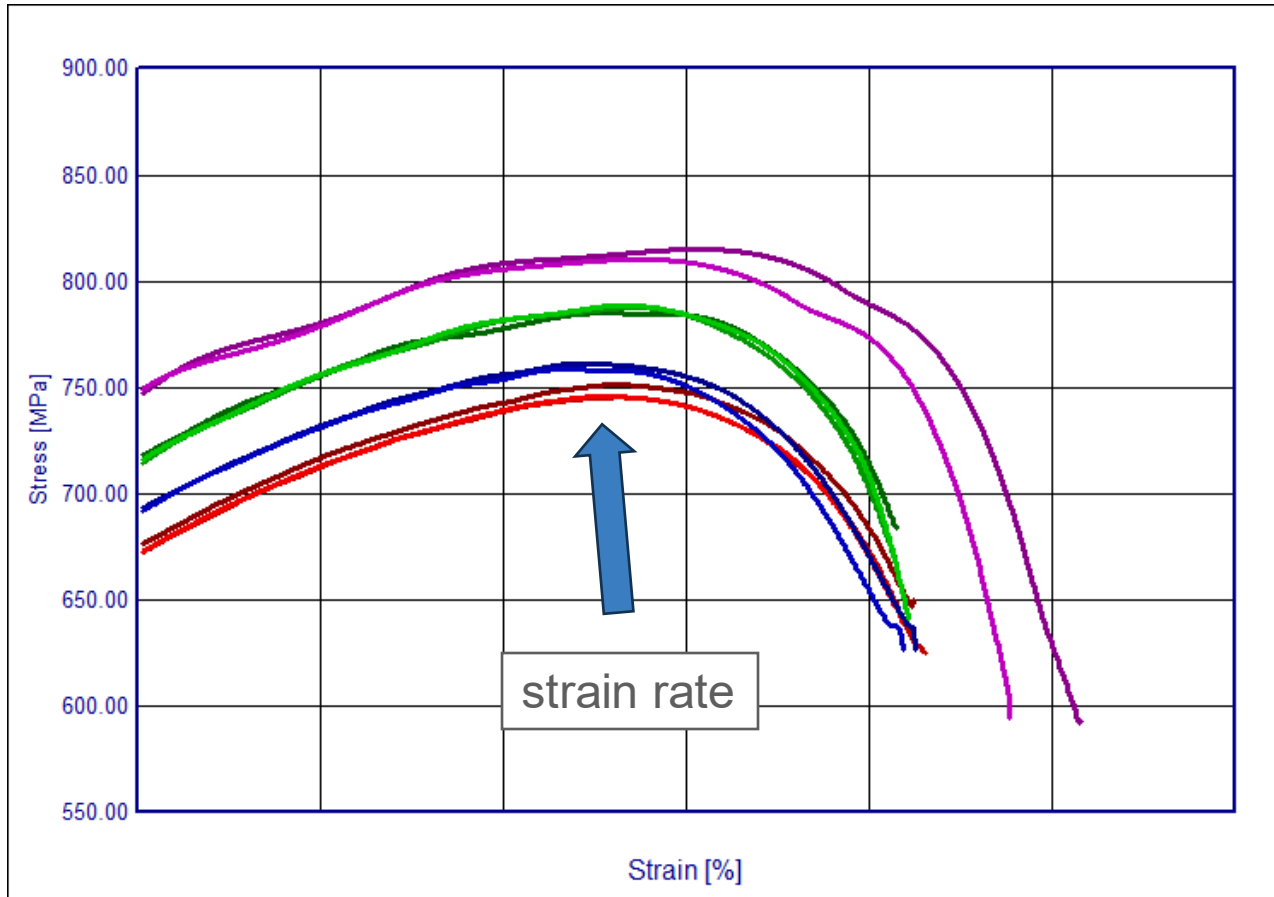
→ Consider FEM discretization (target element size) with regards to fracture modelling

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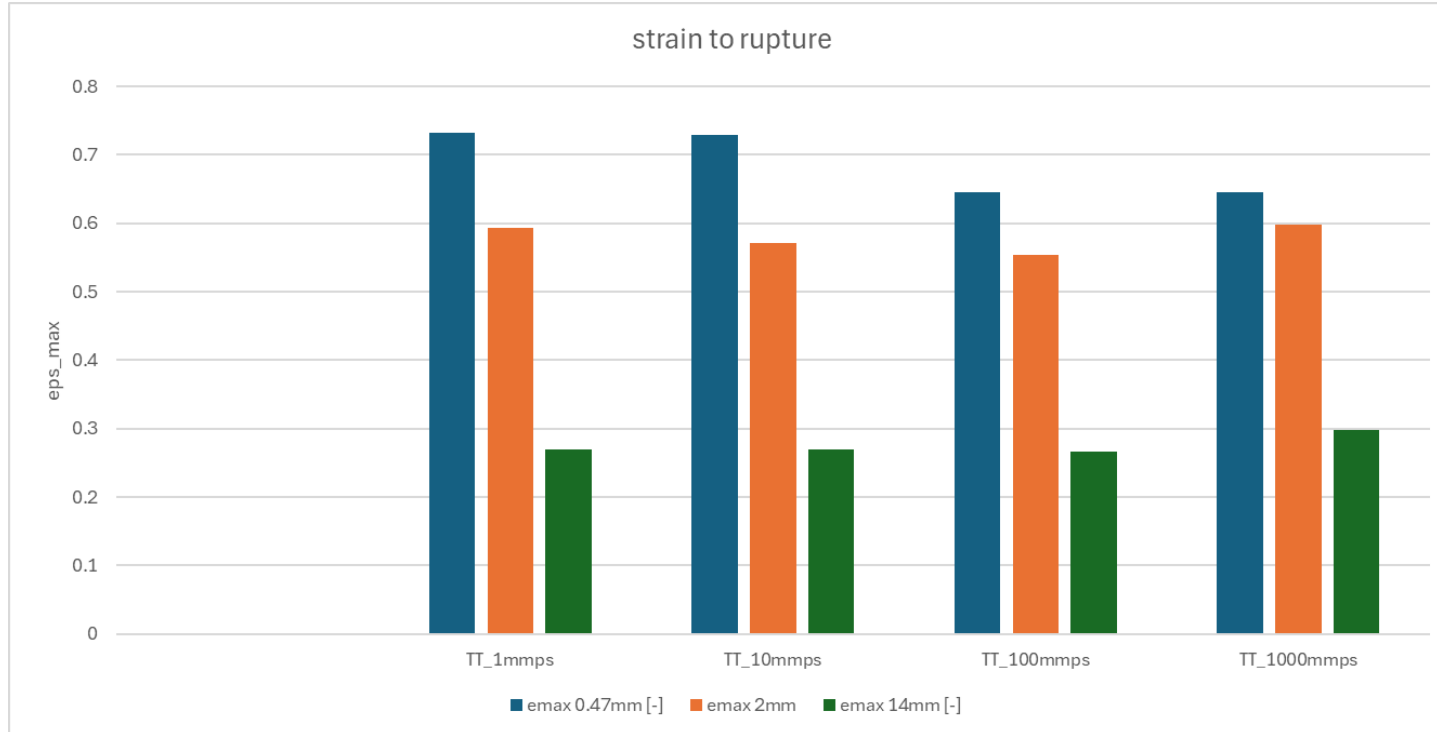
- **Increase of yield strength** by about 100 Mpa (> 20%) from quasi-static to high strain rate loading

