

15th German LS-DYNA Forum

Identification of Material Parameters with LS-OPT®

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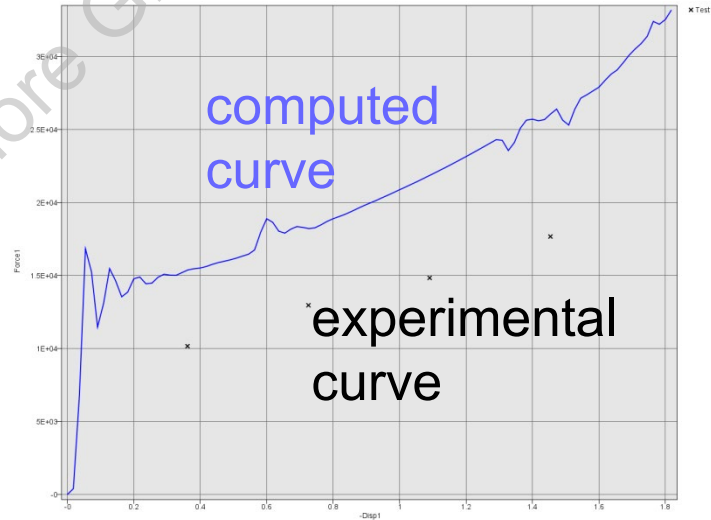
Bamberg, 16.10.2018

Outline

- Parameter Identification – Standard approach
- Parameter Identification using DIC
 - New Features in LS-OPT 6.0
 - Interfaces to import DIC data
 - Alignment of test and simulation geometry
 - Extraction of Multihistories from simulation
- Curve Matching Metrics
- Example
 - Live demonstration
- Remarks

Parameter Identification

- Parameter Identification problems are non-linear inverse problems solved using optimization
- Computed curves (from LS-DYNA[®]), dependent on parameters, are matched to experimental curves
- Optimization provides a calibration of the unknown parameters

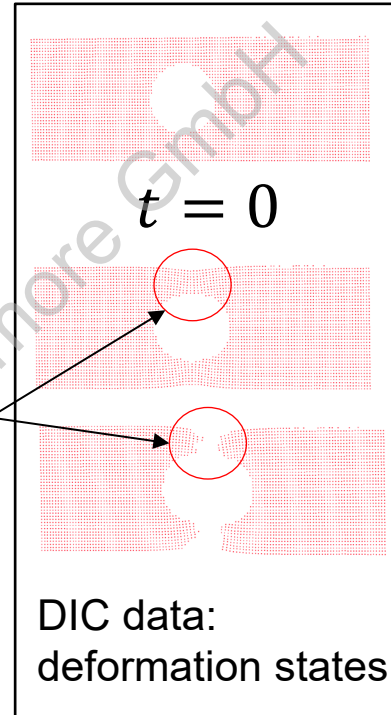


Calibration of material parameters - Standard approach

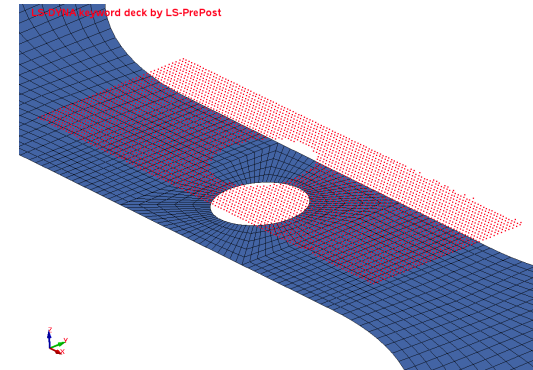
- Global data from experiment is used
- Problems:
 - Instability typical in calibration problems, especially complex models with many parameters
 - Local phenomena such as coupon necking/barreling missed

