Zwick TestXpo 2016

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

GOM mbH | October 12, 2016

Harald Friebe

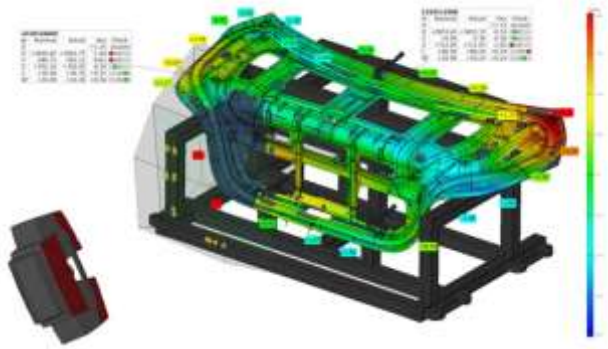
# GOM - Precise Industrial 3D Metrology

Over 25 years experience in the development and production of optical 3D metrology solutions and measuring systems

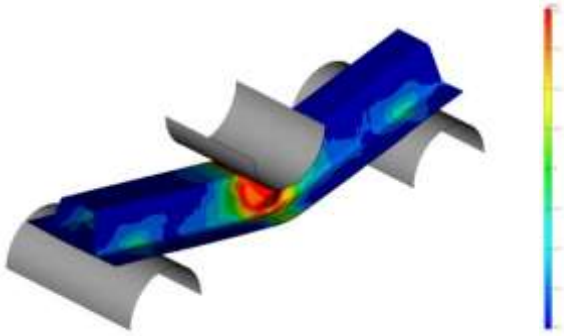
**Optical measuring Systems**

Hardware und Software

3D coordinate measurement



Material and component testing



# GOM


GOM

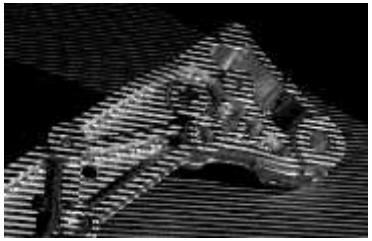
- Founded in 1990
- Private, owner managed company
- Development, production and administration in Braunschweig, Germany

GOM Network

- GOM Group
  - 9 companies and branches
  - over 450 employees within GOM Group
- 36 sales and support partners with over 55 offices worldwide
- 800 employees in worldwide network

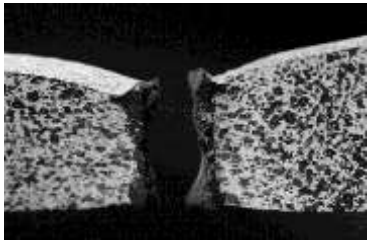
**Over 10.000 system installations worldwide**

# GOM – Our know-how

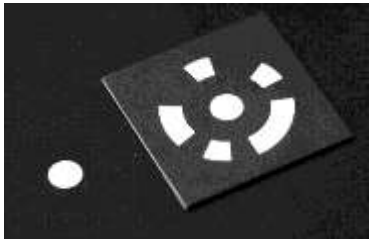


Projected pattern

Regular pattern



Stochastic pattern



Point markers

Digital image processing

3D coordinate measurement techniques

Quality control

Material parameters

Automation

# GOM Measuring Systems

**3D Coordinate Measurement**

**Material and Component Testing**

## ATOS

Full-field
3D Scanning

Projected pattern

## TRITOP

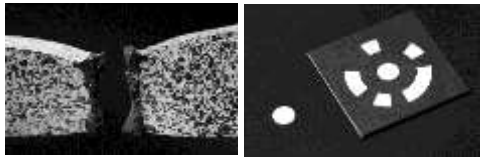
Mobile
Optical CMM

Dot marker

## ARAMIS (PONTOS)

Optical 3D Motion and
Deformation Analysis

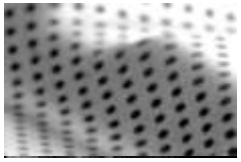
Dot marker and stochastic pattern



## ARGUS

Optical
Forming Analysis

Regular dot pattern



GOM Inspect Professional

GOM Inspect

GOM Correlate Professional

GOM Correlate

# ATOS

## 3D Scanning


# ATOS - 3D Digitizing

**Applications**

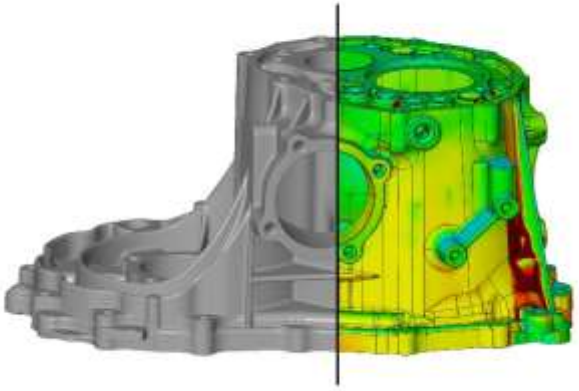
Quality control / Inspection

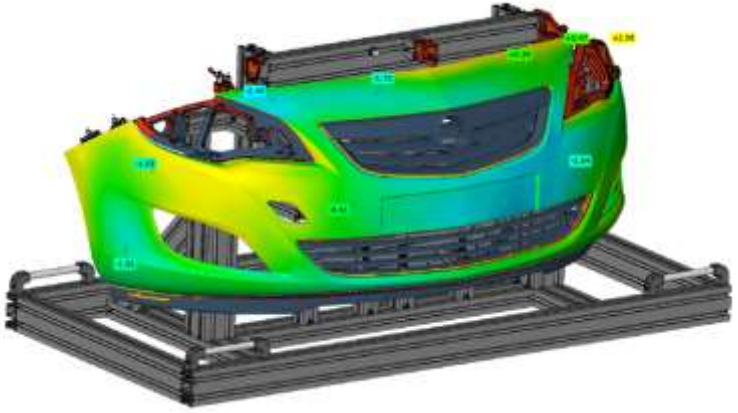
Reverse Engineering

Rapid prototyping

Manufacturing

Virtual assembly





Colour Source: Full-field deviation measurement to CAD

# ATOS - System

## Standard Solution

- Sensor on tripod
- Manual positioning

## First automation steps

- Turntables
- Lift for Sensor

# ATOS ScanBox
# Optical 3D Measuring Machine

Automated full-field 3D metrology

- Standardized robot measuring cell
- Fully automated 3D digitizing and inspection
- For different part sizes and applications

ScanBox 8260

4105 5108 5120 6130 7260 8260

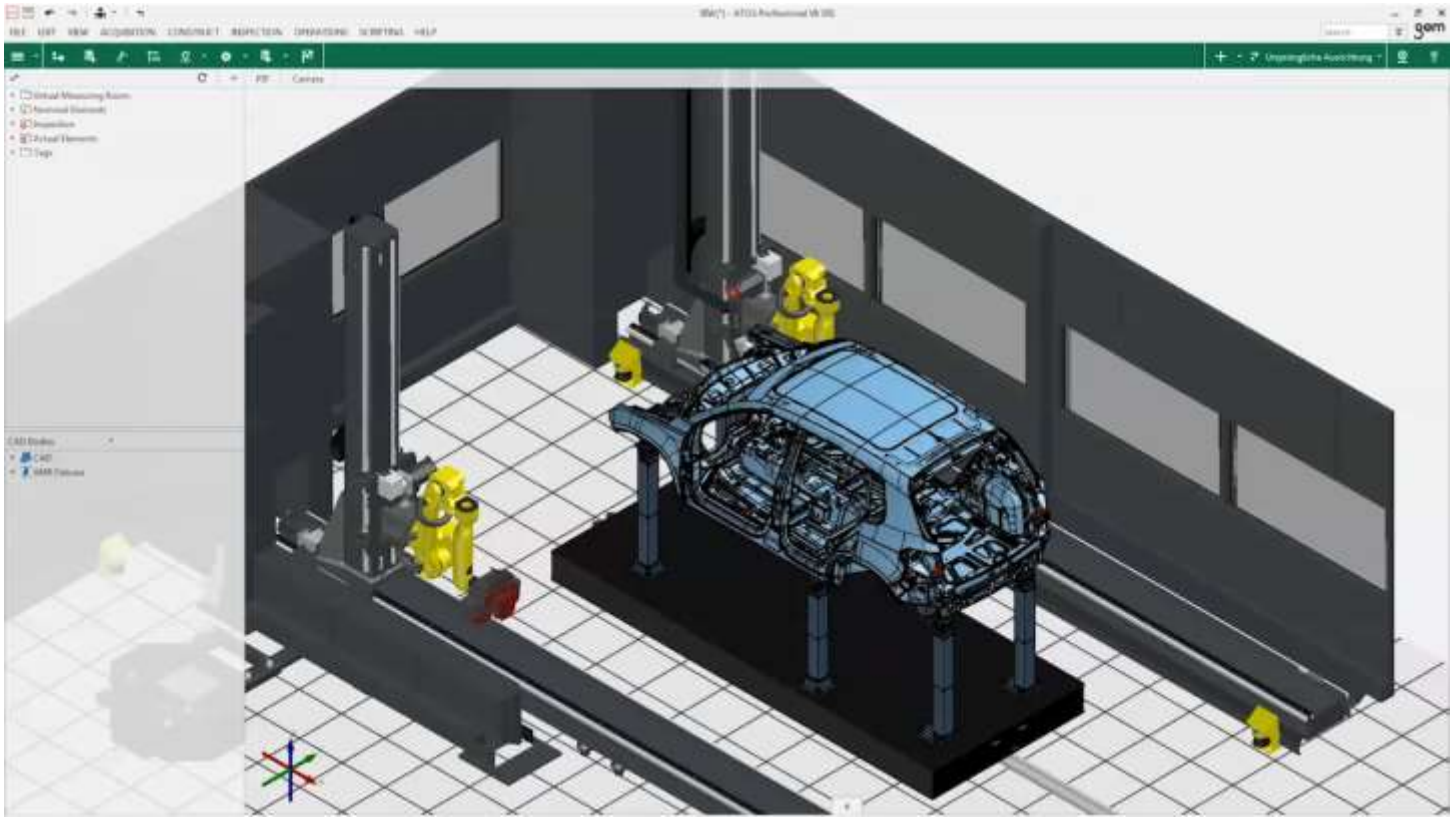
# ATOS ScanBox Optical 3D Measuring Machine

