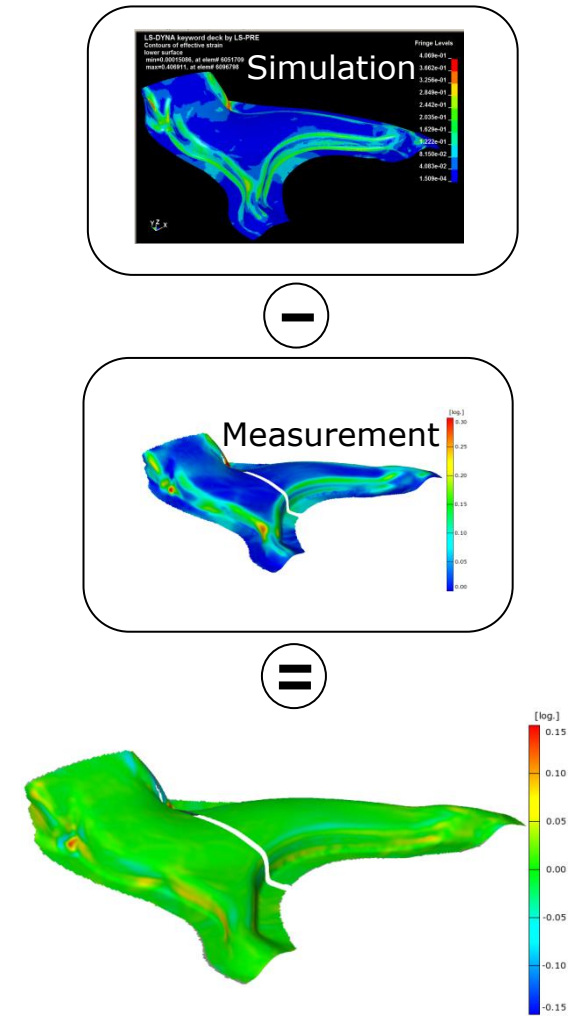
LS-DYNA Forum 2012

Validation and Optimization of Numerical Simulations by Optical Measurements of Tools and Parts

Theodor Möller

October 9th 2012



gom Optical Measuring Techniques

GOM
Branches

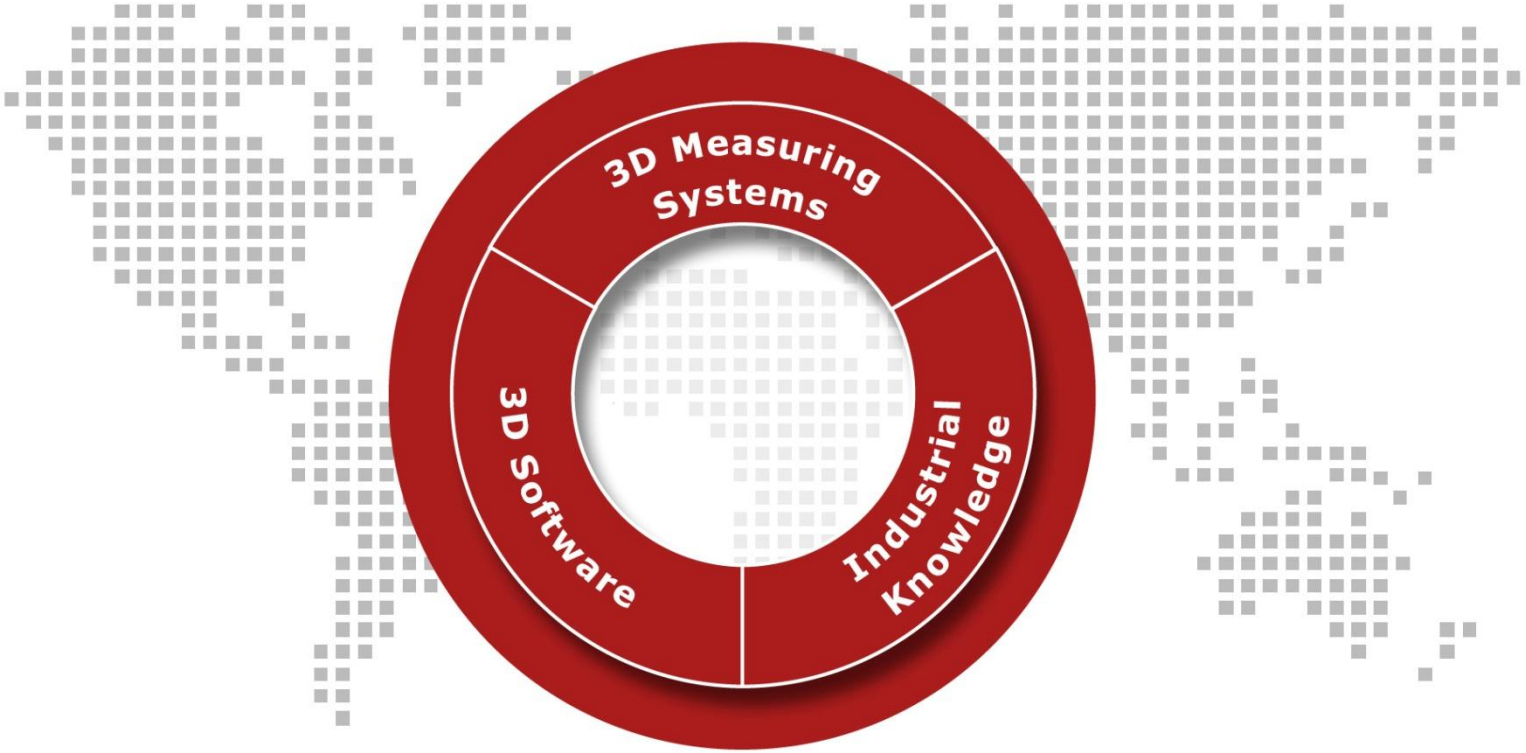
Gesellschaft für optische Messtechnik

- Founded 1990
- Spin-off of the Technical University of Braunschweig
- Privately owned
- Today: 250 Employees

- **7 Branches:**
  - Braunschweig
  - Neu Ulm
  - Widen, Switzerland
  - Ris Orangis, France
  - Coventry, England
  - Grez-Doiceau, Belgium
  - Milano, Italy

GOM
Partners

GOM
Know How



- GOM is a single source for measuring systems, software solutions, technical services and professional support
- Integrated solution optimizes implementation procedures and shortens inspection ramp-up time and offer long term support due to secured compatibility

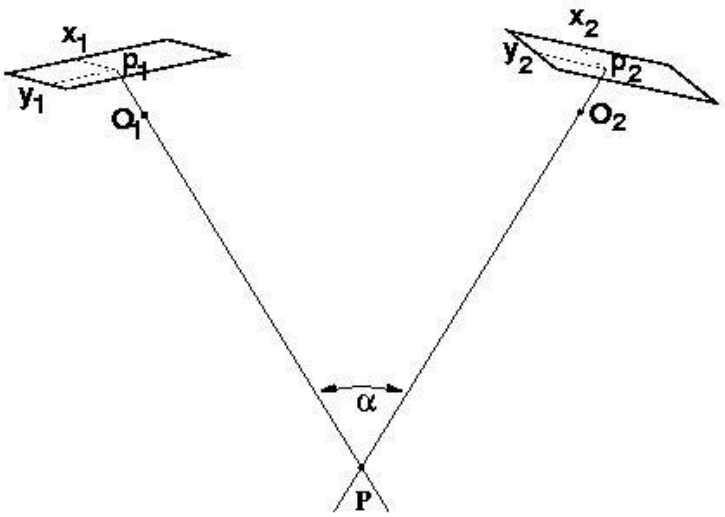
GOM
Measurement Principle

- Camera based sensors
  - Stereo camera system
  - Single camera system

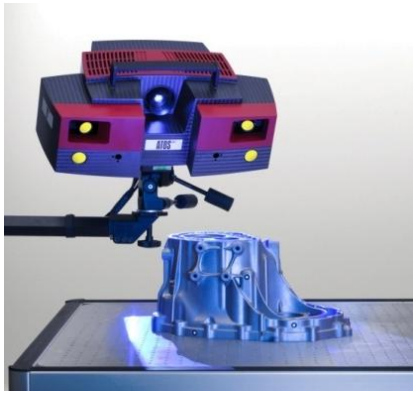
- Optical characteristics are identified in camera images
  - Point targets
  - Fringe projection
  - Stochastic pattern

- Triangulation

- Results:
  - 3D Coordinates
    - Surface or single points
    - Static or dynamic
  - (Deformations)
  - (Displacements)
  - (Strains)

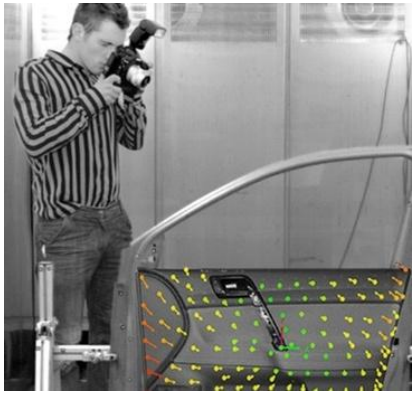


GOM
Product Overview



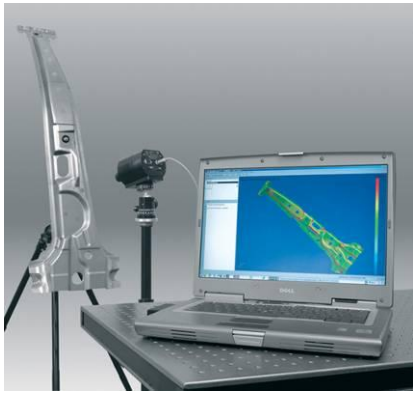
ATOS
3D Digitizing

TRITOP
Photogrammety



TRITOP Deformation
Static Deformation Analysis

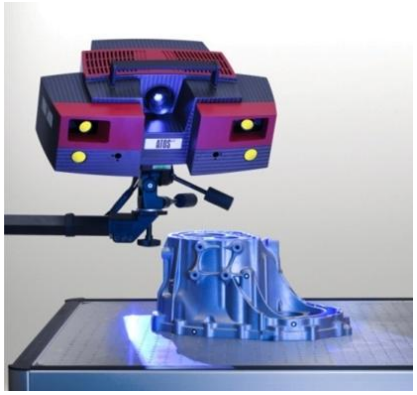
PONTOS
Dynamic Photogrammety



ARGUS
Deformation Analysis in
Sheet Metal Forming

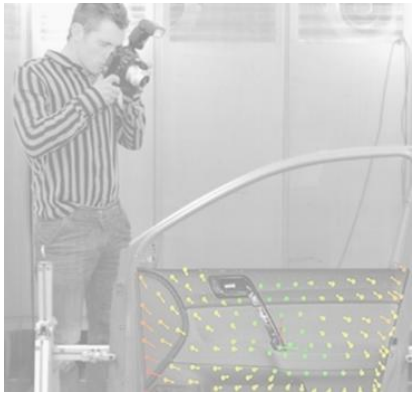
ARAMIS
Deformation Analysis and
Material Testing

