Zwick testXpo 2018

Determination of Material Parameters and Component Testing using Optical 3D Metrology

GOM GmbH| October 2018

GOM Headquarters

Founded in 1990

Private, owner managed company

Research and development, production and administration in Braunschweig, Germany

GOM Metrology Network

60 sites worldwide

1,000 metrology specialists

GOM Group with 8 companies and branches

Continuous growth to over 500 employees in GOM Group

GOM Metrology Network

GOM Support Hubs

Braunschweig, Germany
Shanghai, China
Charlotte, USA

GOM – Customers (Extract)

Automotive

Audi, Avtovaz, Bentley, BMW, Chrysler, Daihatsu Motor, Daimler, Fiat, Ford, GM, Honda, Hyundai , Isuzu, Jaguar, Kia, Land Rover, McLaren, Modenas, NAZA, Nissan, Opel, Porsche, PSA, Renault, Seat, Skoda, Subaru, Suzuki, Tata Motors, Toyota, VW, Volvo, Temsa, …

Automotive Suppliers

Automotive Lighting, Batz, Bertrandt, Bosch, Bombardier, Bridgestone, Carcoustics, DAAZ, Dräxlmaier, Faurecia, Georg Fischer, Gienanth, Goodyear, Hella, Johnson Controls, Kautex Textron, Michelin, Nothelfer, Pininfarina, Siemens, Thule, ThyssenKrupp, ZF Sachs, …

Aerospace

Airbus, Air Force Research Labs, Aselsan, Boeing, Cessna, Chrom Alloy, DLR, DNV, EADS, Eurocopter, FAA, FOI, Goodrich, Gorbynov Aviation, Hansen Transmissions, Hydro, IMPO, JAXA, Lockheed Martin, NASA, NLR, Northrop Grumman, ONERA, Vulcan Air, VZLÚ, …

Over 14,000 system installations worldwide

Turbines

ABB Turbo systems , Alstom, Aviadvigatel, BTL, Chromalloy, Elbar Sulzer, E.ON, GKN, Gorbynov Aviation, Honeywell, Howmet, IMA Dresden, MTU, Pratt & Whitney, Rolls Royce, Salut, Saturn, Siemens PG, Snecma, Solar Turbines, Triumph, Turbine Services, …

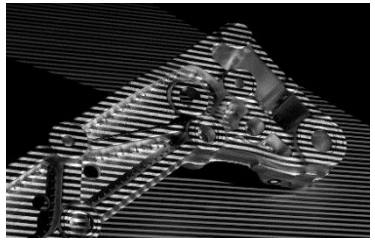
Consumer Goods

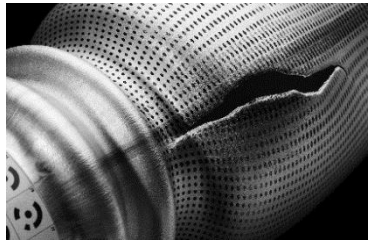
Adidas, Asics, ASUS, Blaupunkt, Bosch, Braun, Ching Luh Shoes, Ecco, FisherPrice, Foxconn, Fuji, Gillette, Greenpoint, Hilti, Lego, LG Electronic Mattel, Microsoft, Motorola, Nautor, Nike, Nokia, Philips, Reebok , Samsung, SANYO, Siemens, Sony, Stihl, Villeroy+Boch, Walt Disney, …

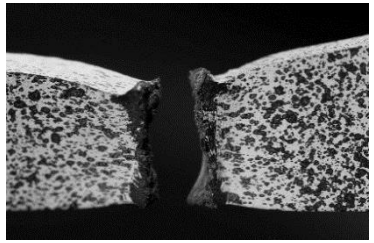
Material Supplier

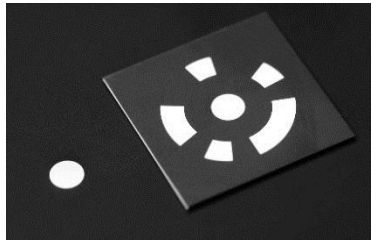
ACTech, Alfa Laval, Alcan (Alusuisse), Arcelor, , BASF, Bayer, Corning, DuPont, EXXON, Hydro (VAW), Pierburg Kolbenschmidt, Salzgitter, Shell, Tata Steel, Thyssen Krupp, Thyssen Nirosta, Tokai Rubber Industries, Voest Alpine Stahl, …

GOM – Our Know-how


Projected pattern


Regular pattern


Stochastic pattern


Point markers

Digital image processing
3D coordinate measuring technology
Quality control
Material parameters
Automation

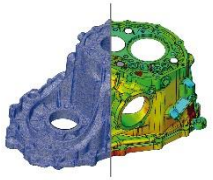
Customer-focused development of precise industrial 3D metrology

Establishing new approaches with GOM technologies in existing processes

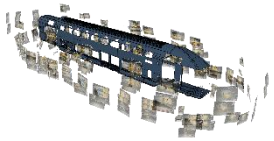
Deploy and support these processes worldwide

Products

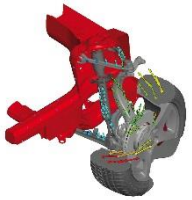
ATOS
Full-field
3D scanning



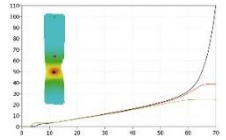
TRITOP
Mobile
optical CMM



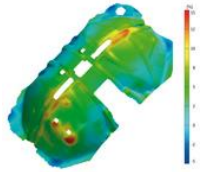
PONTOS Live
3D Position
Tracker



ARAMIS
Optical
3D deformation
analysis



ARGUS
Optical
forming analysis



GOM Inspect

GOM Correlate

ATOS
Full-Field 3D Scanning

Applications

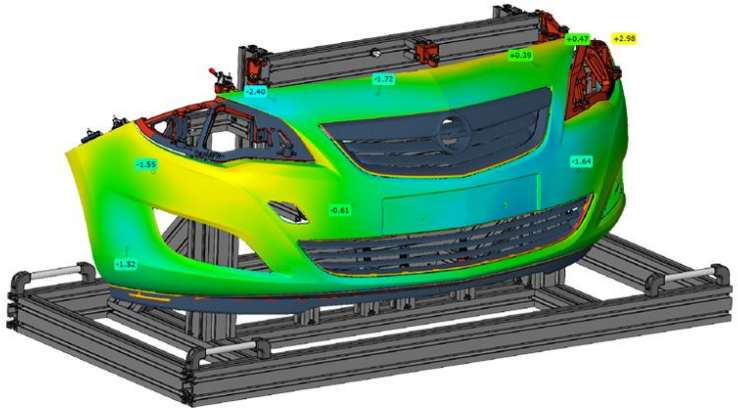
Quality control

Reverse engineering

Rapid prototyping

Manufacturing

Virtual assembly



ATOS ScanBox

GOM Technologies → Optical 3D Measuring Machines

GOM has integrated technologies for automated metrology into optical 3D measuring machines – covering many different applications and part sizes

ARGUS – Sheet Metal Forming Analysis

- **Sheet Metal Forming Analysis**

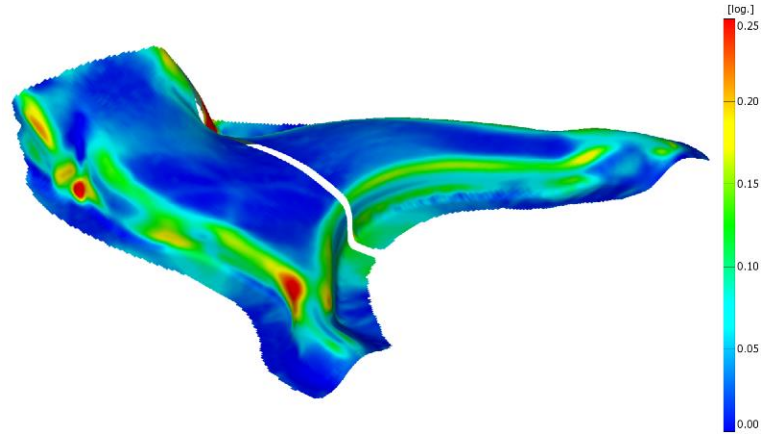
- Determination of

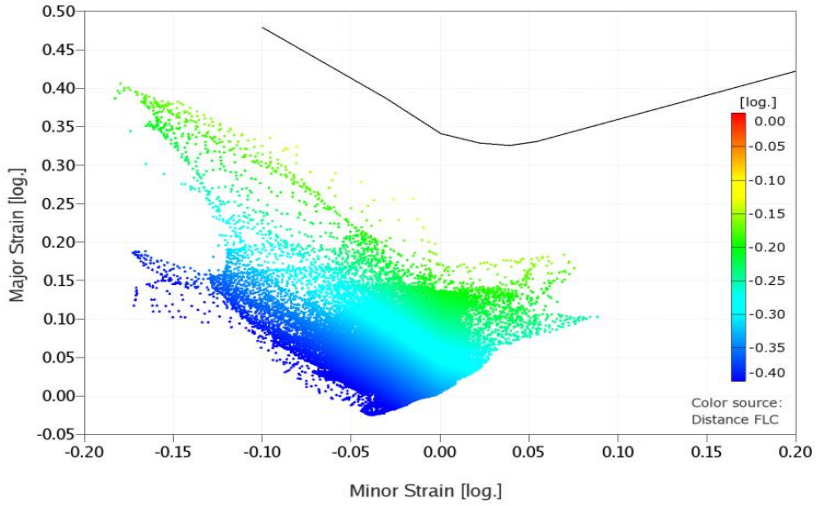
- Surface Strains (Major- and Minor Strain)
- Thickness reduction
- Forming Limit Diagram (FLD)

- Verification of forming simulations

- Tool try-out

- Troubleshooting





Optical 3D Deformation Analysis

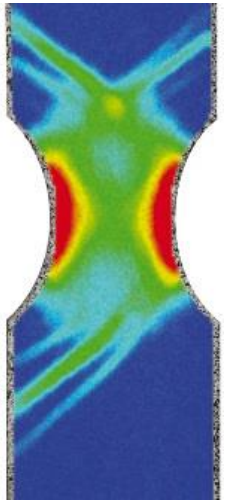
Full-field and Point-based Material and Component Testing

3D surface coordinates

3D displacements, velocity and acceleration

Surface strains

Strain rates



ARAMIS

Non-contact measuring system

Based on the principle of digital image correlation (DIC)

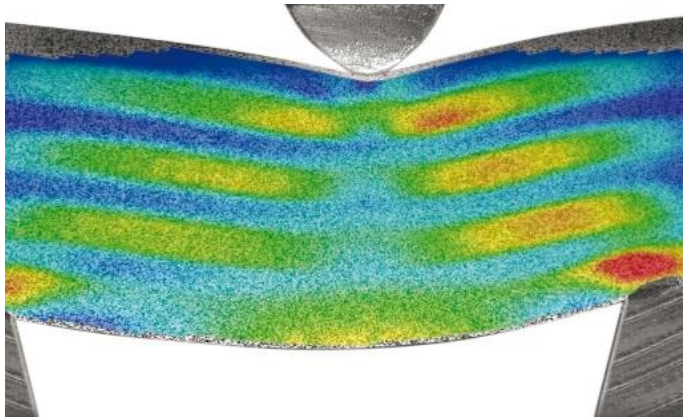
Full-field and point-based analyses of test objects

From a few millimeters up to structural components of several meters

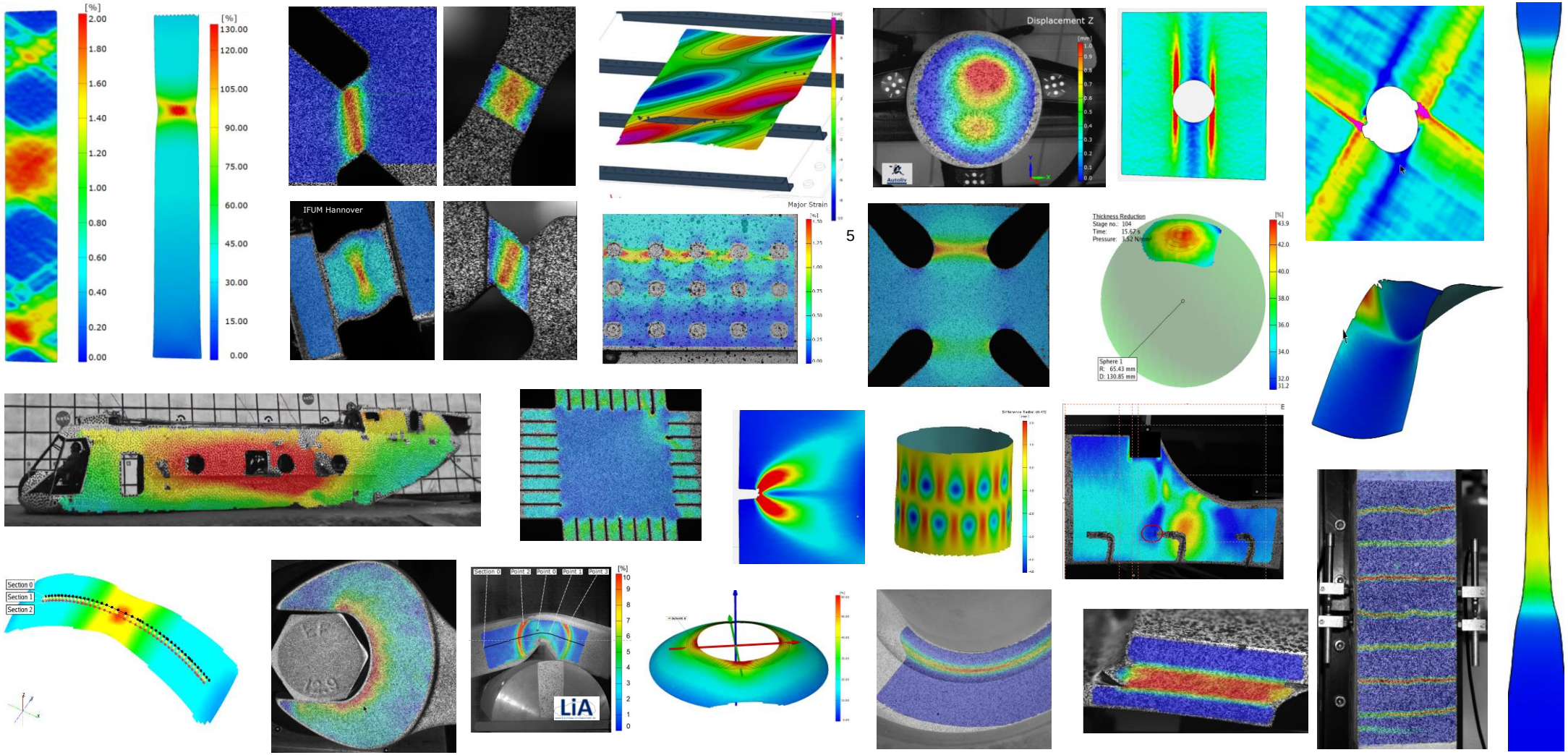
For static and high-speed testing

Independent of material, geometry and temperature

Used in Automotive, Aerospace, Biomechanics, Civil Engineering, etc.



What is Your Measuring Task???



3D Testing Solutions

ARAMIS Adjustable

Flexible solution
for research

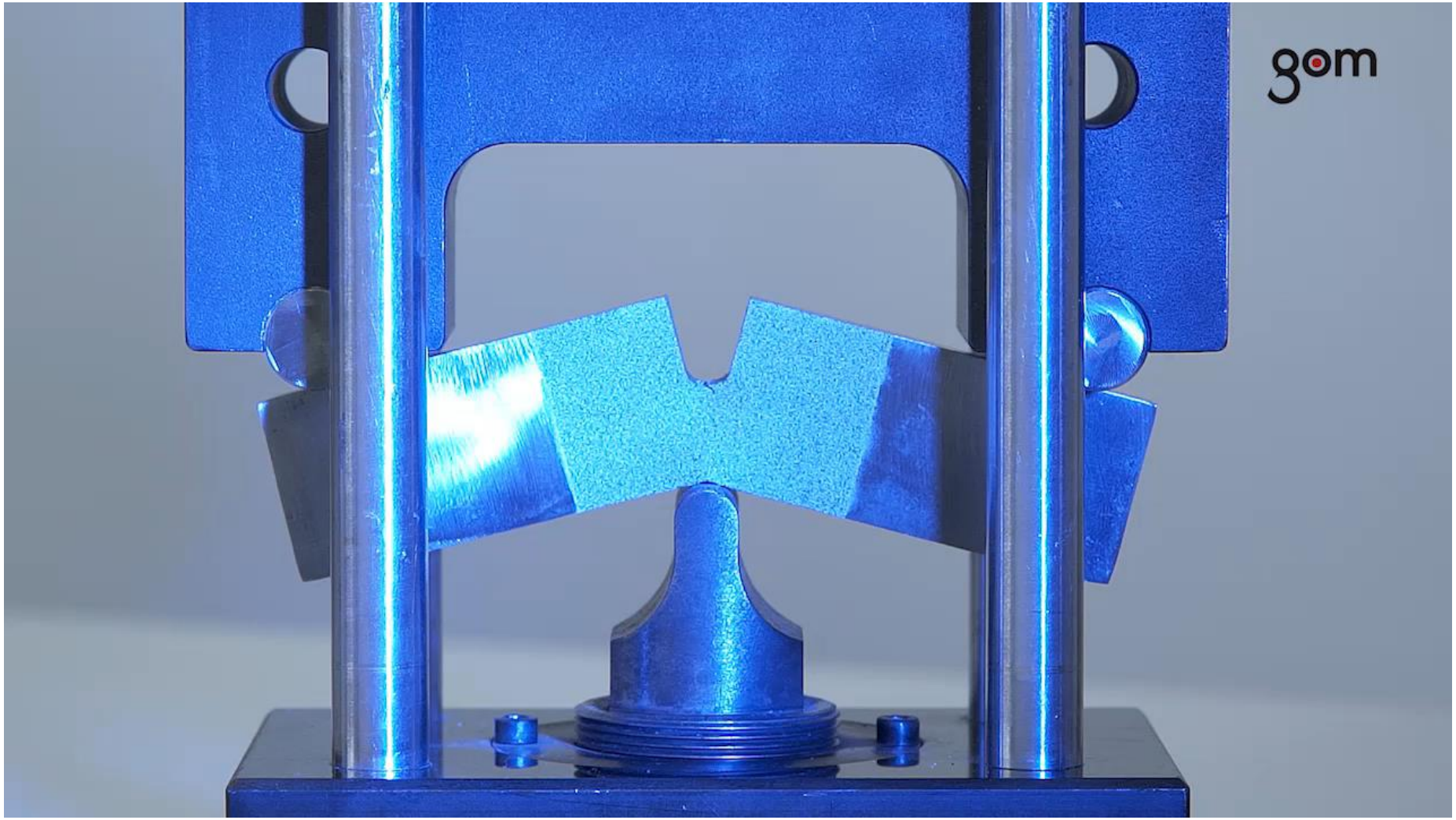
ARAMIS 3D Camera

Robust sensor
for industrial applications

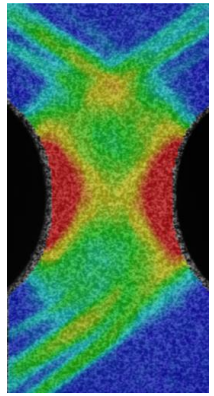
ARAMIS SRX

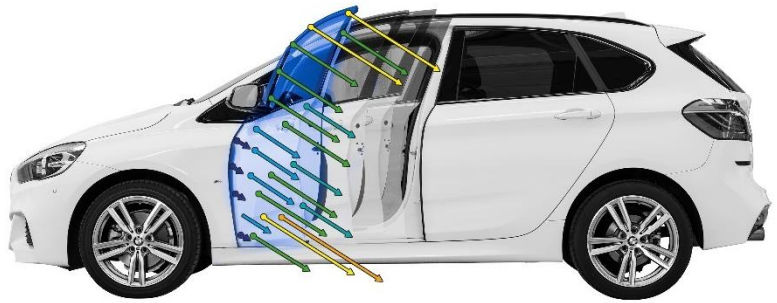
Robust sensor
for high-end applications

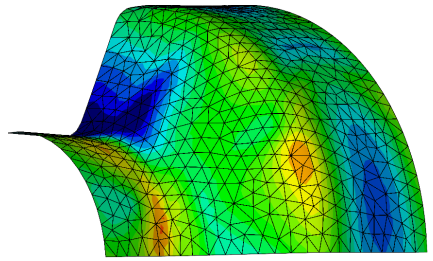
ARAMIS Workflow



ARAMIS in Product Development







Material Properties

Product Design/CAD/ Simulation

Prototype Manufacturing

Prototype Inspection / Testing

Simulation Validation

Production / Series Inspection

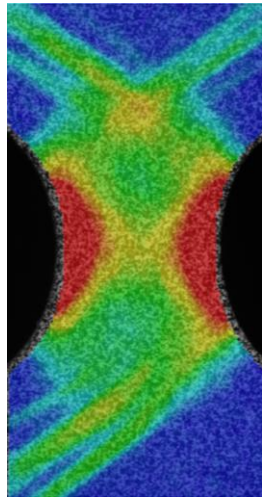
ARAMIS in Product Development

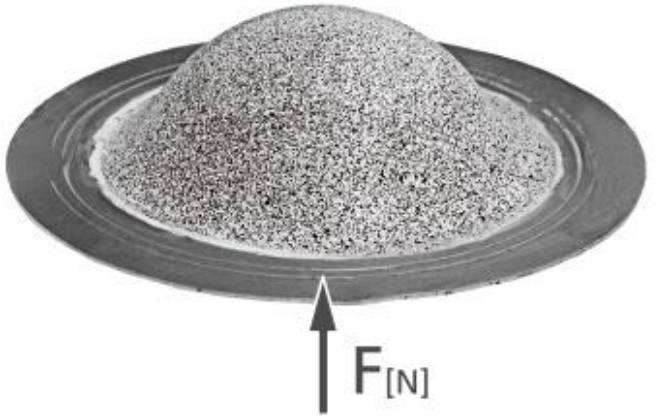
Material Properties

Input data for material models

Sheet metal formability

Edge crack sensitivity





Material Properties | Product Design/CAD/ Simulation | Prototype Manufacturing | Prototype Inspection / Testing | Simulation Validation | Production / Series Inspection