GOM-VMR (Virtual Measurement Room) Software fore automated Component Inspection

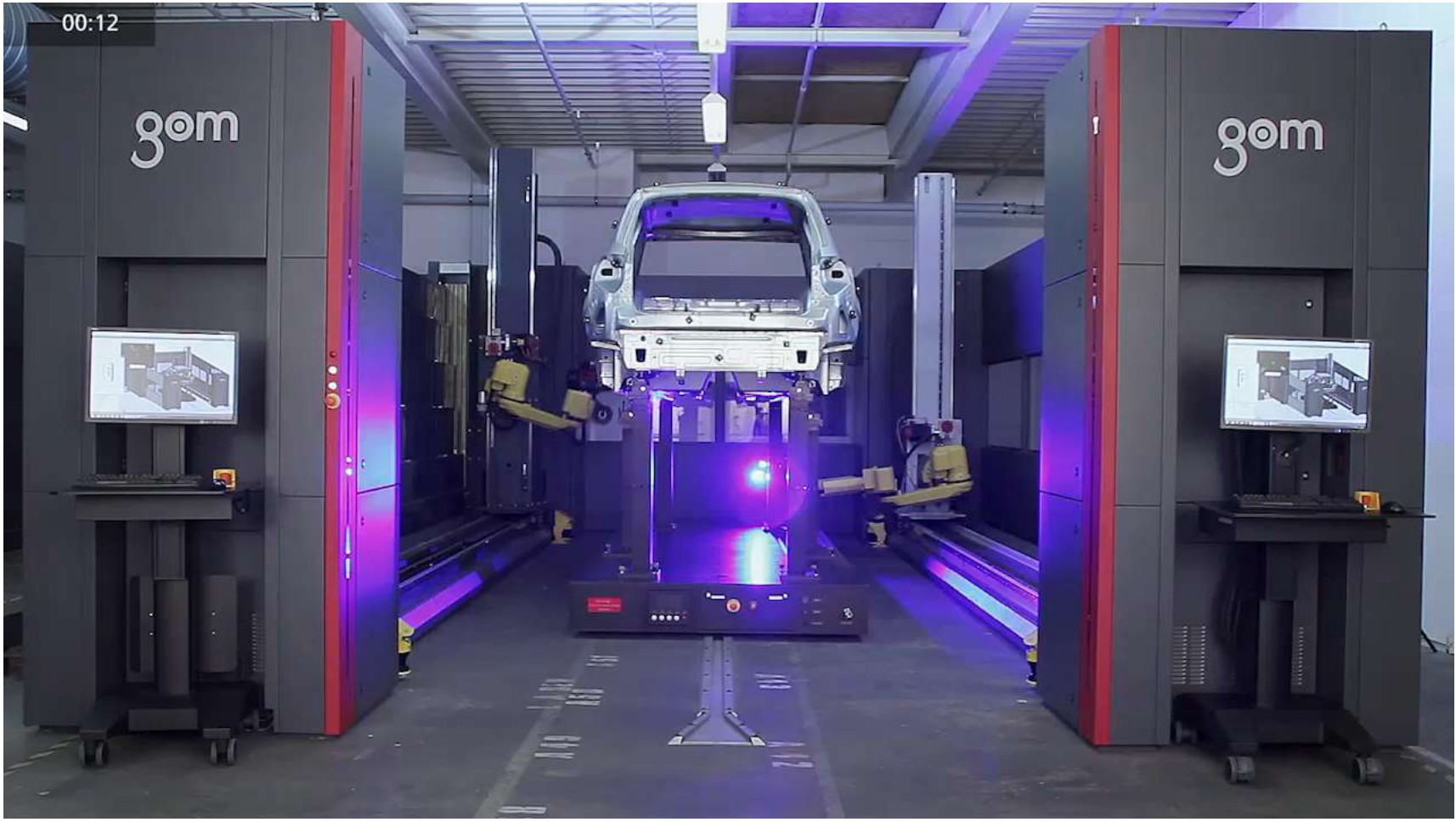
- automated robot teaching

Automatic

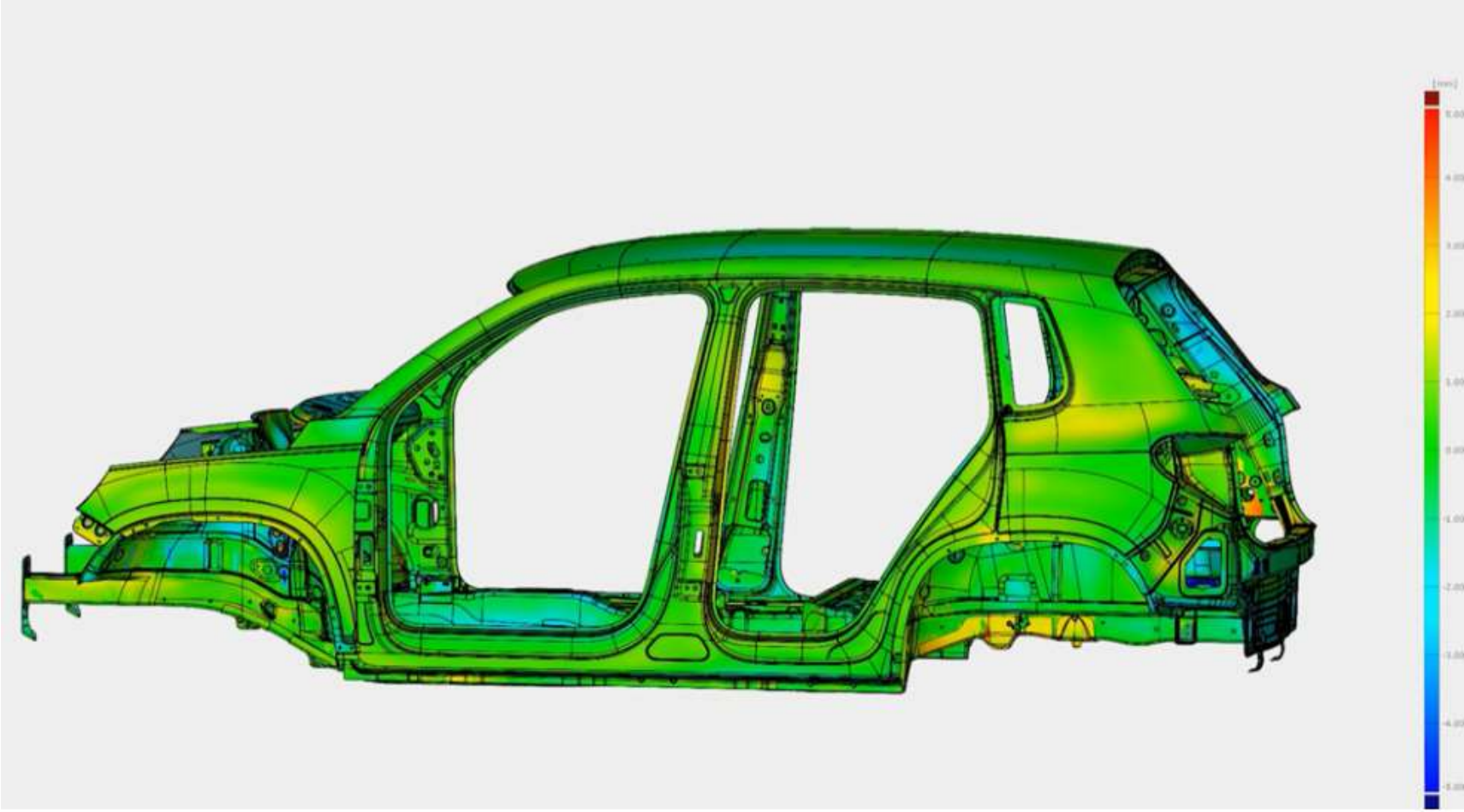
- Measurement
- Inspection
- Reporting
- Export



# ATOS ScanBox Optical 3D Measuring Machine



# ATOS ScanBox Optical 3D Measuring Machine



# TRITOP - Mobile Optical CMM

**Applications**

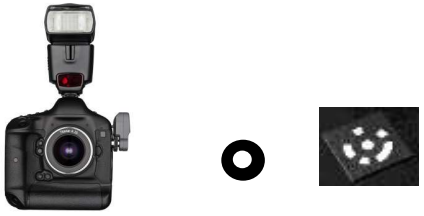
Quality assurance of large objects

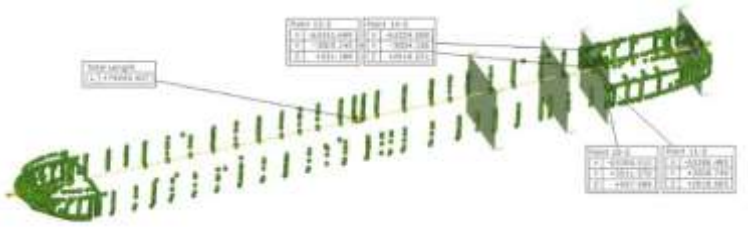
Monitoring of fixtures, gauges, machines

Deformation analysis and testing applications in automotive and aerospace areas

Climate and environmental chambers

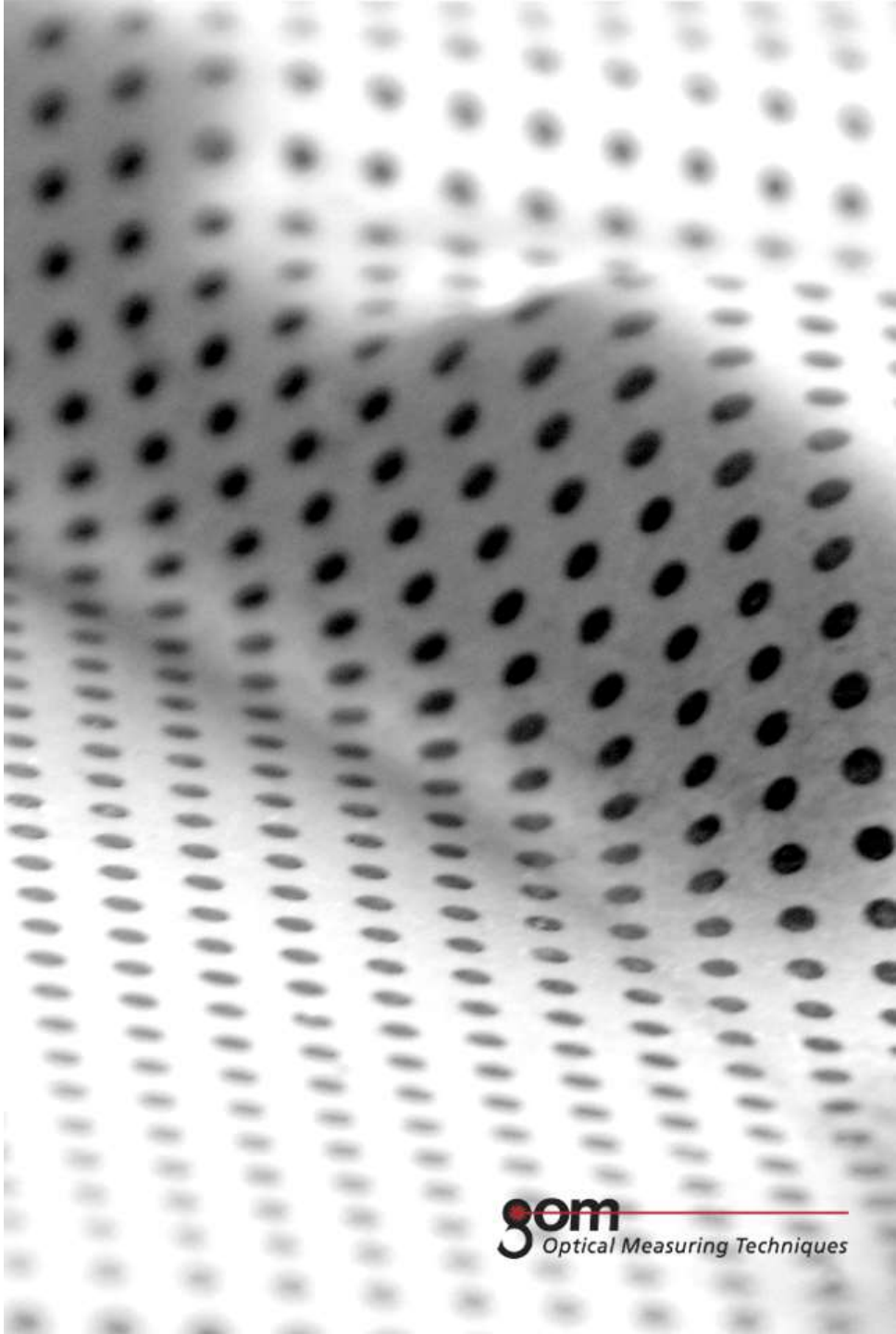
Determination of ATOS reference points





# ARGUS

## Forming Analysis



# ARGUS – Sheet Metal Forming Analysis

**Sheet Metal Forming Analysis**

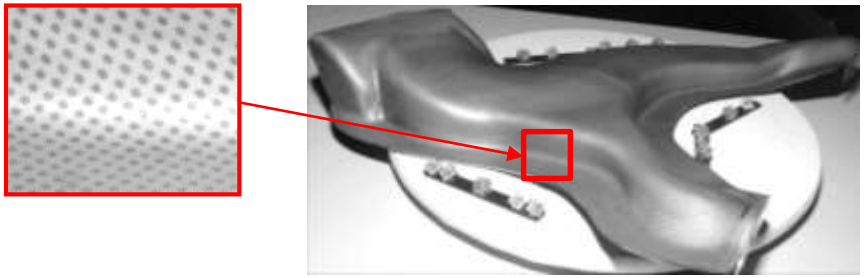
Determination of

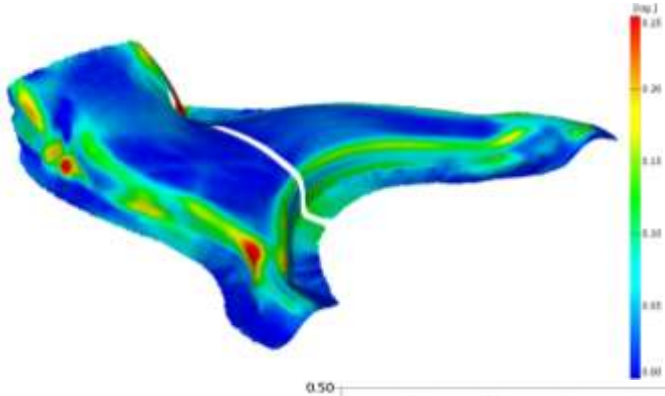
- Surface Strains (Major- and Minor Strain)
- Thickness reduction
- Forming Limit Diagram (FLD)

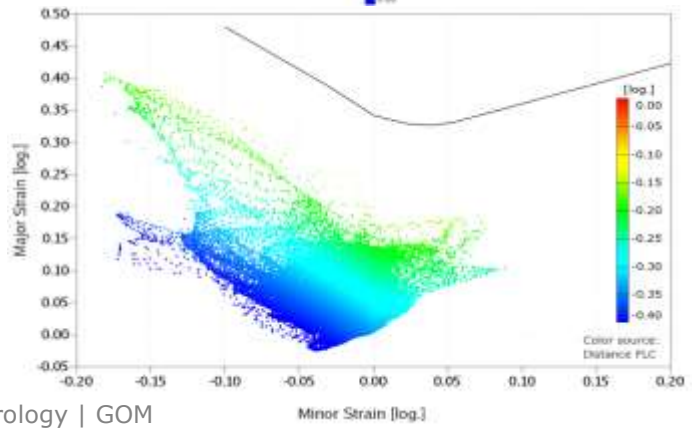
Verification of forming simulations

Tool try-out

Troubleshooting



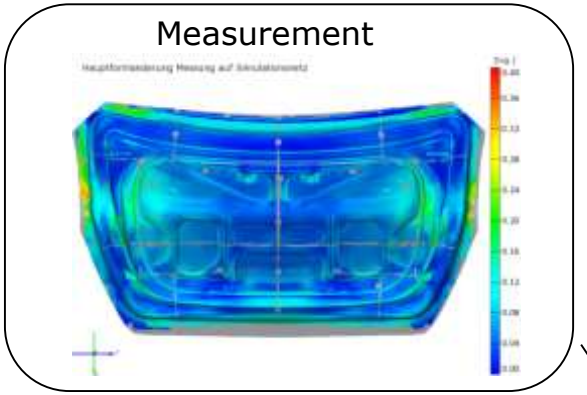


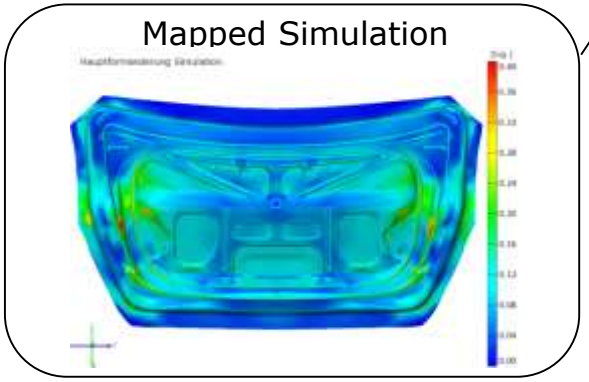


# ARGUS: Verification of Numerical Simulation

Import of FE-Results ➔ Calculation of Deviations for all Measurement Points

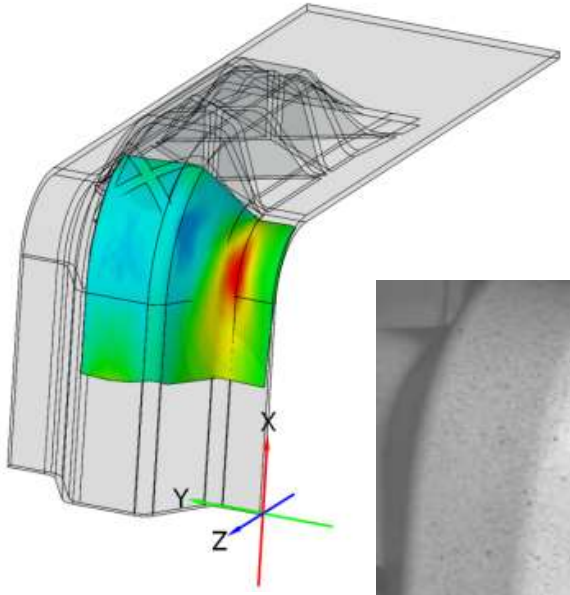
- Major Strain Deviation between Measurement and numerical Simulation