3D Surface Measurement
Fringe Projection (ATOS)

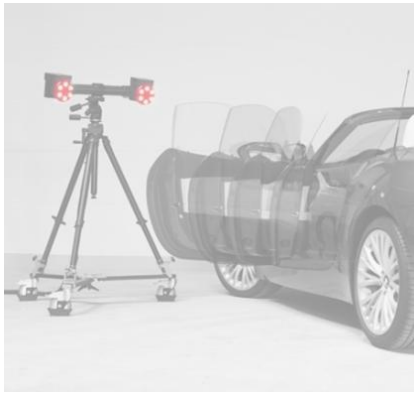


ATOS
3D Digitizing

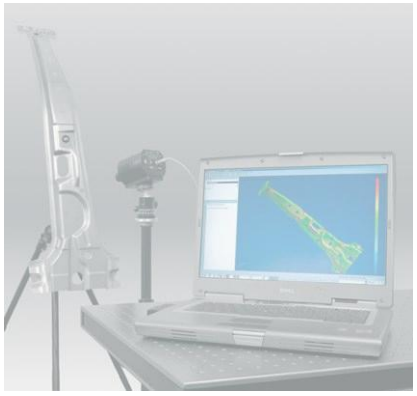
TRITOP
Photogrammety



TRITOP Deformation
Static Deformation Analysis



PONTOS
Dynamic Photogrammety

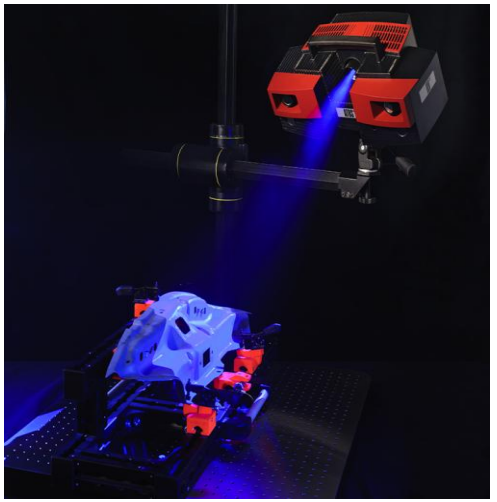


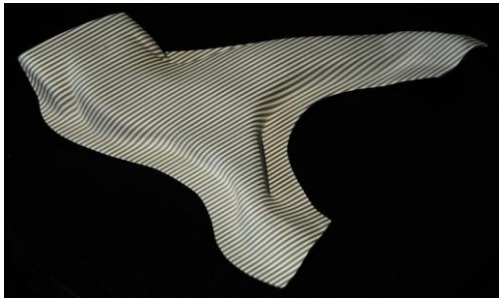
ARGUS
Deformation Analysis in
Sheet Metal Forming

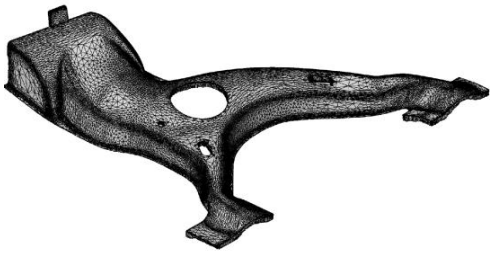
ARAMIS
Deformation Analysis and
Material Testing

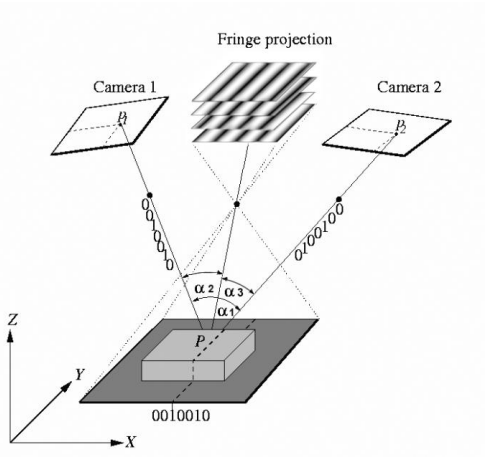
3D Surface Measurement
Fringe Projection (ATOS)

- Static measurements of any 3D geometry / surface
- Full-field component measurement
  - Inspection / GD&T
  - Quality control
  - Reverse engineering / design
  - Rapid manufacturing
- Evaluation in
  - Injection molding und plastics industry
  - Sheet metal and forming industry
  - Casting industry
  - Tooling and molding



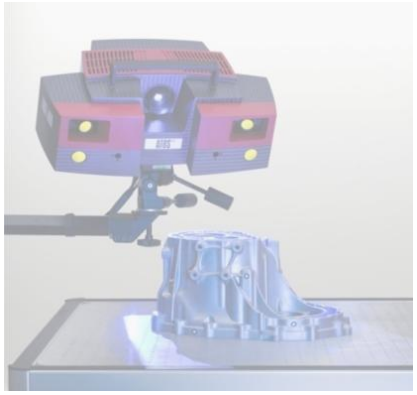






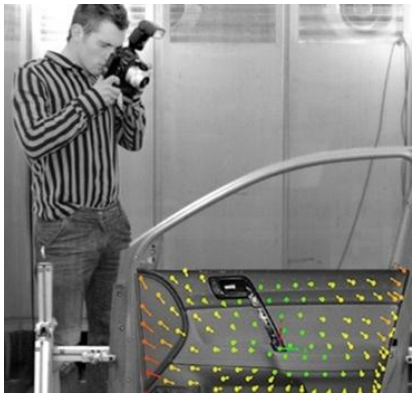
gom Optical Measuring Techniques

3D Point Measurement
Photogrammetry (TRITOP)



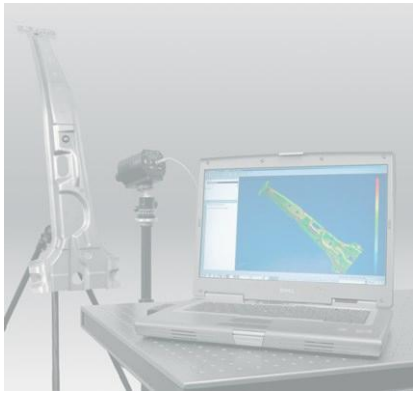
ATOS
3D Digitizing

TRITOP
Photogrammety



TRITOP Deformation
Static Deformation Analysis

PONTOS
Dynamic Photogrammety

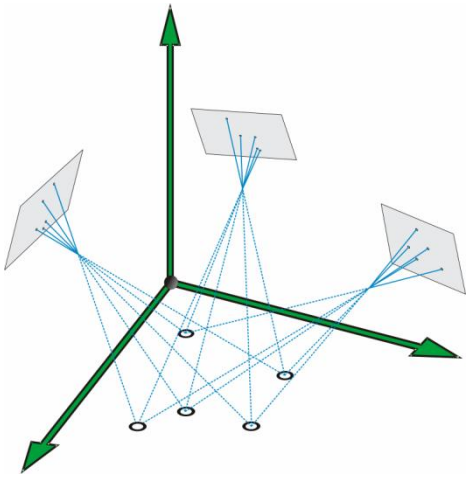


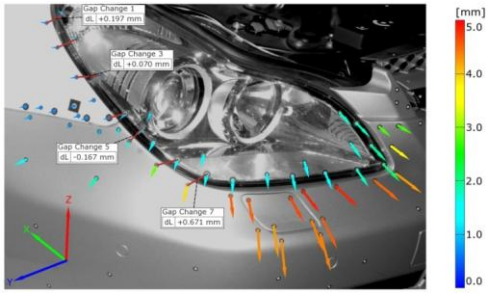
ARGUS
Deformation Analysis in
Sheet Metal Forming

ARAMIS
Deformation Analysis and
Material Testing

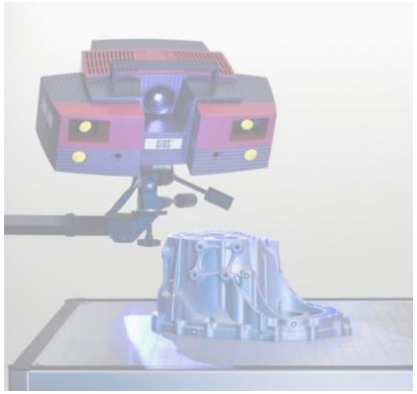
3D Point Measurement
Photogrammetry (TRITOP)

- Static measurement of single 3D coordinates (and displacements)
  - "Portable CMM"
- Inspection of objects (in different loading conditions)
  - 3D Coordinates points versus CAD
  - Distances, angles, radii
  - Mating dimensions, boreholes, bolts
  - (Vectors of movement for each marker)
  - (Deformation analysis)
- Measuring and analysis objects in
  - Ship building
  - Train building
  - Gas turbine casings
  - Rigs
  - (with mechanical load)
  - (with thermal load in climate chamber)



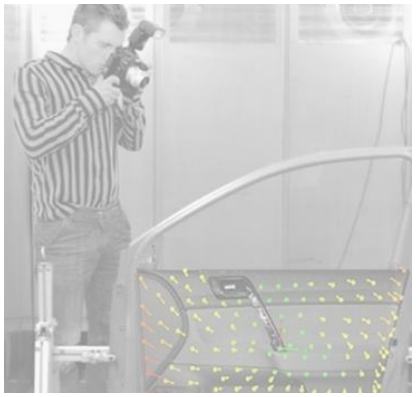


Dynamic 3D Point Measurement
Point Tracking (PONTOS)