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

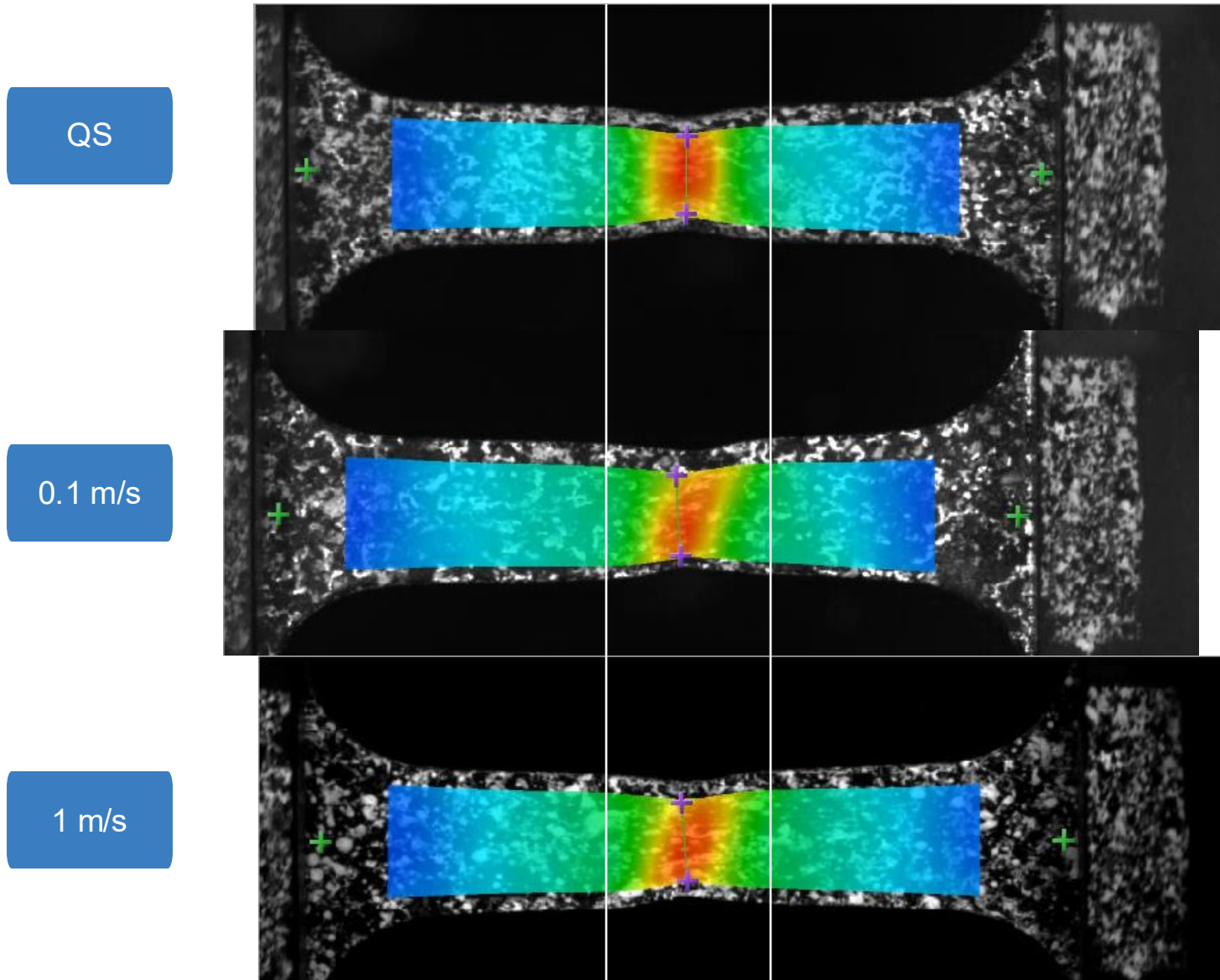
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Strain to rupture:

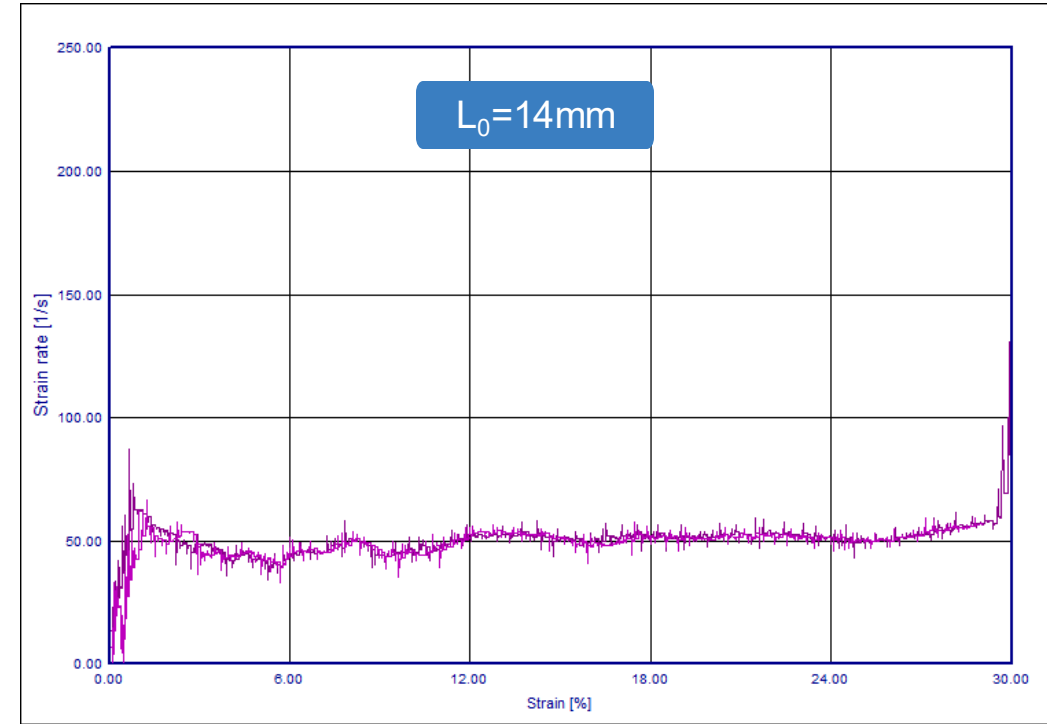
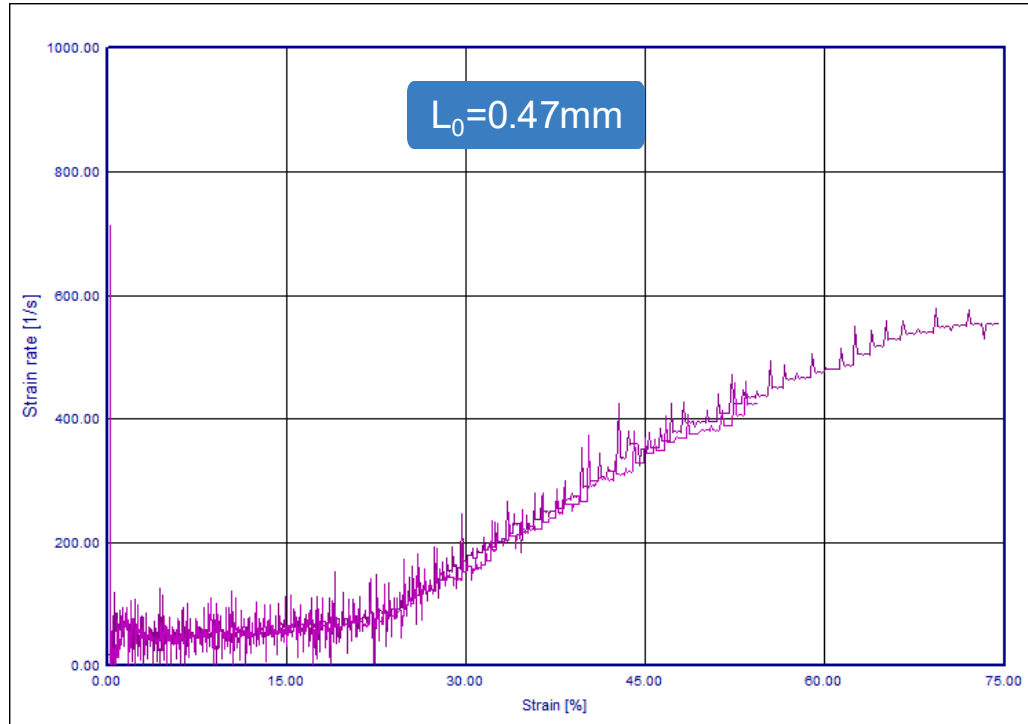
- Local evaluation within necking zone: strain to rupture decreases with increasing strain rate
- Longer gauge lengths: no significant change / slight increase at highest strain rate
- → indication that necking area is increasing with strain rate