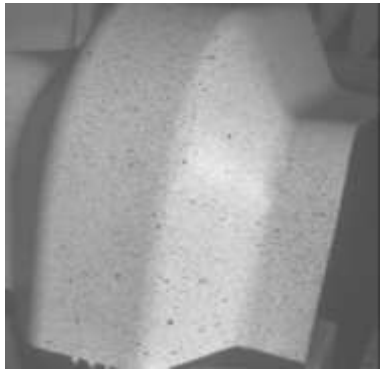



# ARAMIS
(ARAMIS + PONTOS)

## Point and Area Based Material und Component Testing



# ARAMIS - Optical 3D Deformation Analysis

**Full-field and point-based approach for material and component testing**

3D surface coordinates

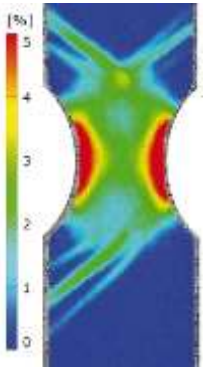
3D displacement

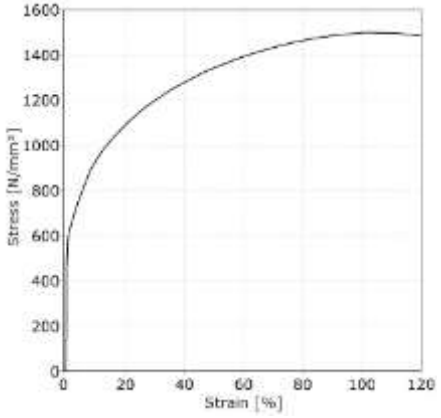
Velocity

Acceleration

Surface strains

Strain rates



# ARAMIS - Optical 3D Deformation Analysis

**Applications**

Determination of material properties

Dynamic behavior of components

Structural testing and vibrations

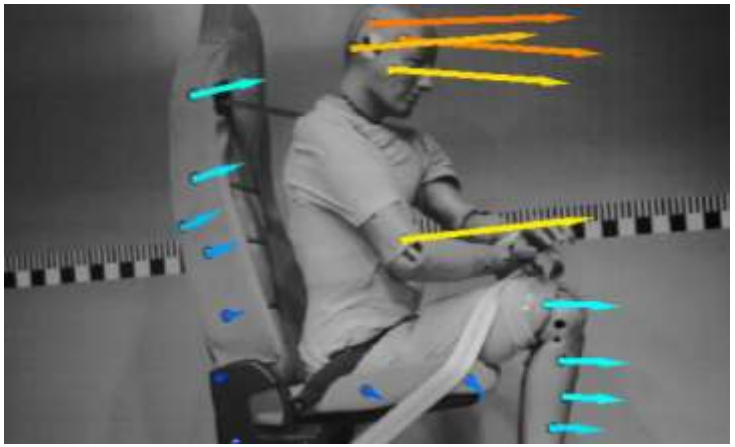
Verification of FE simulations

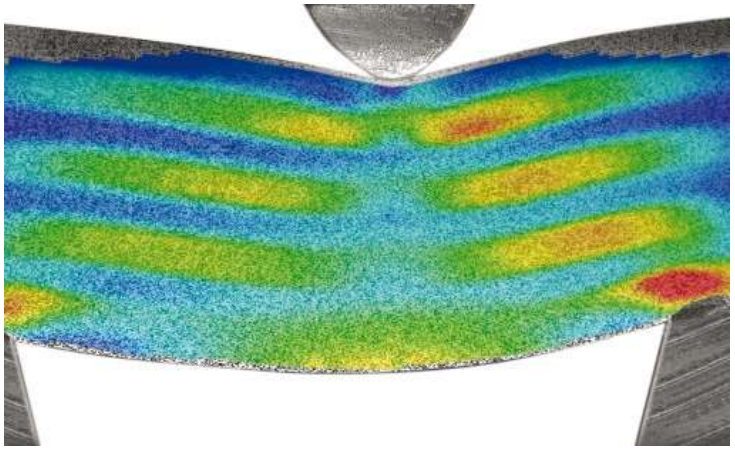
Real-time control of testing machines

Crash and impact tests

Durability and fatigue studies

NDT (Non Destructive Testing)





# ARAMIS - Principle of Full Field Evaluation

## Pattern applied on the specimen

- Stochastic or deterministic
- Pattern follows the deformation of the specimen

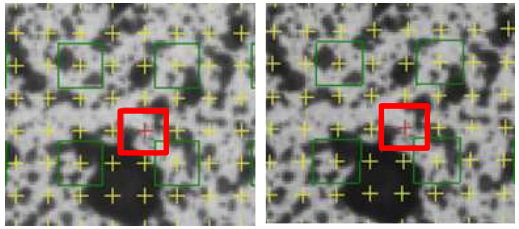
## ARAMIS captures online image pairs of the specimen

…,1Hz, … ,100kHz, … (1MHz)

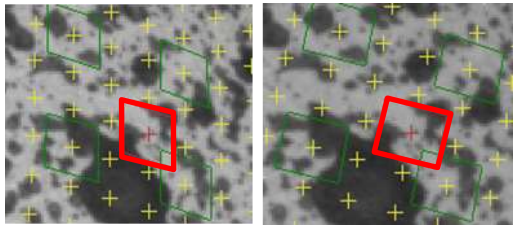
## Digital Image Correlation:

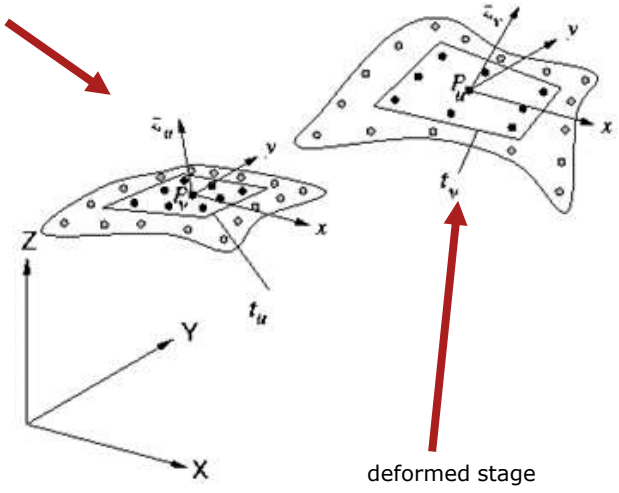
- First image is separated into Facets, Center of Facet = point of interest
- ARAMIS determines 3D coordinates of all facet center for each image pair

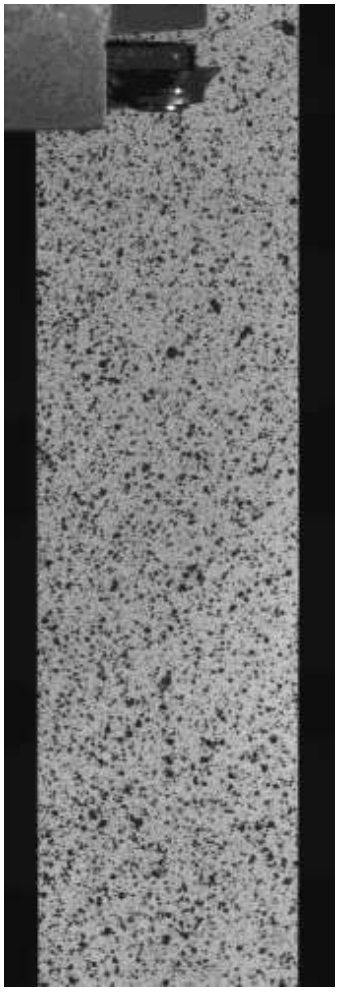
undeformed stage



deformed stage





# ARAMIS - Applications

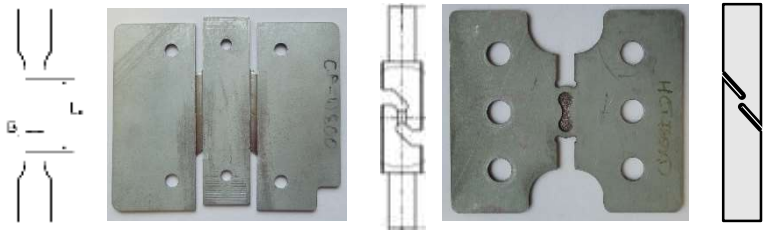
## Test Methods

- Tensile Tests
  - Standard
  - Biaxial
  - Fatigue (LCF)
  - …
- Component Tests
  - Crash Tests
  - Vibration tests
  - Thermal deformations
  - …

- Shear tests
  - Modified tensile tests
  - Miyauchi
  - Sheet torsion
  - …

- Bulge test
- Nakajima test
- Hole expansion tests

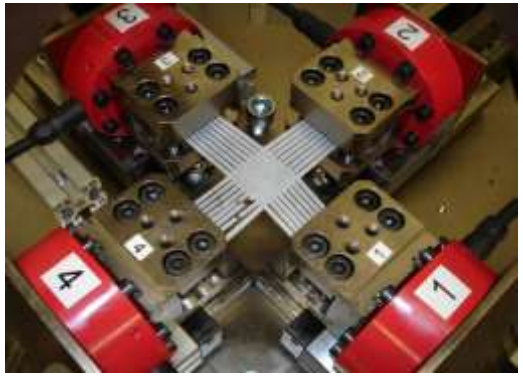
- Layer compression test
- Bending tests
- …



## Application

- Material parameter
- Local effects
  - Hardening
  - Failure criteria
  - Fracture mechanics

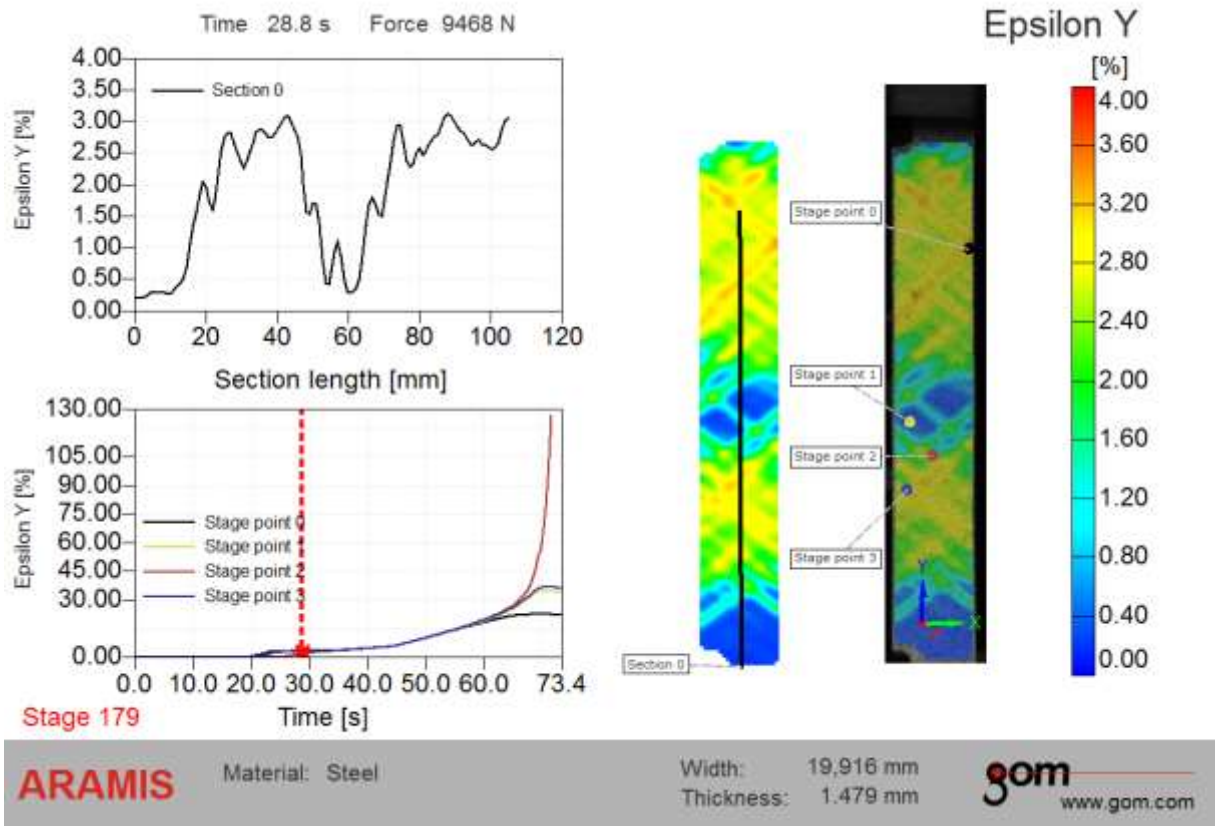
- Component Testing




# ARAMIS – Tensile Test – Local Effects

Steel with distinct yield effect:

- Lueders Bands
- Localized necking



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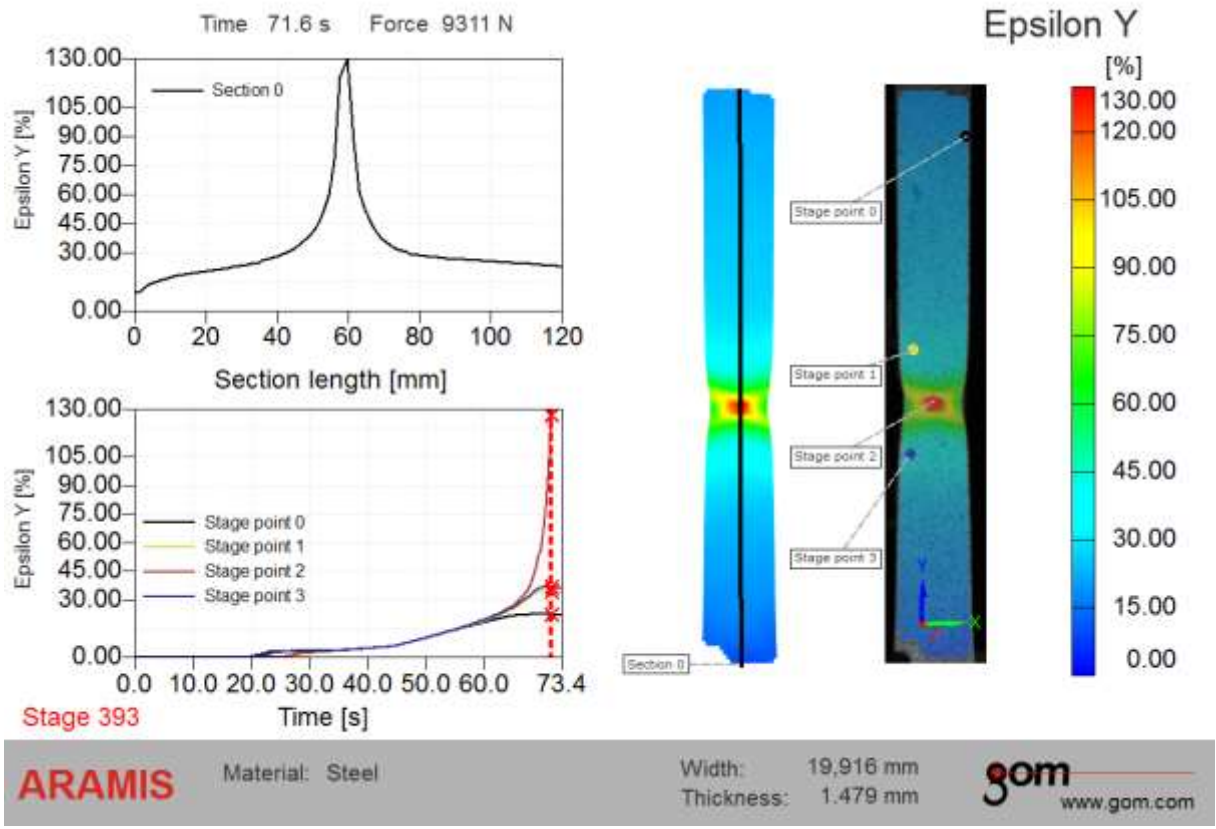
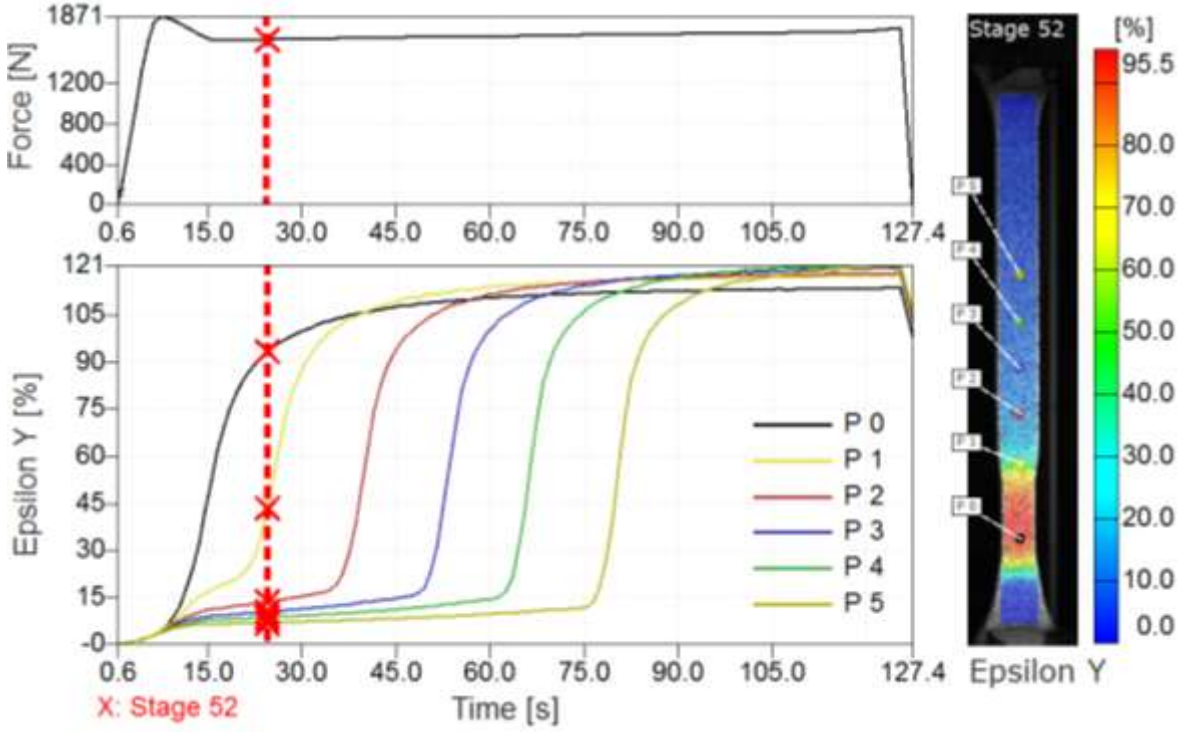