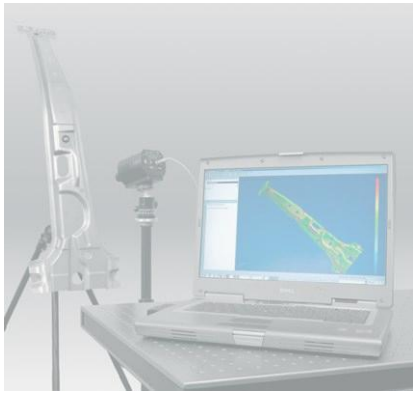
ATOS
3D Digitizing

TRITOP
Photogrammety



TRITOP Deformation
Static Deformation Analysis

PONTOS
Dynamic Photogrammety

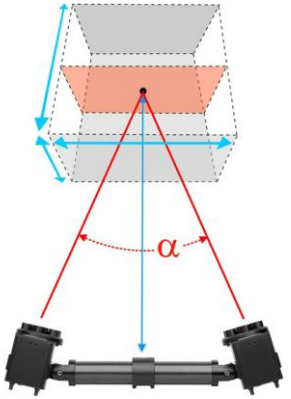


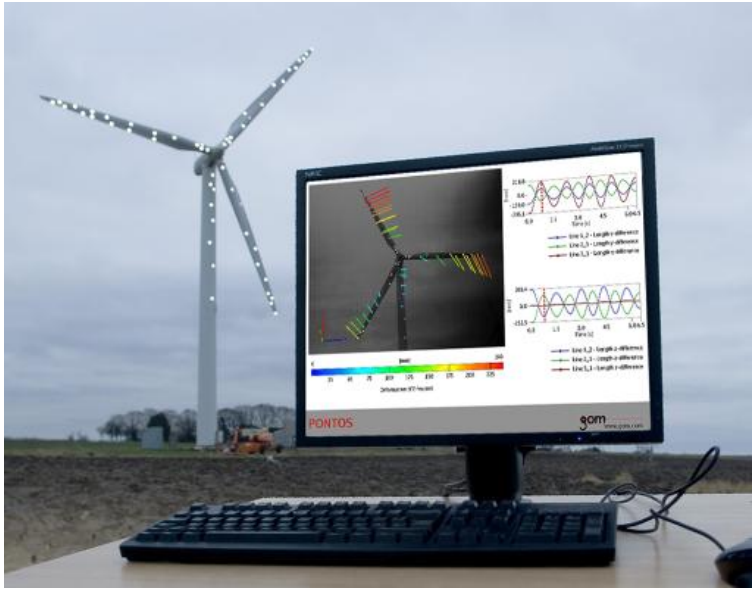
ARGUS
Deformation Analysis in
Sheet Metal Forming

ARAMIS
Deformation Analysis and
Material Testing

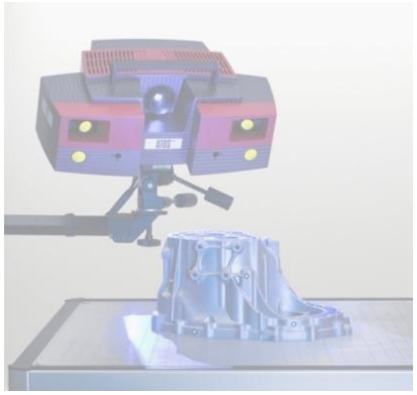
Dynamic 3D Point Measurement
Point Tracking (PONTOS)

- Photogrammetric measurement
- Dynamic measurement
- Deformation analysis and evaluation of multiple load conditions
  - Deformation (Torsion, bending, displacement, etc.)
  - Velocity
  - Acceleration
  - Analysis of vibration
- Dynamic behavior of components
  - Measurements in wind tunnels
  - Drop tests
  - Door slam tests
  - Structural vibrations



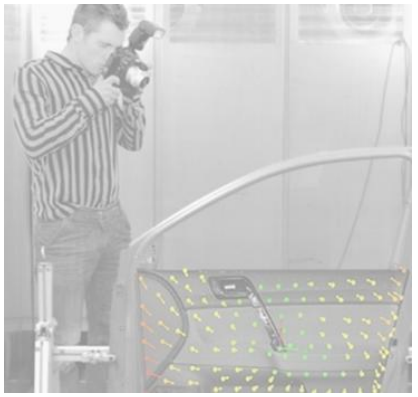


3D Surface Strain Measurement
Photogrammetry (ARGUS)



ATOS
3D Digitizing

TRITOP
Photogrammety



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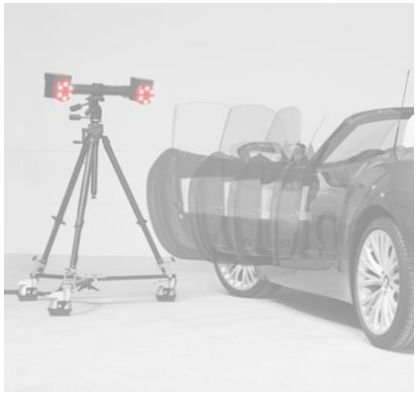
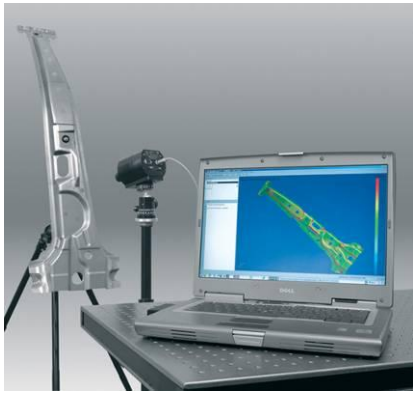
Static Deformation Analysis



PONTOS
Dynamic Photogrammety

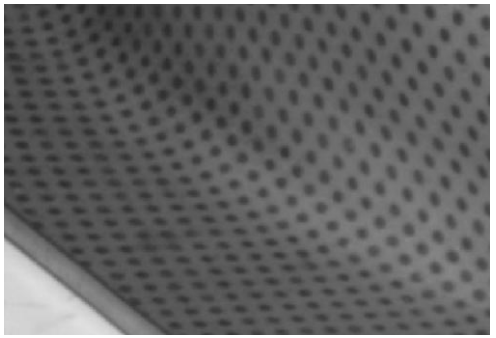


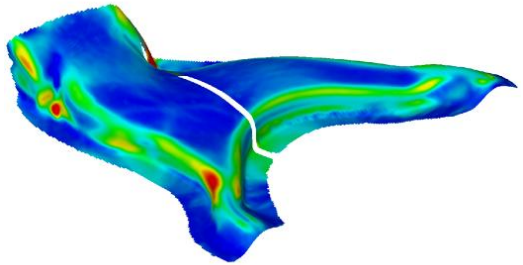
ARGUS
Deformation Analysis in
Sheet Metal Forming

ARAMIS
Deformation Analysis and
Material Testing

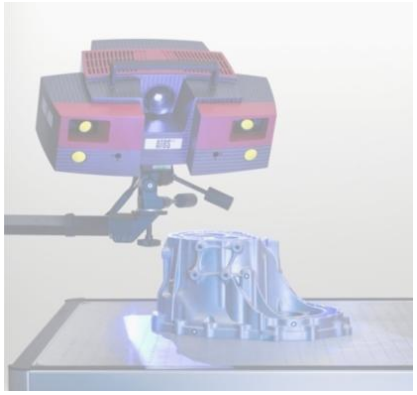
3D Surface Strain Measurement
Sheet Metal Forming Analysis (ARGUS)

- Photogrammetric measurement
- Dense point grid
- Static deformation analysis in sheet metal and forming industry
- Material deformation analysis
  - Detection of critical forming areas
  - Localization of overstretched areas prior to visible cracks
  - Verification and improvement of forming simulations
- Fast improvement of forming tools in try-out phase
  - Adjusting the tool parameters (binders, dies, support plates)
  - Changes in tools



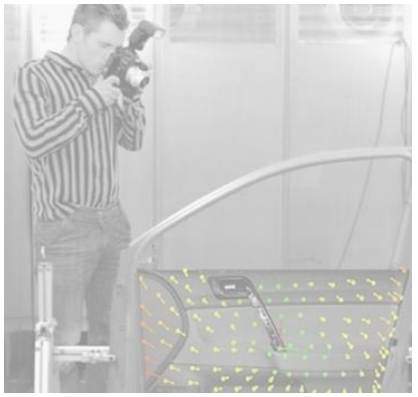


Dynamic 3D Surface Strain Measurement
Digital Image Correlation (ARAMIS)

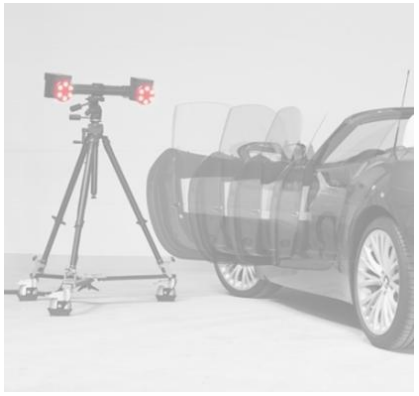


ATOS
3D Digitizing

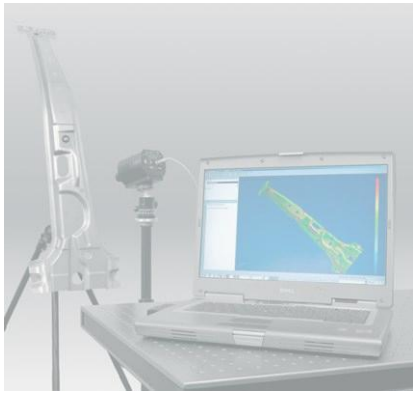
TRITOP
Photogrammety



TRITOP Deformation
Static Deformation Analysis



PONTOS
Dynamic Photogrammety

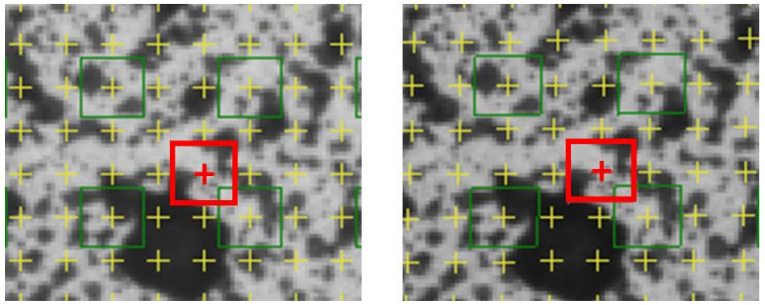


ARGUS
Deformation Analysis in
Sheet Metal Forming

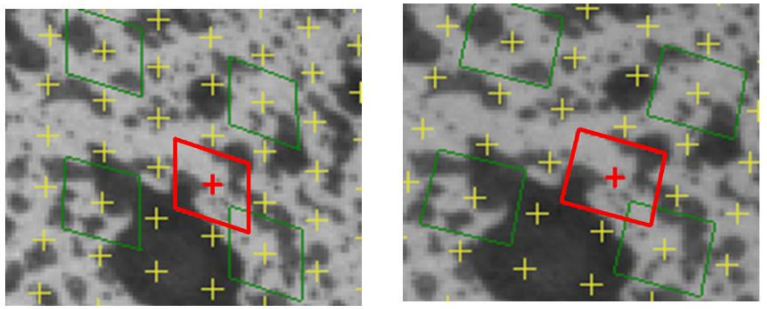
ARAMIS
Deformation Analysis and
Material Testing