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- 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

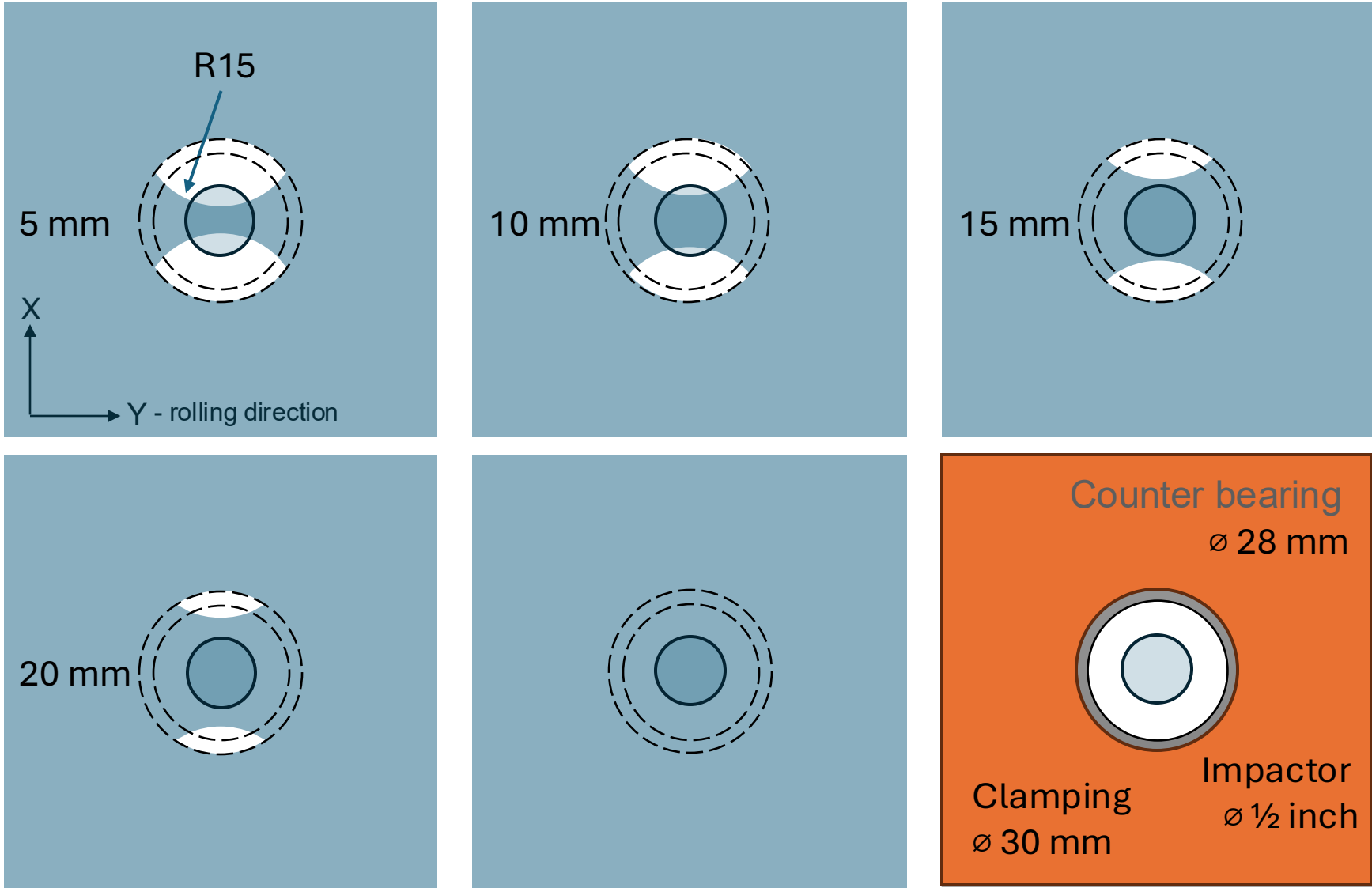
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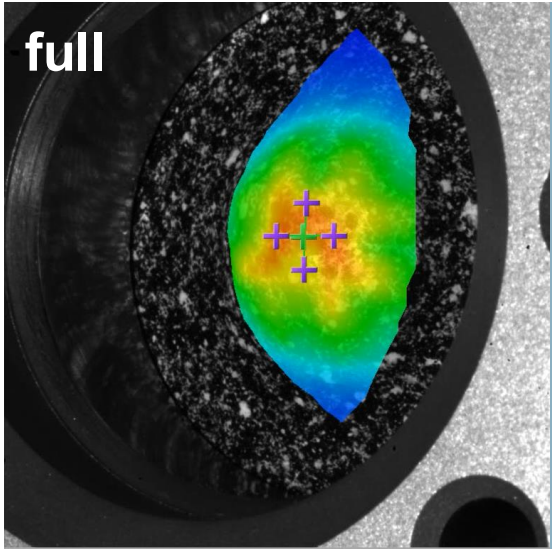
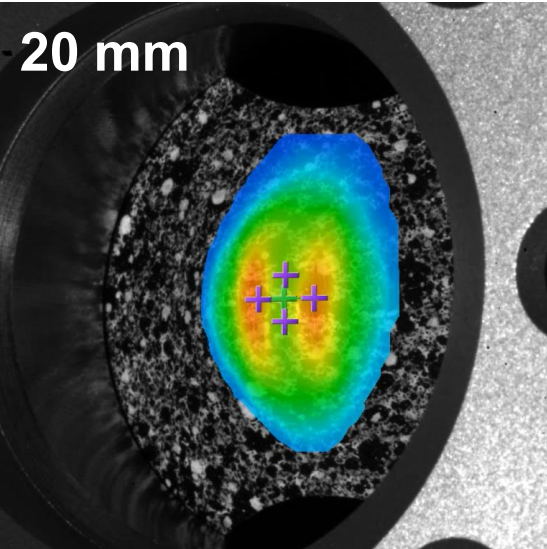
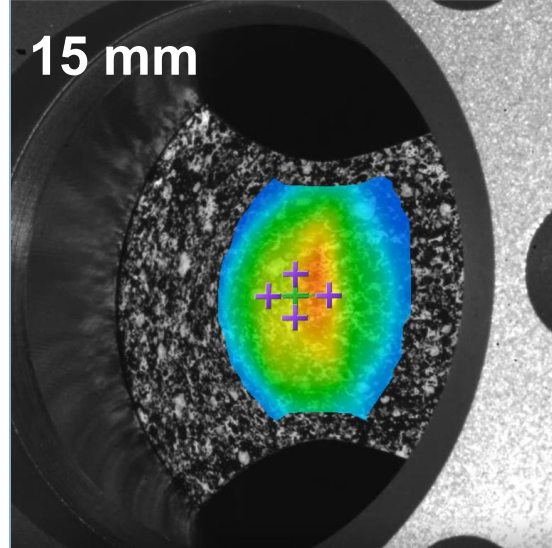
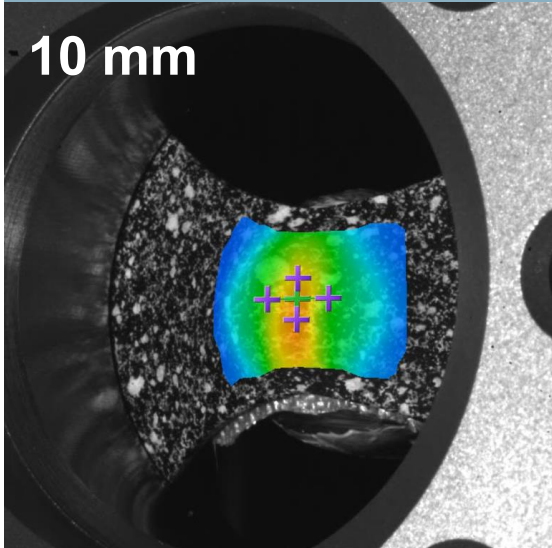
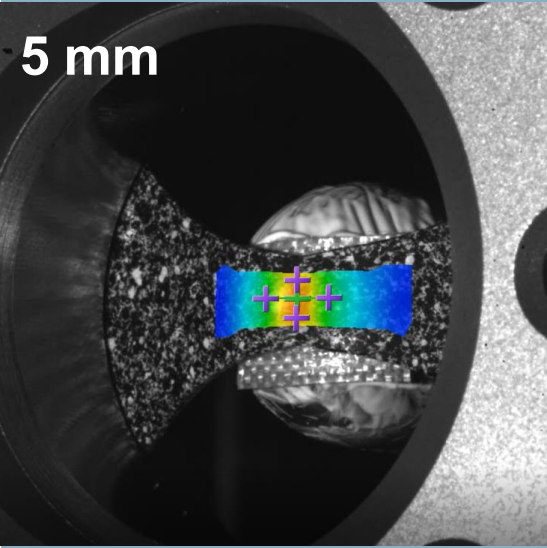
1 m/s tensile test – evaluation of strain rate:

- 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

Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS



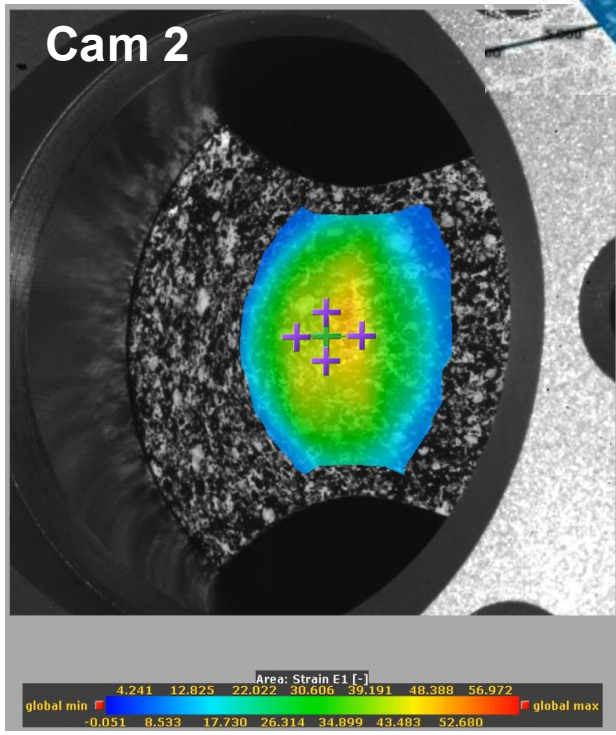
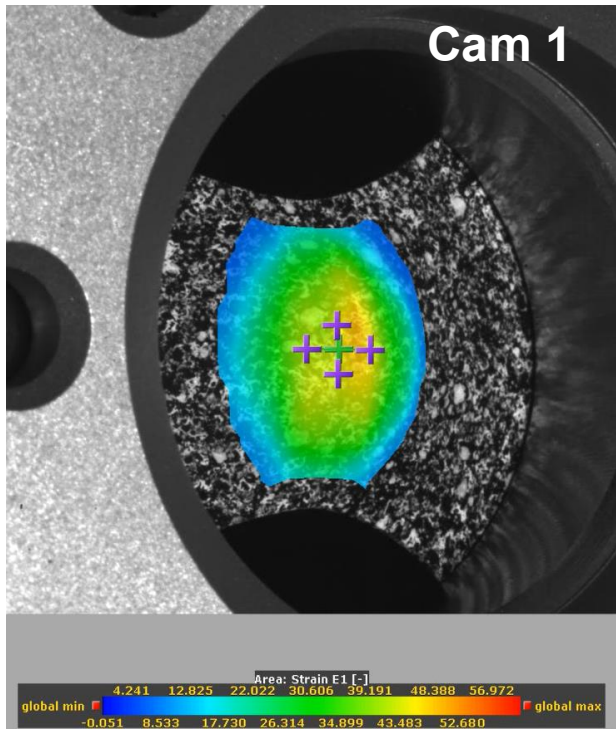
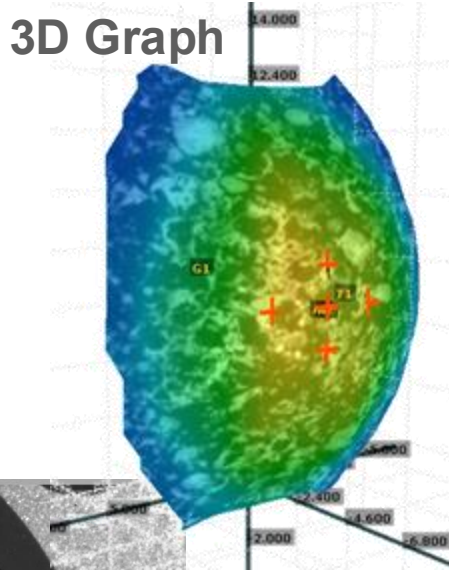
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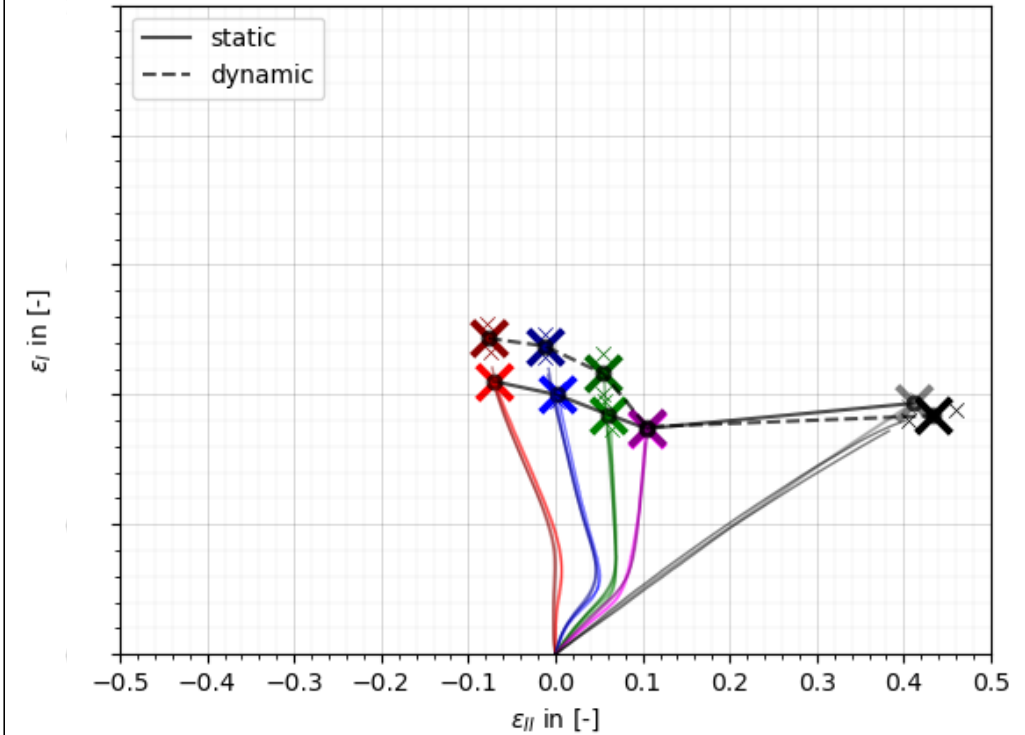
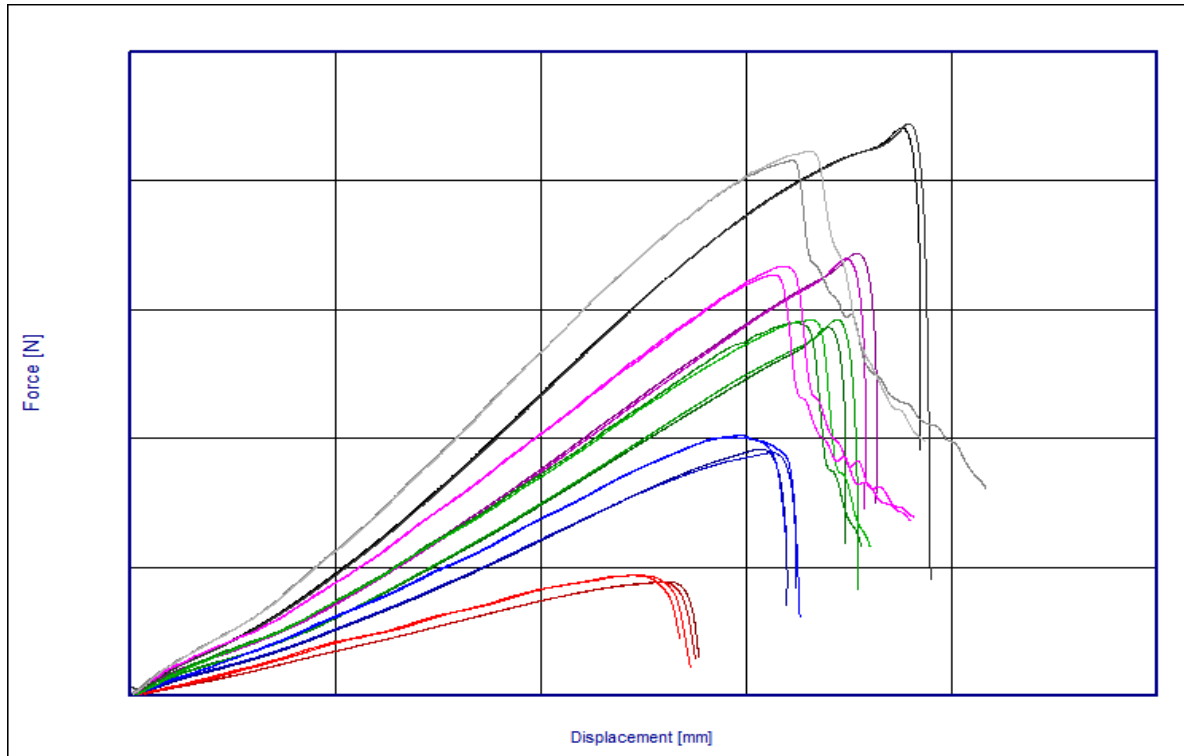
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Local strain measurement: 3D DIC