# ARAMIS – Tensile Test – Local Effects

PCABS

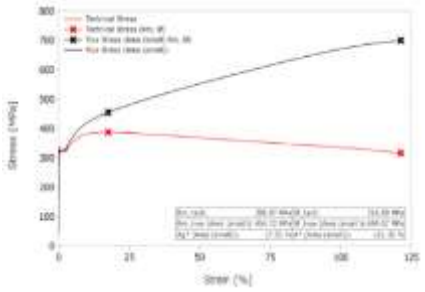
- Localized necking



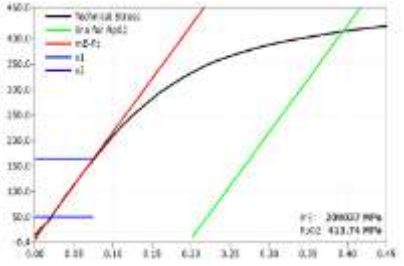
# ARAMIS Tensile Test

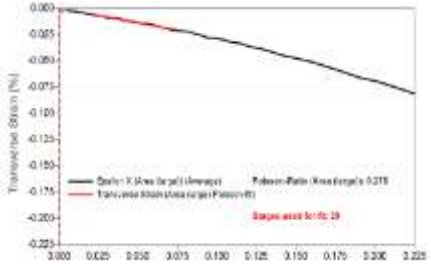
Automated determination of material parameter:

- True stress true Strain Curve
  global und local

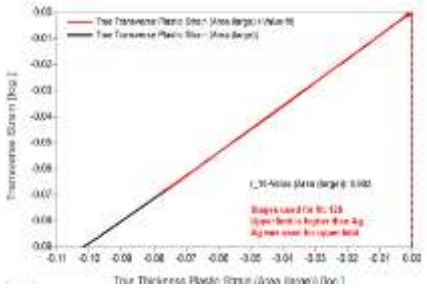


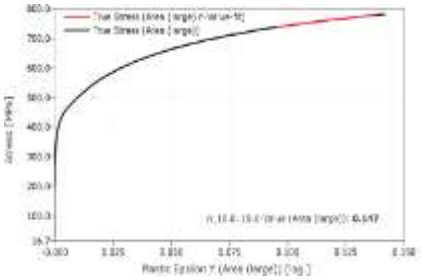
- Young's-Modulus and Poisson ratio





- R- and N-Value





Applicable for:

- different specimen sizes
- Wide temperature range (up to 1600°C)
- different testing speed (also high speed)

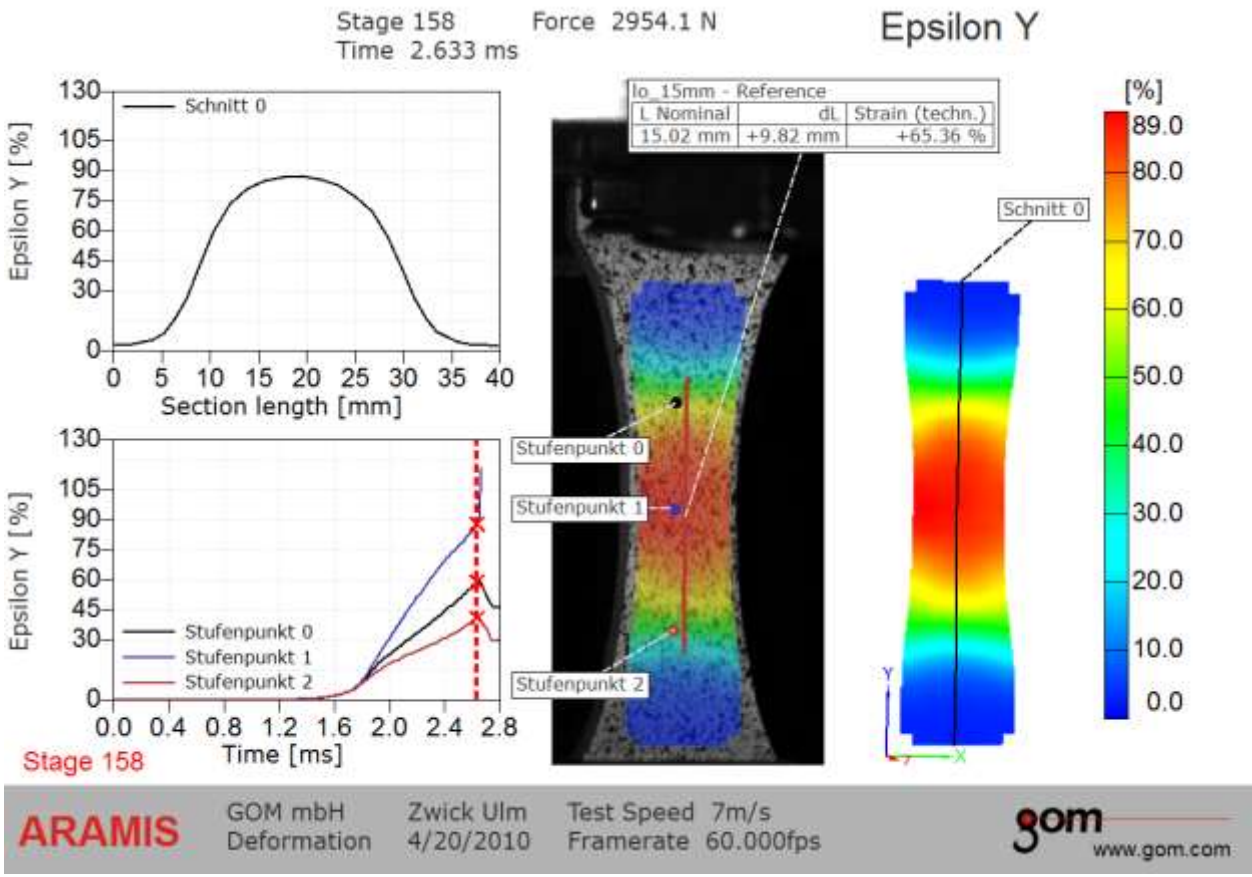
ARAMIS

High Speed Tensile Test

# High Speed Zugversuch

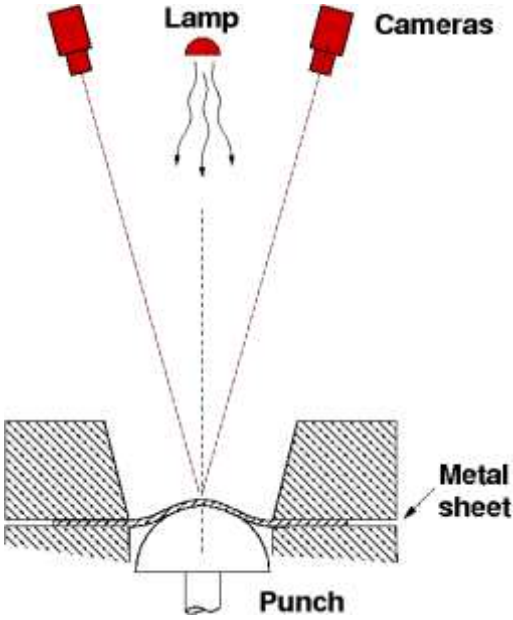
**Parameter**

- Test speed: 10 m/s
- Framerate: **60.000 Hz**



# ARAMIS Nakajima Test - FLC

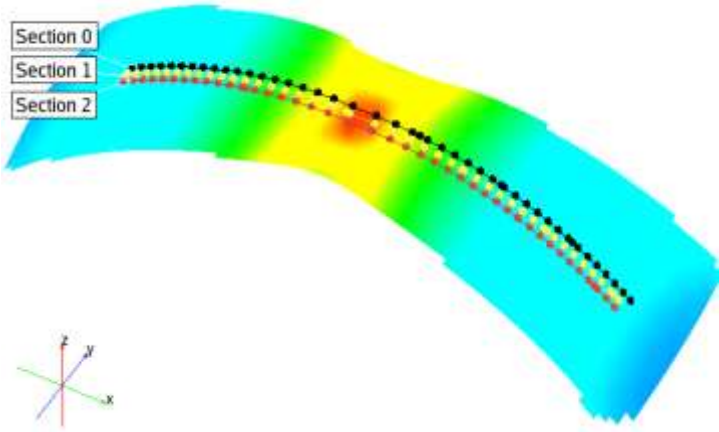
Forming Limit Curve (FLC) Determination

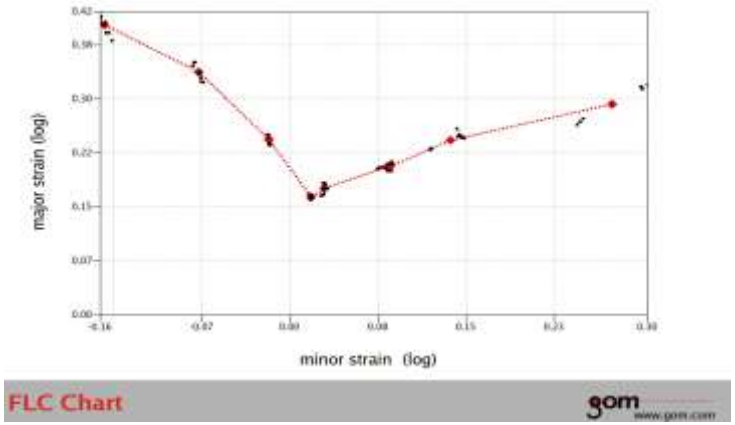


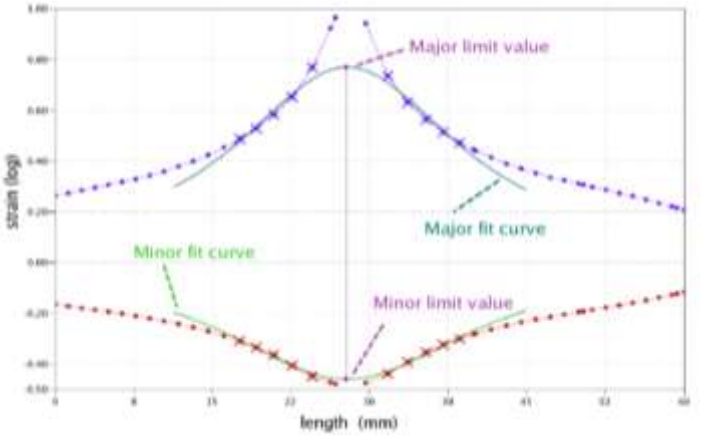

# ARAMIS Nakajima Test - FLC

Forming Limit Curve (FLC)
Determination

- Section based evaluation ISO 12004
- Different time based evaluations
  Proposal for ISO12004



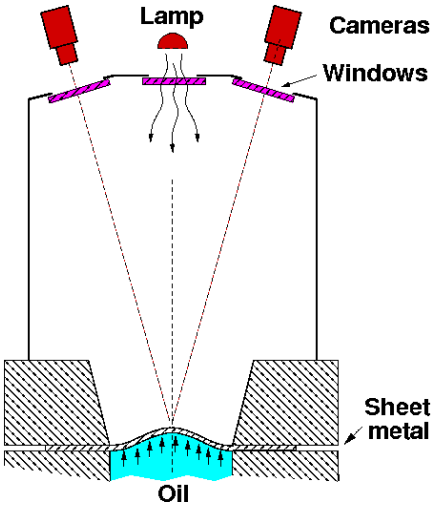



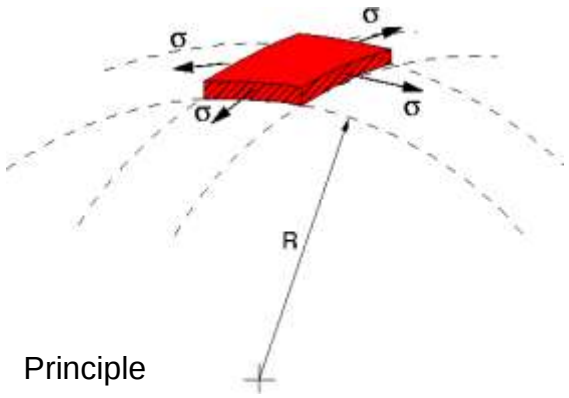
# ARAMIS - Yield Curve from Bulge Test

Yield curve computation from Bulgetest: ISO 16808 –

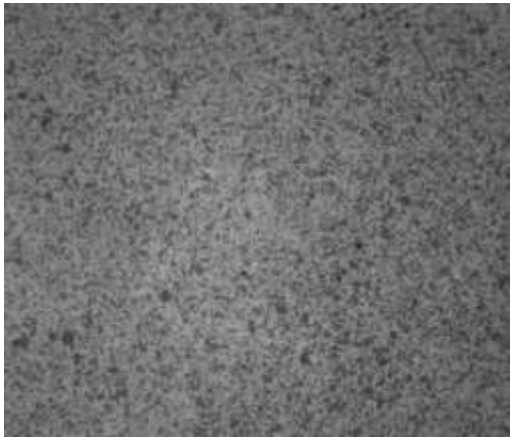
- Pressure
- Radius of curvature*
- Current material thickness*
- Strain*

(*: from ARAMIS)