Dynamic 3D Surface Strain Measurement
Digital Image Correlation (ARAMIS)

- Dynamic analysis of 3D coordinates, movements and strain
- 3D deformation measurement
  - Determination of material properties
  - Component testing
- Flexibility for all applications
  - Standard applications, e.g. tensile tests, …
  - High temperature measurements
  - High speed measurements
  - Real-Time measurements
- Integration in existing testing environments
  - Tensile testing devices, load frames, …
  - Replacement for extensometers and strain gauges
- Validation of Finite-Element simulations



Undeformed Specimen



Deformed Specimen

Dynamic 3D Surface Strain Measurement
Digital Image Correlation (ARAMIS)

- Dynamic analysis of 3D coordinates, movements and strain
- 3D deformation measurement
  - Determination of material properties
  - Component testing
- Flexibility for all applications
  - Standard applications, e.g. tensile tests, …
  - High temperature measurements
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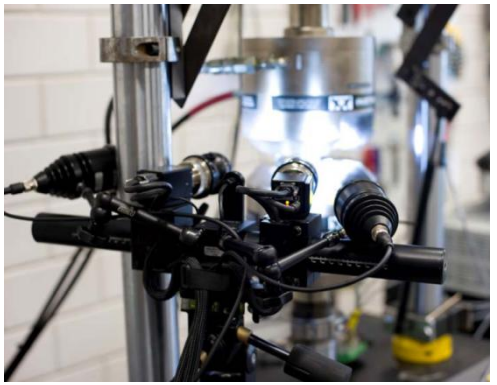
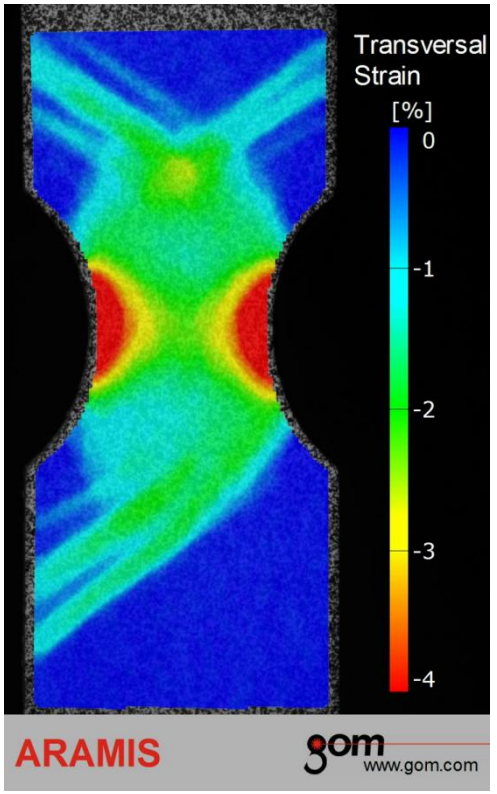
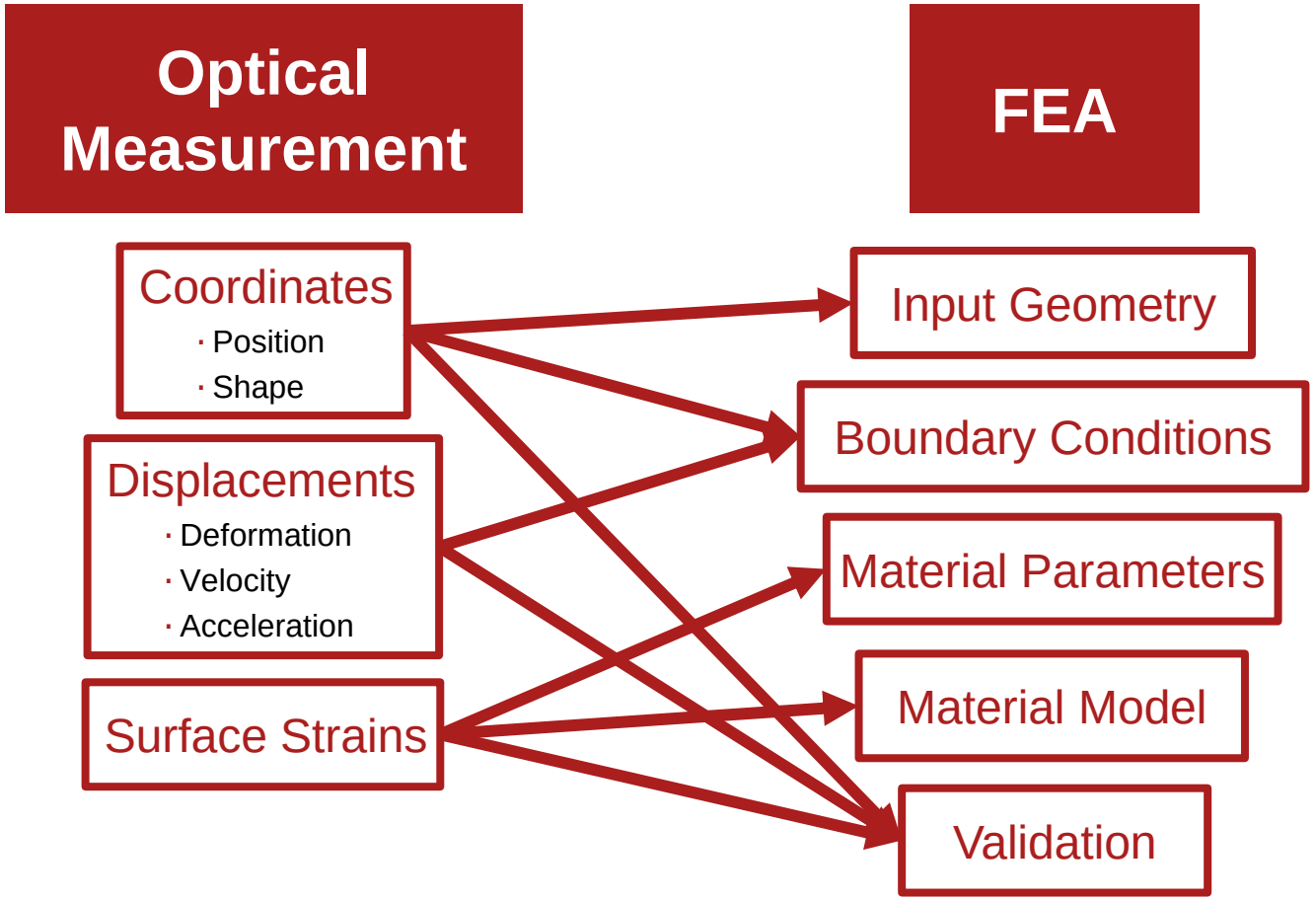
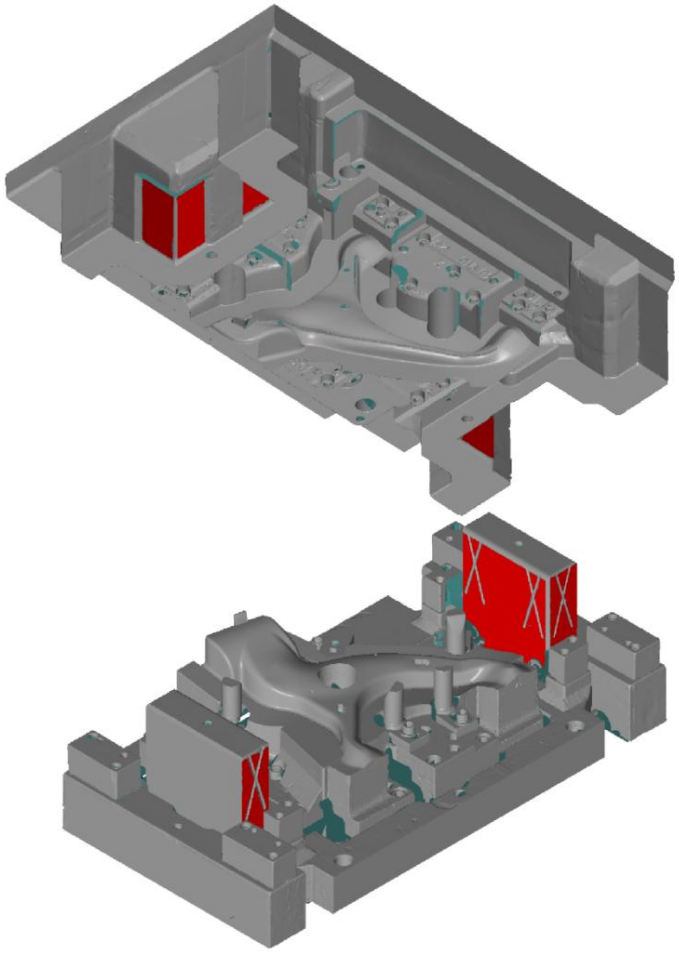





Optical Measurement
FEA
Coordinates
· Position
· Shape
Displacements
· Deformation
· Velocity
· Acceleration
Surface Strains
Input Geometry
Boundary Conditions
Material Parameters
Material Model
Validation

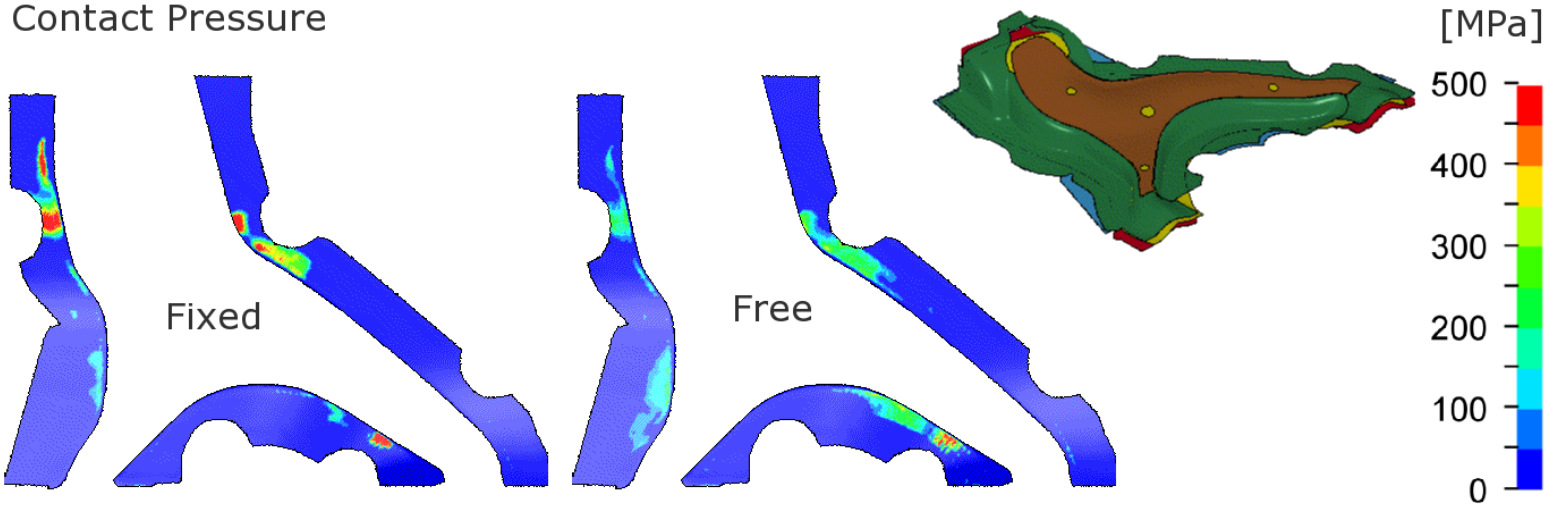
FEA Input
Input Geometry

- Real shape of tools and parts
  - If no CAD data set is available
  - If there is a shape deviation between CAD data set and real object due to
    - Production tolerances
    - Usage
    - “Manual optimization”