Gauge length L_0 : 2 mm
Frame rate: 15.000 fps
Resolution: 768x768 px



Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS



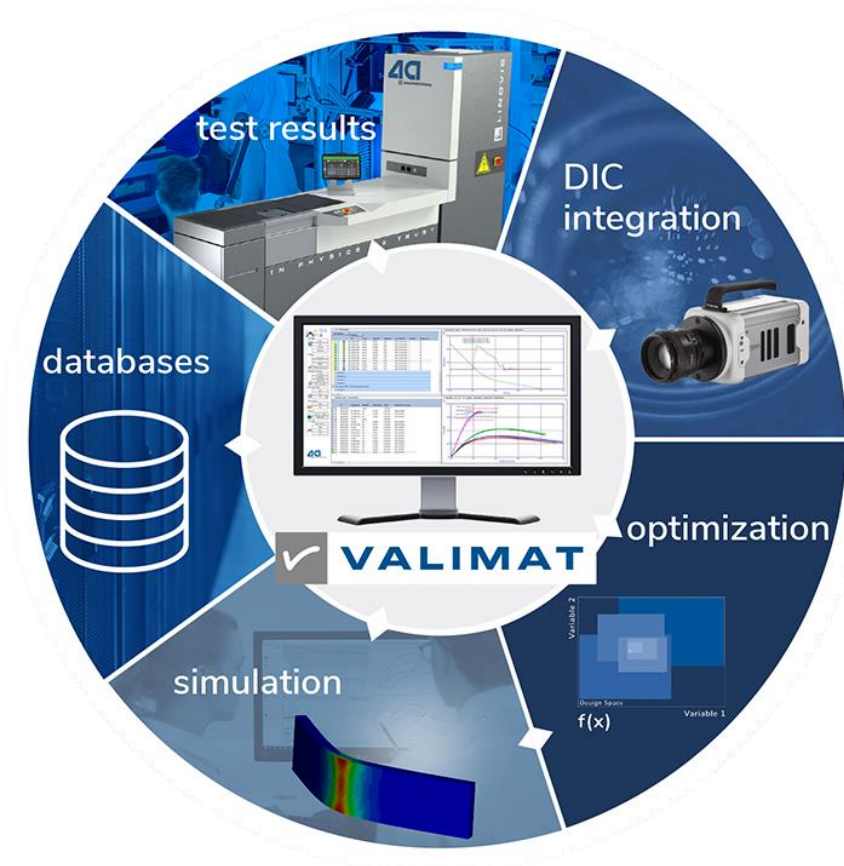
Case	v_0 [m/s]	$l_w \varnothing$ [mm]	b [mm]	t [mm]	Impactor \varnothing [mm]
Nakajima-5mm	0.001	26	5.14	0.79	12.7
Nakajima-10mm	0.001	26	10.14	0.79	12.7
Nakajima-15mm	0.001	26	15.14	0.79	12.7
Nakajima-20mm	0.001	26	20.12	0.79	12.7
Nakajima-full	0.001	26	20.12	0.79	12.7