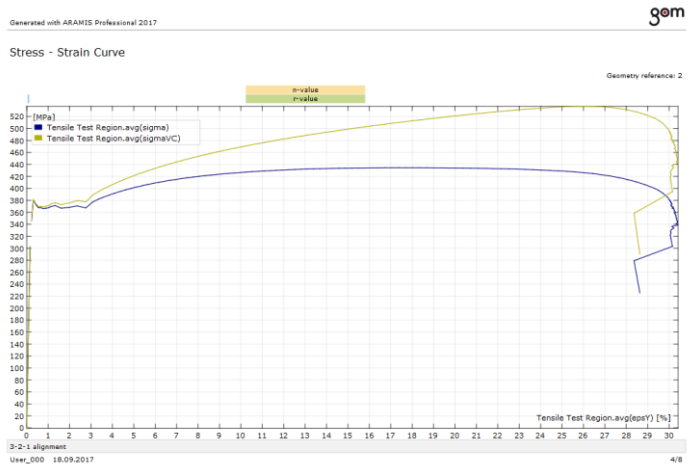
Tensile Test

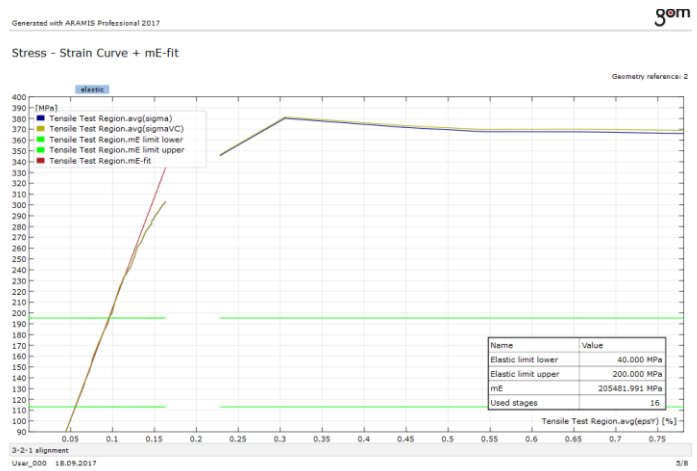
Tensile Test Evaluation

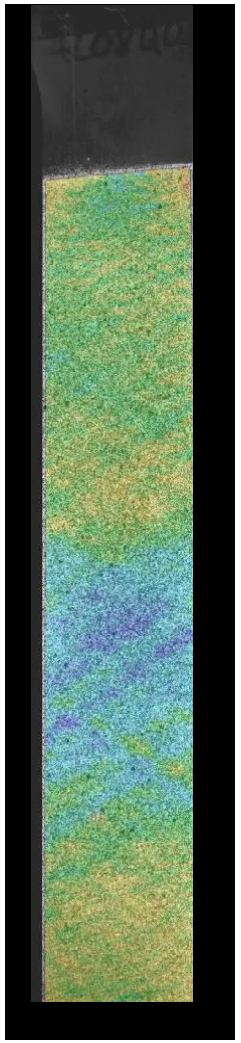
The Tensile Test is performed to determine Material Parameters standardized

Due to high Resolution local Effects are automatically sampled and can thus be analyzed

- Negative effects of clamping (bending, incorrect positioning)
- Lüder’s Bands
- Flow Fronts
- Necking and Failure



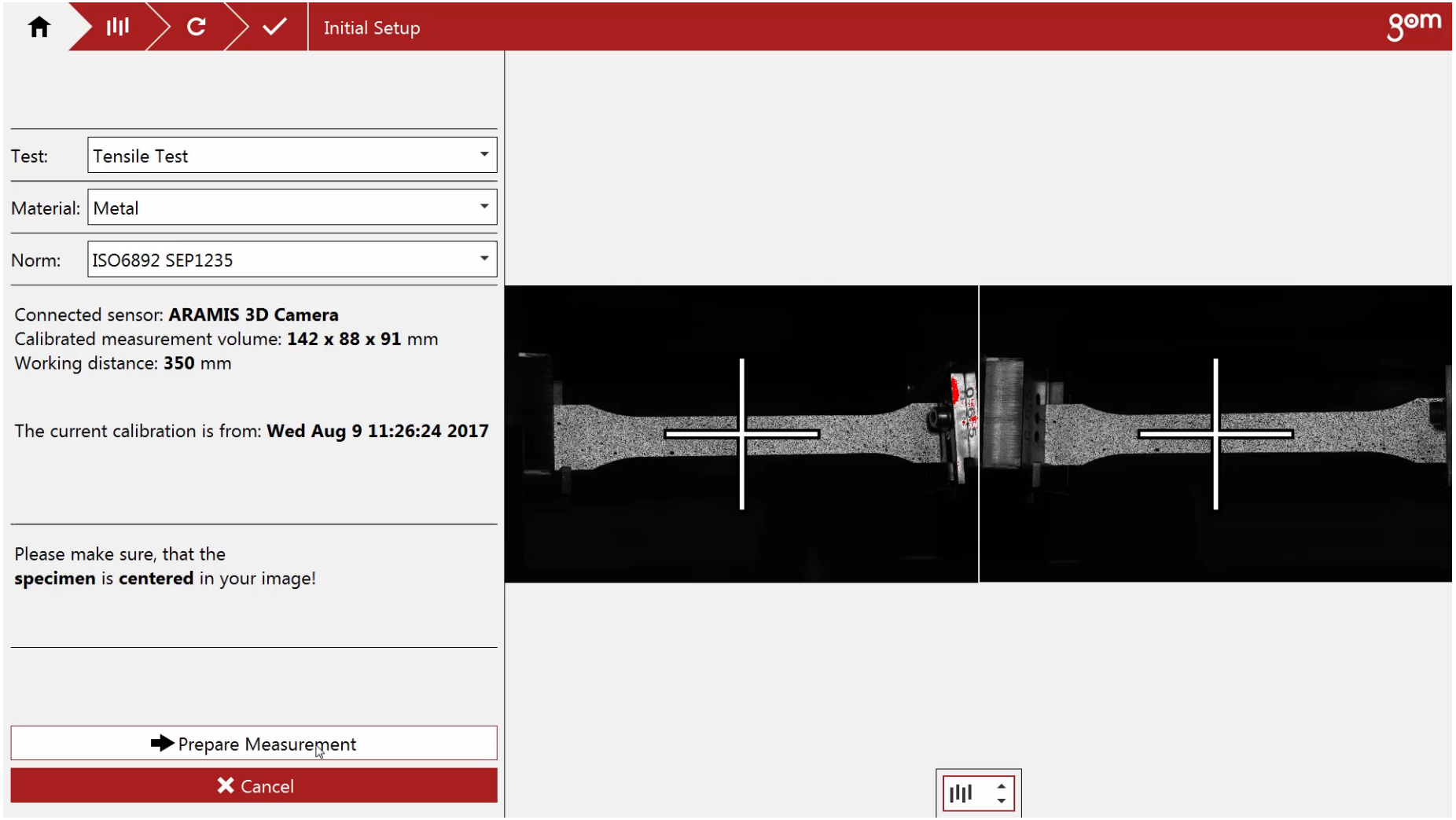




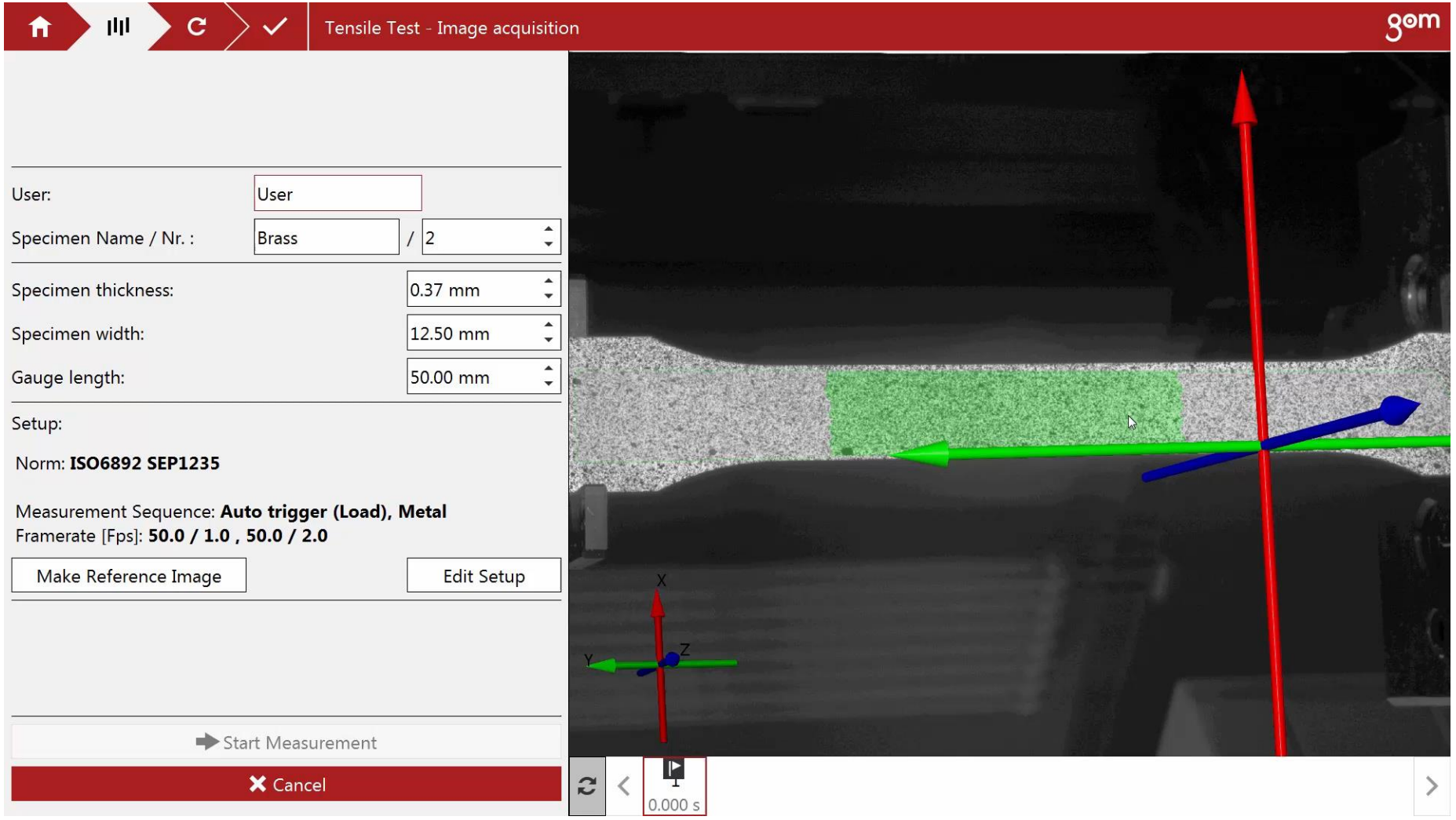
ARAMIS Kiosk Interface for Material Tests

Tensile Testing

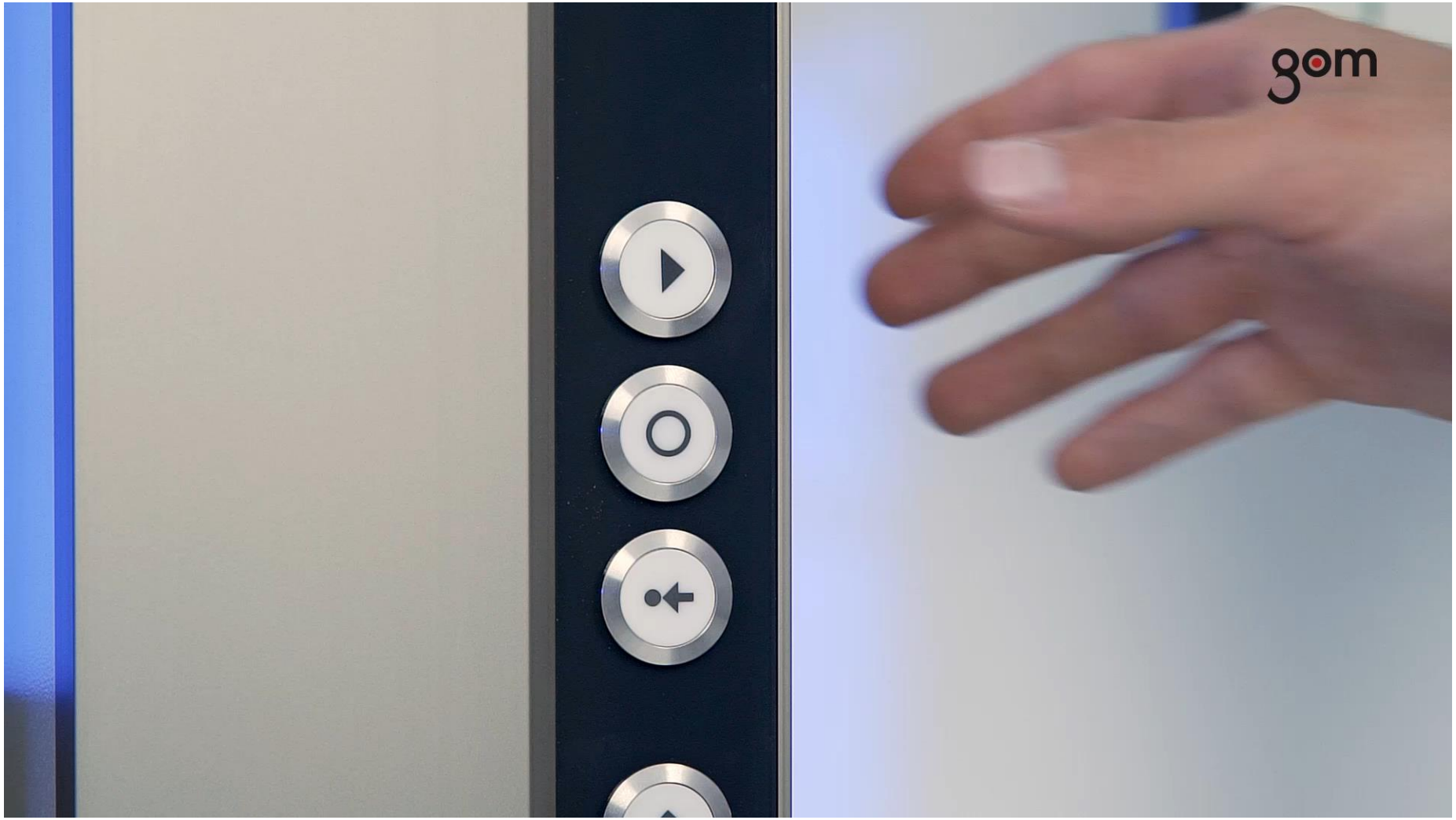
ARAMIS Kiosk Interface



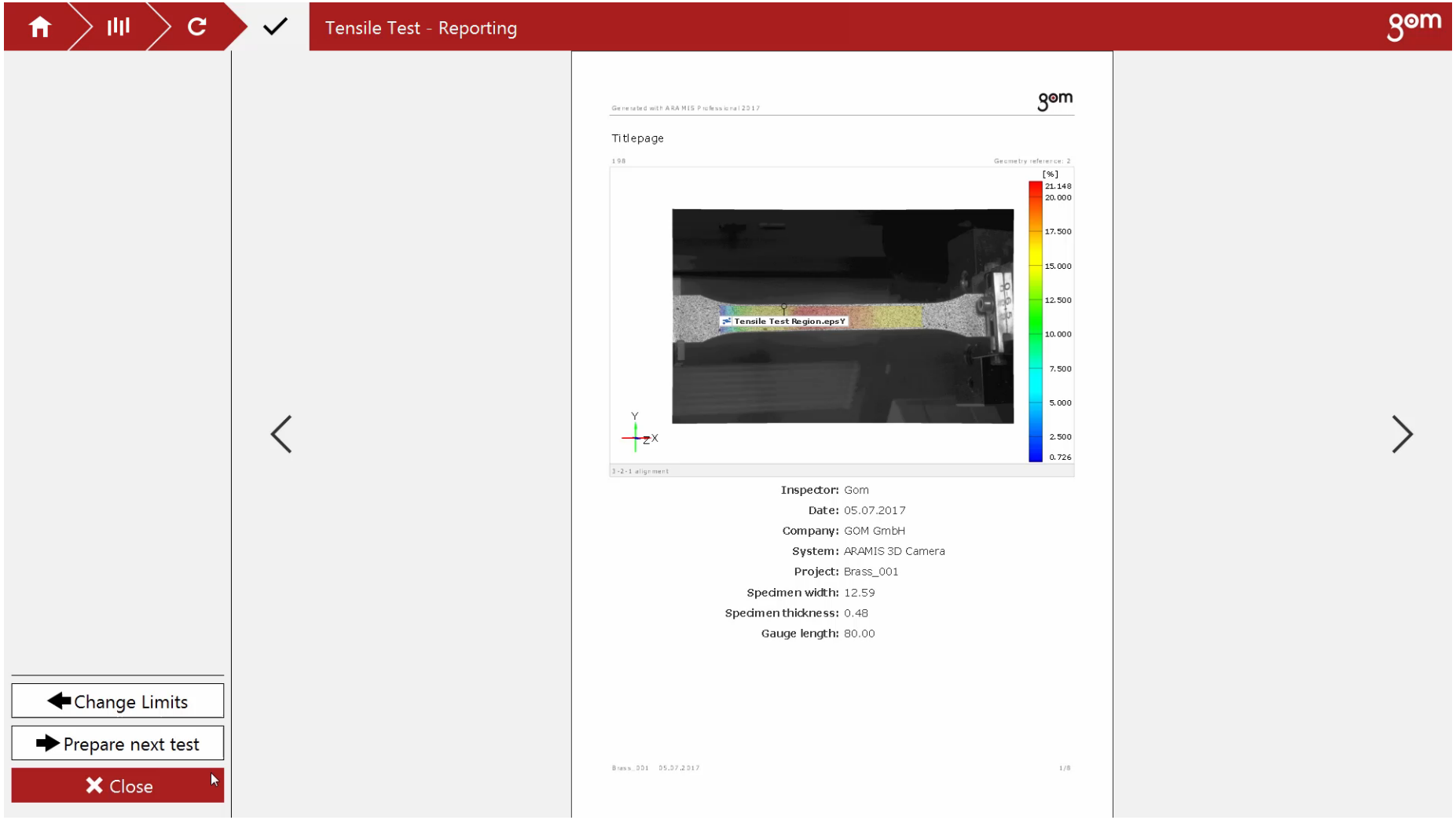
ARAMIS Kiosk Interface



ARAMIS Kiosk Interface



ARAMIS Kiosk Interface



Customizable ARAMIS Kiosk Interface

Enhancements of ARAMIS Kiosk Interface 2018

New included standards:

Determination of Forming Limit Curves – ISO 12004

Bulge Test – ISO 16808

Adapt norms to company specific standards

Customize the Kiosk Interface for your own test

ARAMIS and Thermography

Measuring Setup

Combination of DIC and thermography

Application tensile test

Steel material

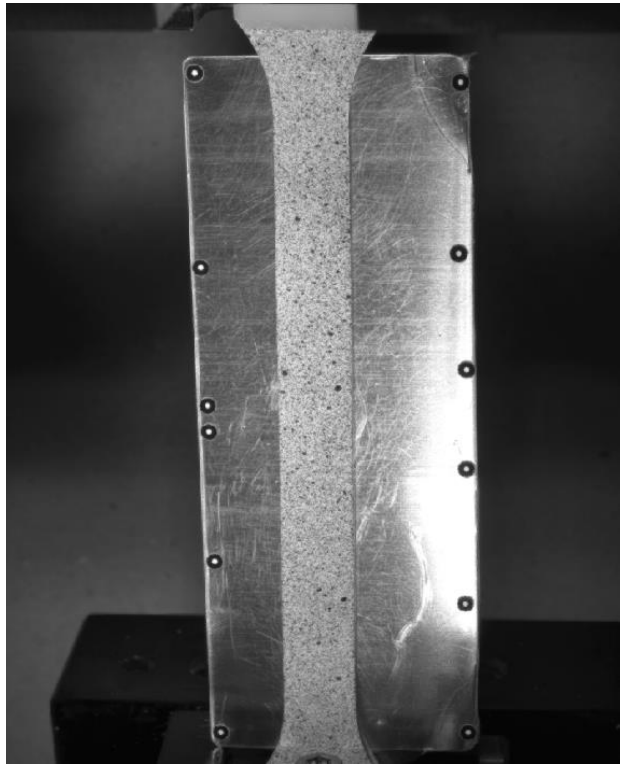
Polymer material

Combine measuring data of displacements, strains and temperature

Understand both mechanical and thermal behavior of specimens under load

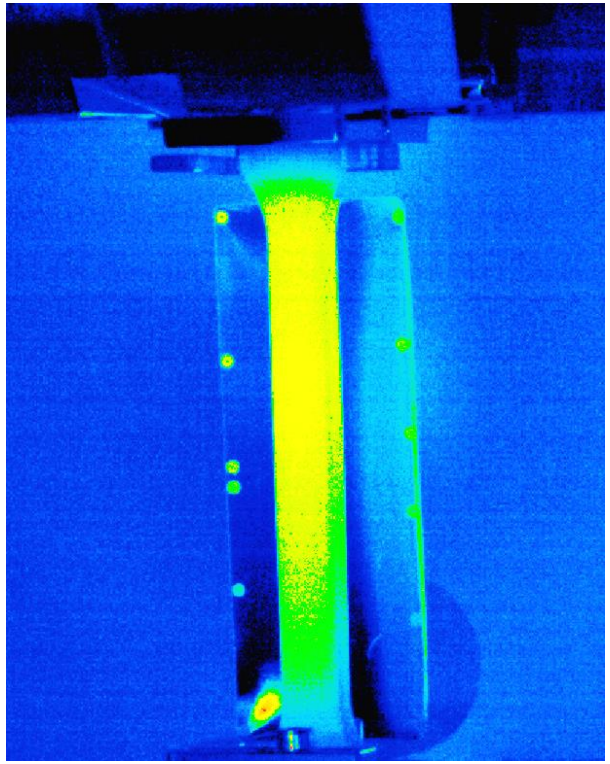
ARAMIS and Thermography – Mapping of Temperature Data

