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

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, VZLU, ...

### Turbines
ABB Turbo systems, Alstom, Aviadigatel, 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, ...

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**Over 14,000 system installations worldwide**
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
Determination of Material Parameters and Component Testing using Optical 3D Metrology

**Products**

- **ATOS**
  - Full-field 3D scanning

- **TRITOP**
  - Mobile optical CMM

- **PONTOS Live**
  - 3D Position Tracker

- **ARAMIS**
  - Optical 3D deformation analysis

- **ARGUS**
  - Optical forming analysis

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**GOM Inspect**

**GOM Correlate**
ATOS
Full-Field 3D Scanning

Applications

Quality control
Reverse engineering
Rapid prototyping
Manufacturing
Virtual assembly
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
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

Determination of Material Parameters and Component Testing using Optical 3D Metrology
ARAMIS in Product Development

Material Properties

Input data for material models

Sheet metal formability

Edge crack sensitivity
Tensile Test
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

Test: Tensile Test
Material: Metal
Norm: ISO6892 SEP1235

Connected sensor: ARAMIS 3D Camera
Calibrated measurement volume: 142 x 88 x 91 mm
Working distance: 350 mm

The current calibration is from: Wed Aug 9 11:26:24 2017

Please make sure, that the specimen is centered in your image!

Press Prepare Measurement or Cancel.
ARAMIS Kiosk Interface

User: User
Specimen Name / Nr.: Brass / 2
Specimen thickness: 0.37 mm
Specimen width: 12.50 mm
Gauge length: 50.00 mm

Setup:
Norm: ISO6892 SEP1235
Measurement Sequence: Auto trigger (Load), Metal
Framerate [Fps]: 50.0 / 1.0, 50.0 / 2.0
Make Reference Image  Edit Setup

Start Measurement  Cancel
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**

Distinct yield effect

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
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**

![Graph showing strain data with labels: Stage 158, Time 2.633 ms, Force 2954.1 N, and strain values. The graph includes a color scale ranging from 0.0 to 89.0%.](image-url)
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
Overview

Numerical forming simulations require accurate material parameters as input.

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

Determination of Biaxial Yield Curve – Bulge Test

Determination of Material Parameters and Component Testing using Optical 3D Metrology
Live Demonstration
Sheet Metal Formability Testing at High Temperatures

FLC and Yield Curve
For press hardening steels
Double Cantilever Beam Tests

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

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

Displacement Y-Direction
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
Exchange Formats: Exports

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

UFF (Universal File Format)
- 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
• 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
  • …
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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- 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
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?

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Data Comparison (FEA)

Compare simulation data and measurement data in ARAMIS Professional

**Simulation**

**Measurement**
Data Comparison (FEM)

Comparison

Measurement

Widening measured
L +0.25 mm

[mm]

Widening

Widening measured L

0.00
0.05
0.10
0.15
0.20
0.25

Index

1
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3
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5
6

Simulation

Widening FEA
L +0.24 mm

[mm]

Deviation

[mm]

0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
-0.11
-0.12
-0.13
-0.14
-0.15
Simulation Verification Improvements in GOM Software 2017

Point components fully supported too
- For structured parts
- Former PONTOS applications
- TRITOP applications

In cooperation with:
Simulation Verification Improvements in GOM Software 2017

ATOS included
- Shrinkage
- Spring back
- Thickness comparison
- Draw in
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