Case	v_0 [m/s]	$l_w \varnothing$ [mm]	b [mm]	t [mm]	Impactor \varnothing [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

Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS

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>

Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS



Valimat ver. 3.7

Database

- Data directory
- Test plan
- DB-Import

Test data

- New
- Copy

Measurement

- Setup / Start
- Import
- Show curves

Evaluation of the test

- Evaluate
- Load Plots
- Unload Plots
- Mean value plots

Parameter model

- New
- Copy

Optimization

- Create
- Edit
- Start

Postprocess

- Plot material
- Compare Model
- Create Report

Create card

Test Test database

Material Test method Velocity Temperature of the test specimen Orientation of the test specimen

ID	Tester	Project name	Customer	Material	Name of th...	Series	Ambient te...	Ambient m...
Material: material								
Test method: 3PB (3-Point Bending)								
Test method: 3PBC (3-Point Bending clamped)								
Test method: TT (Tensile test)								
Test method: PT (Puncture test)(b)								

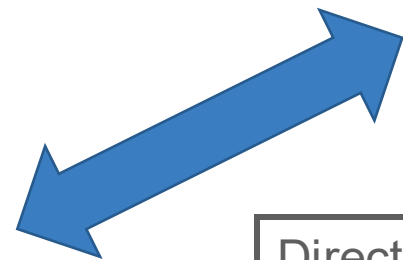
Tests



Test Test database

Material Test method Velocity Temperature of the test specimen Orientation of the test specimen

ID	Tester	Project name	Material	Name of th...	Series	Ambient te...	Ambient m...	
Test method: TT (Tensile test)								
Velocity: 0.0001								
Temperature of the test specimen: 23								
Orientation of the test specimen: 0								
240403_211	hkoe		AlSi	4_2_4	02 - standard	0	0	
240403_212	hkoe		AlSi	9_2	02 - notched	0	0	
240403_214	hkoe		AlSi	14_1	02 - notched	0	0	
240403_215	hkoe		AlSi	14_2	02 - notched	0	0	
240403_216	hkoe		AlSi	15_1	02 - notched	0	0	
240403_217	hkoe		AlSi	15_2	02 - notched	0	0	
240403_218	hkoe		AlSi	16_1	02 - notched	0	0	
240408_003	hkoe		AlSi	18_1	02 - standard	0	0	
240408_004	hkoe		AlSi	18_2	02 - standard	0	0	
240408_005	hkoe		AlSi	19_1	02 - standard	0	0	
240408_006	hkoe		AlSi	19_2	02 - standard	0	0	
240408_007	hkoe		AlSi	20_1	02 - standard	0	0	
240408_008	hkoe		AlSi	20_2	02 - standard	0	0	



Parameter model Model database

Series

ID	Dataset name	Modeller	Series	Validation/...	Material na...
Series:					
Series: MC3-Autofit					
200224_171	0_VISUAL_AUTO				Kunststoff
200224_172	00_Validation_3PB_AUTO	mr	MC3-Autofit	Validation	Kunststoff
200224_160	1_Optimization_Youngs				
200224_161	2_Optimization_flow_d				
200224_162	3_Optimization_strainr				
200224_163	4_Validation_3PB	mr	MC3-Autofit	Validation	Kunststoff
Series: MC5					
200224_164	5_Optimization_T/Bfactor_3PBC	mr	MC5	Optimization	Kunststoff
200224_165	6_Optimization_strainrate2_3PB_MAT187	mr	MC5	Optimization	Kunststoff
200224_166	7_Validation_3PB_MAT1				
200224_167	7_Validation_3PBC_MAT1				
200224_170	7_Validation_PunctureT				
200224_169	7_Validation_PunctureTest_static_MAT187	mr	MC5	Validation	Kunststoff
200224_168	7_Validation_TensileTest_MAT187	mr	MC5	Validation	Kunststoff