ARAMIS



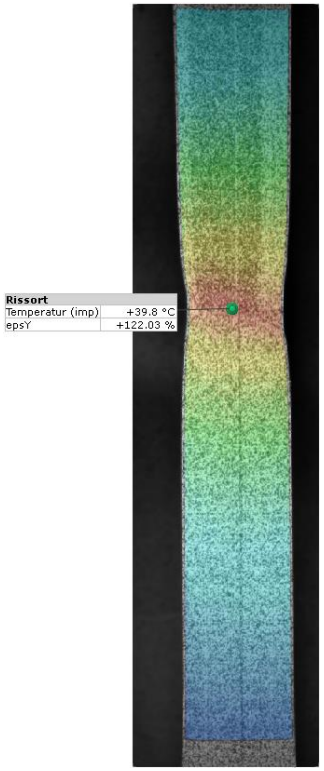
3D coordinates
Displacements
Strains

Thermal Camera



Distribution of temperature

Combination in ARAMIS



Data on strains and temperature

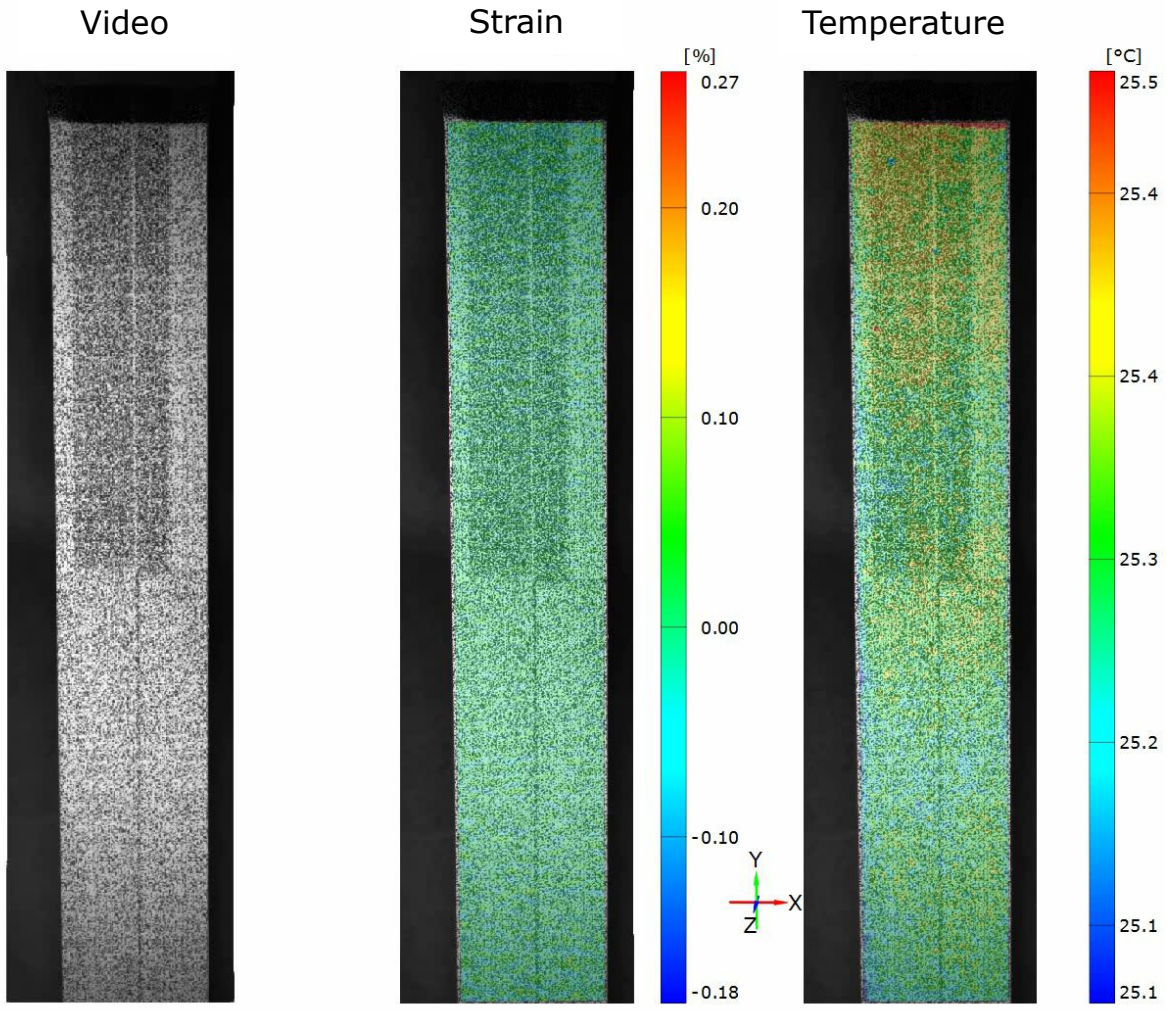
ARAMIS and Thermography

Tensile Test Steel

Distinct yield effect

Measured 3D points over time

Temperature data mapped on measured 3D points



ARAMIS and Thermography

Tensile Test Steel

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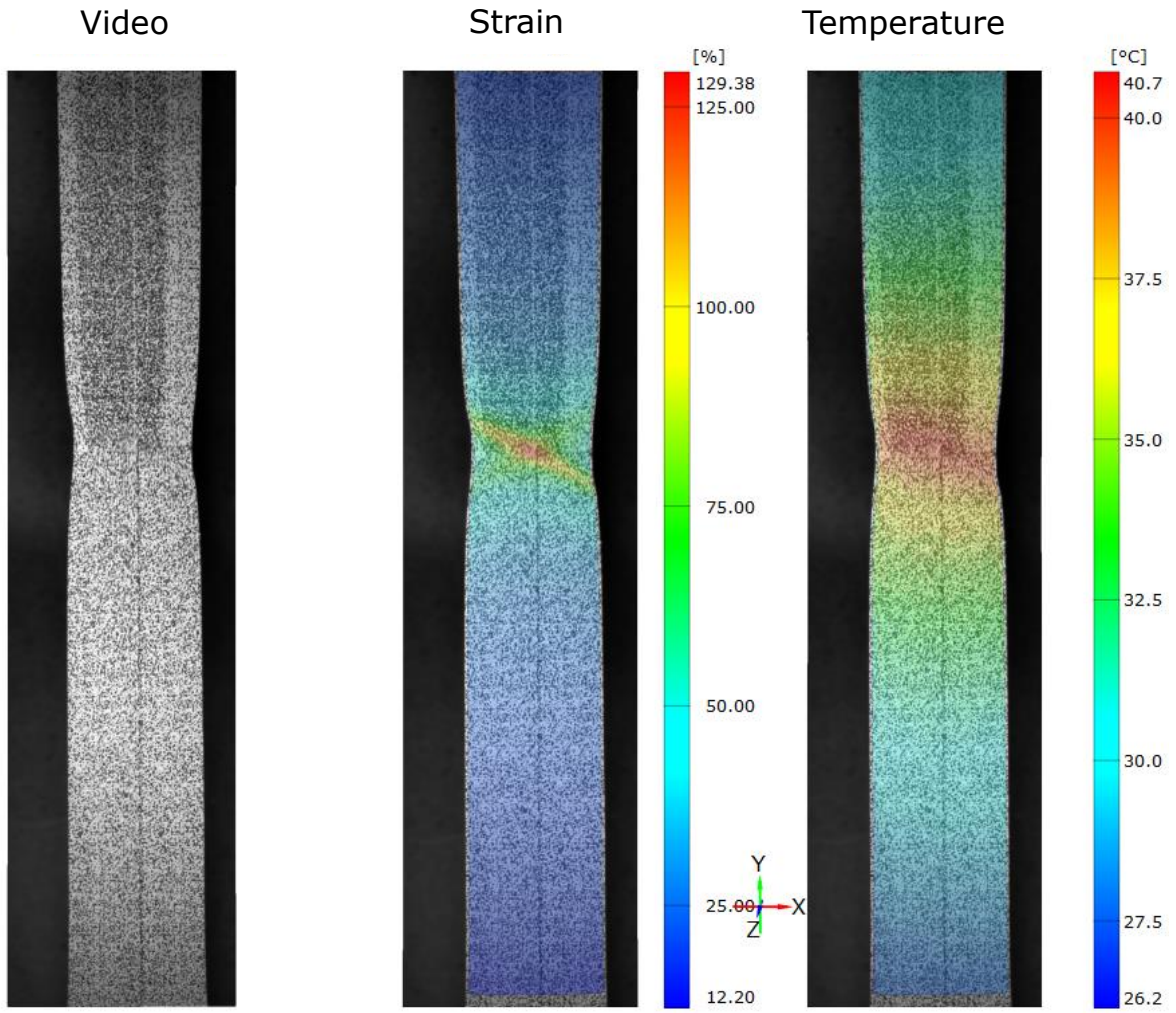


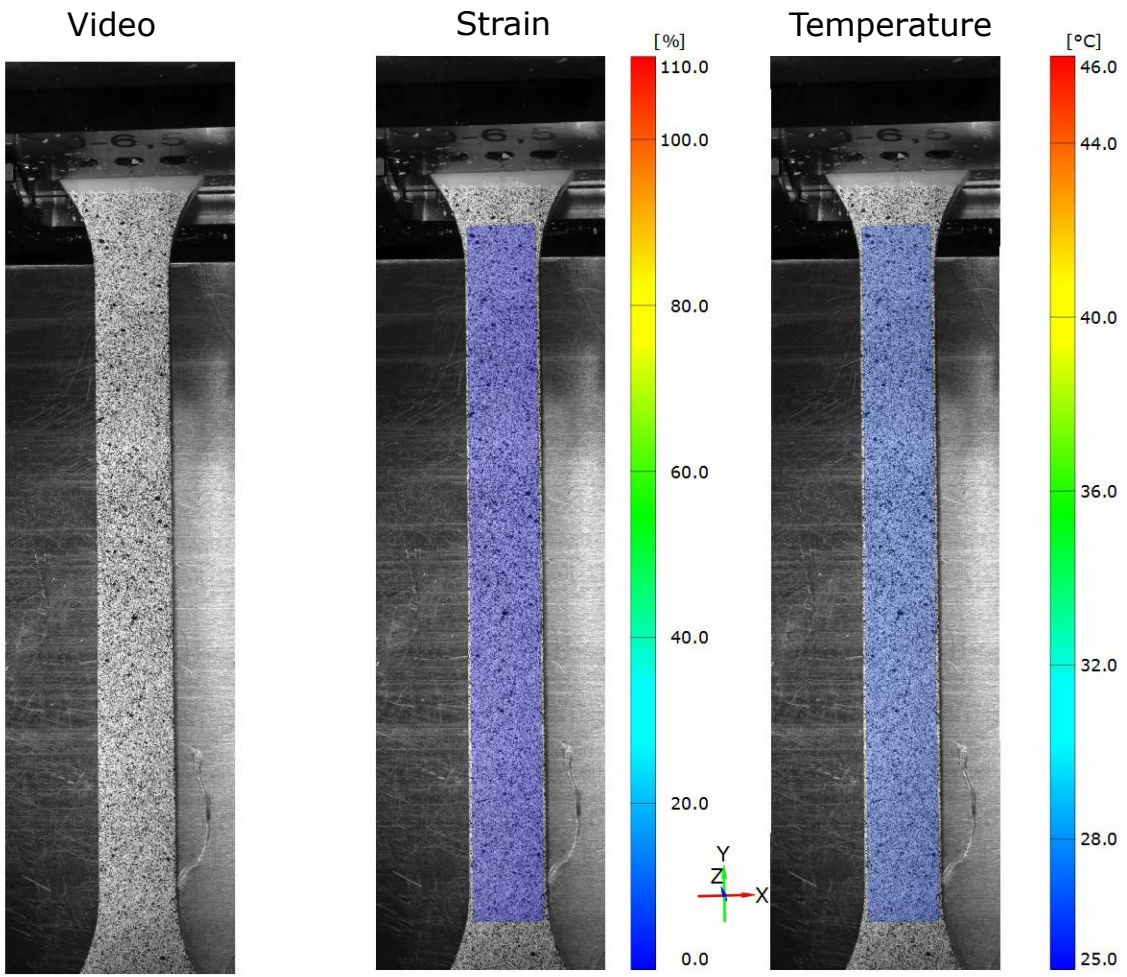
ARAMIS and Thermography

Tensile Test Polymer

Flow fronts

Measured 3D points over time

Temperature data mapped on measured 3D points



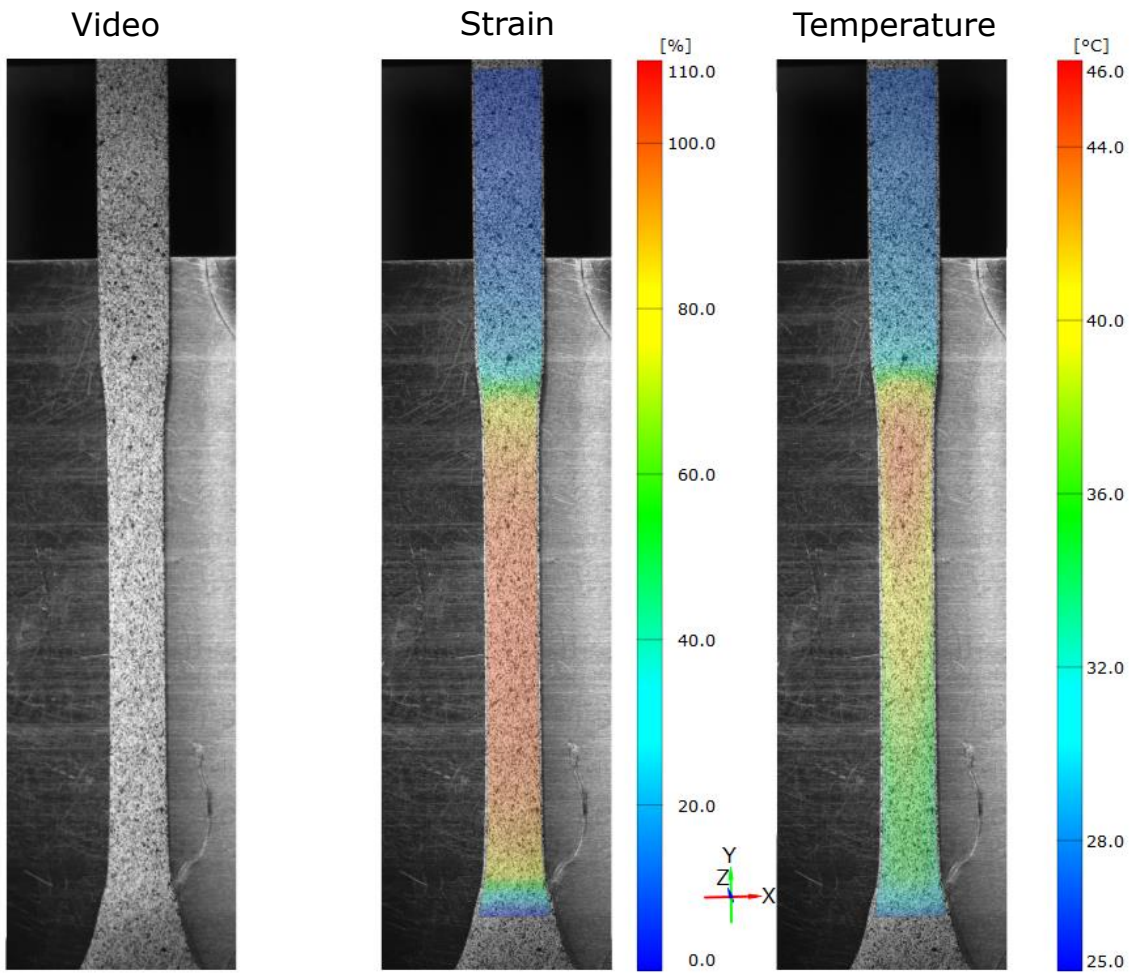
ARAMIS and Thermography

Tensile Test Polymer

Flow fronts

Measured 3D points over time

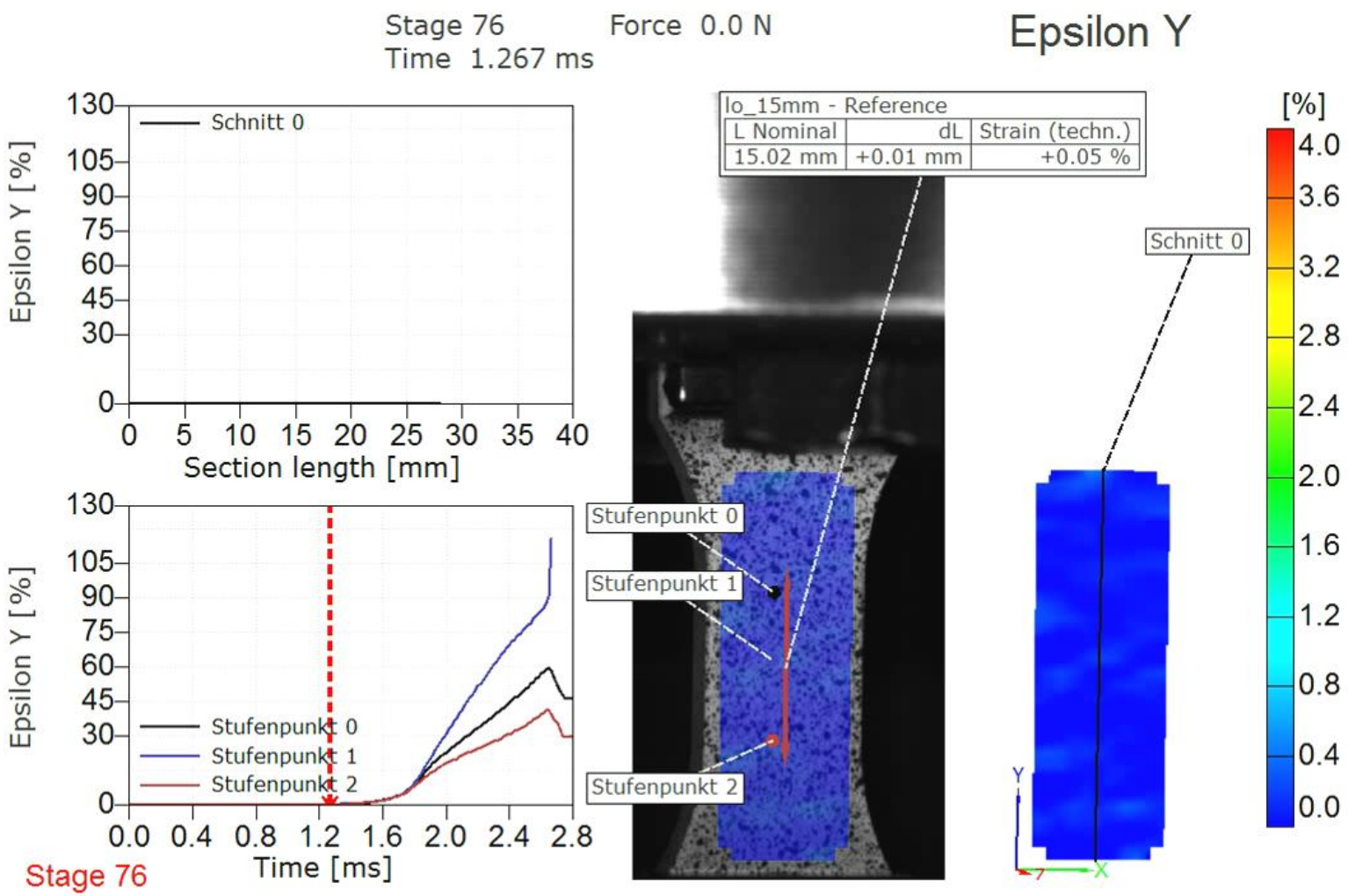
Temperature data mapped on measured 3D points



High Speed Tensile Test

Overview

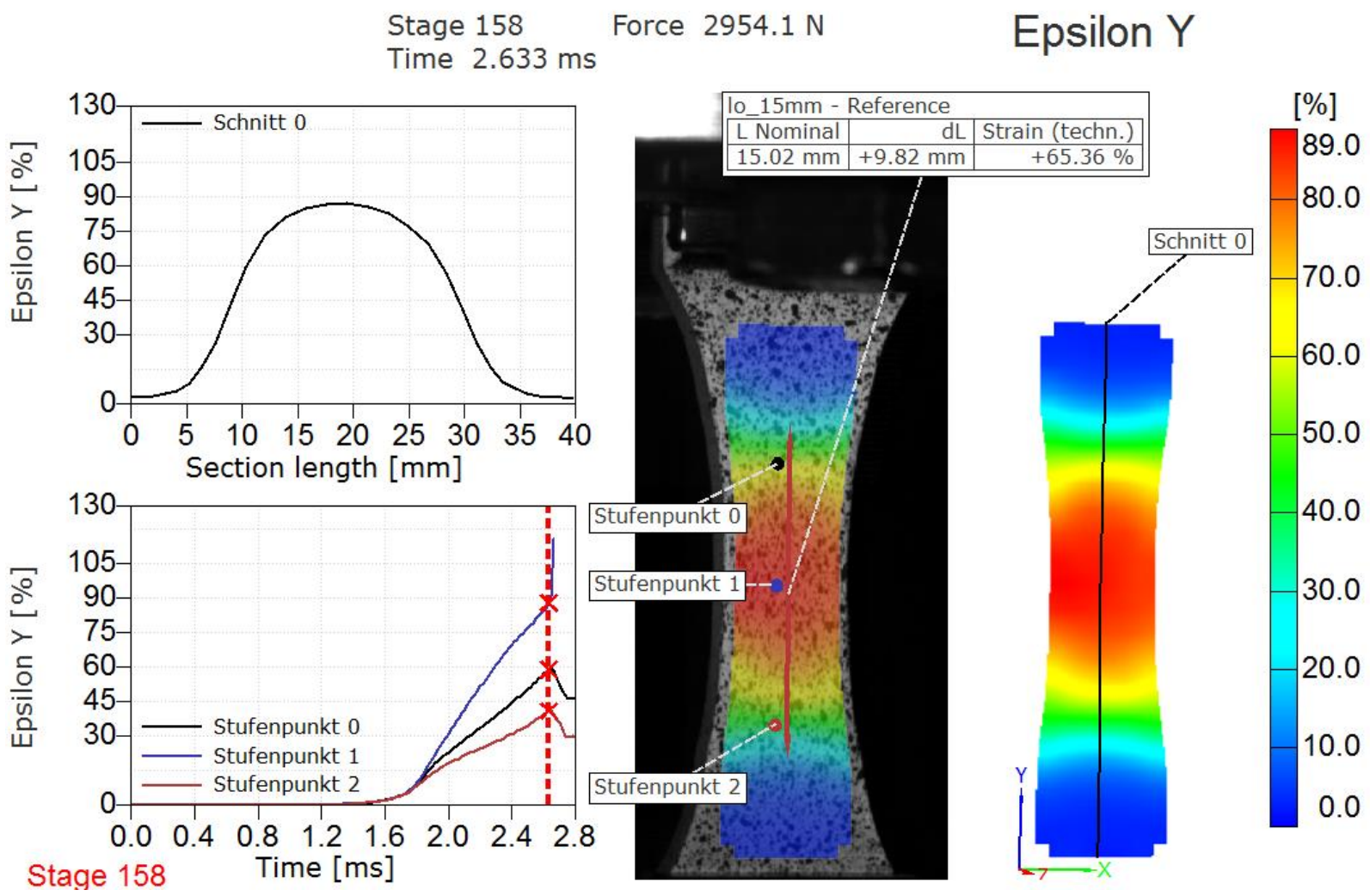
- Test speed:
  10 m/s
- Frame rate:
  60.000 Hz