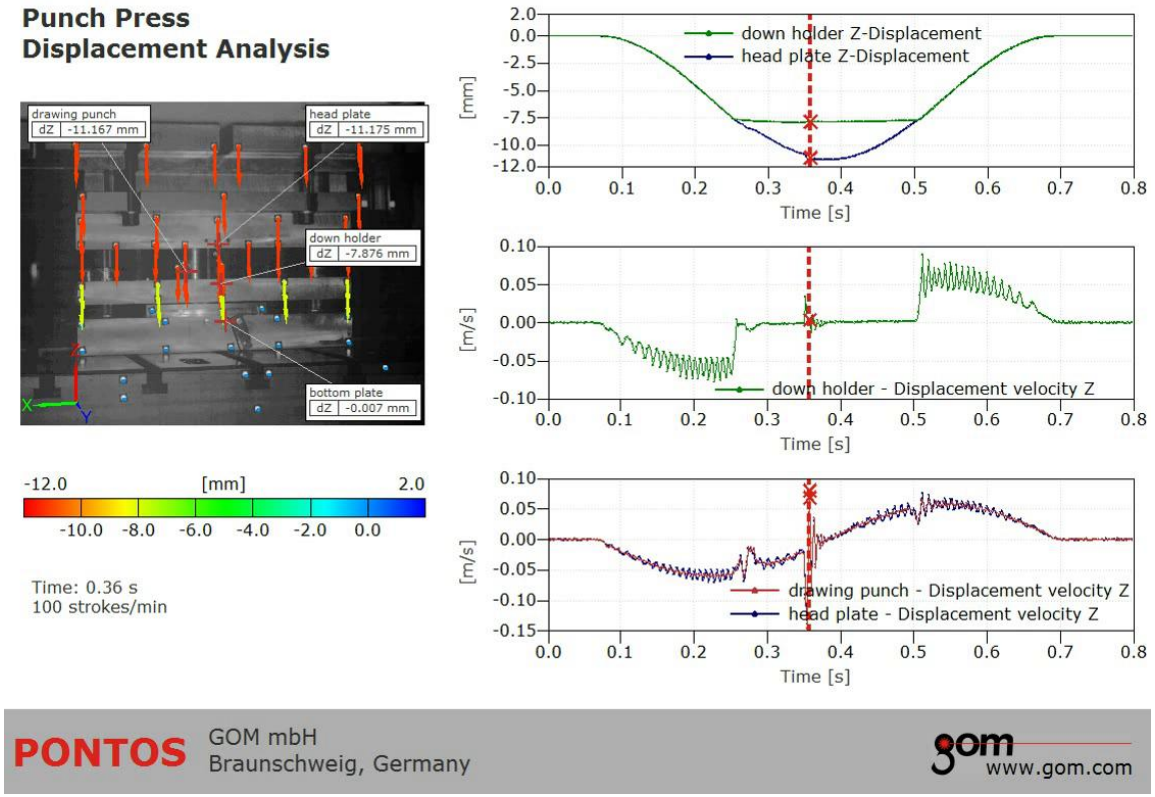
FEA Input
Boundary Conditions

- Shape and behavior of
  - Fixtures
  - Rigs
  - Tools
  - Loading devices
  - …
- Sample:
  - Blank holder movement degree of freedom



FEA Input
Boundary Conditions

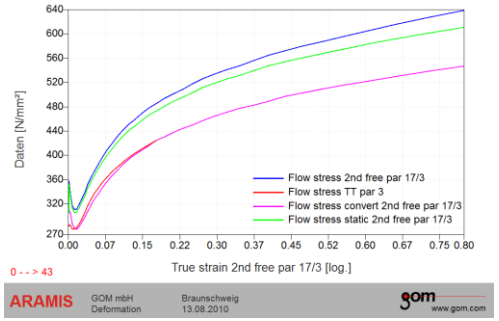
- Shape and behavior of
  - Fixtures
  - Rigs
  - Tools
  - Loading devices
  - …
- Sample:
  - Press behavior

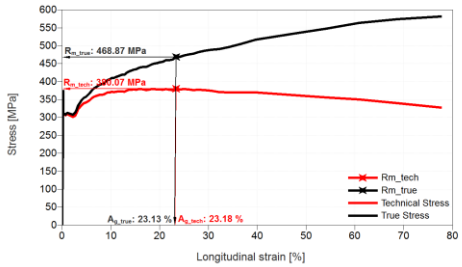


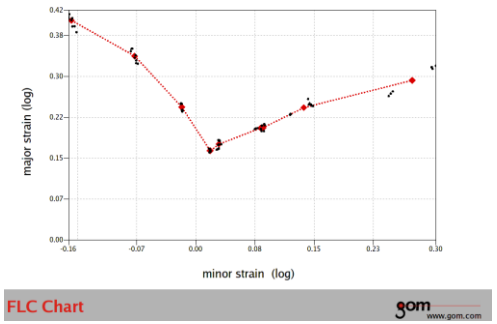
PONTOS GOM mbH
Braunschweig, Germany
www.gom.com

FEA Input
Material Parameters

- Optical surface strain measurement is used to get:
  - Yield curve (true stress – true strain curve)
    - From Tension Test
    - From Bulge Test (ISO16808)
  - FLC (Forming Limit Curve) (ISO12004)
  - n-Value (Hardening Exponent)
  - r-Value (Anisotropy)
  - Young's Modulus
  - Poisson's Ratio
  - Shear
  - …







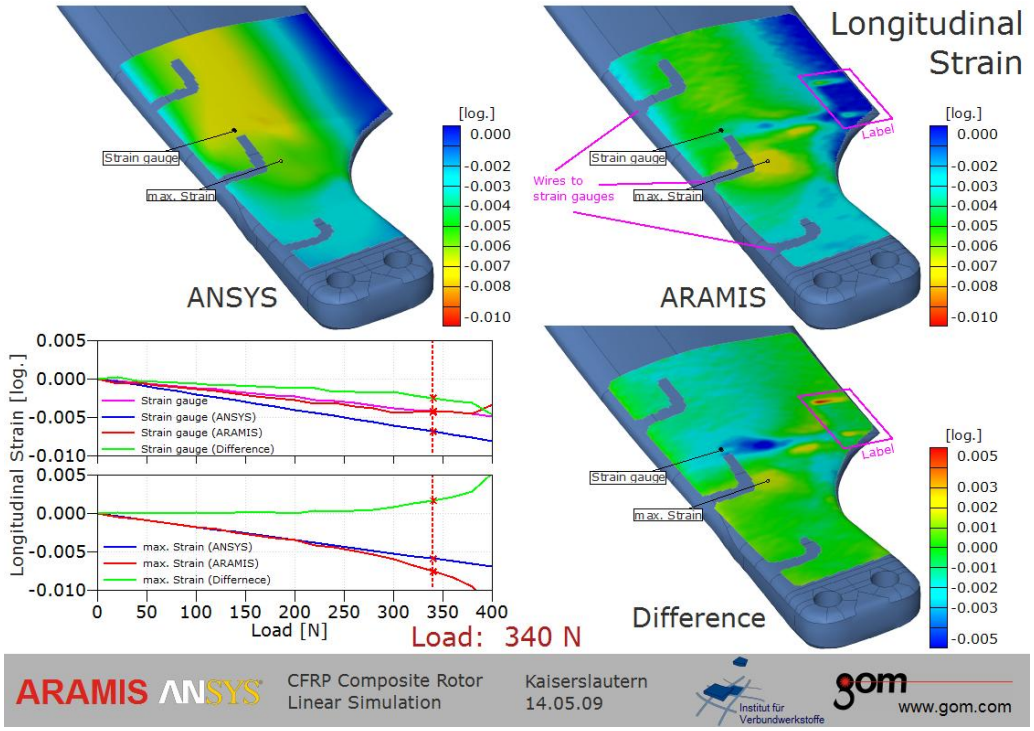
tensile_test_tt_eval_Area (large).txt

```
Tensile test evaluation (flat specimen)
E-Modulus (Area (large)): 202951 MPa
Rp02 (Area (large)): 308.06 MPa
Poisson-Ratio (Area (large)): 0.284
r_20-Value (Area (large)): 1.316
n_10..20-Value (Area (large)): 0.171
Rm_tech: 380.07 MPa
Ag_tech (Area (large)): 23.18 %
Rm_true (Area (large)): 468.87 MPa
Ag_true (Area (large)): 23.13 %
"true stress";"true strain"

-0.000008;0.000000
54.399945;0.000264
141.759072;0.000731
226.656480;0.001151
310.976396;0.001521
363.122239;0.002102
313.697550;0.002120
307.432369;0.002354
308.255944;0.002969
309.826715;0.003942
310.149269;0.004977
309.184724;0.005963
```

FEA Input
Material Model

- Validate choice of right
  - Element type
  - Material model
  - Simulation model
    - Linear
    - Nonlinear
  - Simplifications
- Get right compromise for
  - Computation time
  - Degrees of freedom
  - Validity
- Sample:
  - Helicopter blade with linear simulation but nonlinear behavior for loads greater than 200N