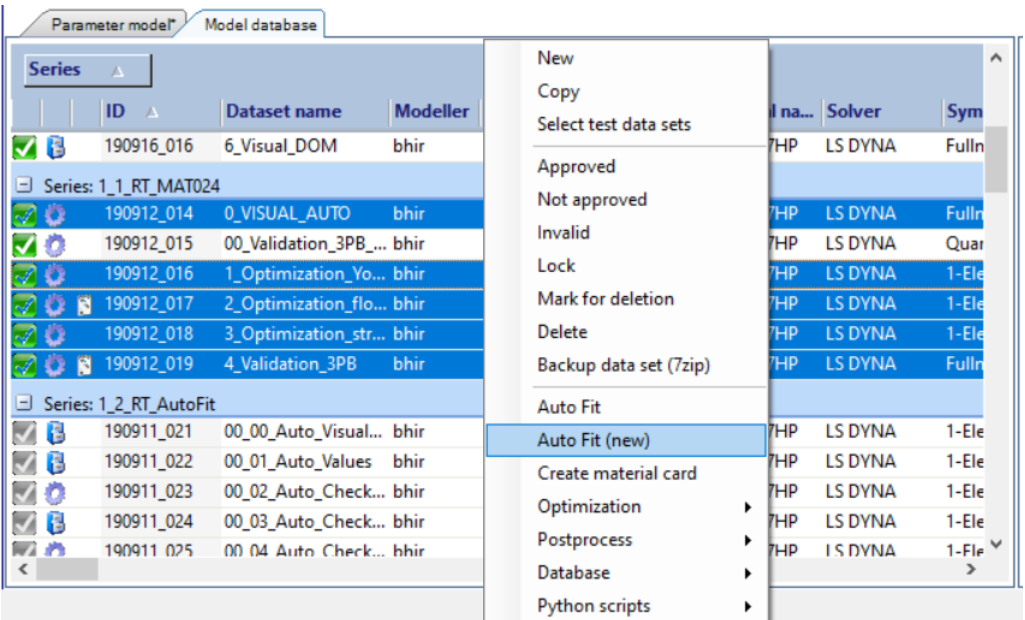
Simulation models

Generation of the material card

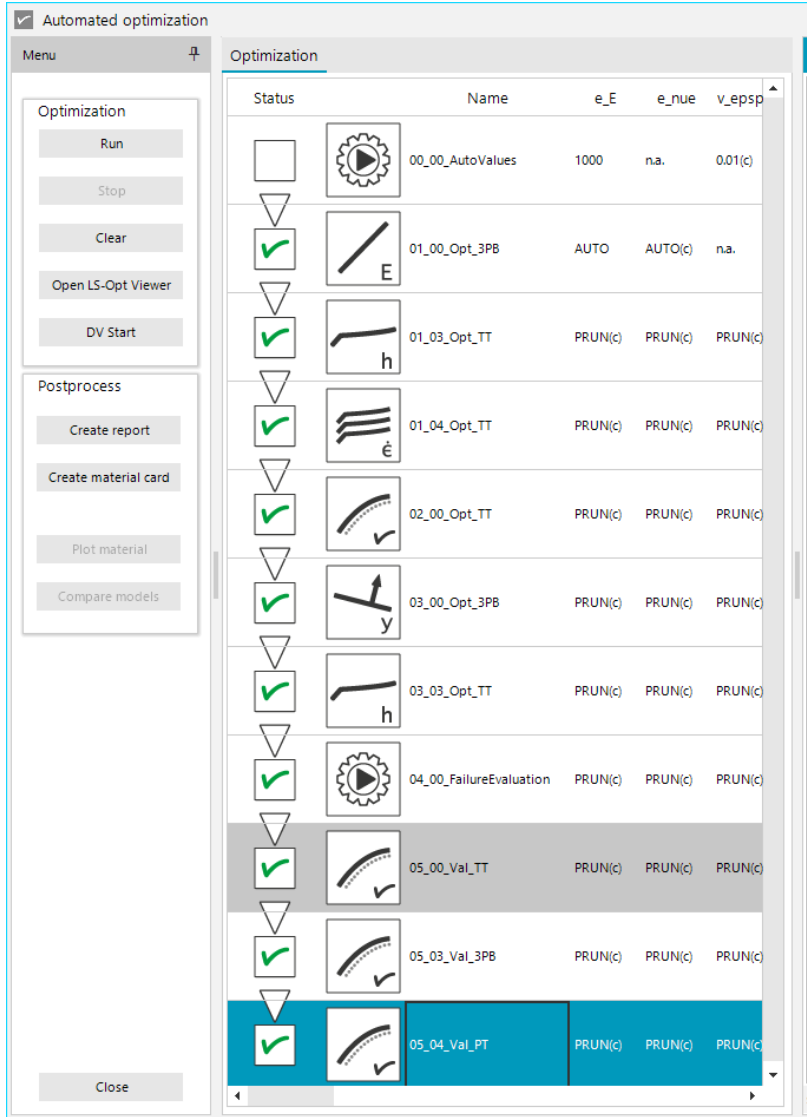
Validation of the material card

Direct link between simulation models and test data

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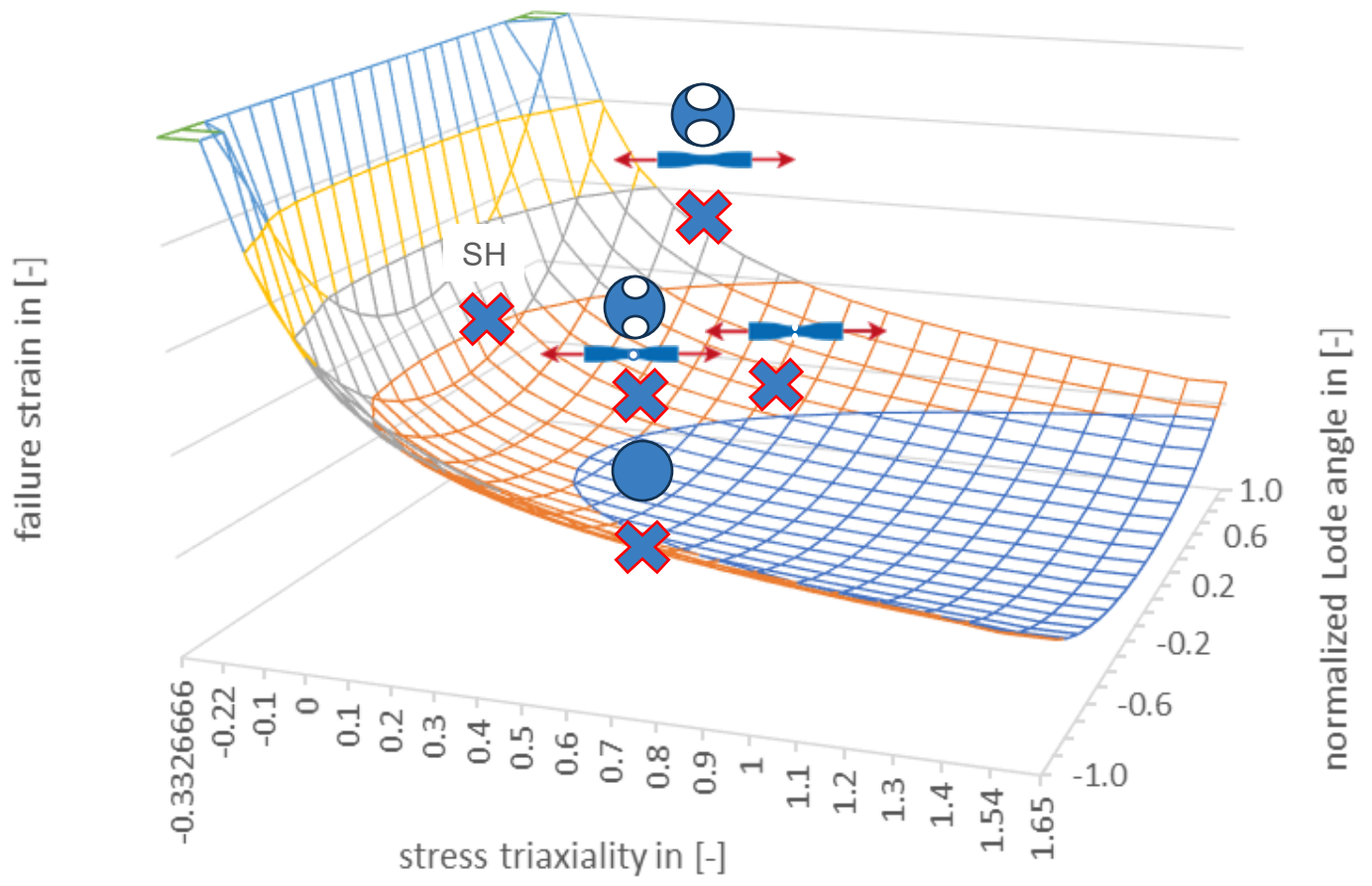
AutoFit workflow for automated parameter identification



Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS



Generalized failure surface

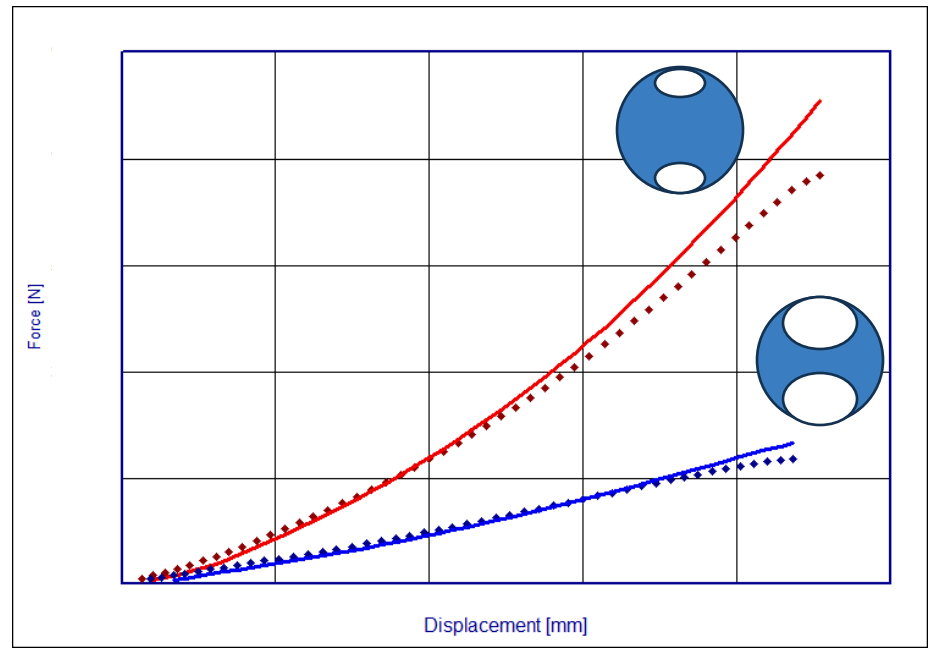
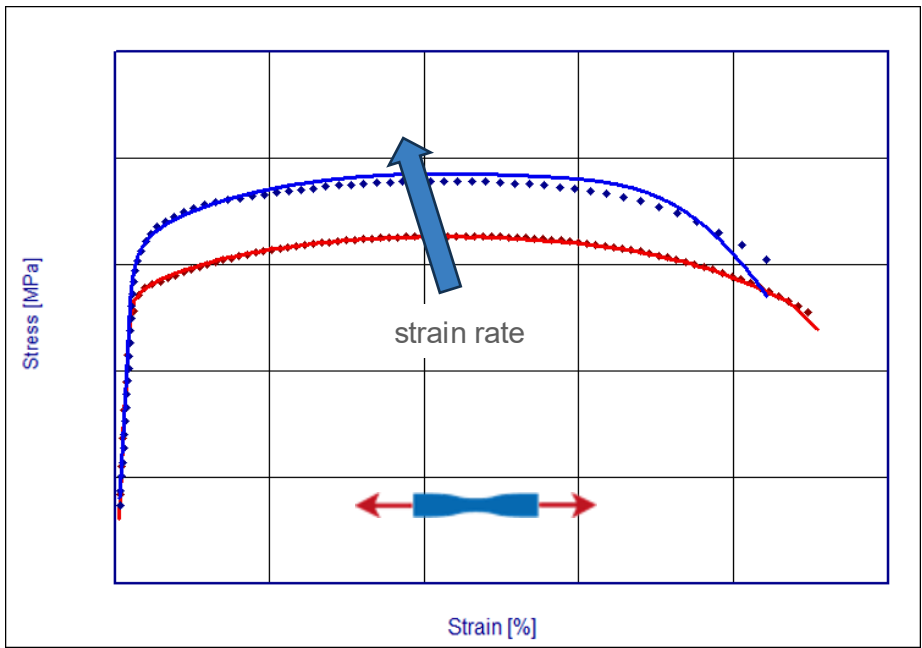


- Failure surface also depends on stress state: 3D solid elements vs. Shell elements (plane stress)

Digital Twin Material Characterization of Dual-Phase Steels using LINOVIS



Correlation between simulation and test



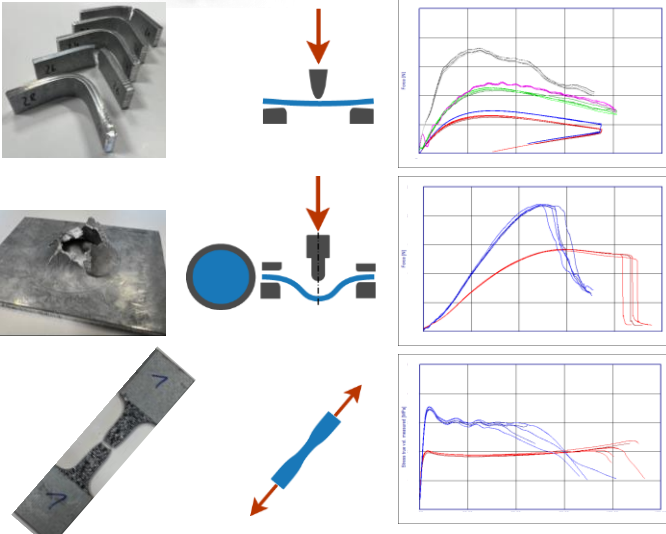
— simulation result
◆◆◆ average curve of test results

Thank you!

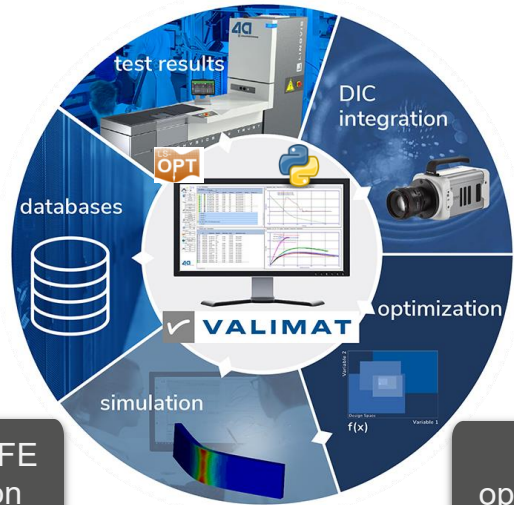
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Static and dynamic mechanical characterization

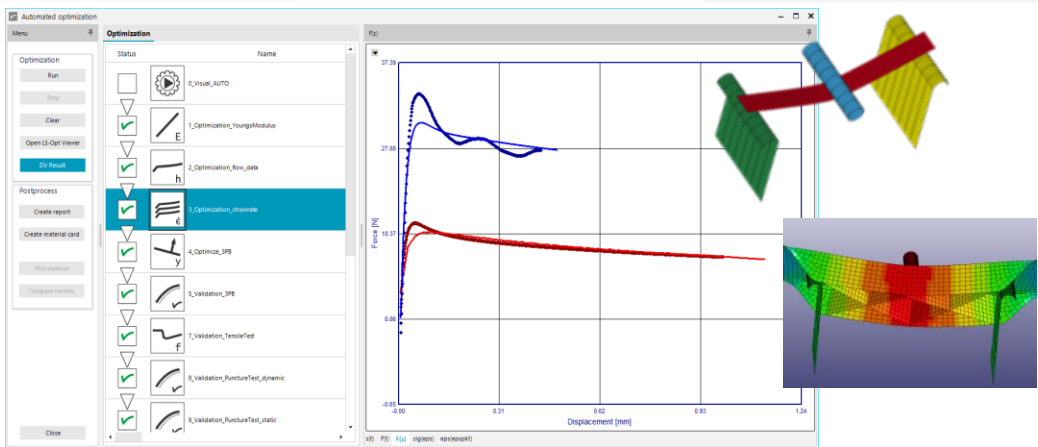


Modelling and parameter identification



Fully automated FE model generation

Automated optimization workflows



Validation and implementation to bigger models