High Speed Tensile Test

Strain

- Test speed:
  10 m/s
- Frame rate:
  60.000 Hz



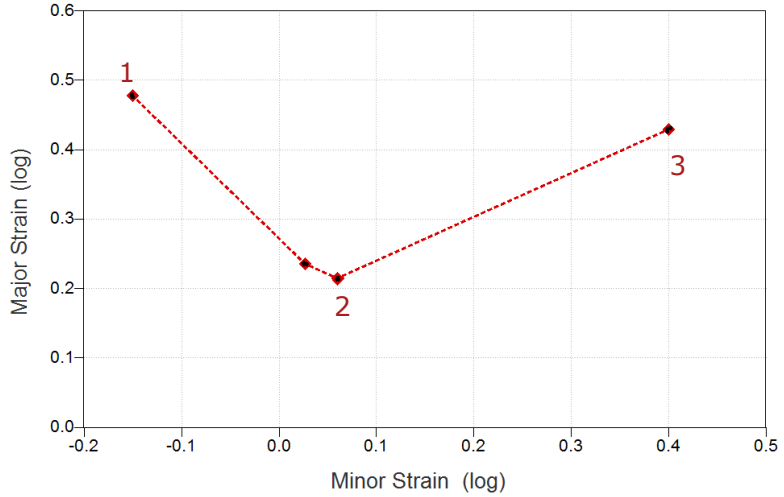
ARAMIS for Sheet Metal Formability Testing

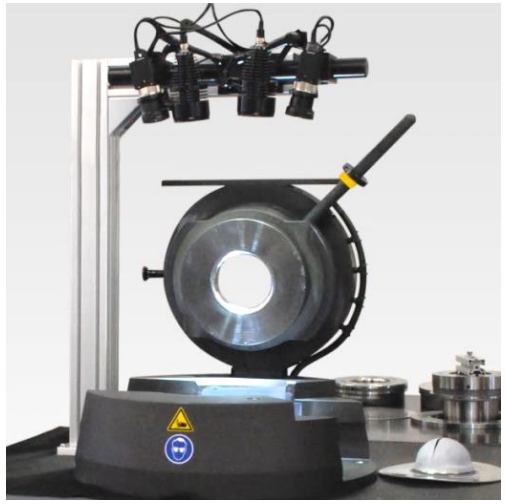
Forming Limit Curve (FLC)

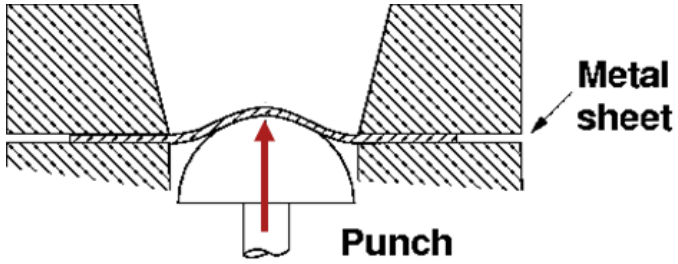
Material parameter curve describing the limit of forming of sheet metal materials

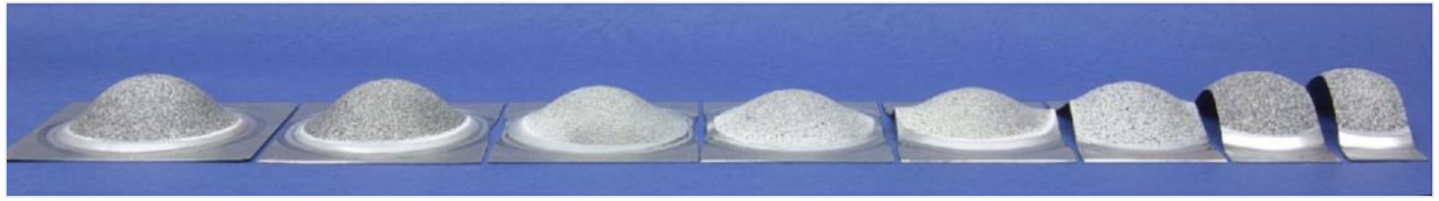
The FLC curve describes the formability in the range from uniaxial to biaxial deformation

Used for deep drawing and stamping applications in the automotive and consumer goods industry









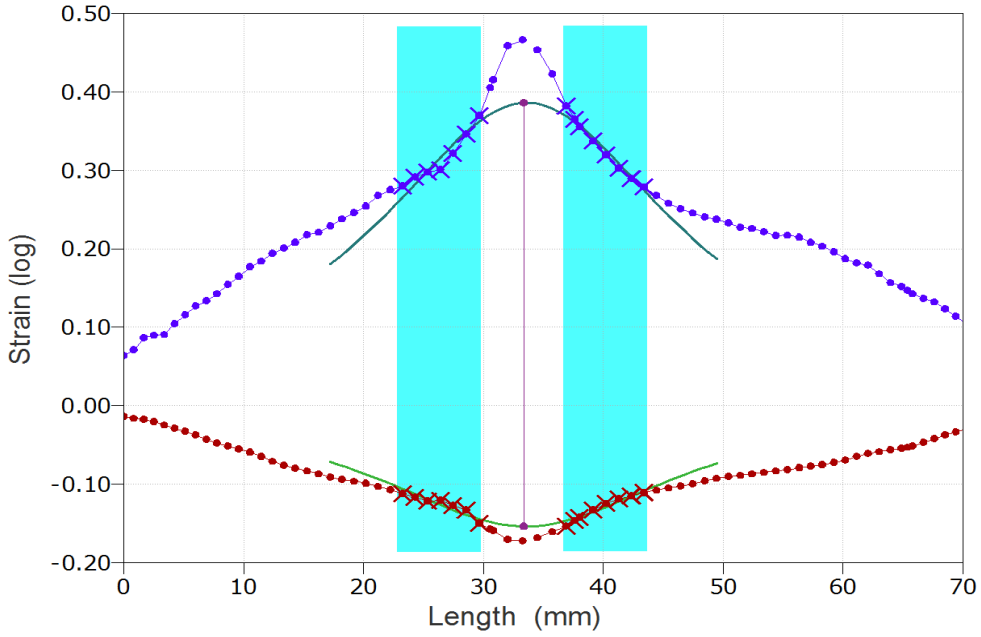
Determination of Forming Limit Curves (FLC) – Section-Based Method

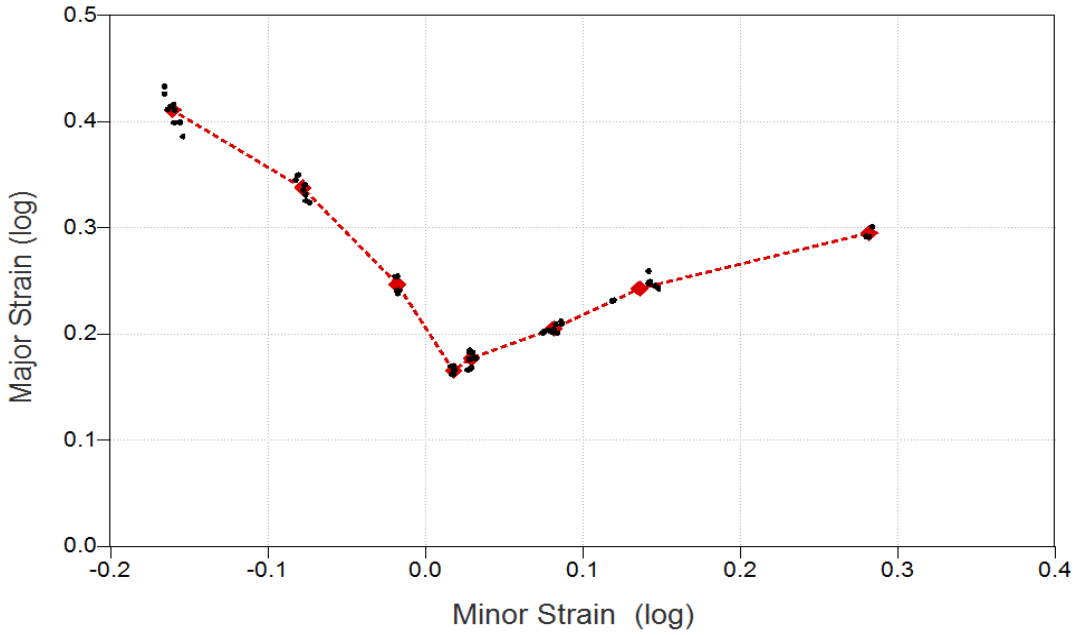
Fitting of inverse parabola

Calculation of major and minor strain points

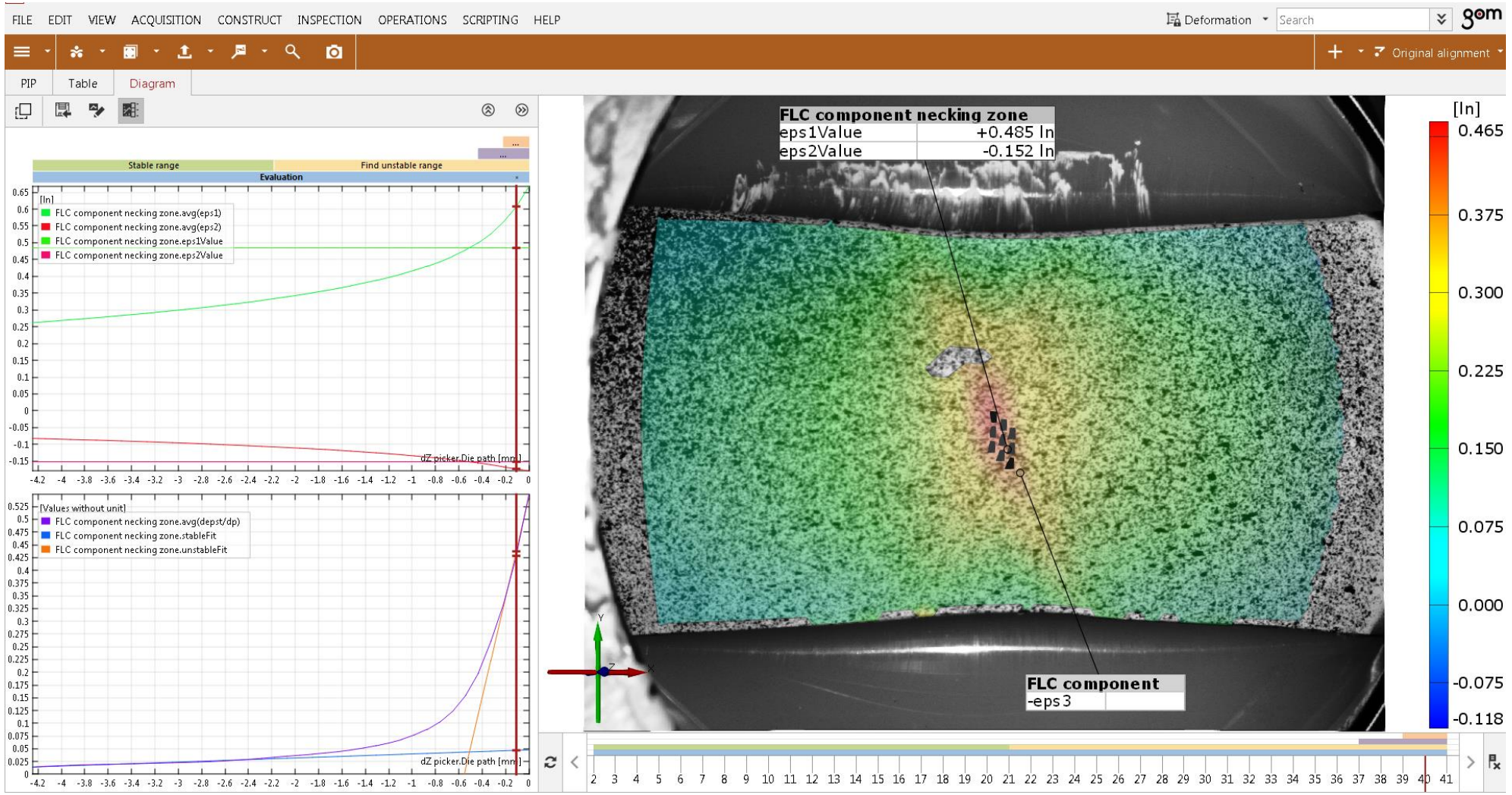
Best-fit data point for each geometry is created

Final FLC curve is shown





Determination of Forming Limit Curves (FLC) – Time-Based Method

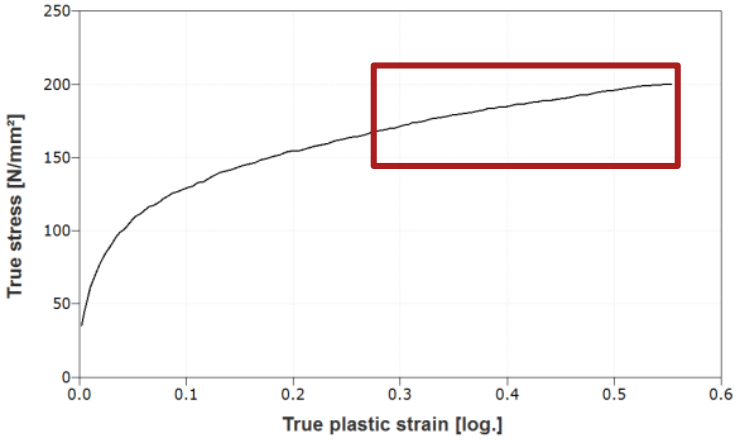


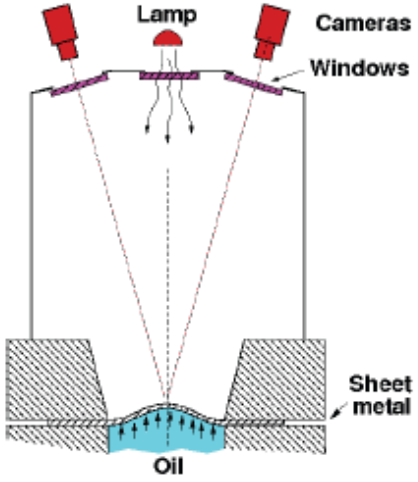
Determination of Biaxial Yield Curve – Bulge Test

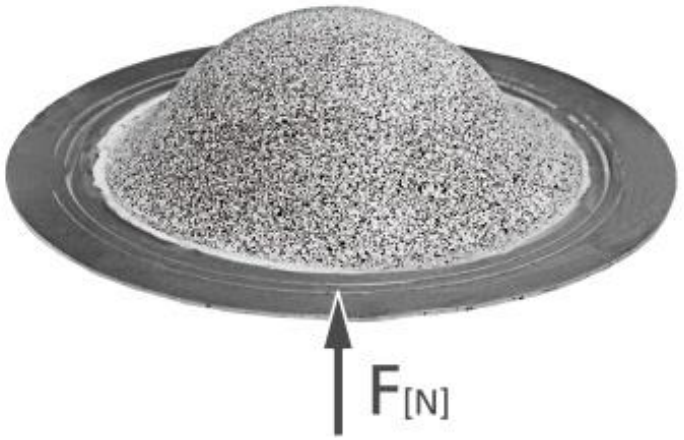
Overview

Numerical forming simulations require accurate material parameters as input

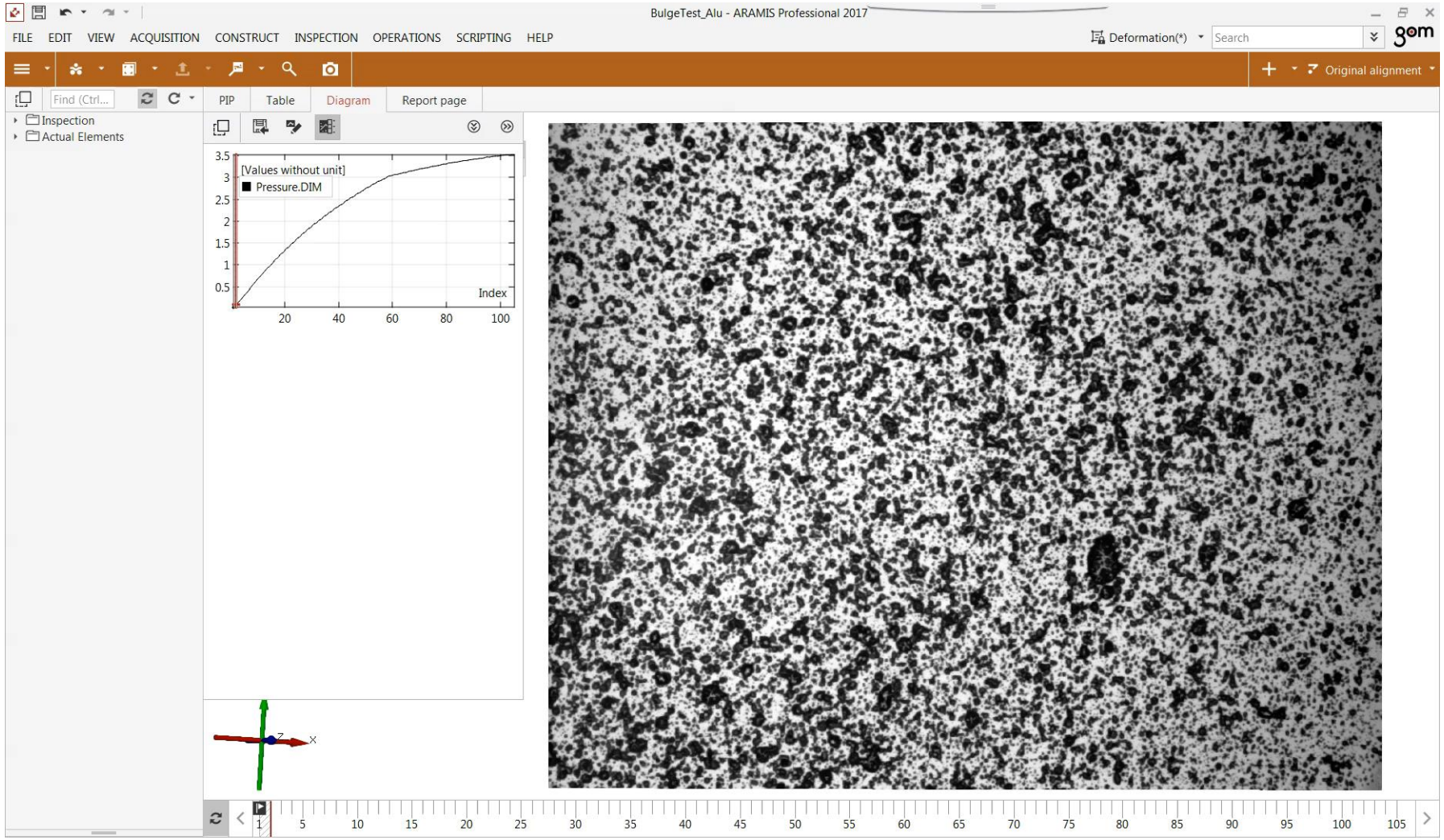
An important input parameter is the yield criterion of sheet metal materials