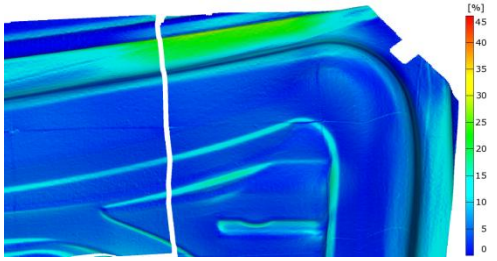


FEA Input
Material Model

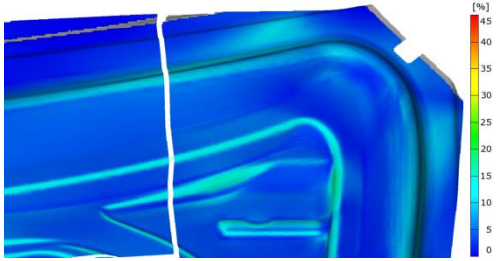
- Validate choice of right
  - Element type
  - Material model
  - Simulation model
    - Linear
    - Nonlinear
  - Simplifications

- Get right compromise for
  - Computation time
  - Degrees of freedom
  - Validity

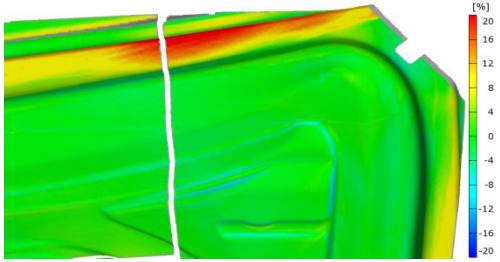
- Sample:
  - Trunk lid forming simulated without seam for simplification (only small area is affected)



Major true strain measurement



Major true strain FEA

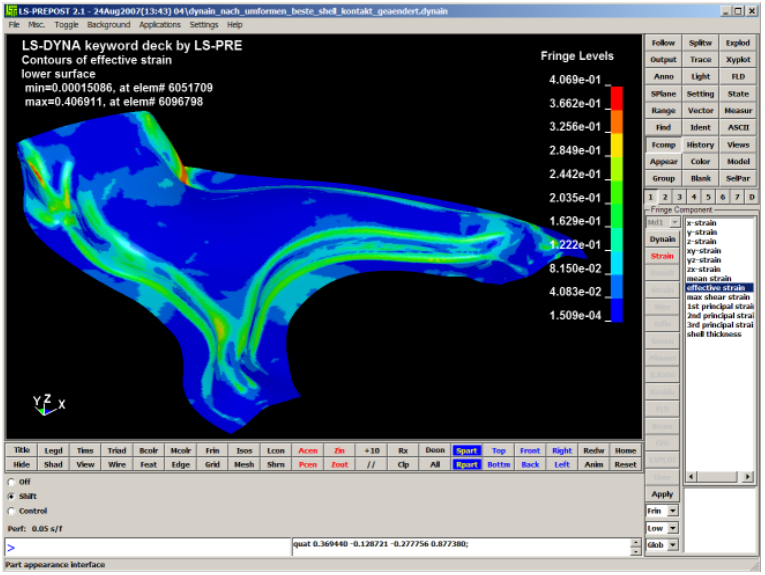


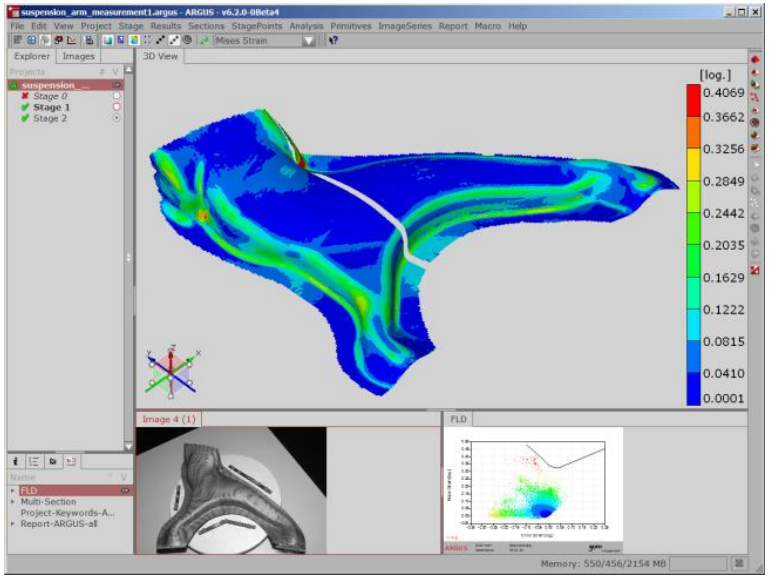
Major true strain deviation

FEA Validation
Comparison

- Simulation and optical measurement provide
  - Full field result data

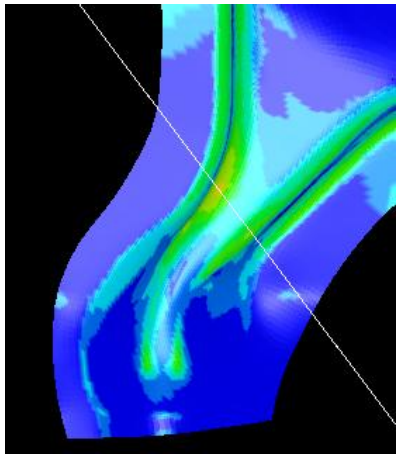
- But are different in:
  - Coordinate system
  - Result presentation

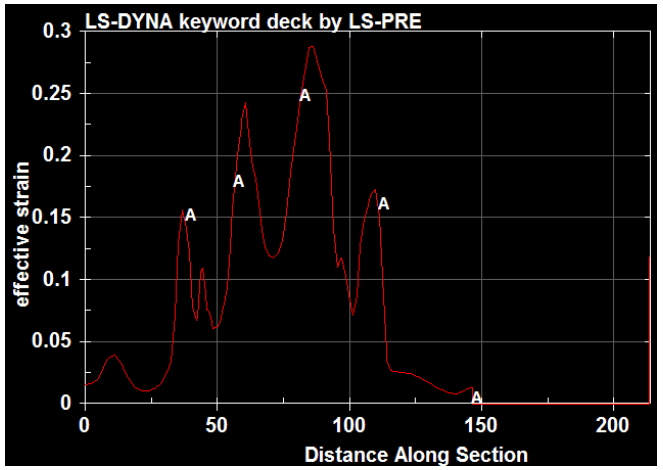


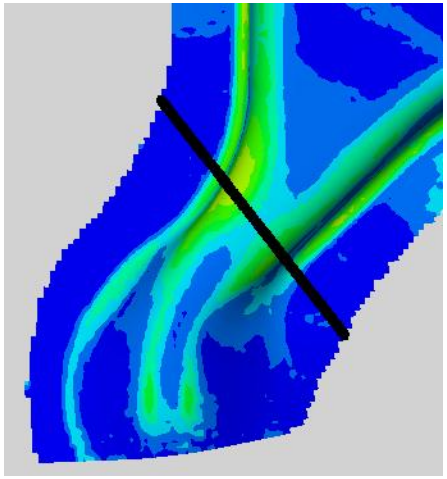


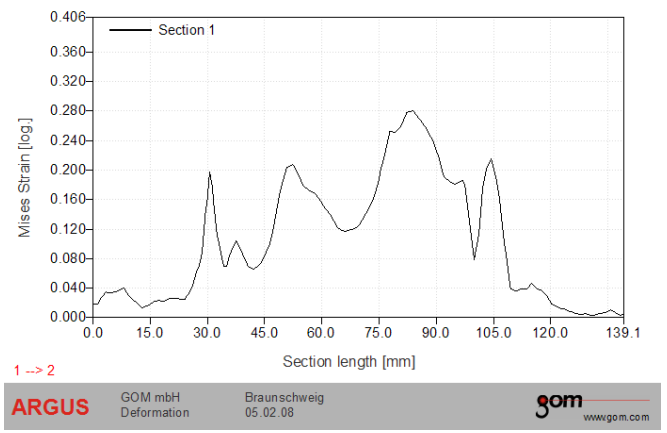
FEA Validation
Comparison

- Simulation and optical measurement provide
  - Full field result data
- But are different in:
  - Coordinate system
  - Result presentation
- Often only subsets of data are compared







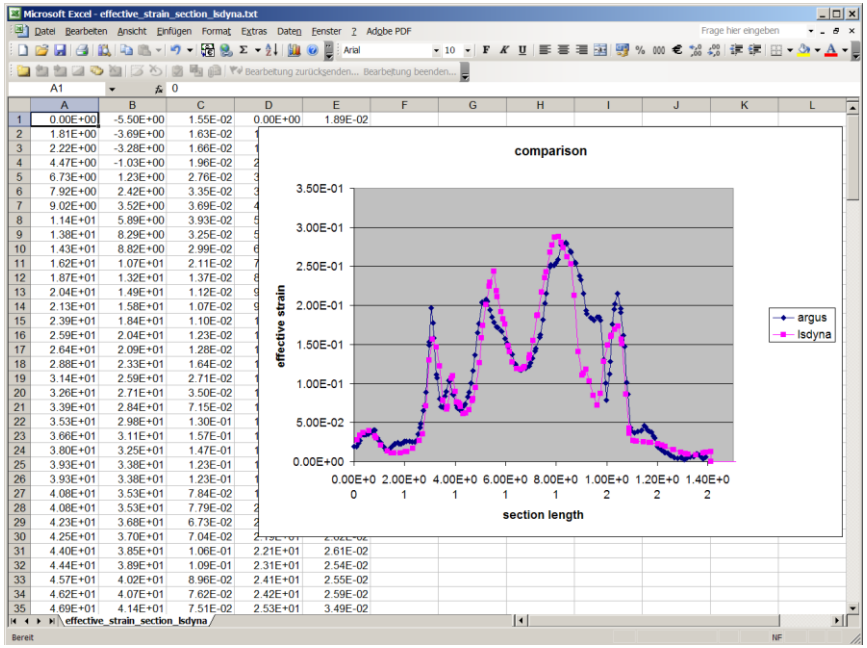


FEA Validation
Comparison

- Simulation and optical measurement provide
  - Full field result data
- But are different in:
  - Coordinate system
  - Result presentation
- Often only subsets of data are compared manually in external tools