Principle

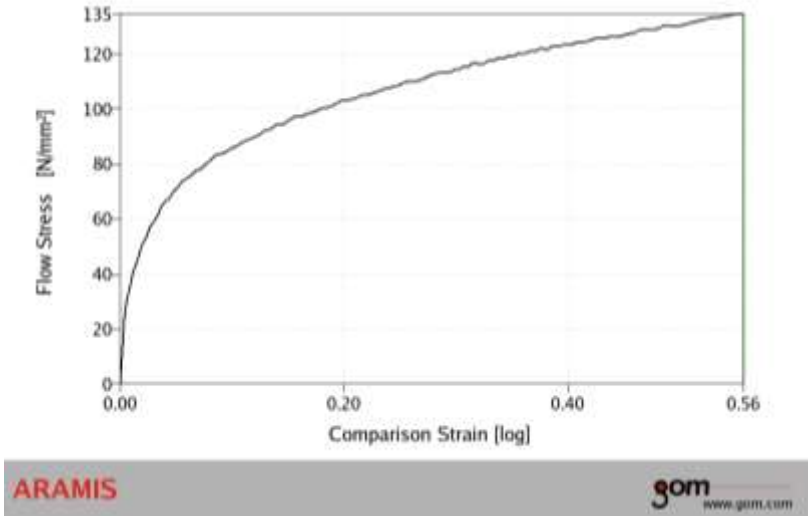


# ARAMIS - Yield Curve from Bulge Test

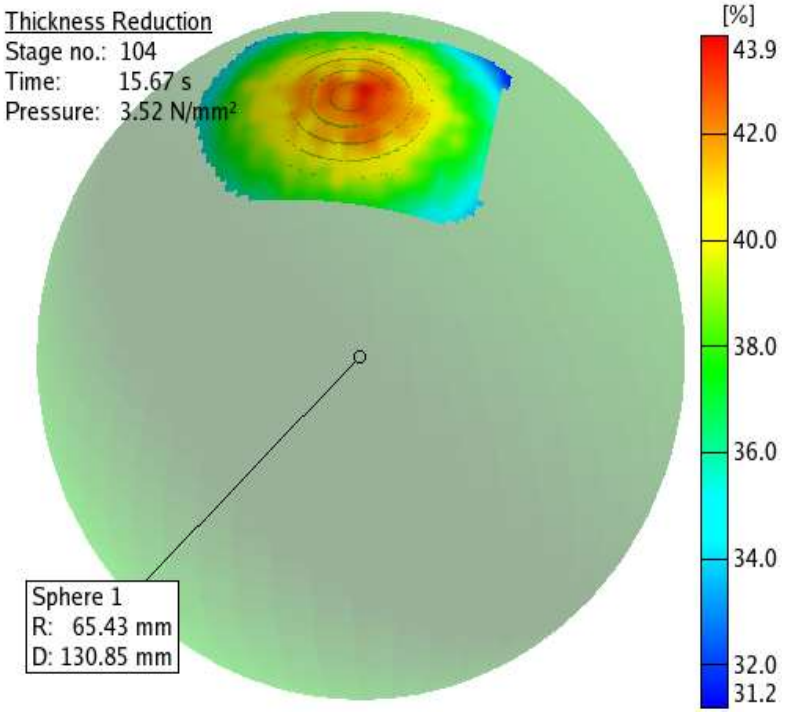
ISO 16808 – Yield curve from Bulgetest:

Radius determination based on
- 3D coordinates
- Dynamic sphere computation

Thickness determination based on
- Current thickness reduction
- Original material thickness




Result: Flowcurve



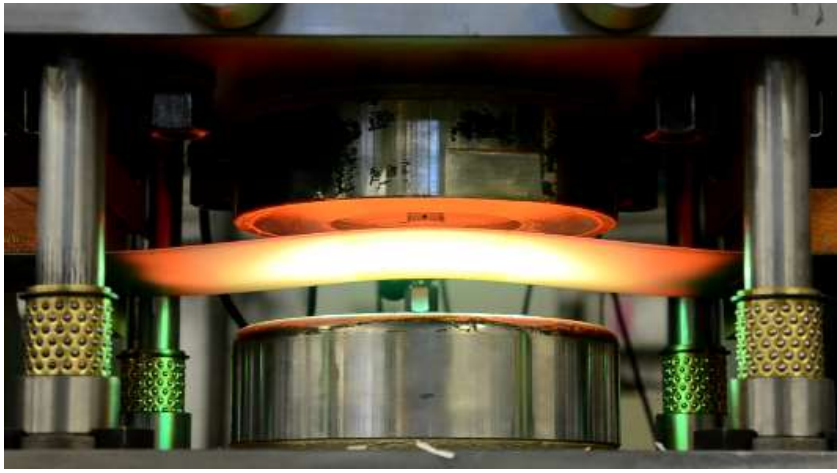

Fit of a sphere

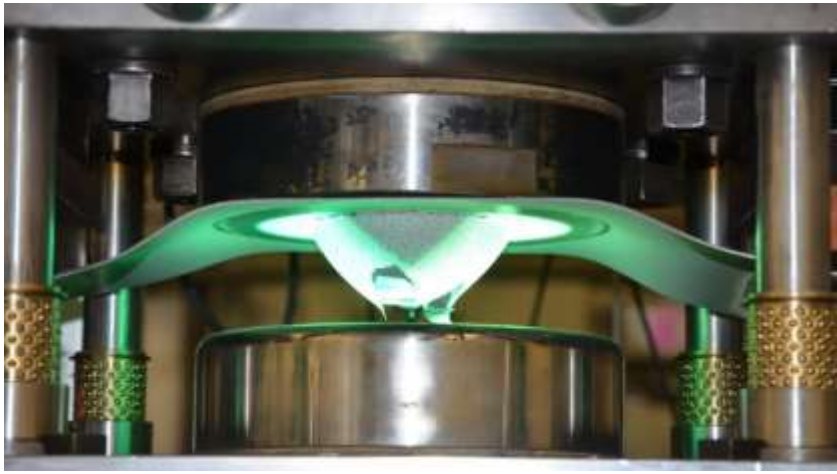
# ARAMIS Hot Gas Bulgetest

Steel for press hardening
- Yield curve = f(T, φ)

Challenging boundary conditions:
- Temperature 700°C – 900°C
  - Smoke
  - Inhomogeneous air
  - Optical properties of pattern
- Test speed Strain rate up to φ=0.7
- Available space

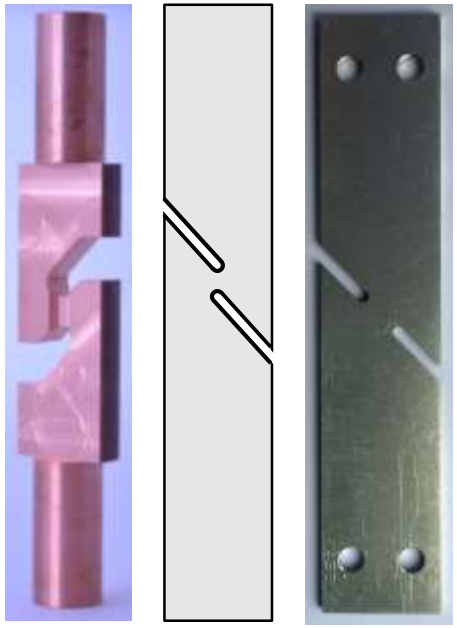
Measuring System:
- ARAMIS 4M 3D System with 168Hz





# ARAMIS - Shear Tests

Some examples of shear specimens



# Shear Test – Challenge for Measurement

## Challenges for the measurement

Small area of interest

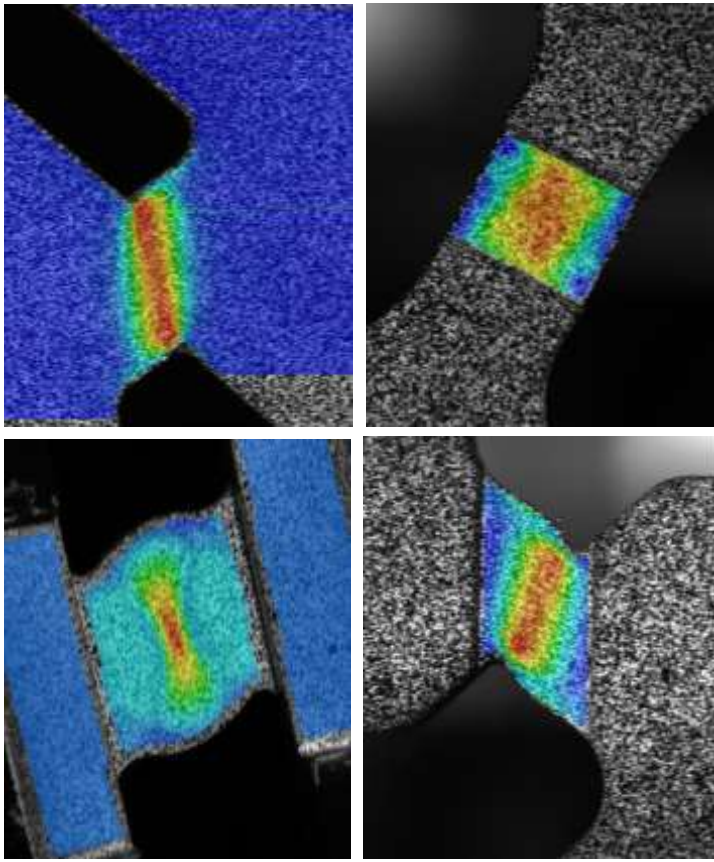
- Small width of shear zone (e.g. 1…4 mm)
- High local gradients in deformation

Very large and local deformation

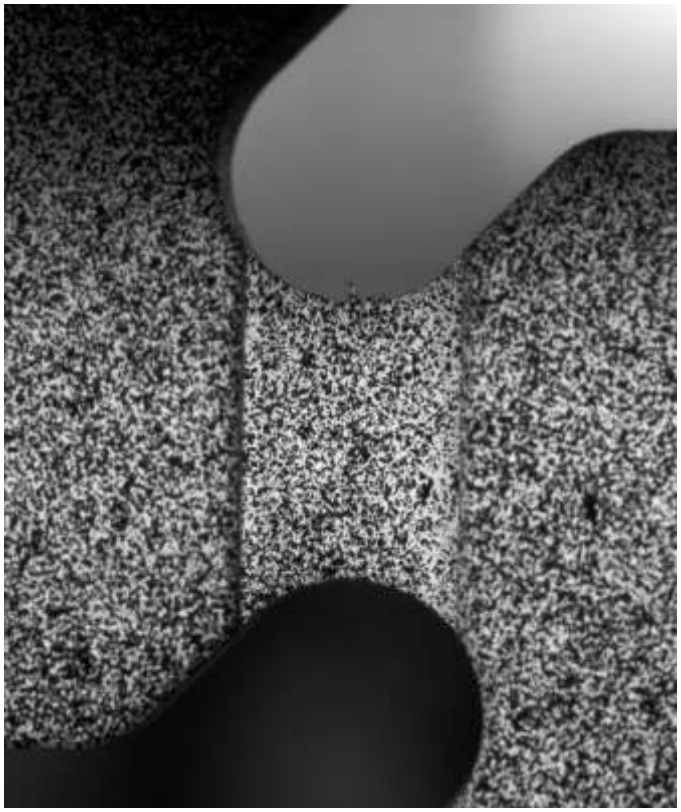
- Major Strain up to … 100 … 280 %
- Minor strain down to … -50 … -70 %
- Shear angle up to … 50°… 80°…

## System requirements

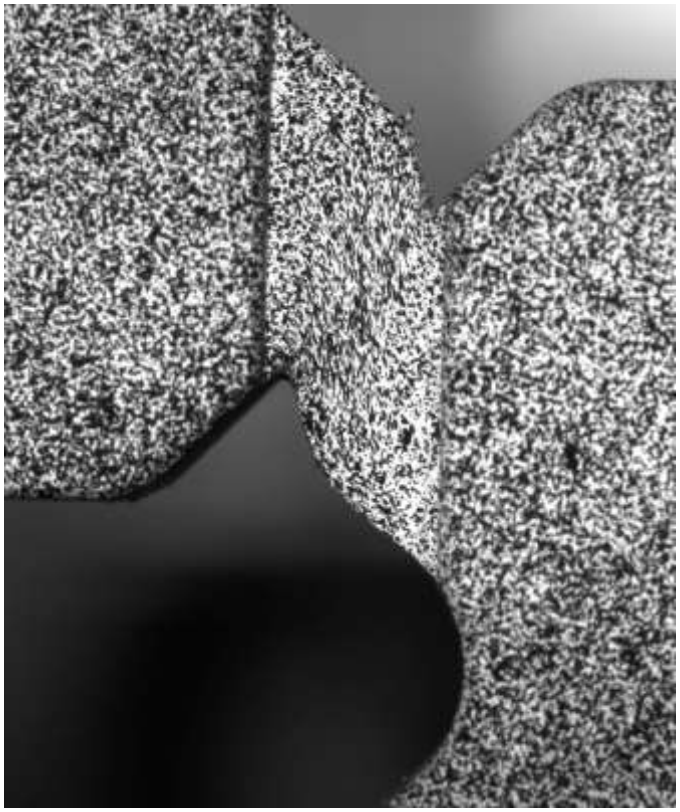
- **high local resolution -** small measurement area
- Optimized pattern size
- Optimized evaluation parameter