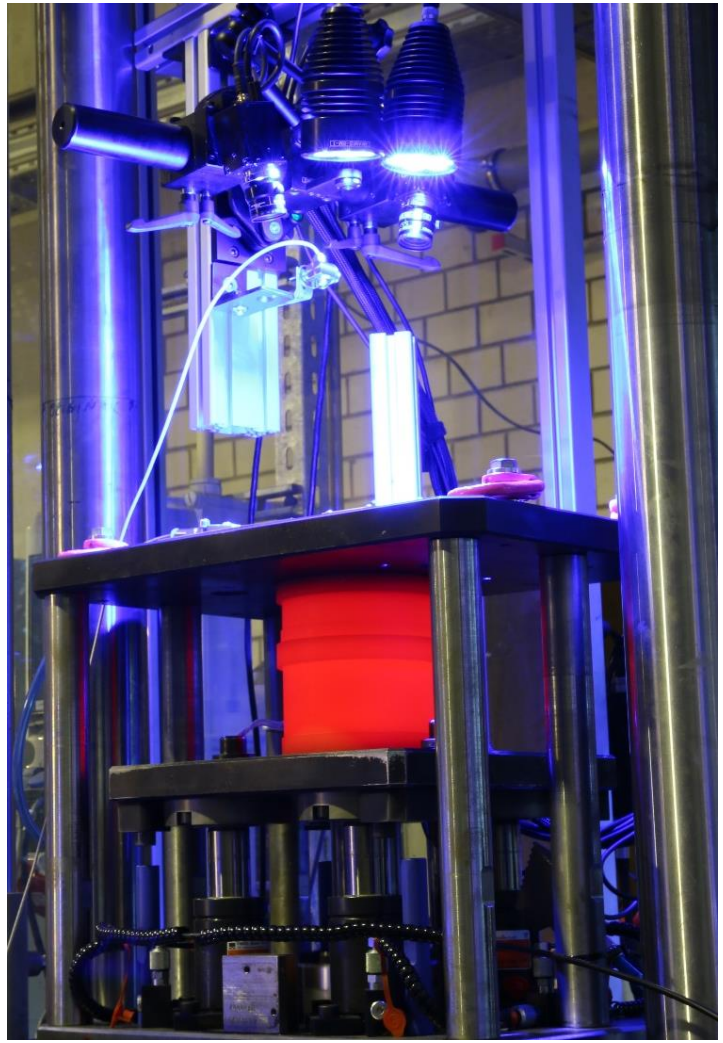


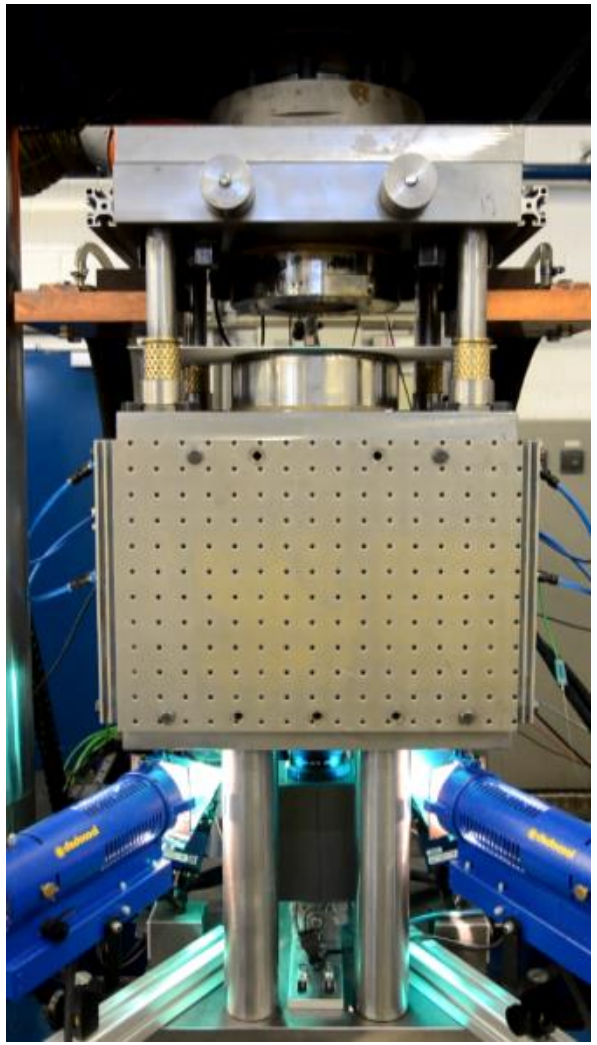
Live Demonstration



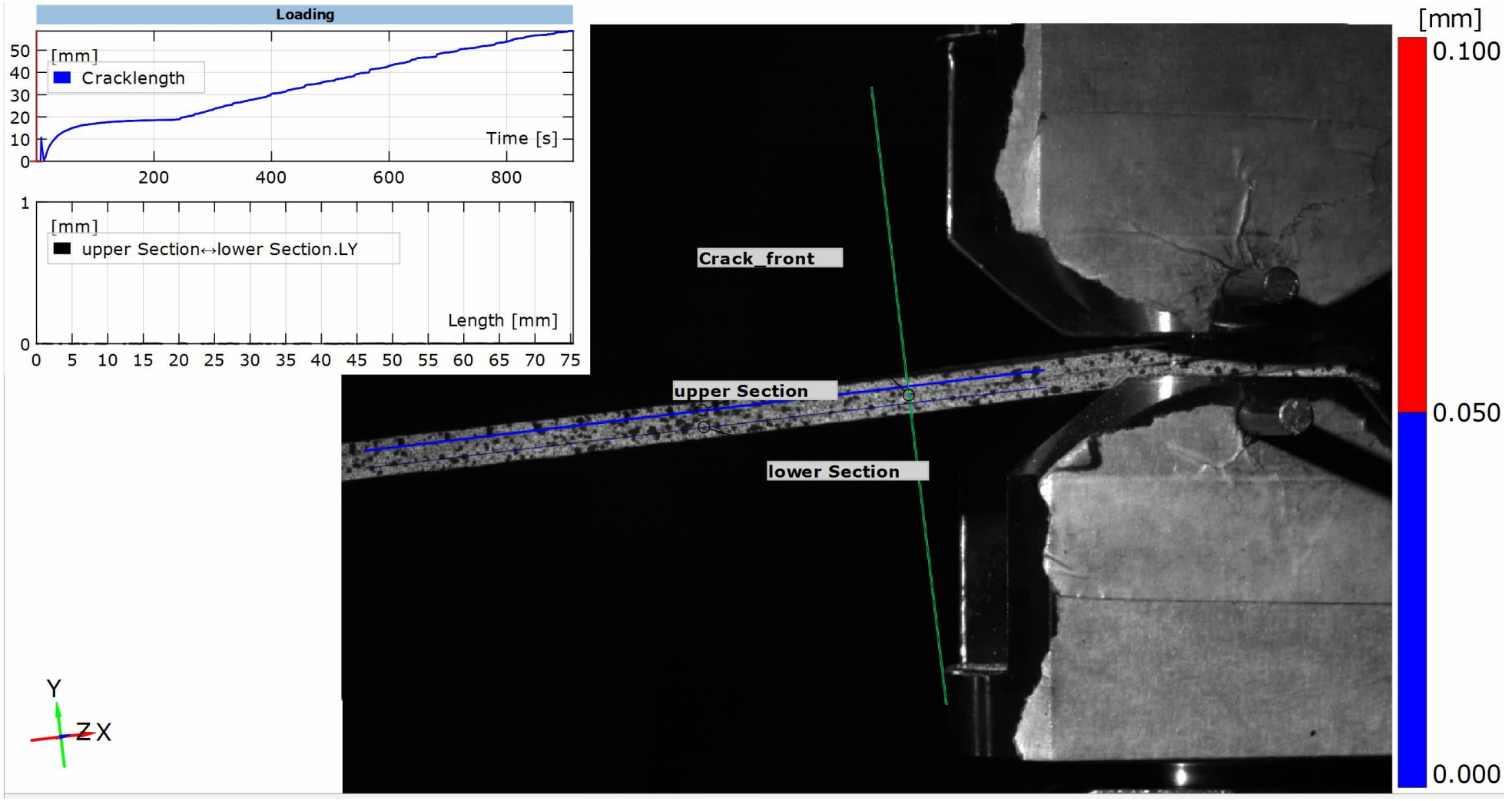
Sheet Metal Formability Testing at High Temperatures

FLC and Yield Curve
For press hardening steels



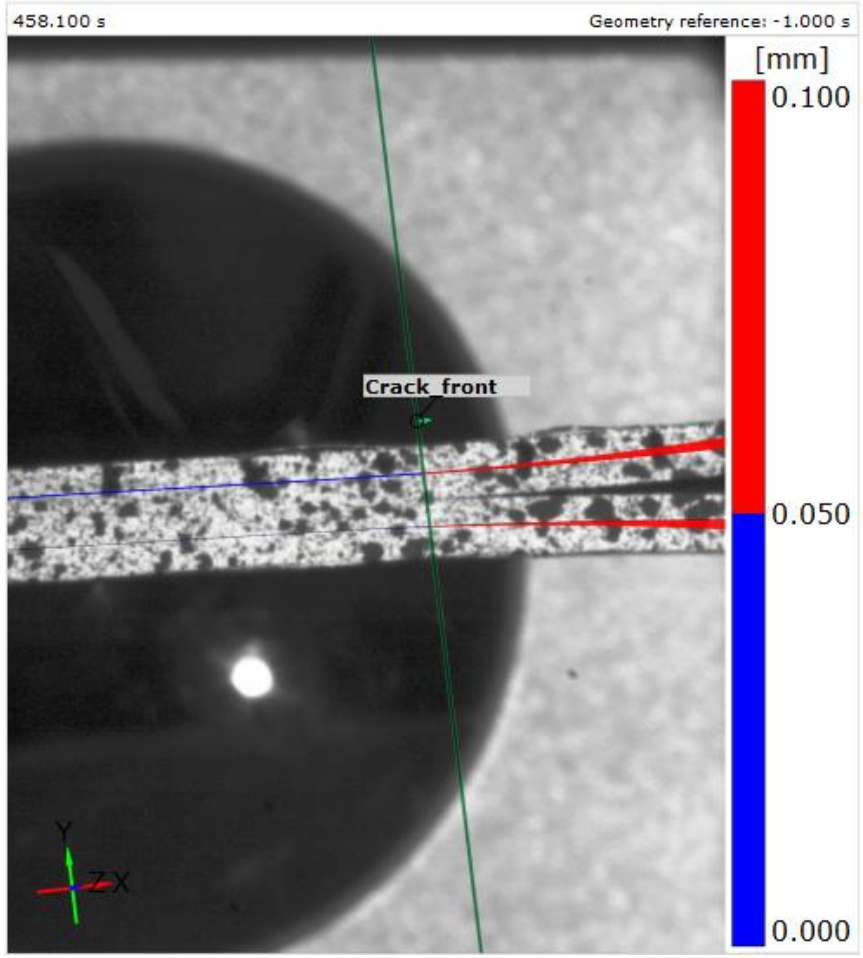


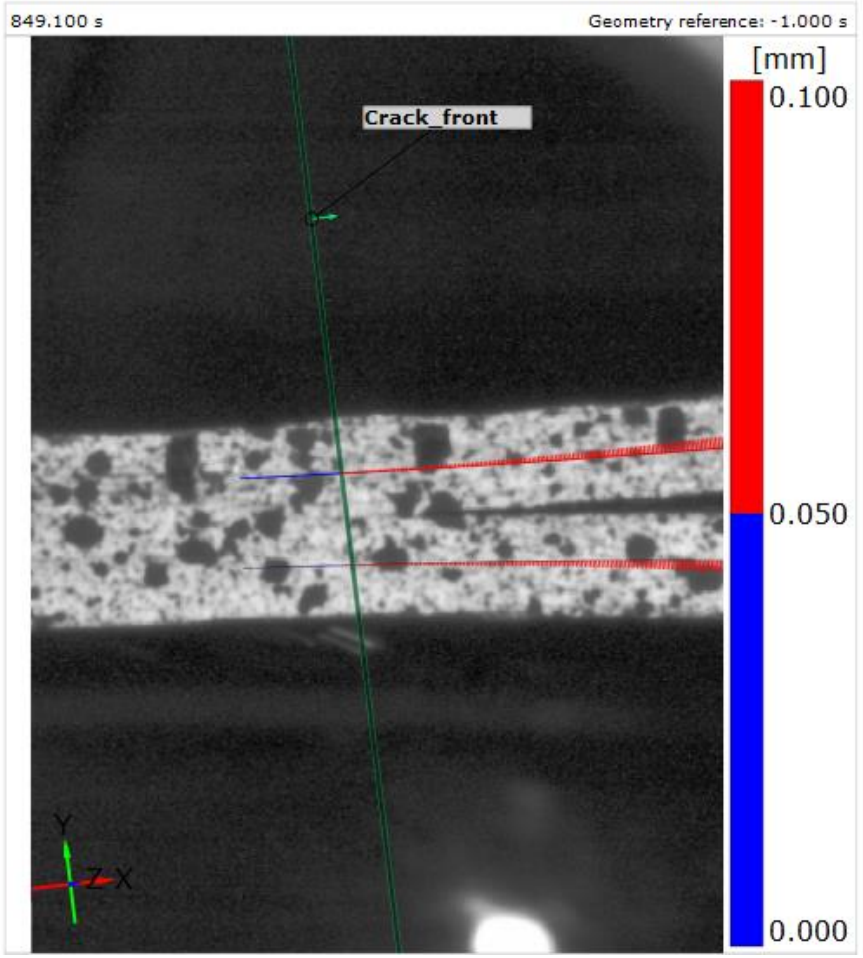
Double Cantilever Beam Tests



Double Cantilever Beam Tests

Close Up on calculated Crackfront position



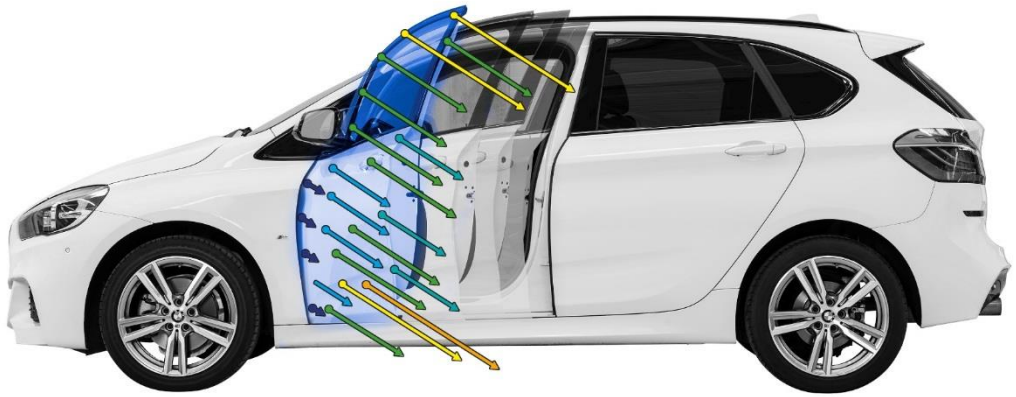


ARAMIS in Product Development

Prototype Inspection / Testing

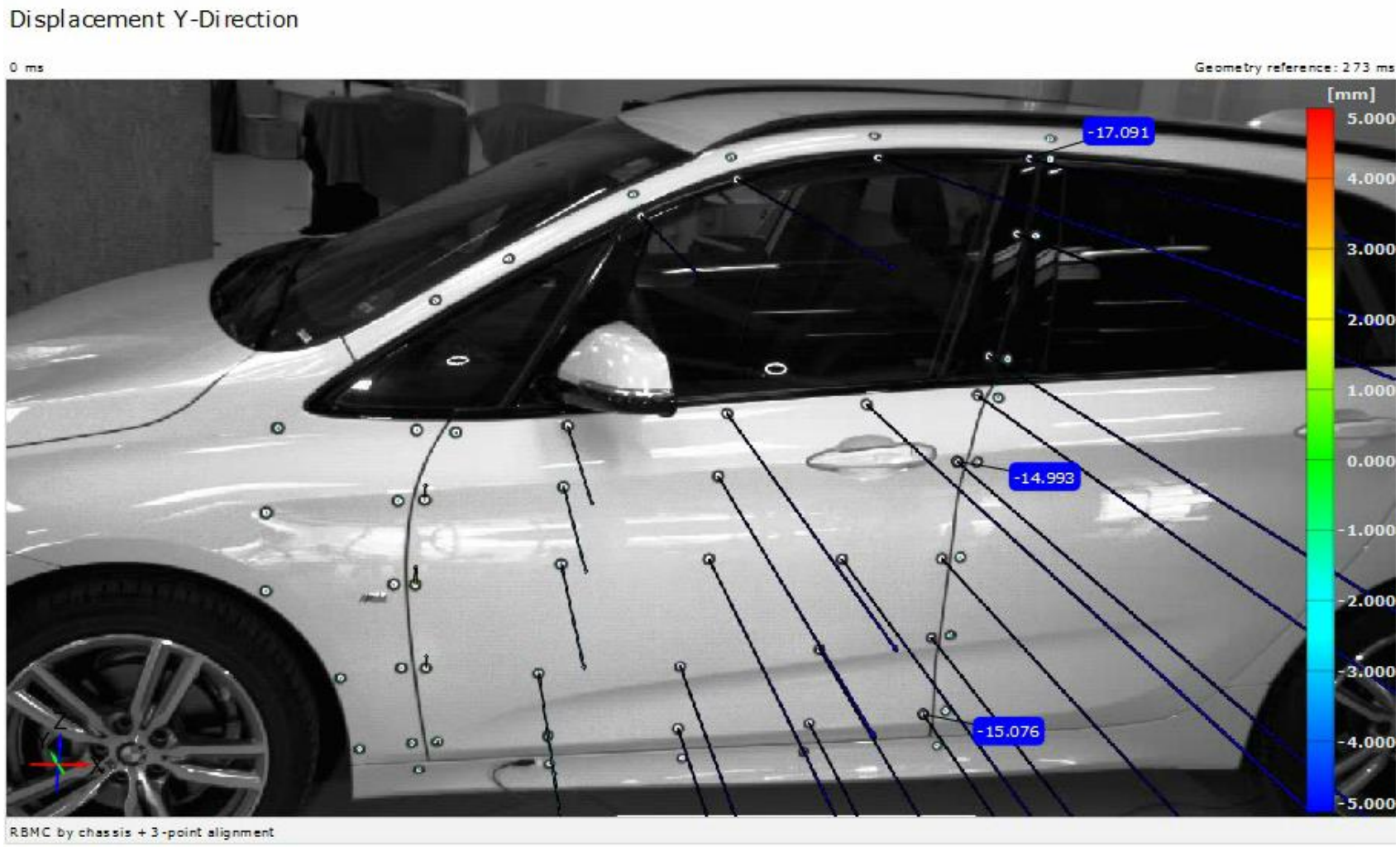
Geometry quality control

Motion and deformation analysis



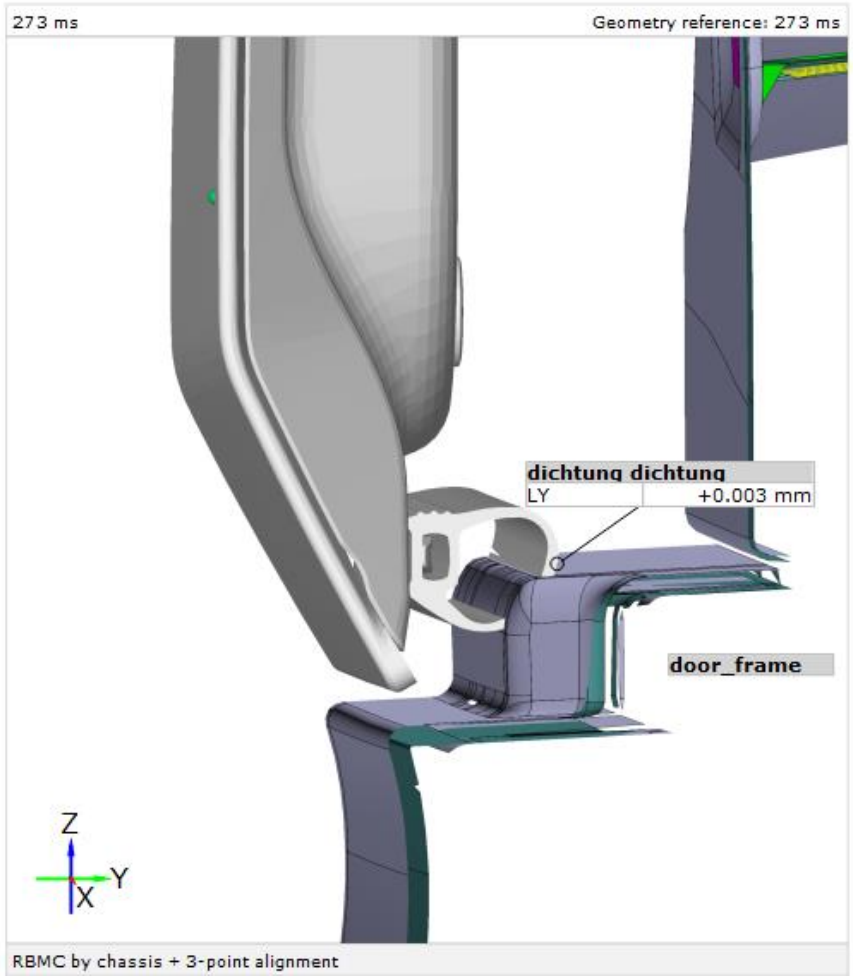
Material Properties | Product Design/CAD/ Simulation | Prototype Manufacturing | Prototype Inspection / Testing | Simulation Validation | Production / Series Inspection

Door Slam Test



Door Slam Test

static distance seal - chassis by closed door



Static Compression Test on Drive Cabine - Excavator

Static loading

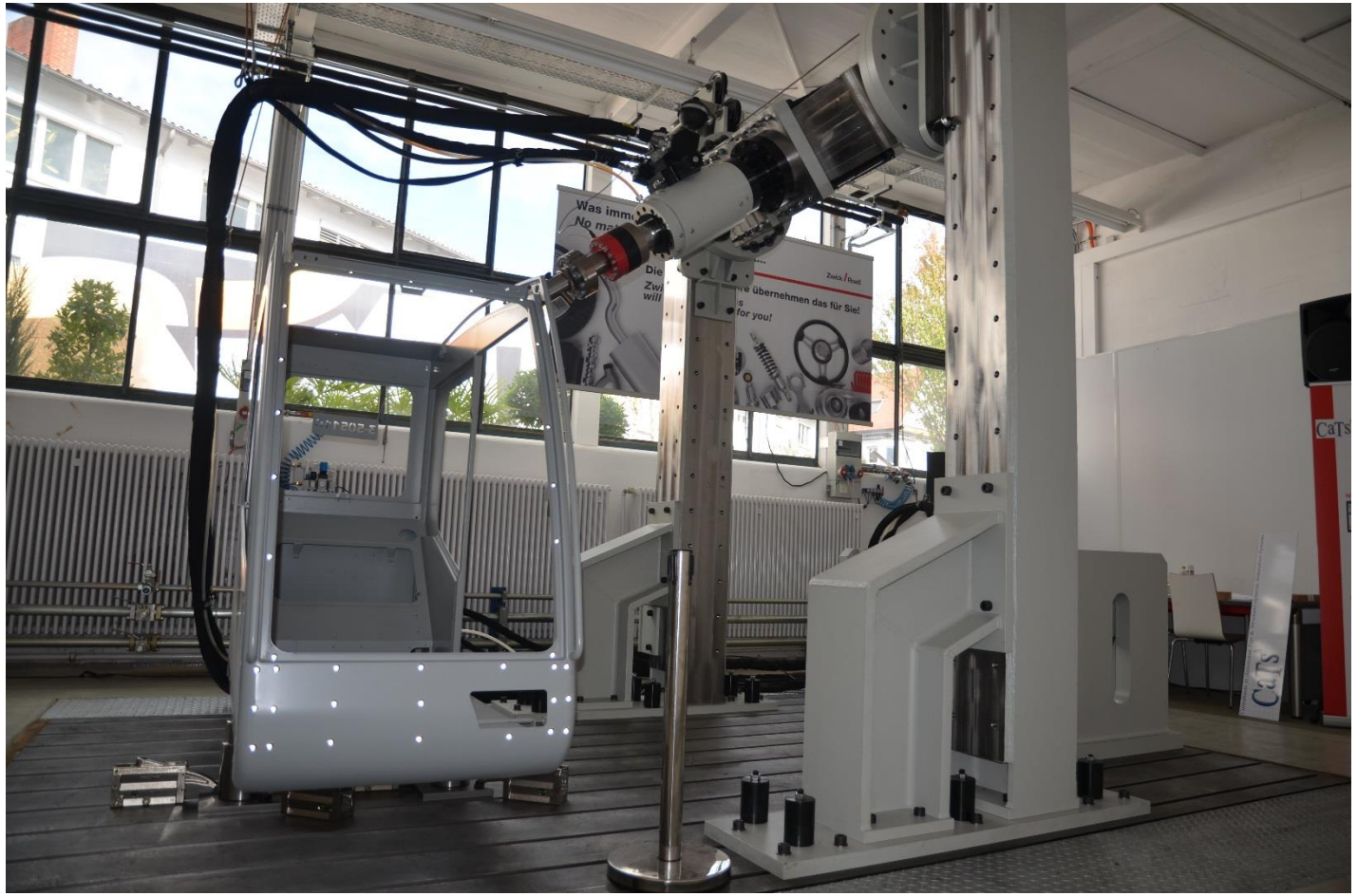
- Evaluation of the max. load in the elastic deformation area