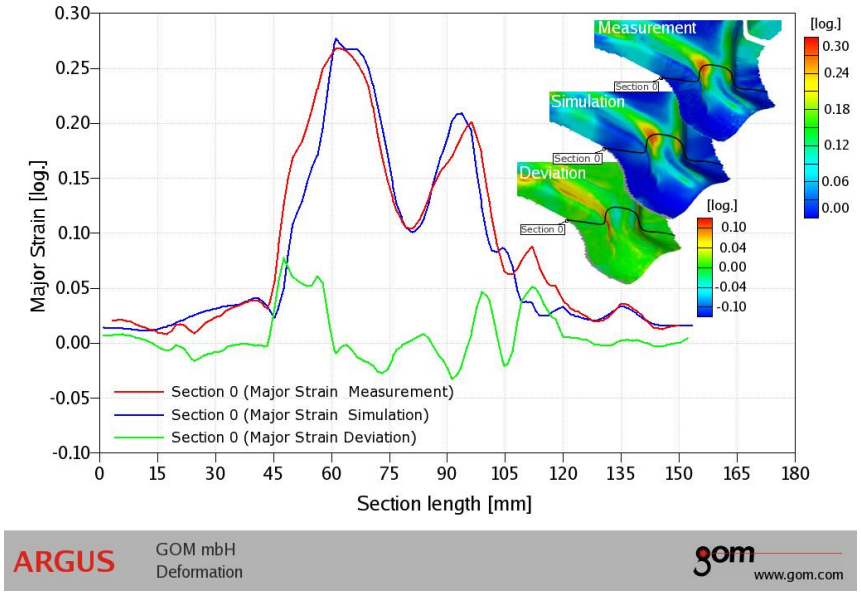
```
Curveplot
LS-DYNA keyword deck by LS-PRE
Distance Along Section
effective strain
State #(Time)
1(0.000000) #pts=122
* Minval=   0.000000e+000 at time=     146.820206
* Maxval=   2.882687e-001 at time=      86.537910
  0.0000000000e+000  1.5464207157e-002
  1.8137018681e+000  1.6314780340e-002
  2.2232160568e+000  1.6561787575e-002
  4.4665336609e+000  1.9550947472e-002
  6.7324752808e+000  2.7604339644e-002
  7.9226703644e+000  3.3493842930e-002
  9.0180034637e+000  3.6880731583e-002
  1.1390533447e+001  3.9287075400e-002
  1.3792483330e+001  3.2486289740e-002
  1.4319003105e+001  2.9909165576e-002
  1.6222316742e+001  2.1135060117e-002
  1.8687896729e+001  1.3651171699e-002
  2.0365554810e+001  1.1161450297e-002
  2.1334554672e+001  1.0696235113e-002
  2.3852067947e+001  1.1028897017e-002
  2.5904327393e+001  1.2307016179e-002
```

```
# <defaultcodec>utf-8</defaultcodec>
Multi section export
Section: Section 1
Strain stage: 1 -> 2
Point stage: 2
Point position  X coordinate diagram [mm] Mises Strain [log.]
0  0.00000000e+00  1.88783538e-02
1  1.13995982e+00  1.90515704e-02
2  1.74325705e+00  2.30977498e-02
3  2.29016245e+00  2.68231370e-02
4  3.45129419e+00  3.48011442e-02
5  3.78401087e+00  3.43100168e-02
6  4.61806434e+00  3.42791863e-02
7  5.78508535e+00  3.53378393e-02
8  5.80343281e+00  3.53698879e-02
9  6.96218367e+00  3.79324630e-02
10  7.82181427e+00  4.04795222e-02
11  8.14933575e+00  4.00959477e-02
12  9.33068582e+00  3.02152913e-02
13  9.86396652e+00  2.70399004e-02
14  1.04822619e+01  2.44328231e-02
15  1.16448408e+01  1.96492150e-02
16  1.19060188e+01  1.81768052e-02
17  1.27939982e+01  1.39724957e-02
```



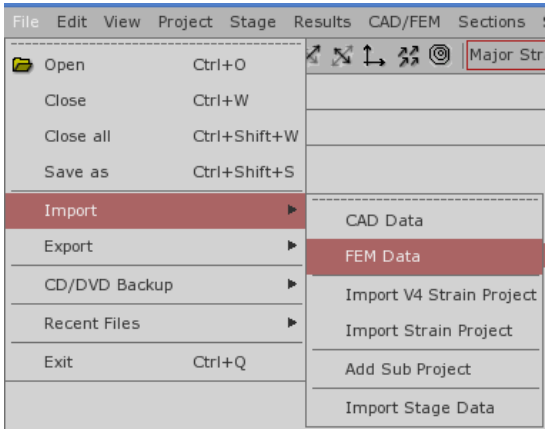
FEA Validation
Comparison

- Simulation and optical measurement provide
  - Full field result data
- But are different in:
  - Coordinate system
  - Result presentation
- Often only subsets of data are compared manually in external tools
- Handling of both data sets in a single post processor will give advantages



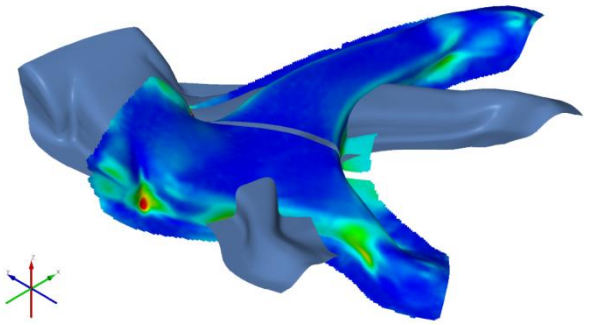
FEA Validation
Comparison Workflow

- Import of FEA results in GOM software

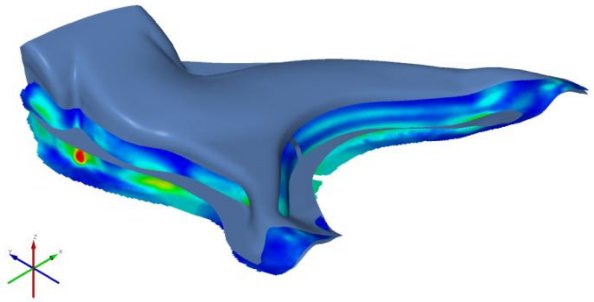


FEA Validation
Comparison Workflow

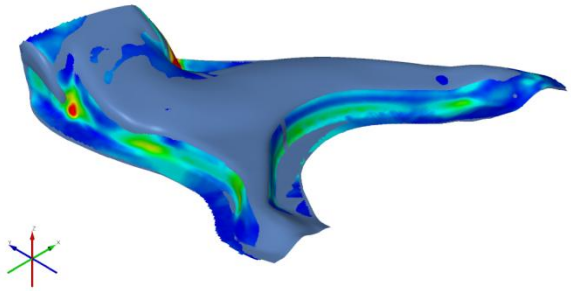
- Import of FEA results in GOM software
- Alignment of Coordinate System
  - By surface (best fit)



Without alignment



After pre-orientation

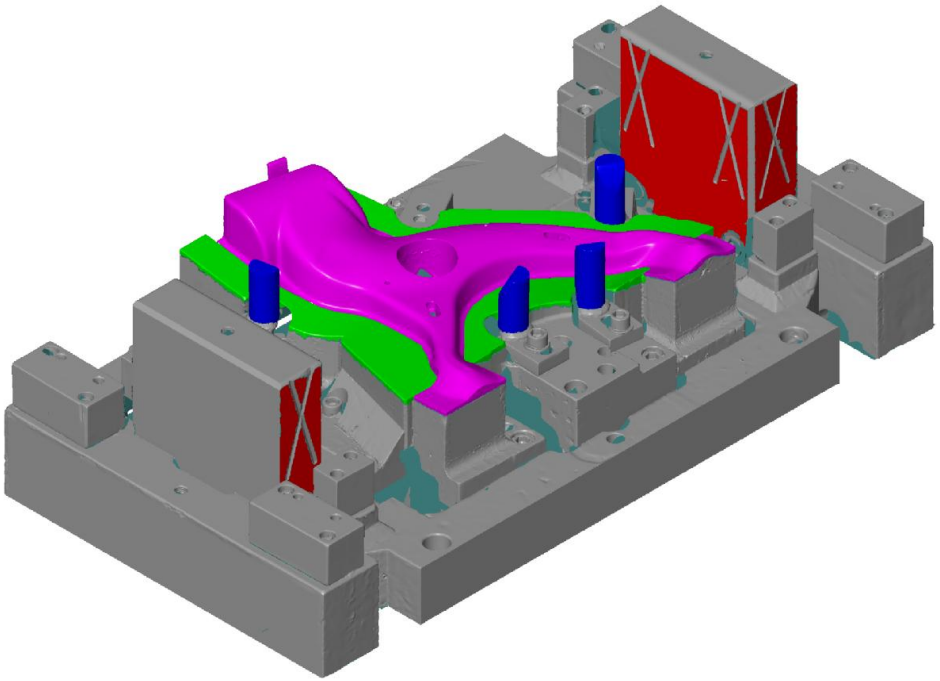


After best-fit by surface

FEA Validation
Comparison Workflow

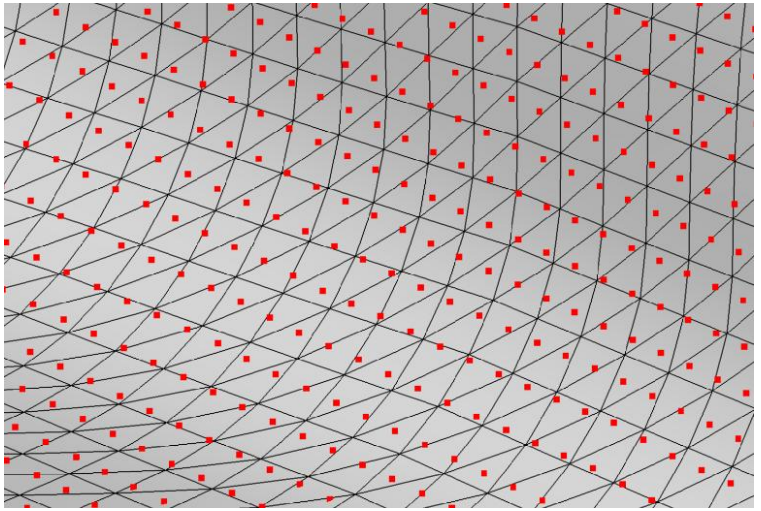
- Import of FEA results in GOM software

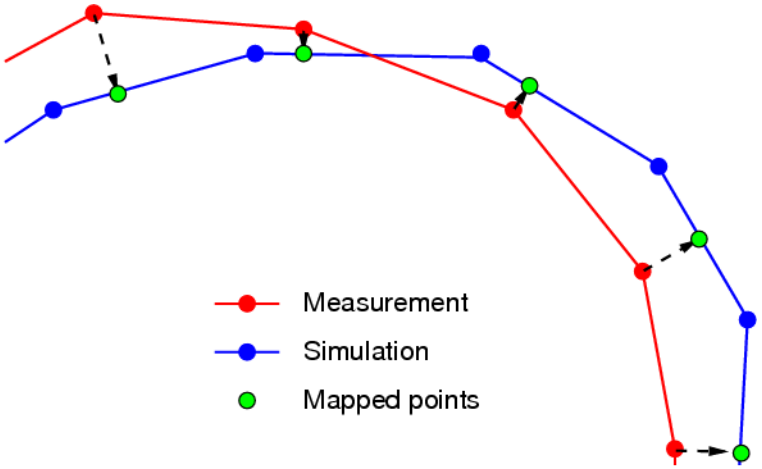
- Alignment of Coordinate System
  - By surface (best fit)
  - By frame (reference points, 3-2-1, translation, rotation)