# Shear Test

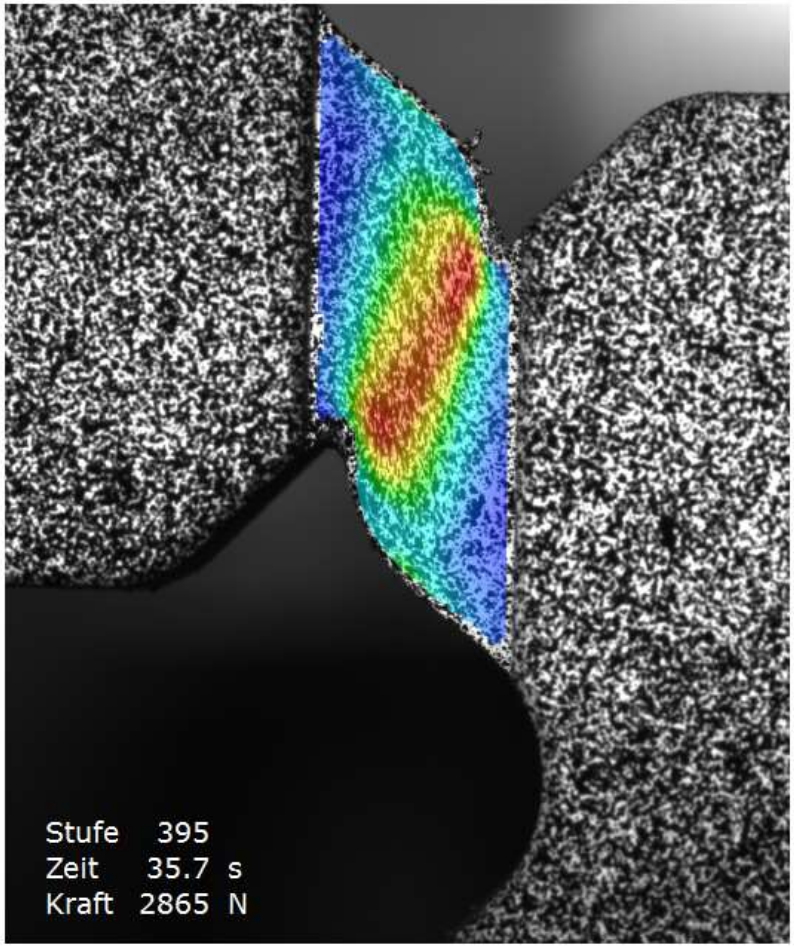


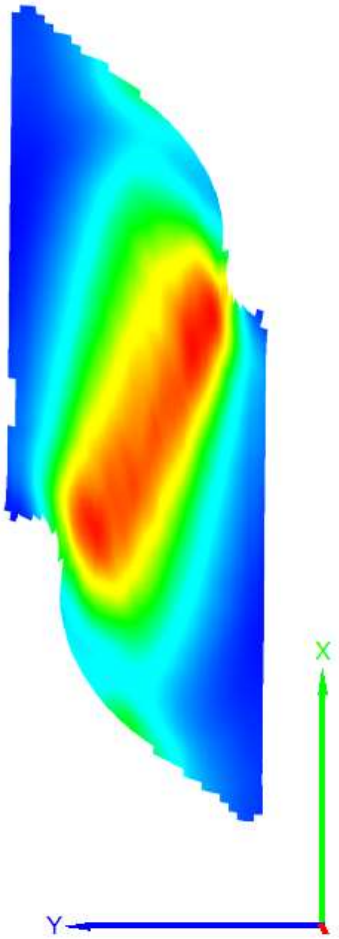
Undeformed specimen

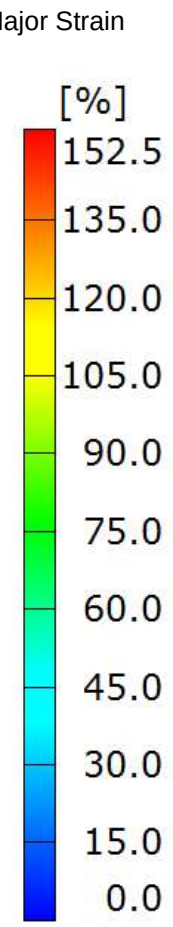


Specimen before failure

# Shear Test

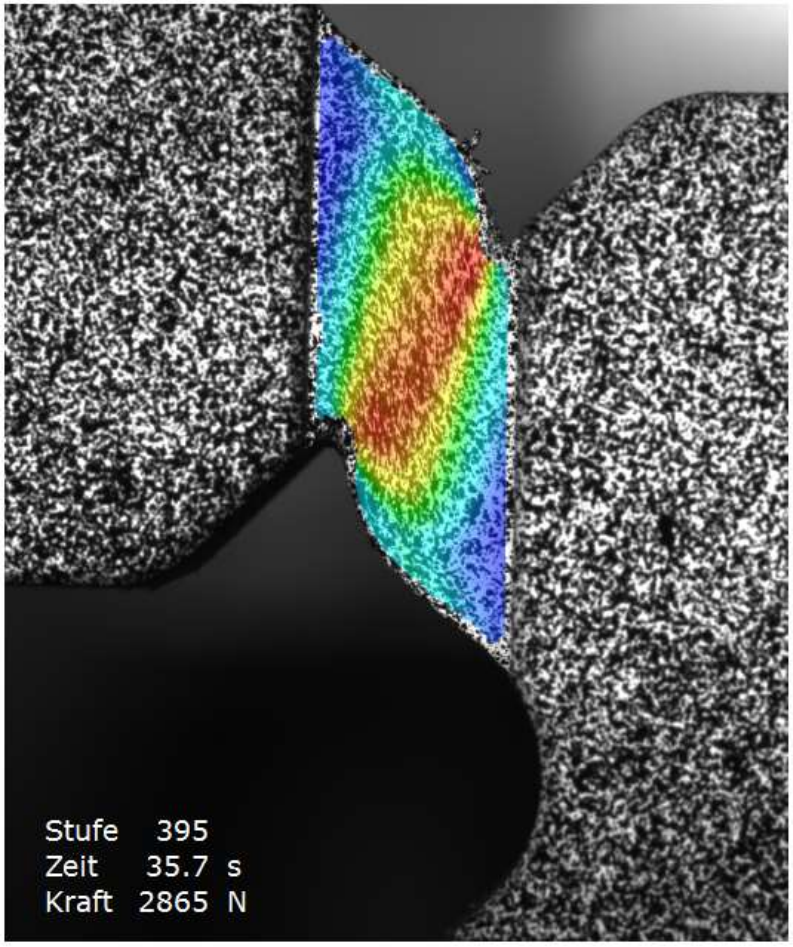


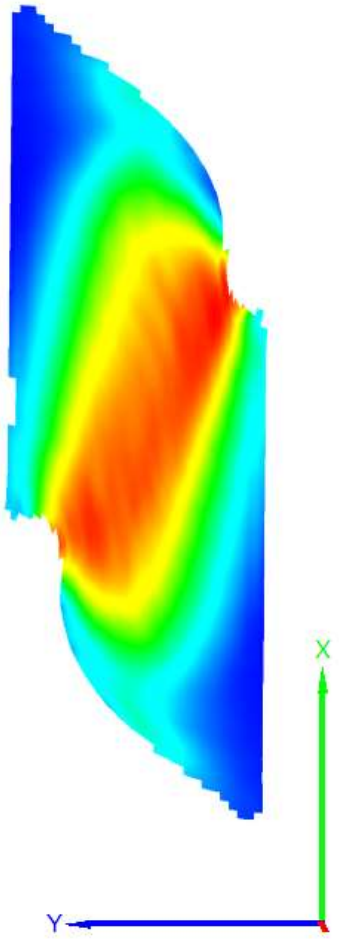



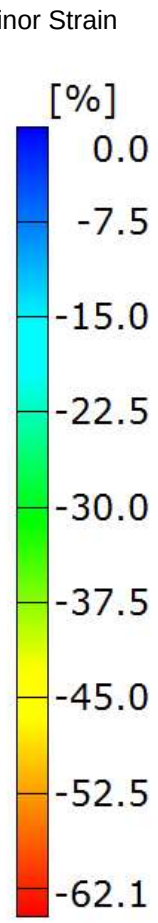




High local gradients in deformation require high local resolution in measurement
(Distance between measurement points = 0,075mm)

# Shear Test

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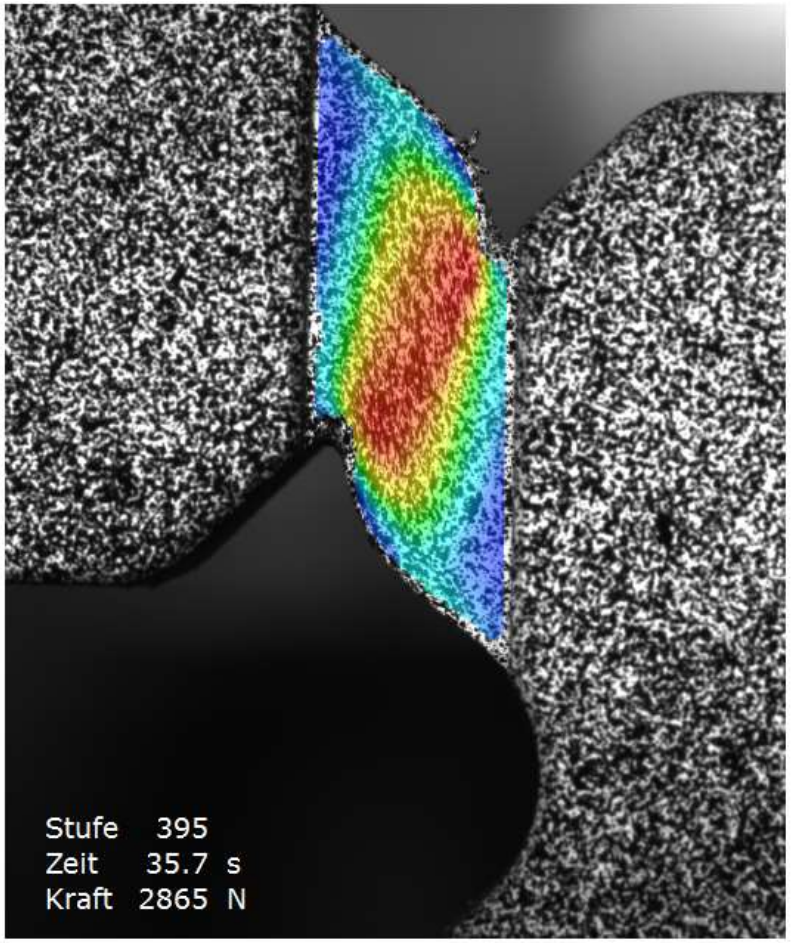
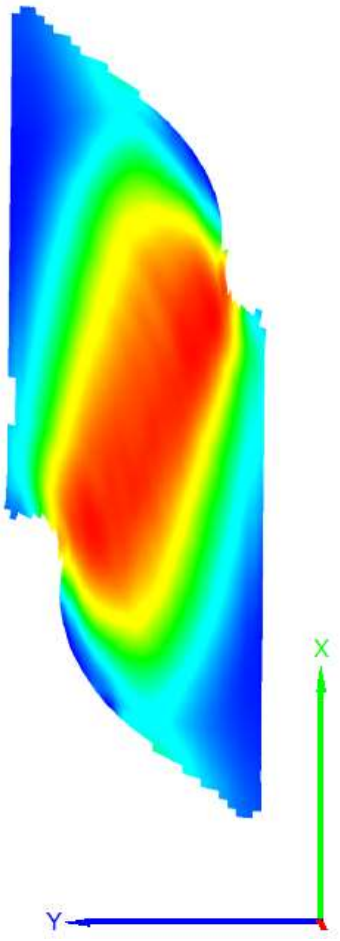
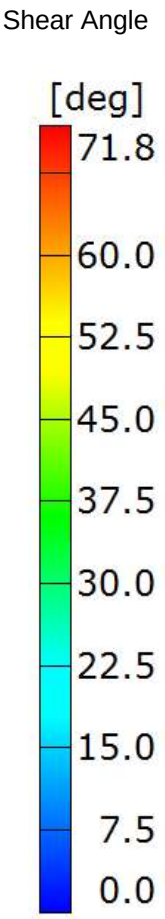
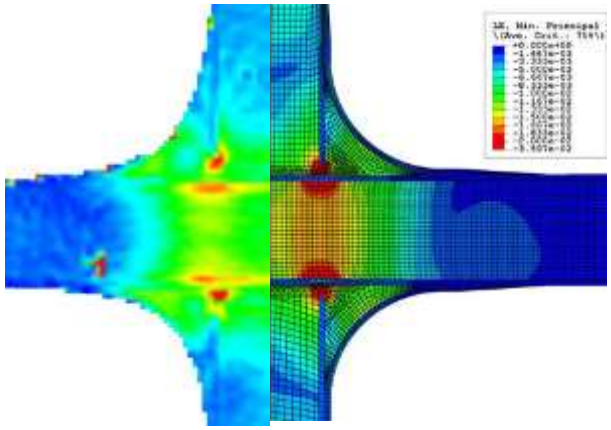
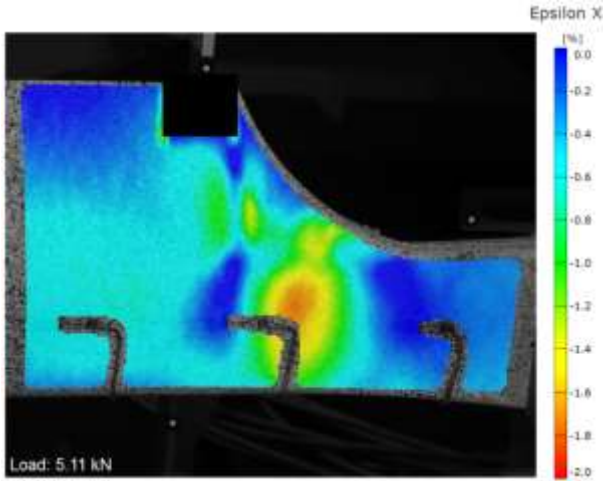

Stufe 395
Zeit 35.7 s
Kraft 2865 N

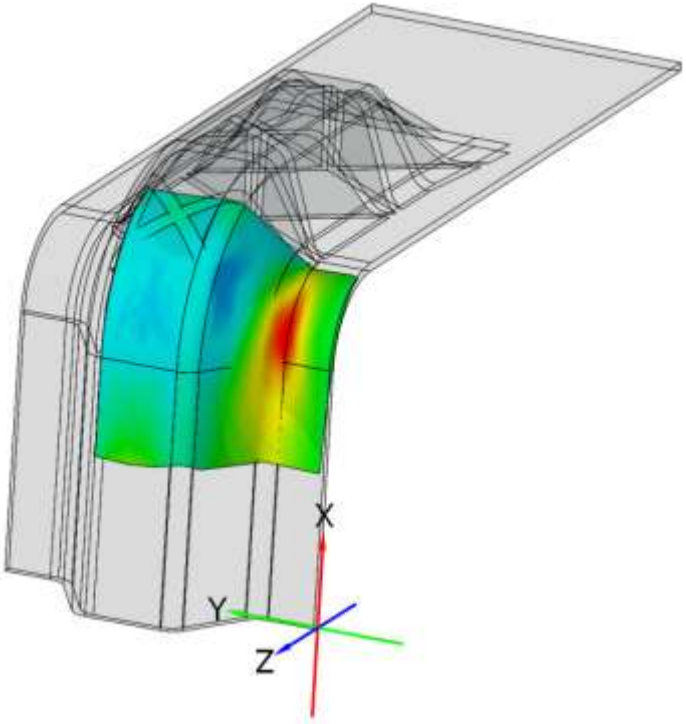

X
Y


Shear Angle
[deg]
71.8
60.0
52.5
45.0
37.5
30.0
22.5
15.0
7.5
0.0

# Component Testing





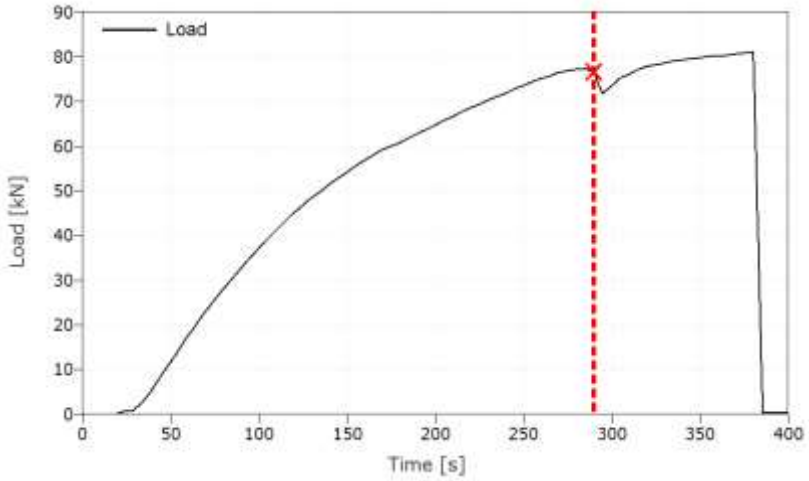
# Component Testing – Rivet Failure

Evaluation of rivet connections in aerospace testing

# Component Testing – Rivet Failure

Evaluation of rivet connections in aerospace testing

The evaluation of load over time shows that at approx. 280s the load drops due to rivet failure