Structural testing to

- Protect the driver

Test Condition

- ARAMIS SRX
- Measuring Frequency 5 fps
- Load max. 3.5 kN

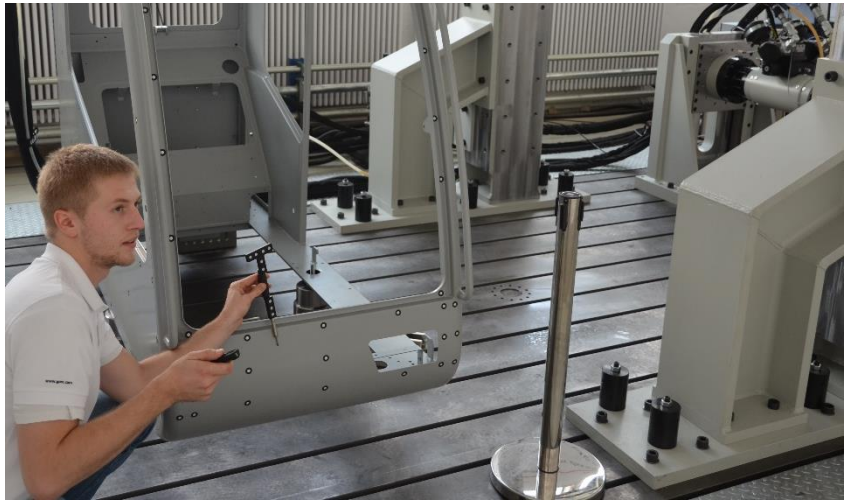


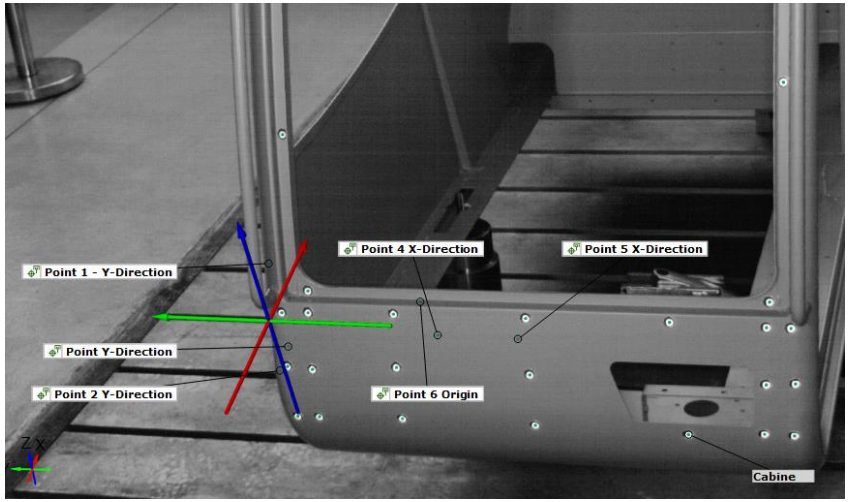
Definition of the Coordinate System

GOM Touch Probe

Tracking the Touch Point to probe
- Geometric elements
- Points

Alignment via constructed Points
e.g. 3-2-1 Alignment

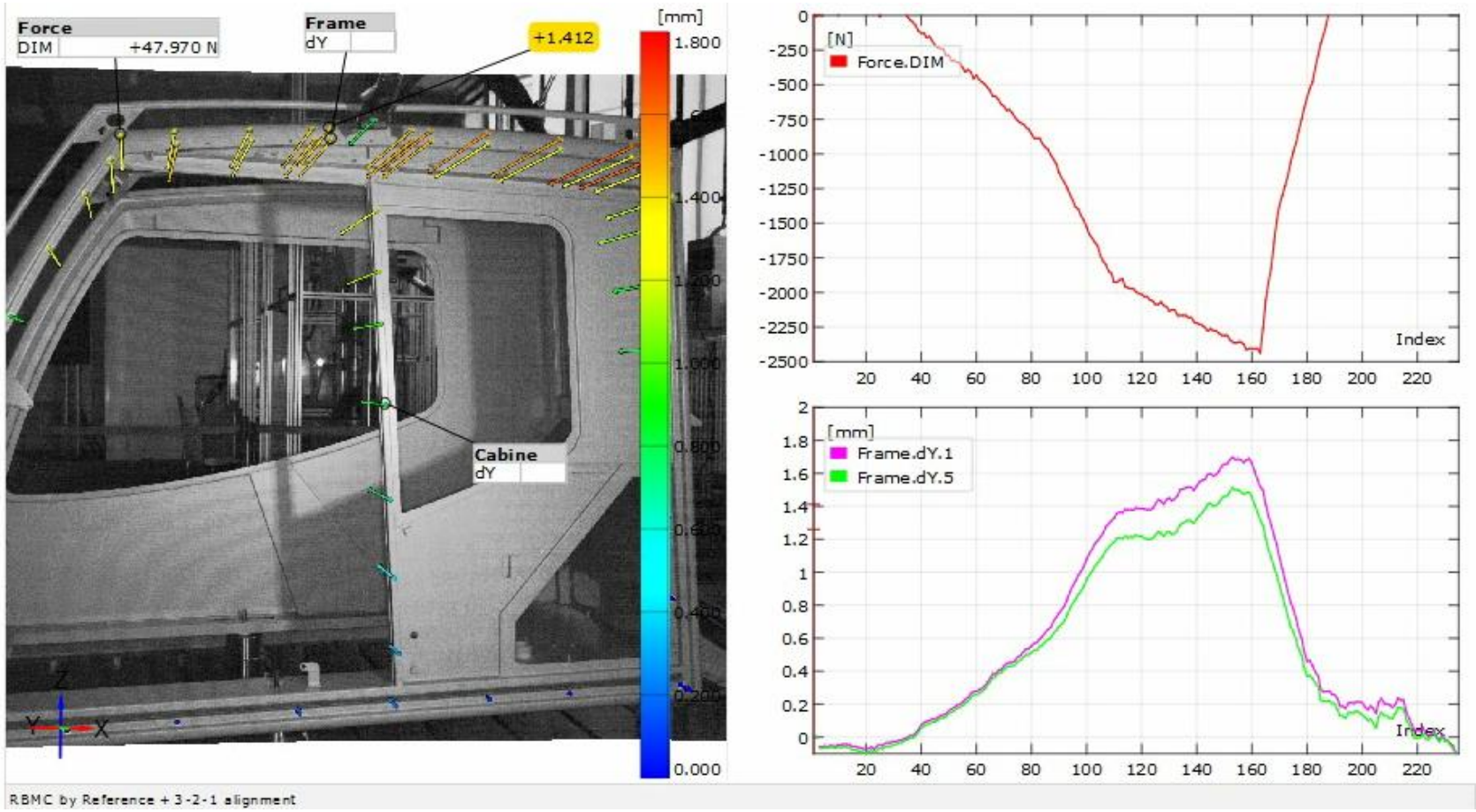




Measuring on the Side

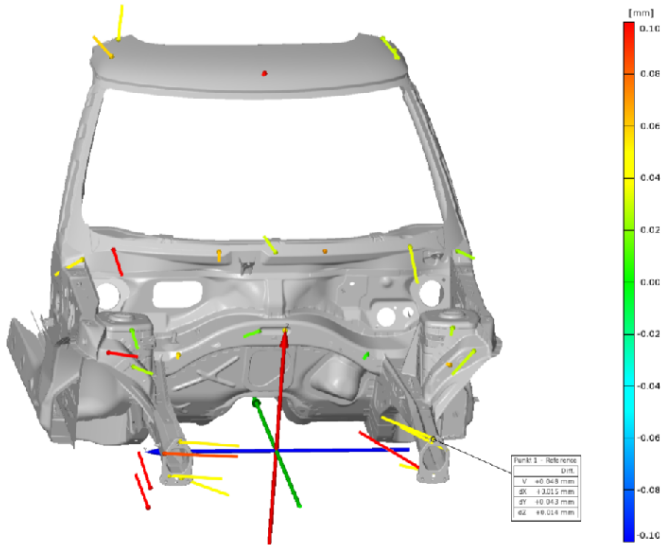
Deformation in Y- Direction

- Max. Load 2.5 kN
- Deformation 2 mm (Elastic deformation)



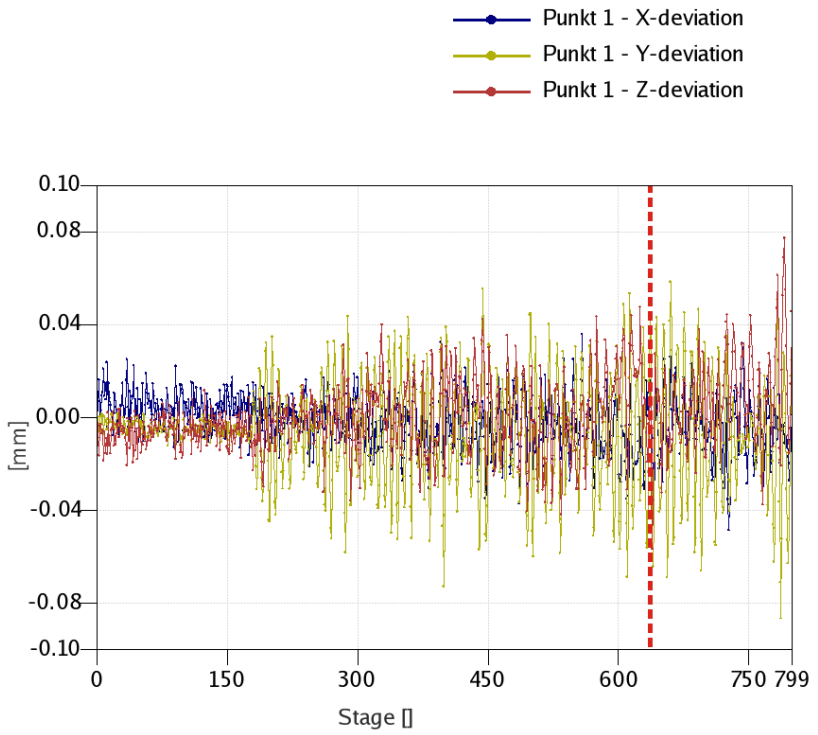
Vibration Analysis: Vehicle

- Modal analysis on front vehicle
- Comparison with conventional acceleration sensors
- Visualization of measurement results



Deformation (Vector)

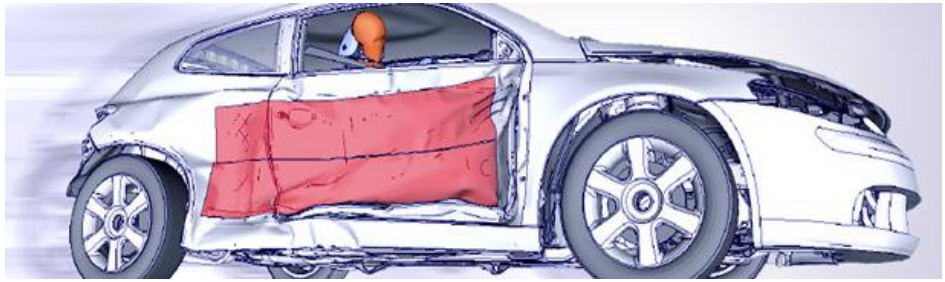
Vibro1_mov_cor.dyn
Date: 9/29/09
Stufe 636
Modalanalyse



Exchange Formats: Exports

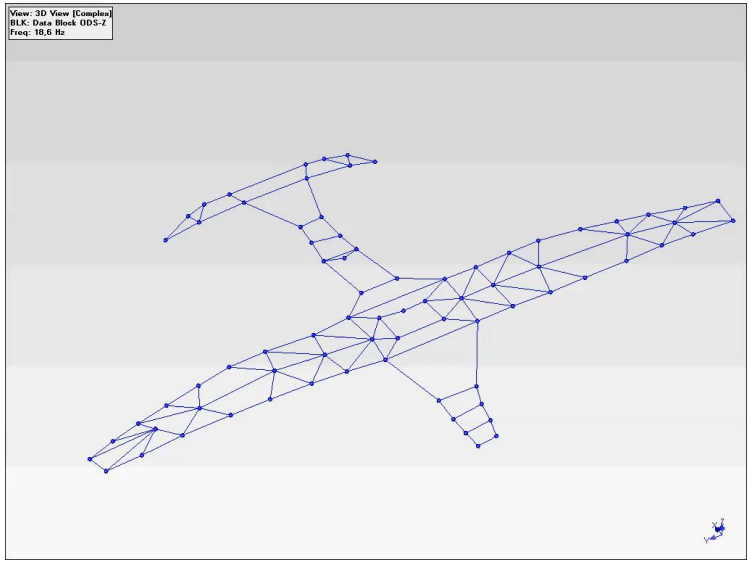
Animator (GNS, http://gns-mbh.com/animator.html)

- Post-processing tool for a wide range of FEA applications
- Special XML format including ASCII values

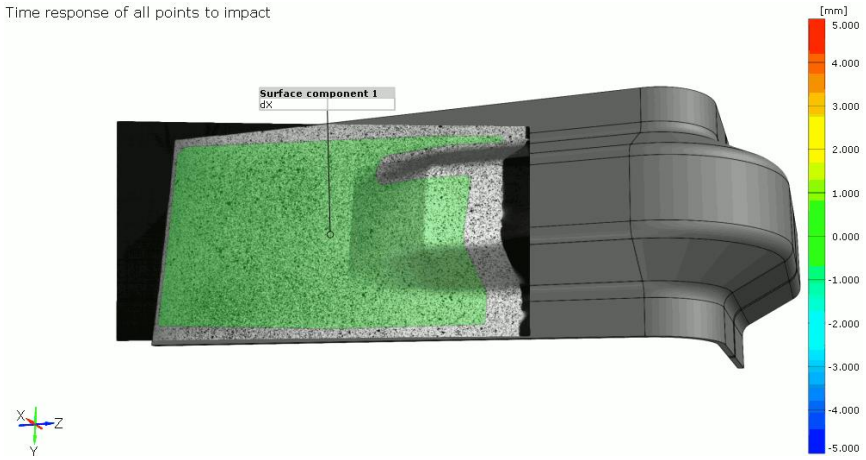


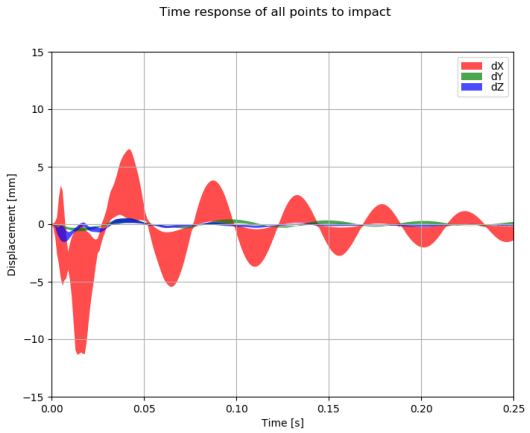
UFF (**U**niversal **F**ile **F**ormat)

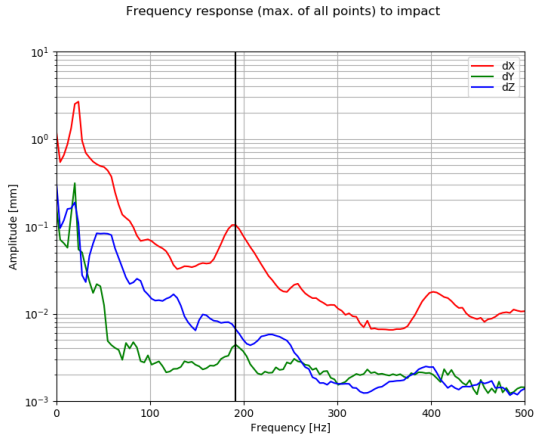
- Standard format for vibrational analysis
- Use for typical modal analysis software packages
  - ME'scope (Vibrant Technology)
  - PAK (Müller-BBM)
  - LMS Test.Lab (Siemens)
  - PULSE (Brüel & Kjær)

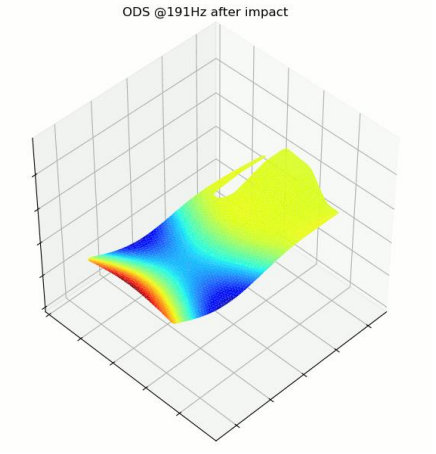


Vibration Analysis with ARAMIS



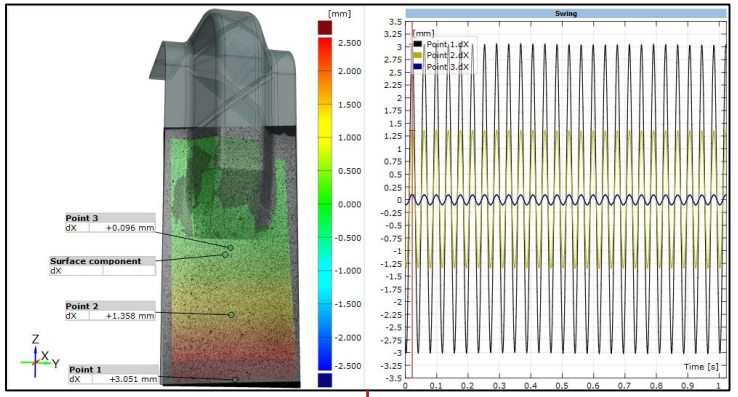


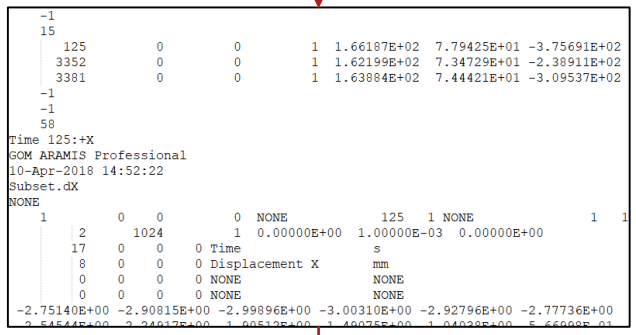




Workflow

- Measure with ARAMIS
- Evaluate full field 3D data
  - Surface Components
  - Point Components
    - *which can be meshed and used as Surface Components as well*
- Alignment to CAD or FEA or global measurement coordinate system, RBMC
- Advanced evaluation
  - Point Inspection
  - Sections
  - 6DoF
  - Geometry Elements
  - derived result values
  - …
- **Export results in UFF format**
  - UFF block 58 – signals
  - UFF block 15 – geometry
  - UFF block 82 – mesh, sections
  - UFF block 2412 – surface
- **Import and evaluate data in 3rd party vibration analysis tool**
  - ME'Scope
  - PAK
  - PULSE, BK-Connect
  - LMS
  - …