FEA Validation
Comparison Workflow

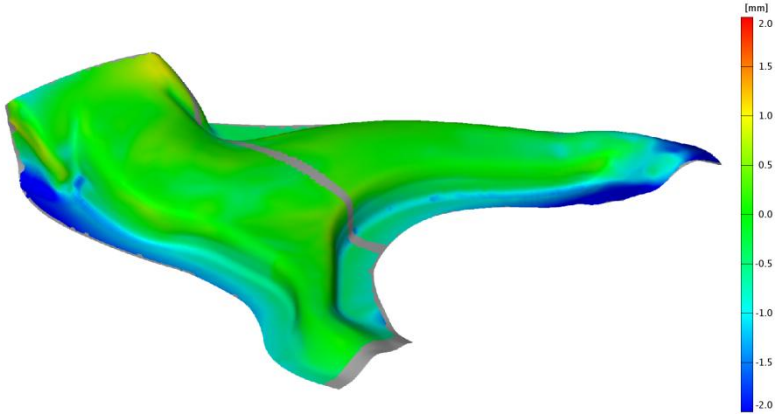
- Import of FEA results in GOM software
- Alignment of Coordinate System
  - By surface (best fit)
  - By frame (reference points, 3-2-1, translation, rotation)
- Mapping
  - Find corresponding points for non congruent meshes
  - Interpolate result values for mapped points



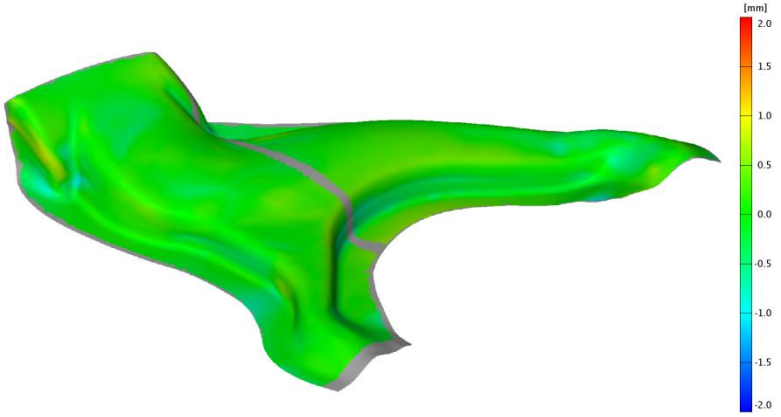


FEA Validation
Comparison Workflow

- Import of FEA results in GOM software
- Alignment of Coordinate System
  - By surface (best fit)
  - By frame (reference points, 3-2-1, translation, rotation)
- Mapping
- Comparison of
  - Geometry
    - Depth of drawing
    - Shape of die
    - Spring back
    - Wrinkling



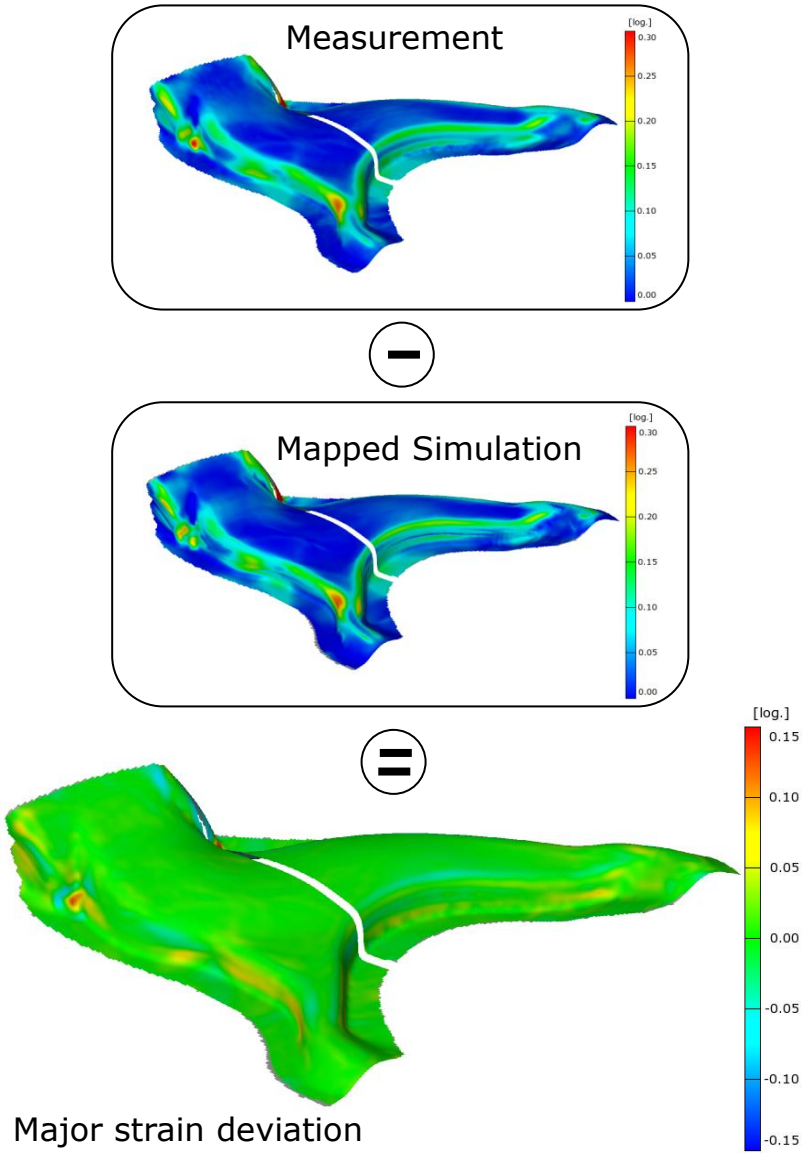
Surface deviation without spring back simulation



Surface deviation with spring back simulation

FEA Validation
Comparison Workflow

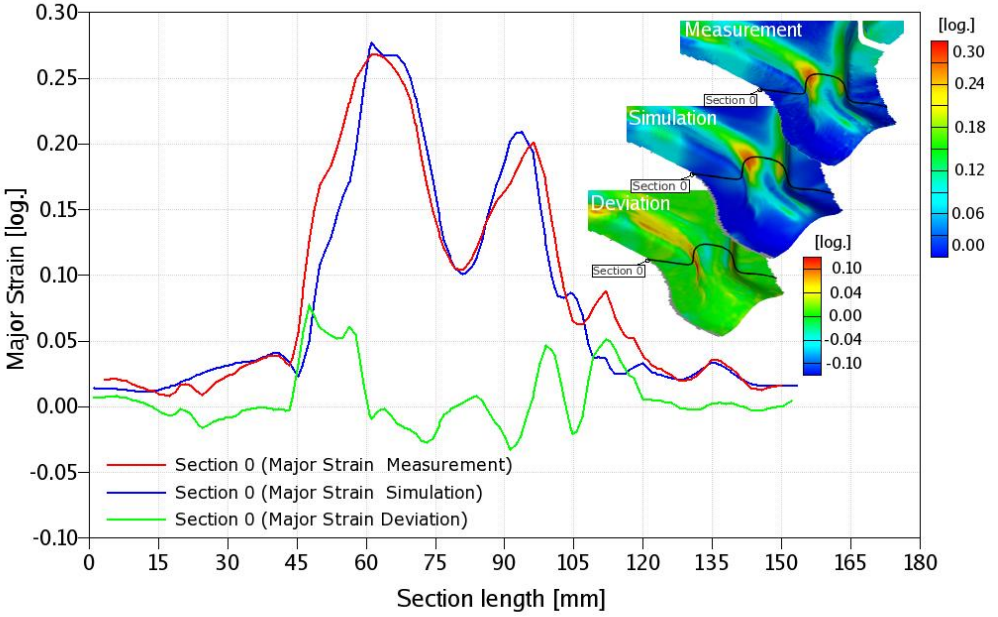
- Import of FEA results in GOM software
- Alignment of Coordinate System
  - By surface (best fit)
  - By frame (reference points, 3-2-1, translation, rotation)
- Mapping
- Comparison of
  - Geometry
  - Displacements and Strains
    - Strain distribution
    - State of strain
    - Thinning
    - Distance to FLC



Major strain deviation

FEA Validation
Comparison Workflow

- Import of FEA results in GOM software
- Alignment of Coordinate System
  - By surface (best fit)
  - By frame (reference points, 3-2-1, translation, rotation)
- Mapping
- Comparison of
  - Geometry
  - Displacements and Strains
- Postprocessing
  - Full field data
  - Section
  - Point markers
  - 3D view
  - Diagrams
  - Reports
  - Export
- Interpretation …



Thank you for your attention

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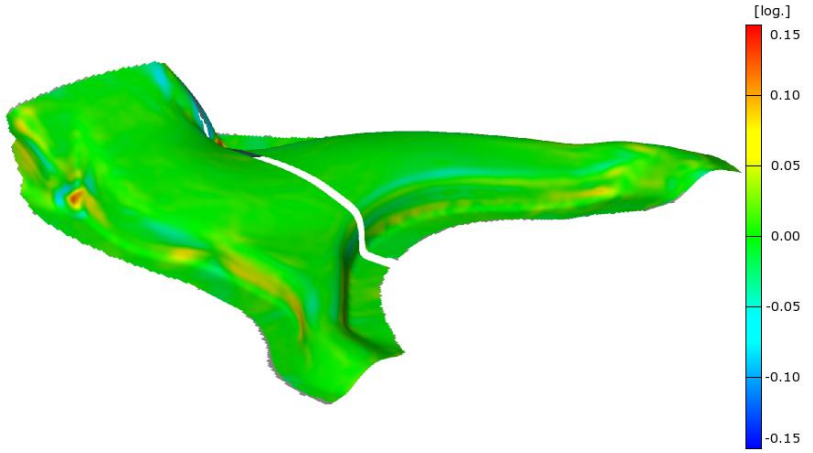

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