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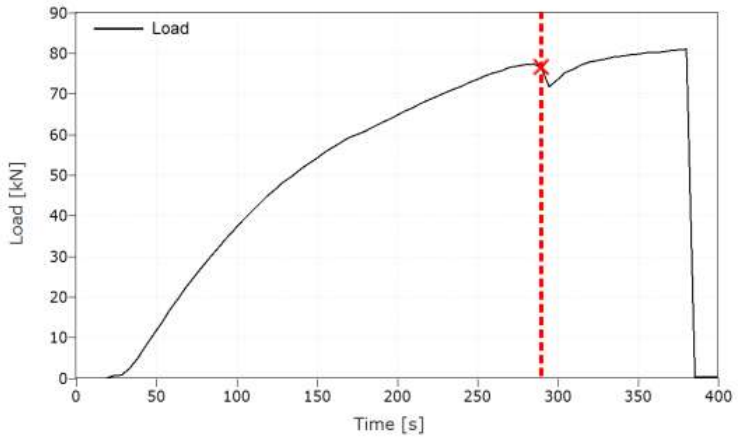
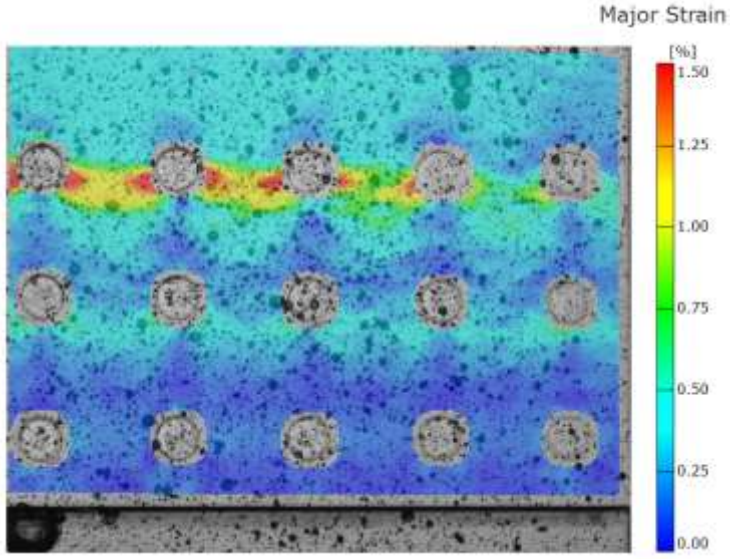
Strain evaluation using ARAMIS

Point in time of rivet failure



# Component Testing – Rivet Failure

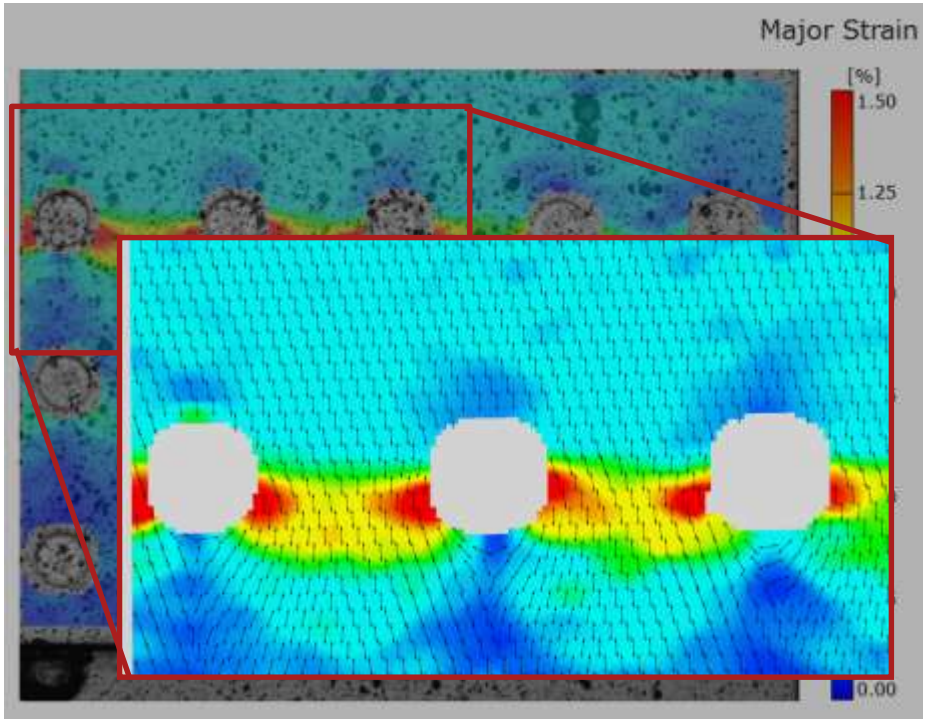
Evaluation of rivet connections in aerospace testing

The evaluation of load over time shows that at approx. 280s the load drops due to rivet failure

Strain evaluation using ARAMIS

Point in time of rivet failure

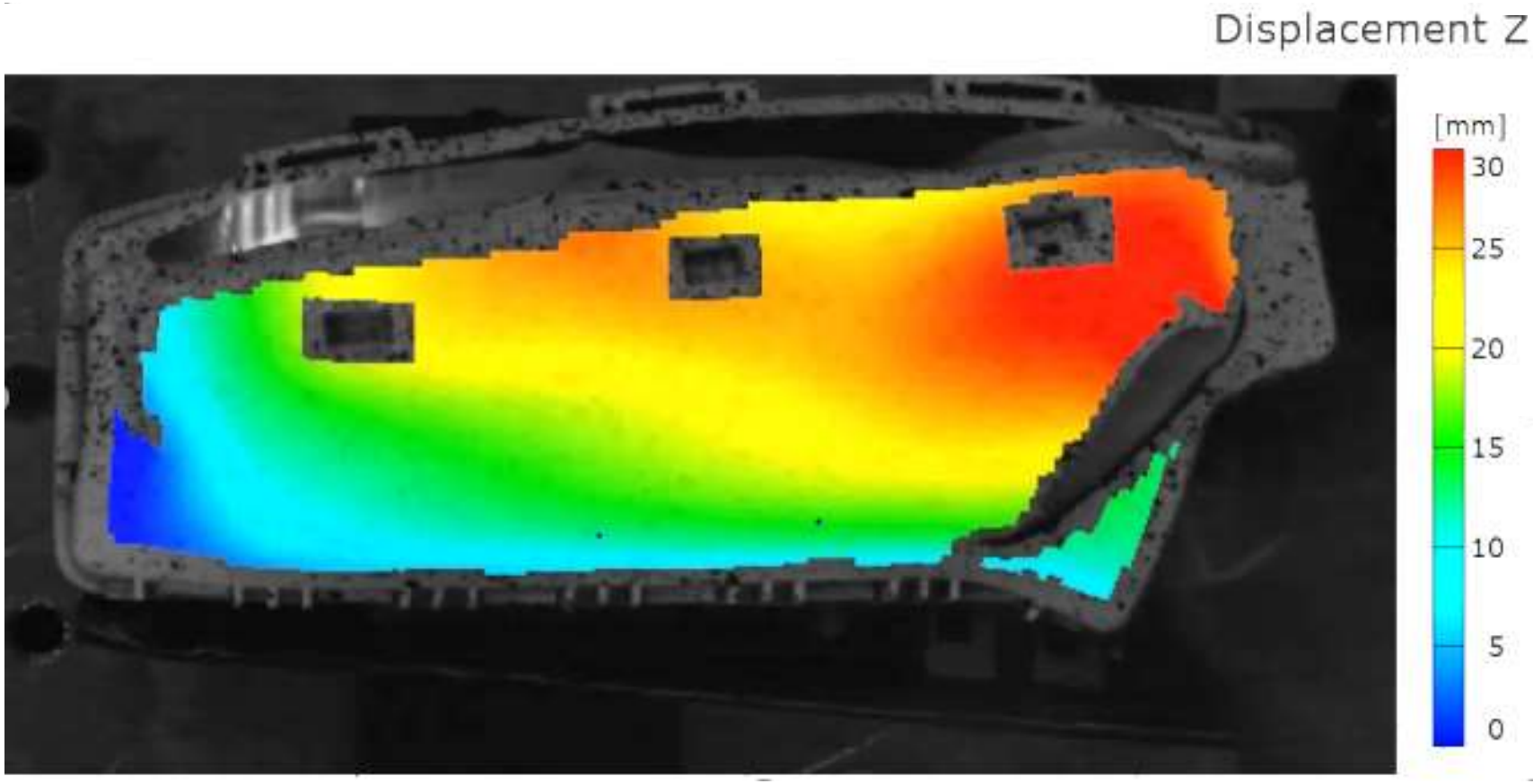
Maximum strain directions visualized for the area of the three rivets on the top left



# High Speed Testing
# Automotive Safety

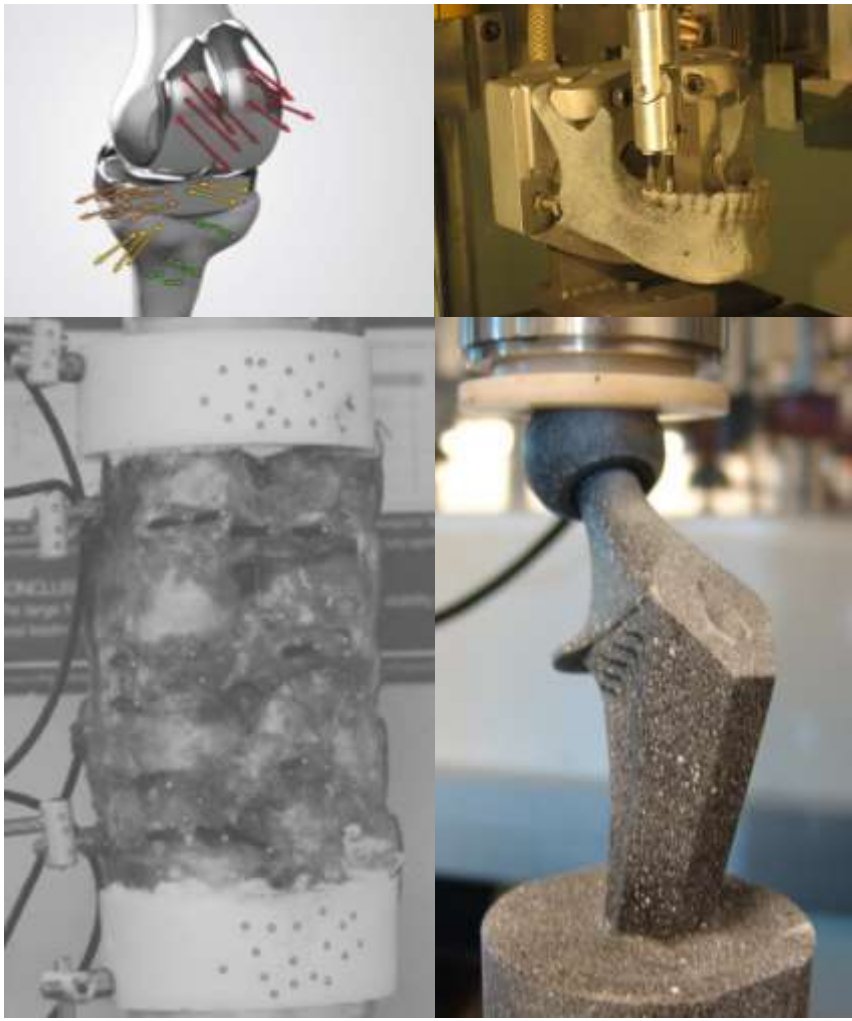
# Deformation of Airbag Housing

# Deformation of Airbag Housing



# Sled Crash Testing

# Biomechanics

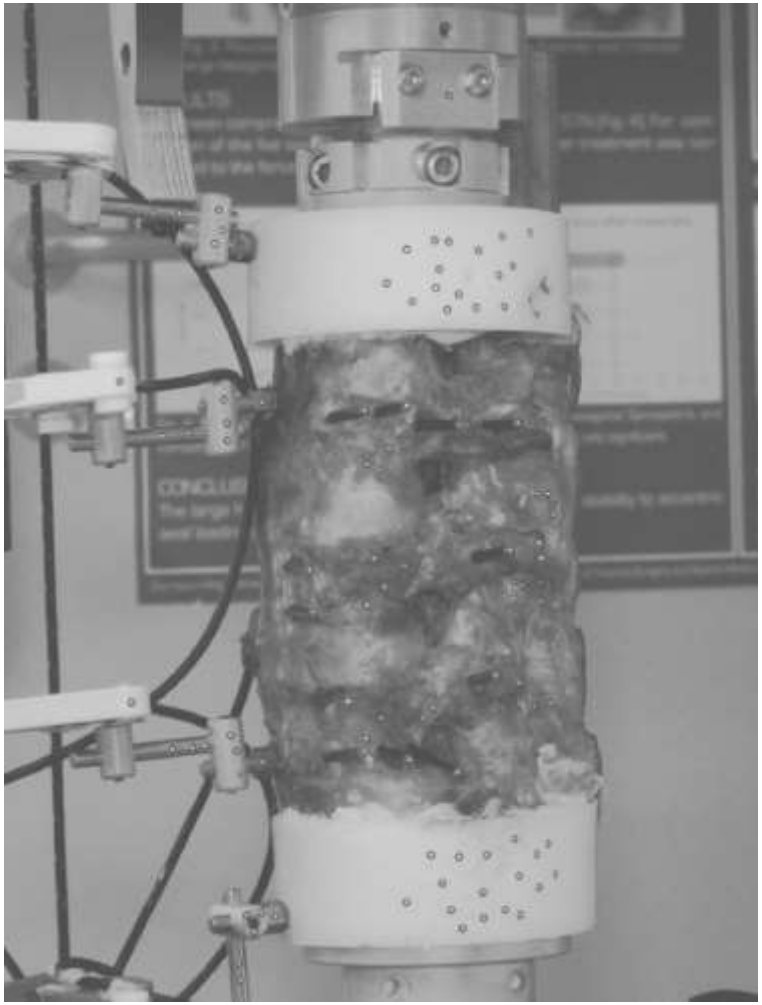


# Spine – Vertebra - Motion Analysis

Optical measurement to analyse three-dimensional fracture motion

Simulation of natural motion for the analysis of stability

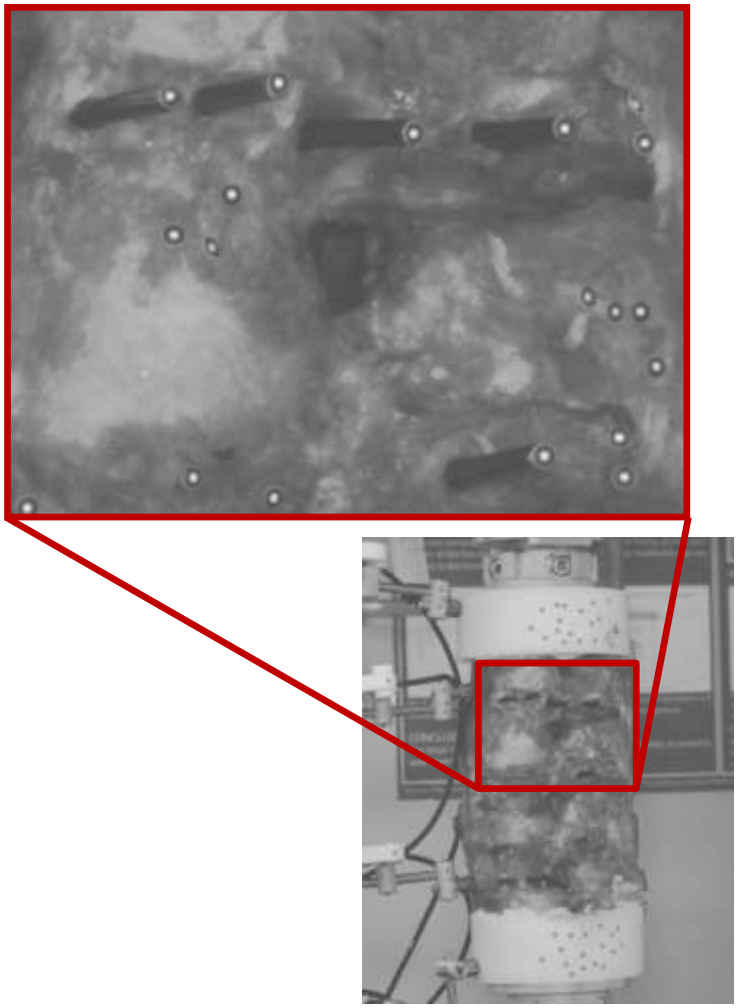
Analysis of fracture motion to ensure the natural healing process