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      3352         0         0         1  1.62199E+02  7.34729E+01 -2.38911E+02
      3381         0         0         1  1.63884E+02  7.44421E+01 -3.09537E+02
    -1
    -1
    58
Time 125:+X
GOM ARAMIS Professional
10-Apr-2018 14:52:22
Subset.dX
NONE
     1         0    0         0  NONE             125    1 NONE               1    1
          2      1024         1  0.00000E+00  1.00000E-03  0.00000E+00
         17    0    0    0 Time                    s
          8    0    0    0 Displacement X        mm
          0    0    0    0 NONE                  NONE
          0    0    0    0 NONE                  NONE
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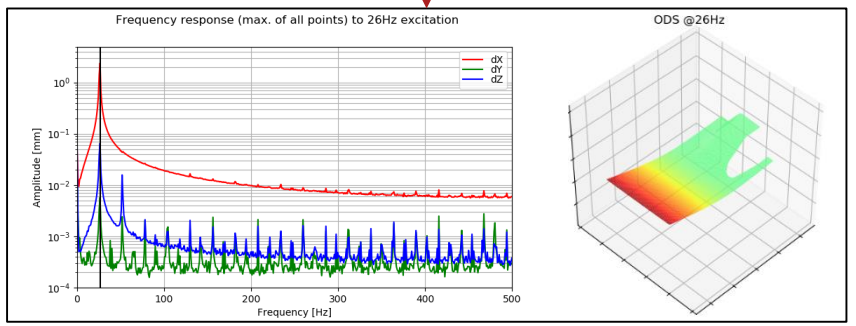
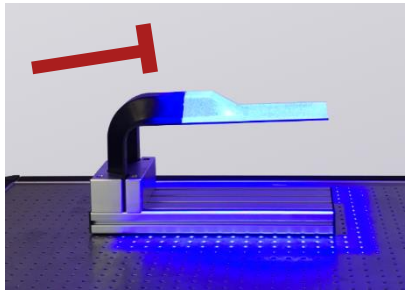
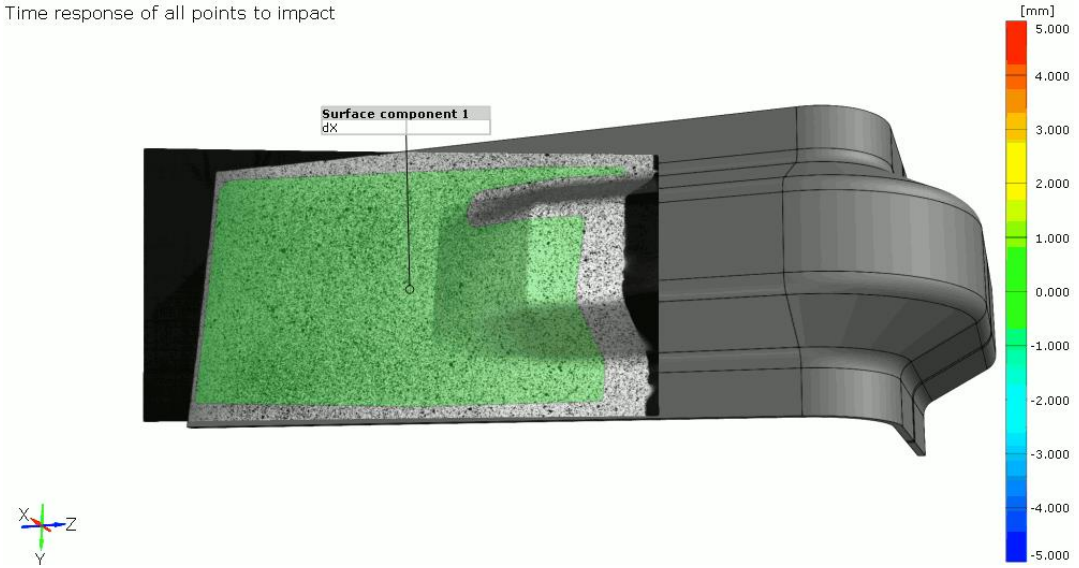


Example: Impact

- Excitation with hammer impact



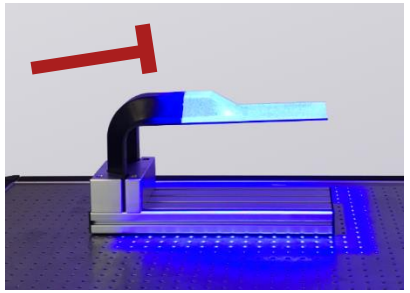


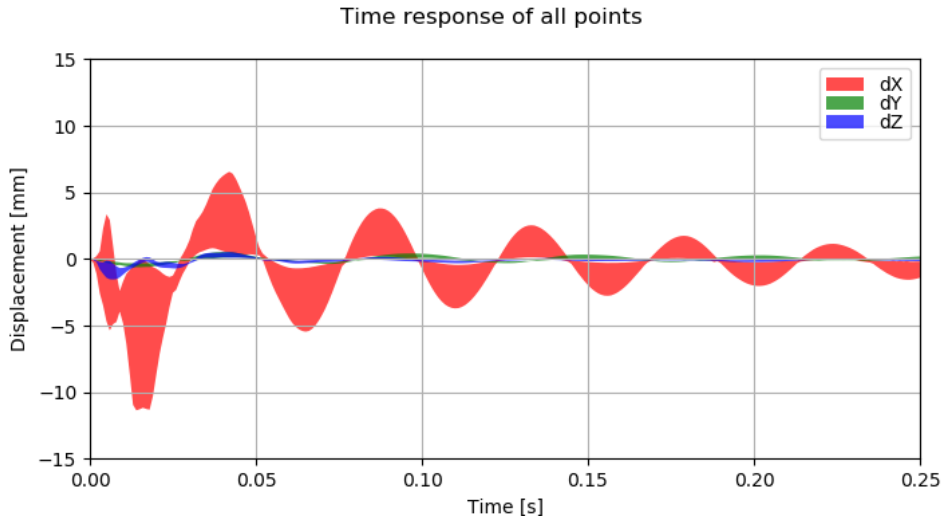
Example: Impact

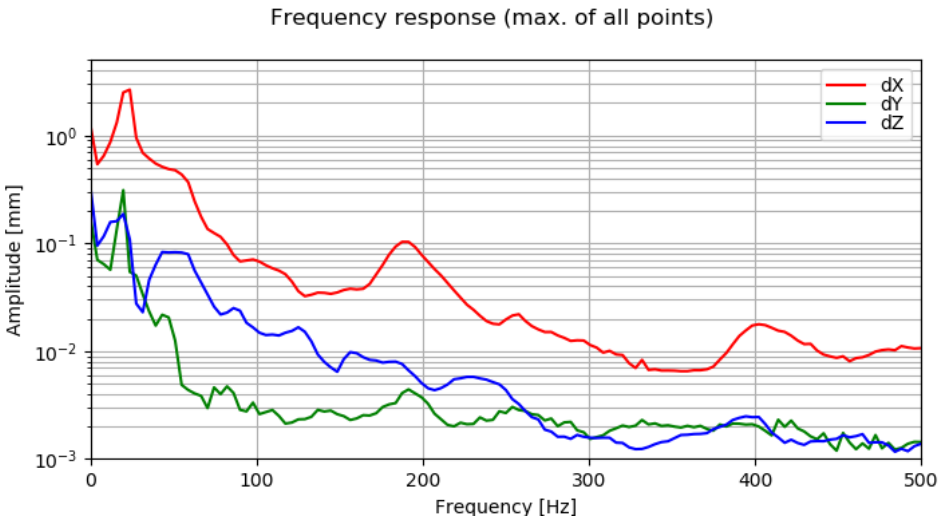
- Excitation with hammer impact.

- To get resonance frequencies
  - it can be measured with short term high speed measurements (here with 1000 fps for 1 s).
  - *a single impact without load signal is enough, because all points are measured in 3D simultaneously.*

- The local maxima in the frequency response give feedback of the resonance frequencies.
- In this case
  - in the range of 20..30 Hz
  - in the range of 170..190 Hz
  - in the range of 395..405 Hz







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- The local maxima in the frequency response give feedback of the resonance frequencies.
- In this case
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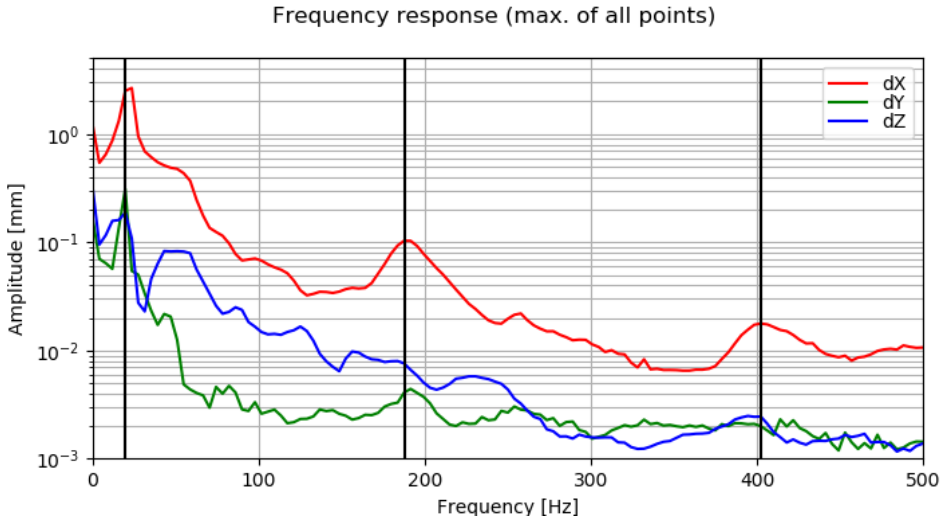
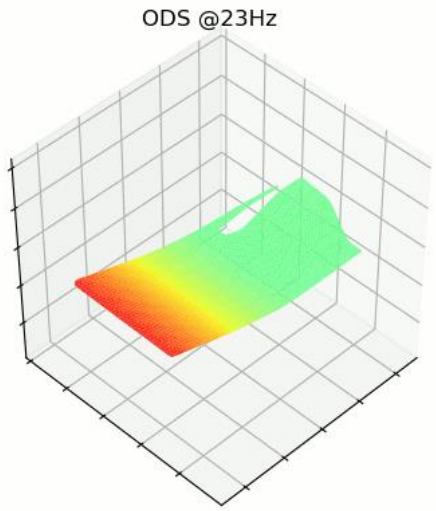
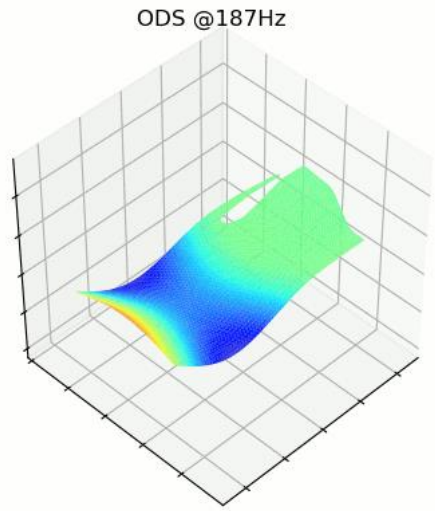
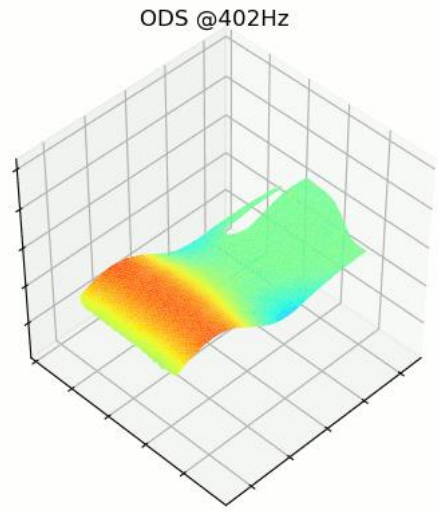
- Deflection shapes can be evaluated at resonance frequencies.



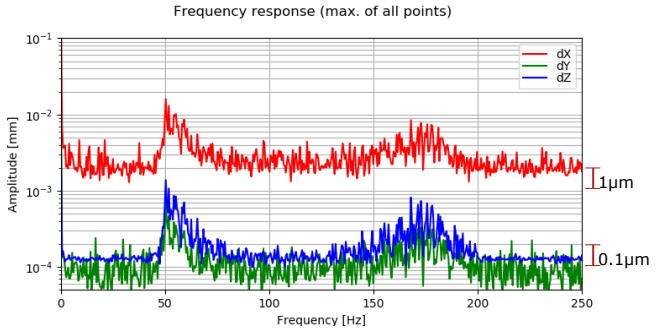




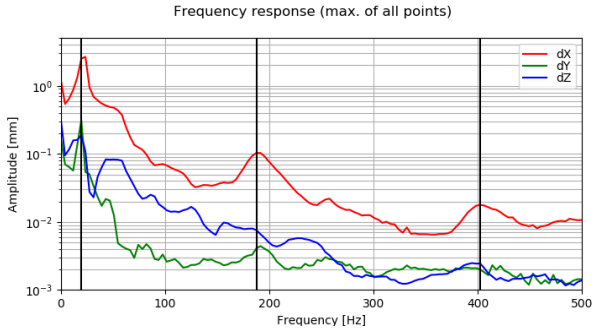


Conclusion and Outlook

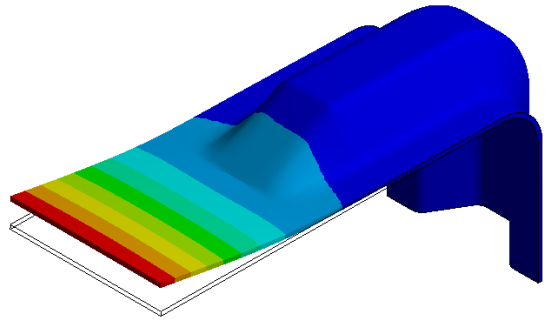
- Amplitudes in the range of sub-micrometers can be evaluated in the frequency response.



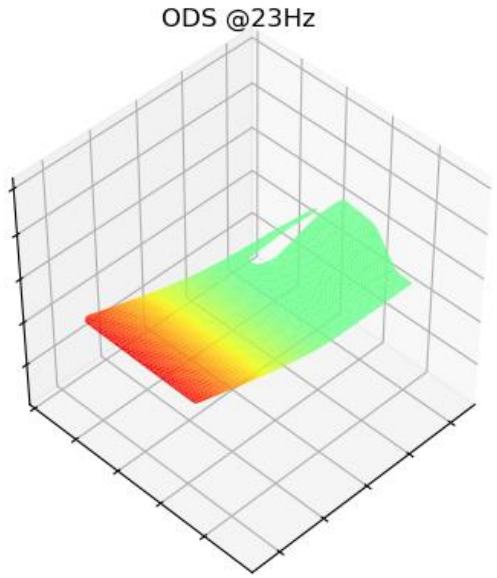
- For this particular sample all excitation methods (sweep, noise and impact) show similar mode shapes at similar frequencies.
  - Hammer impact gives good results with minimized effort.

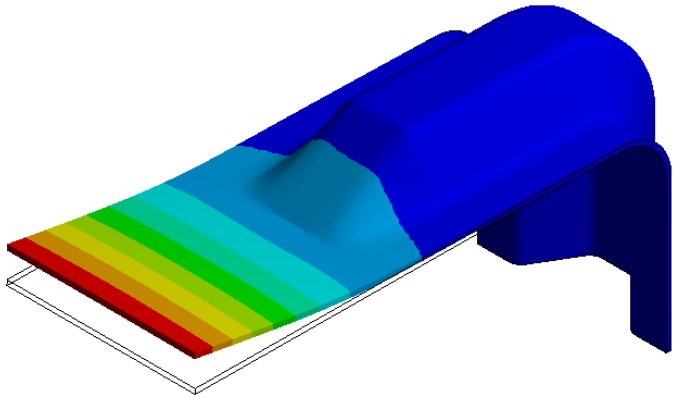


- The vibration analysis results can be used for further evaluation e.g. for FEA comparison.
  - *Only X-deflection shapes are excited and therefore measured.*

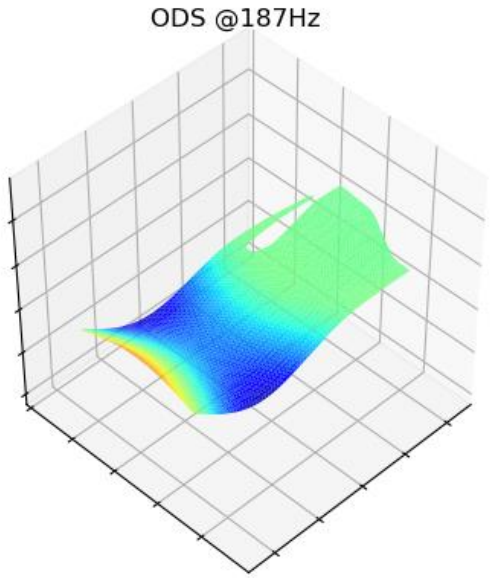


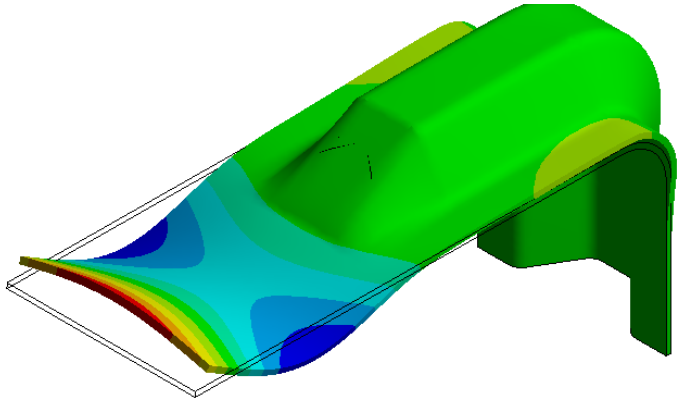
FEA Comparison



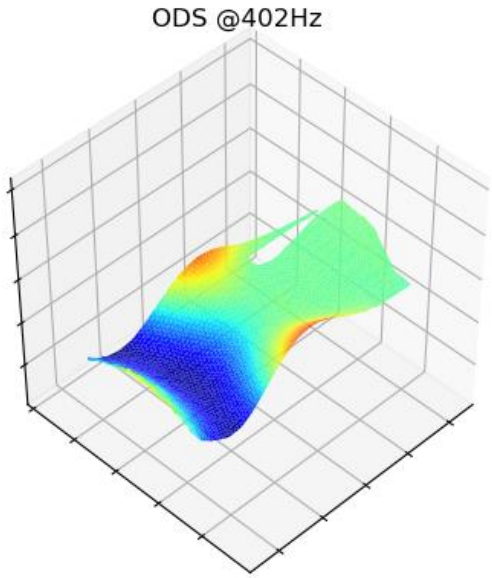


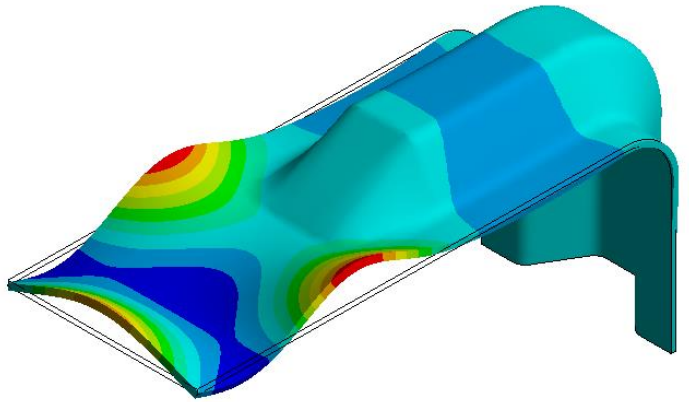
1st Mode





5th Mode





11th Mode

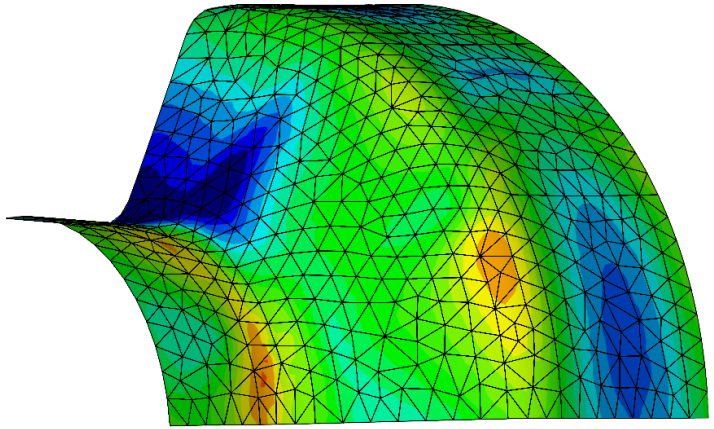
ARAMIS in Product Development

Simulation verification

Validation of numerical simulations

Improving simulation capabilities

Knowledge building for future product developments



Material Properties

Product Design/CAD/ Simulation

Prototype Manufacturing

Prototype Inspection / Testing

Simulation Validation

Production / Series Inspection

Numerical Simulations

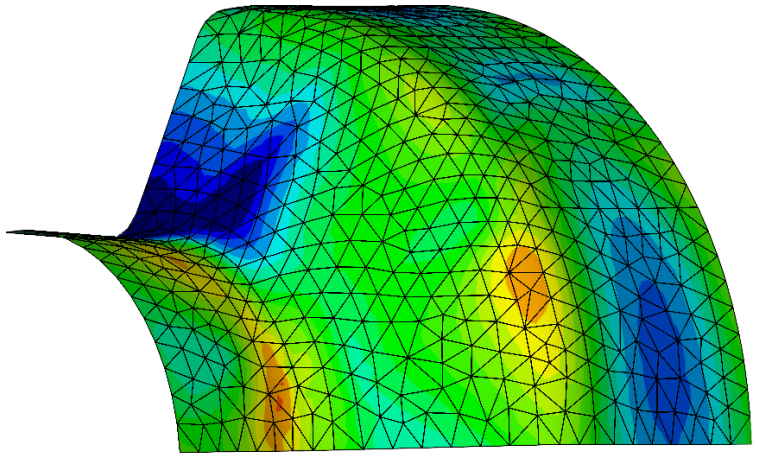
FEA input parameters

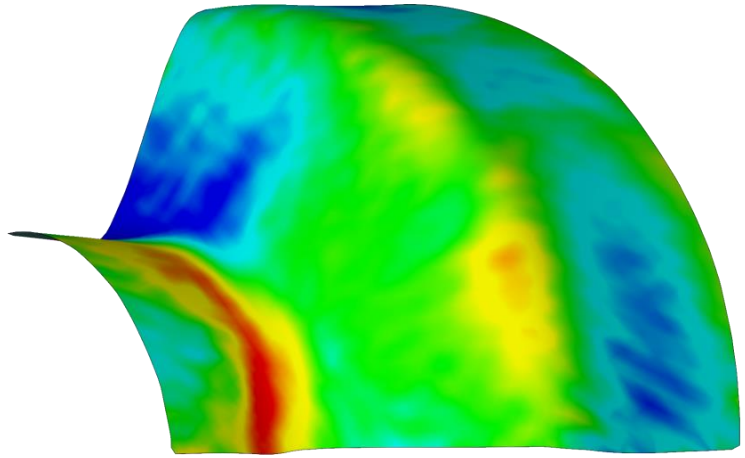
Geometry

Material model / data

Boundary conditions

Validation of FEA results
- Deviations in shape
- Deviations in displacement and deformation
- Deviations in strain





Simulation Verification Improvements in GOM Software 2017

Checks are using same mathematics for simulation and measurement data

Directly comparable results (e.g. strains)

Import of result values (contours) is still supported.

Lagrange or Euler notation?

2D or 3D strain tensor?

Element or nodal strain?

Right or left stretch tensor?

Plastic or absolute strain?

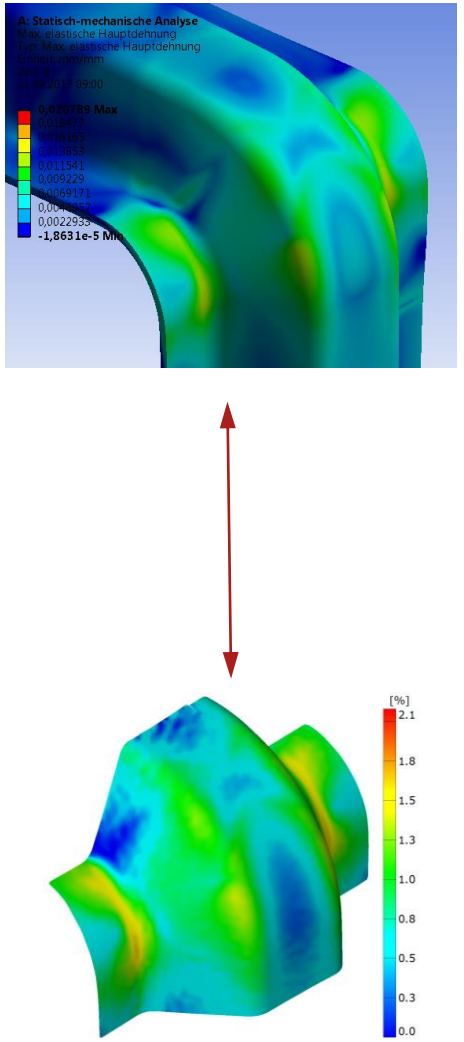
Engineering or true strain?

Definition of comparison strain?

Naming vs. definition of strain values?

Surface or middle-layer strain?

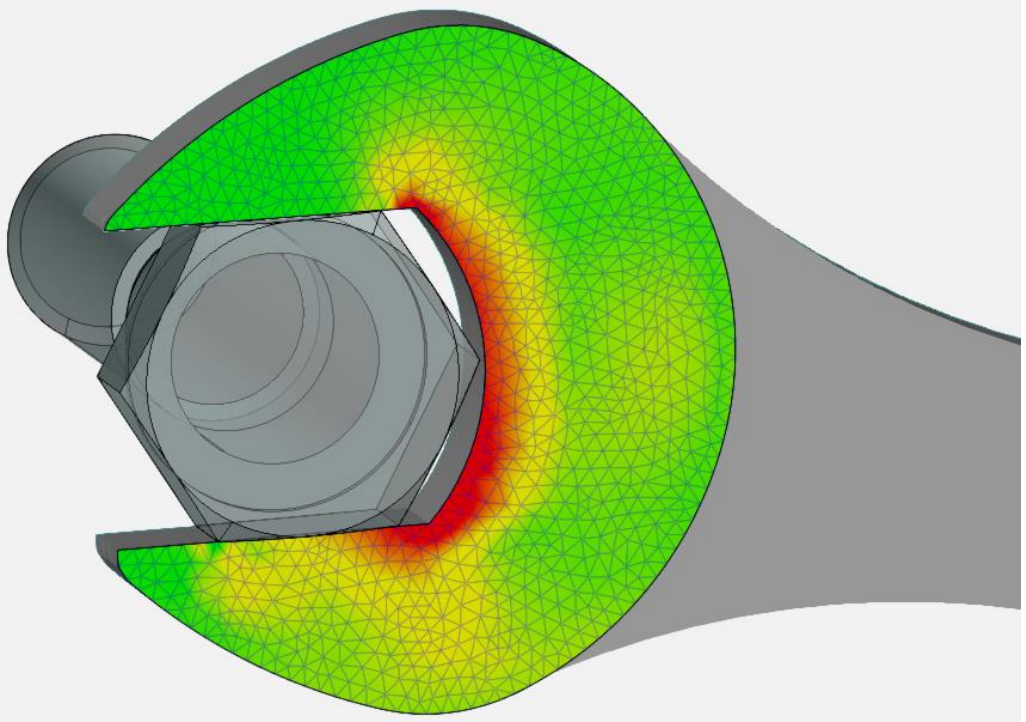
Major strain in thickness direction?



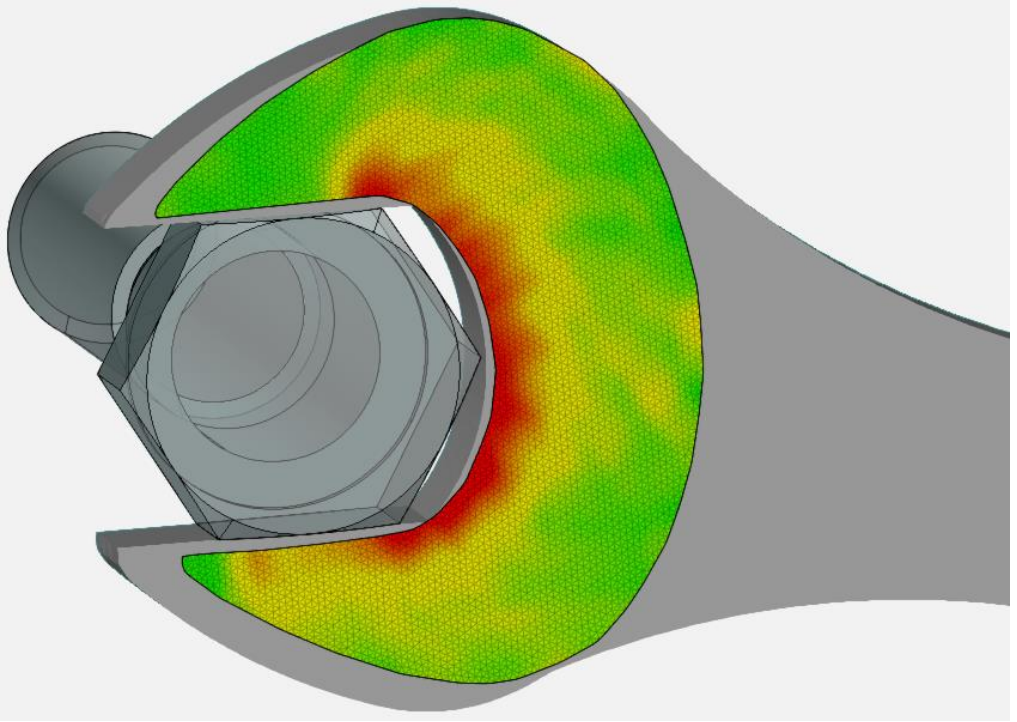
Data Comparison (FEA)

Compare simulation data and measurement data in ARAMIS Professional

Simulation



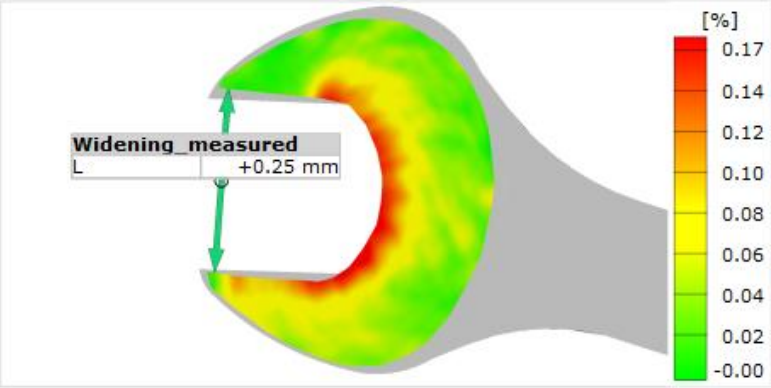
Measurement



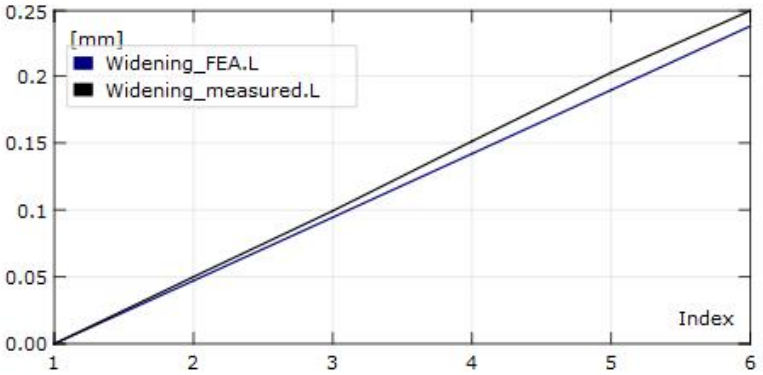
Data Comparison (FEM)

Comparison

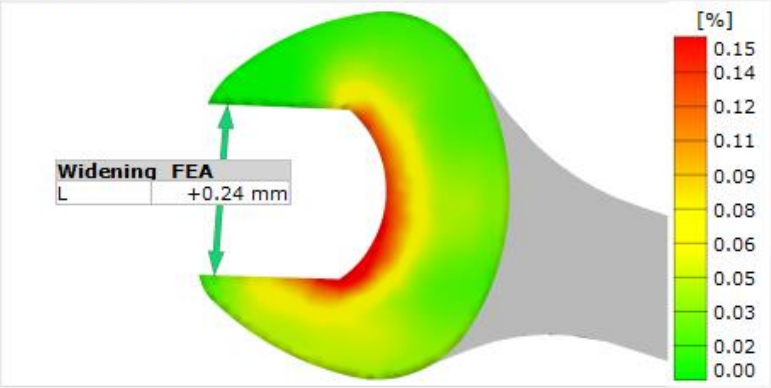
Measurement



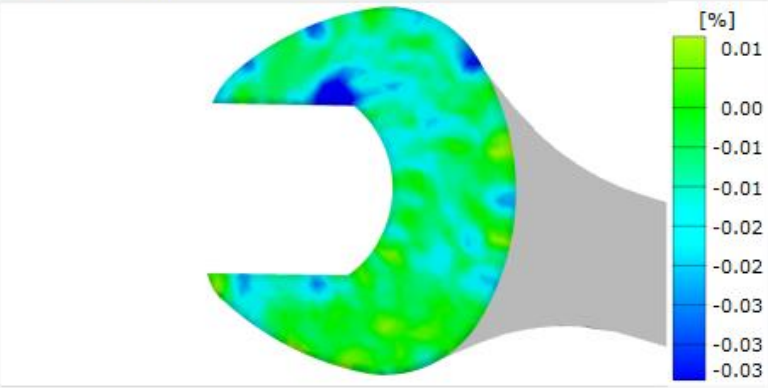
Widening



Simulation



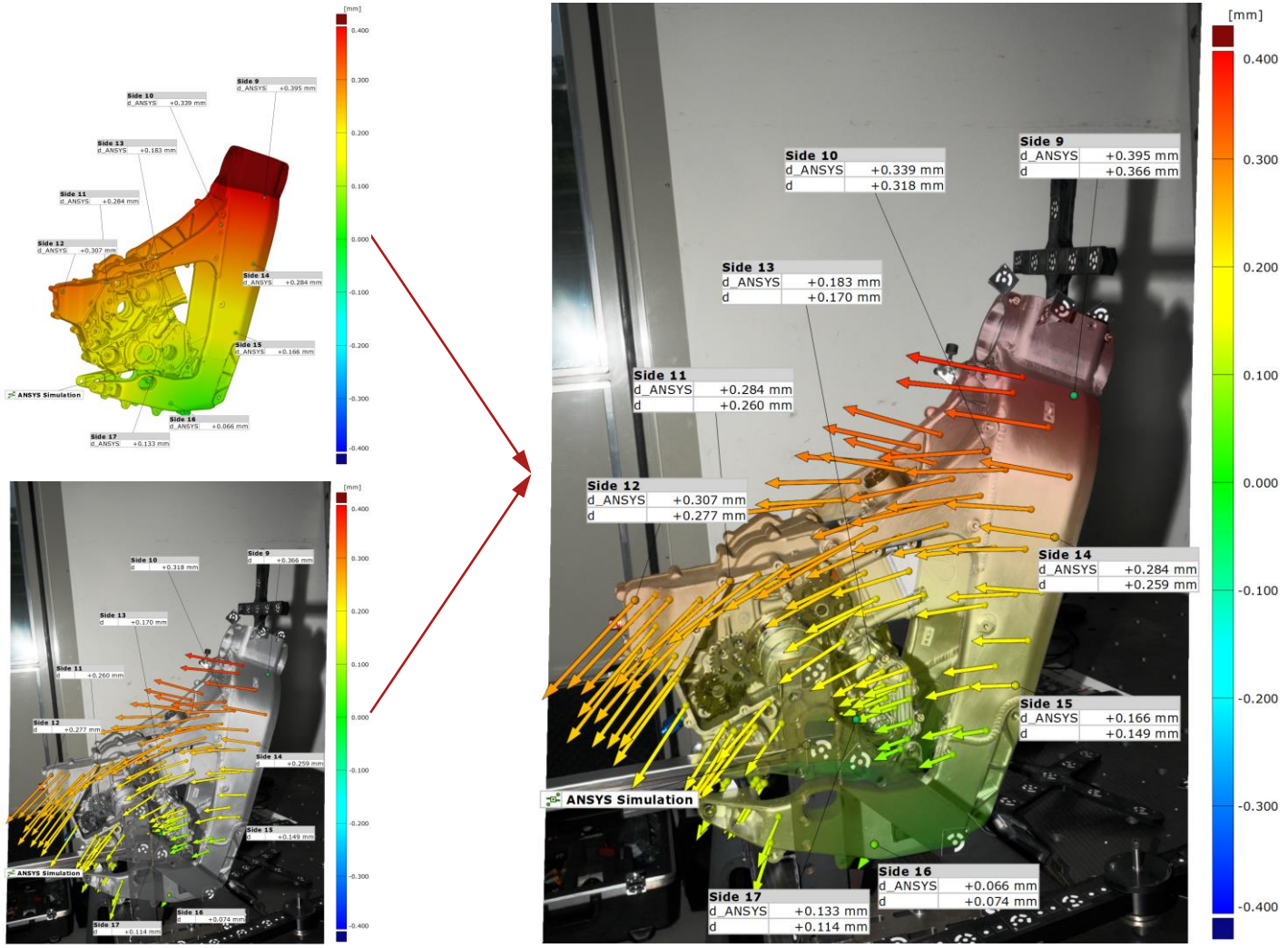
Deviation



Simulation Verification Improvements in GOM Software 2017

Point components fully supported too

- For structured parts
- Former PONTOS applications
- TRITOP applications



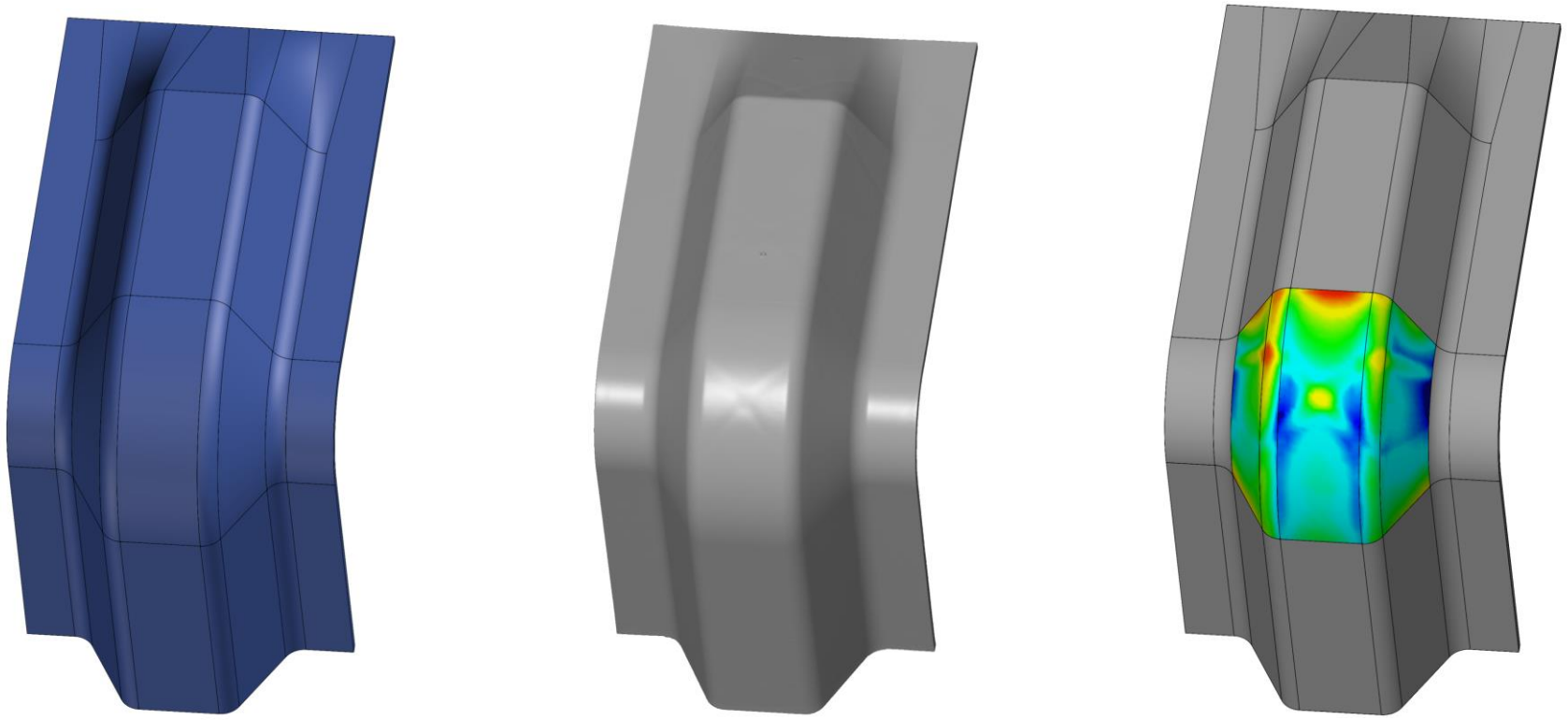
In cooperation with:

SUTER RACING CADFEM

Simulation Verification Improvements in GOM Software 2017

ATOS included

- Shrinkage
- Spring back
- Thickness comparison
- Draw in



Simulation Verification Improvements in GOM Software 2017

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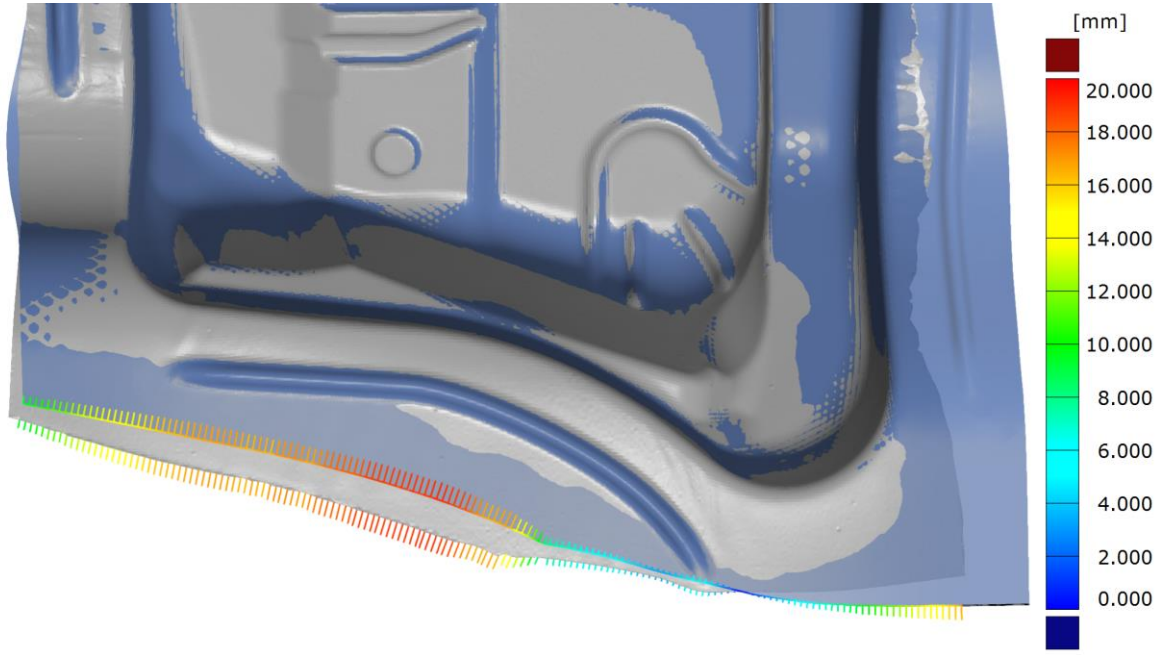

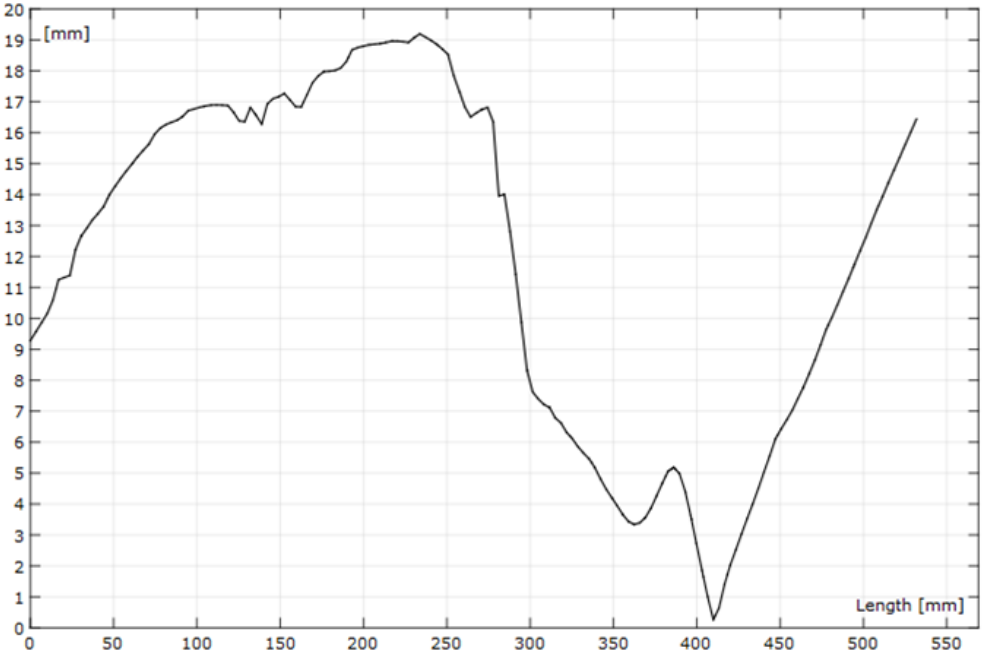

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