# Spine – Vertebra - Motion Analysis

Pins prepared in vertebras for point marker application and better optical accessibility

Additionally point markers are prepared on directly accessible areas on the vertebras



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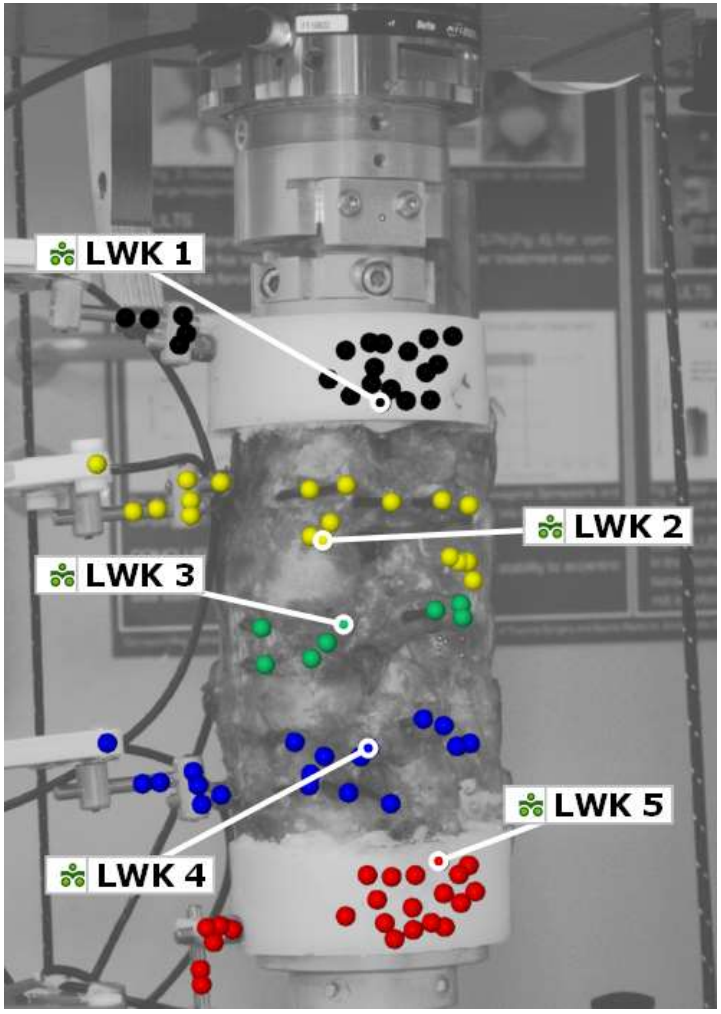
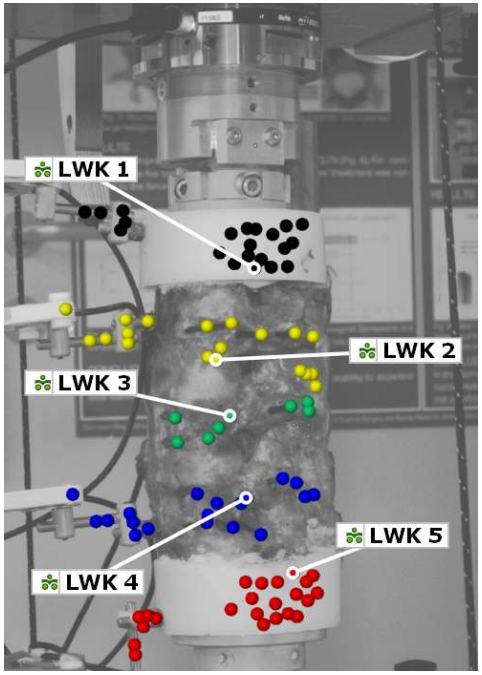
Point group definition for motion analysis on all individual vertebras

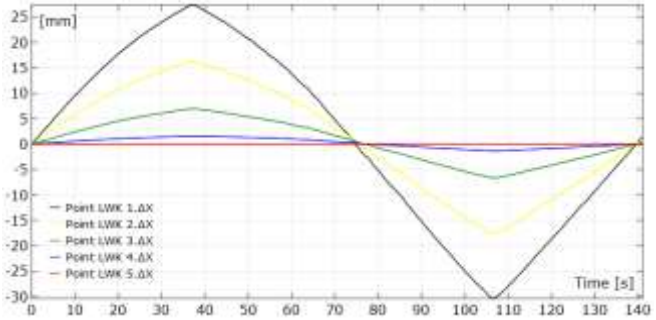


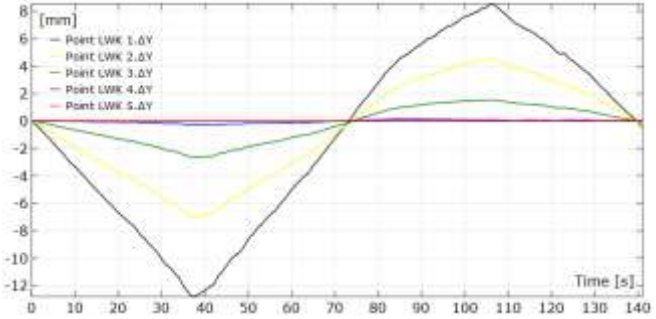
# Spine – Vertebra - Motion Analysis

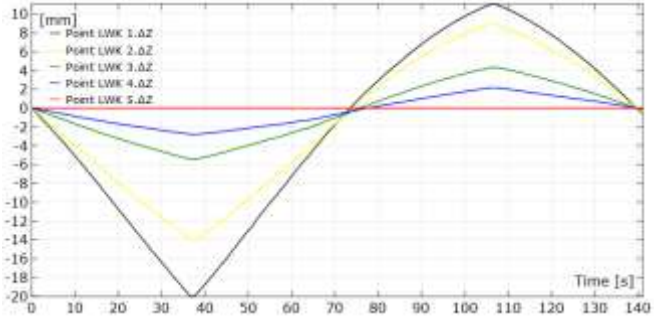
Motion analysis

- 3D displacement visualized mapped on the recorded camera images
- Point-wise X, Y and Z motion analysis



# Structure Test

A350 Winglet Bending Test

# Strukturtests und Ermüdungsversuche

A350 Winglet Bending Test

- Load- and fatigue test on Winglet (Airbus A350) at FACC (CoLT)
  - Winglet: 8m x 3m x 2m (LxWxH)
  - Testrig: 14m x 10m x 8m (LxWxH)

Target

- Verification of simulation with approx. 200 3D measurment points

- Replacement of multiple mechanical displacement transducer by 2 optical GOM ARAMIS 3D-Sensors

Images and results by courtesy of FACC (CoLT)

# Strukturtests und Ermüdungsversuche

A350 Winglet Bending Test

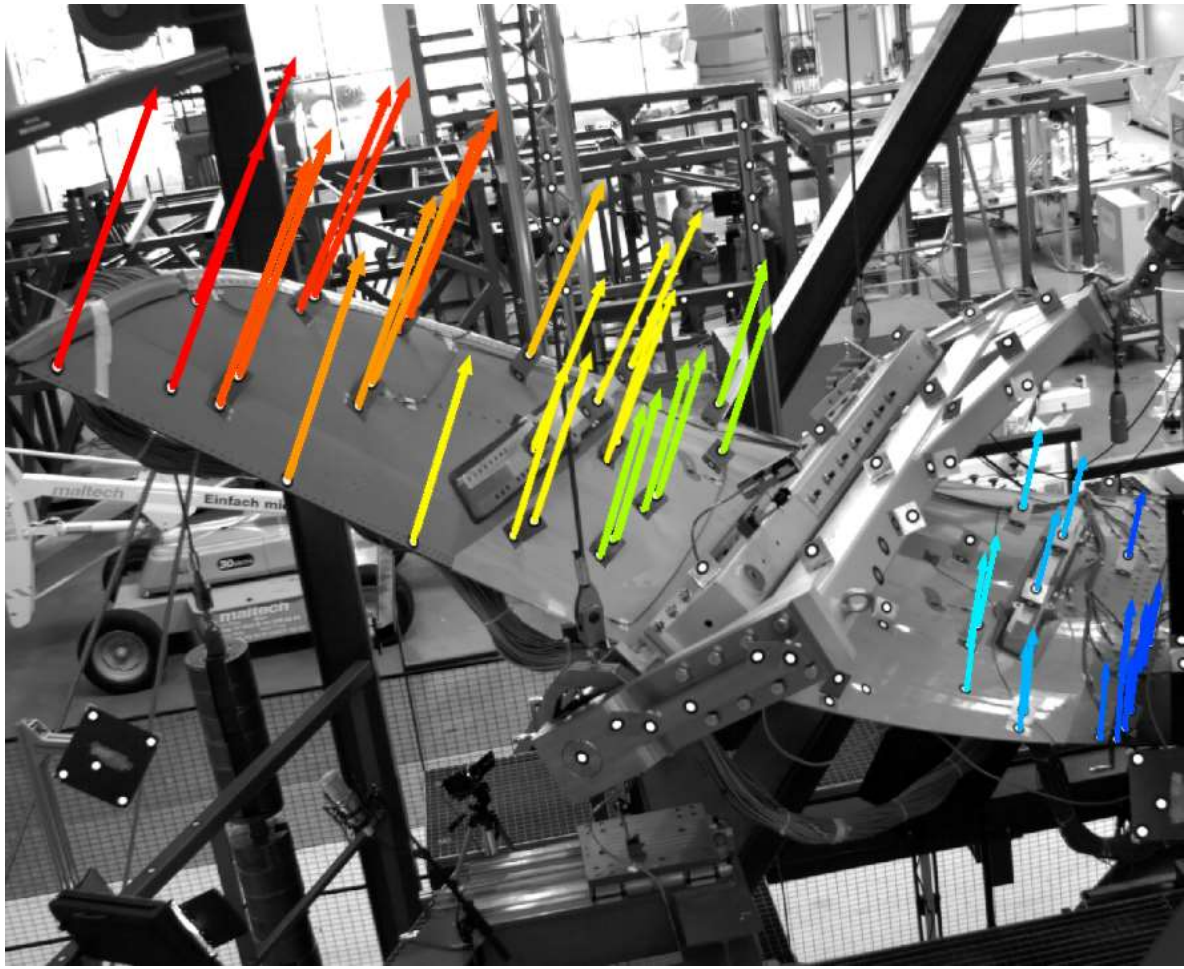
- Load- and fatigue test on Winglet (Airbus A350) at FACC (CoLT)

Result:

- 3D-displacements, speed and acceleration
- Complete 6DoF-Analysis

Live measurement and live data transfer for all points

- 3D-displacements for 200 points
- via TCPIP (SCPI protokol)



Images and results by courtesy of FACC (CoLT)

# GOM – Precise Industrial 3D Metrology

Thank you for your attention.

info@gom.com
www.gom.com

# GOM Inspect
## Evaluation Software for 3D Point Clouds

**Mesh Processing**

Import of point clouds from ATOS and external measuring devices

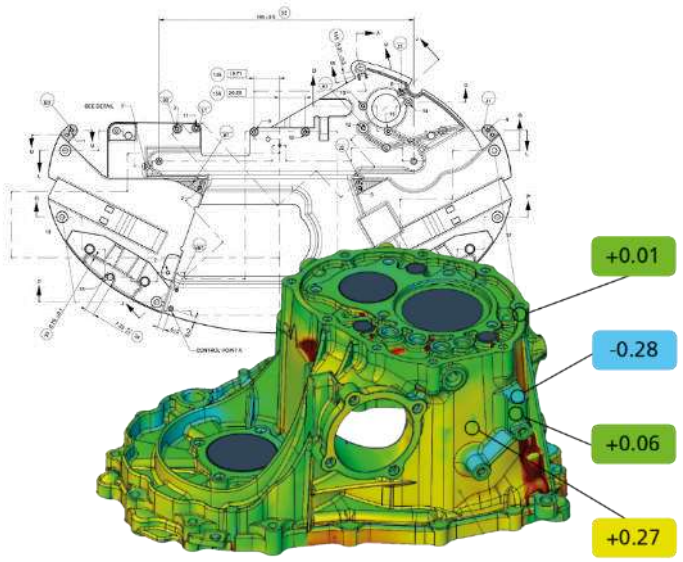
- Third party scanners
- Computer tomography (CT)

Polygonization of point clouds

**Viewer**

For ATOS Professional, TRITOP Professional, GOM Inspect Professional

3D viewing & presentation




GOM Inspect

GOM Inspect Professional

**Download at www.gom-inspect.com**

# GOM Correlate
## Evaluation Software for DIC and Motion Analysis

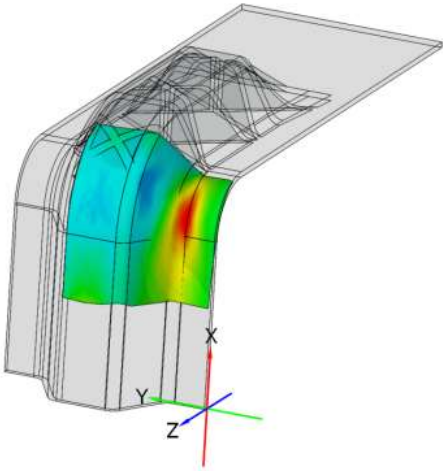
**3D evaluation software**

3D digital image correlation

- Area-based, full-field evaluation of applied stochastic patterns

3D motion analysis

- Point-wise evaluation of applied measurement markers




**Complete free 2D DIC and motion analysis software**

- Importing of any images for DIC
- Support for standard USB3 cameras
- 2D Digital Image Correlation
- 2D Marker Tracking

GOM Correlate

GOM Correlate Professional

**Download at www.gom-correlate.com**

# Spine – Vertebra - Motion Analysis

Pins prepared in vertebras for point marker application and better optical accessibility

Additionally point markers are prepared on directly accessible areas on the vertebras

Point group definition for motion analysis on all individual vertebras

Alignment of point components to CT-scan data or 3D Scan Data

- Visualization purposes
- 3D coordinate system transformation