→ Use full-field data

Local deformation



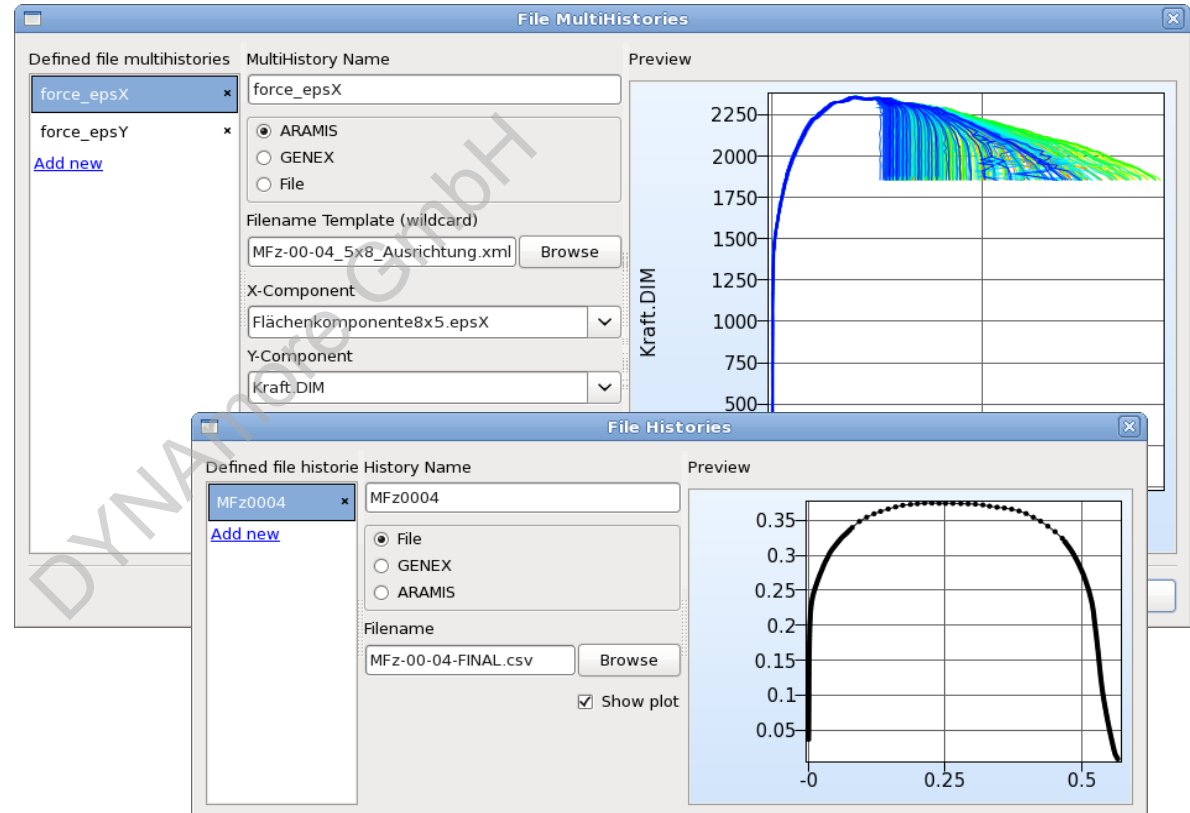
Full field test result
(4557 pts)
from optical scan is
mapped and tracked



Import DIC data into LS-OPT

■ Interfaces (LS-OPT 6.0) Multihistories and Histories

- ARAMIS (gom)
- GENEX
 - Extraction from ASCII files
- DIC data may be stored in multiple files
 - One file per time stage

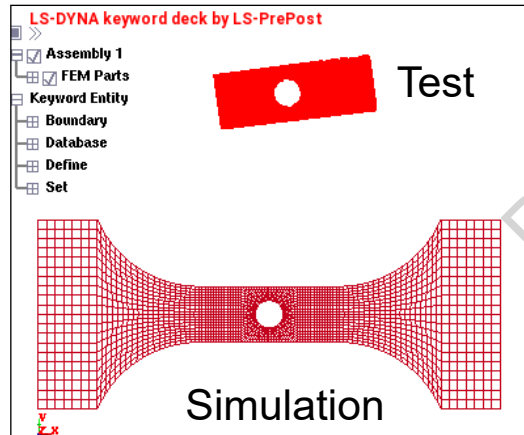


Alignment of test and simulation data

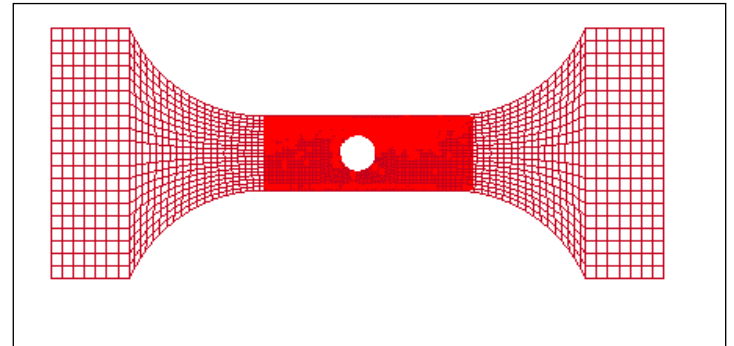
- Test and simulation geometries are typically in different coordinate systems
- Transformation of coordinates using least square formulation

$$\min_T \|\hat{s} X_{\text{Test}} T - X_{\text{FE}}\|$$

- X_{Test} : Test points (subset), X_{FE} : FE model points, T : transform, \hat{s} : Isotropic scaling



Alignment



Extraction of Multihistories from simulation

■ D3PLOT Interface (LS-OPT 6.0)

Name: D3PlotXStrain00

Subcase: [dropdown]

Results Type: Ndv Stress Result Strain Misc Infinitesimal Green-St Venant FLD Beam

Component: L_surf_plastic_strain U_surf_xy_strain U_surf_yz_strain L_surf_xx_strain U_surf_zx_strain M_surf_xx_strain L_surf_zz_strain M_surf_yy_strain L_surf_xy_strain M_surf_zz_strain L_surf_yz_strain M_surf_xy_strain L_surf_zx_strain M_surf_yz_strain M_surf_xx_strain M_surf_zx_strain L_surf_max_princ_strain L_surf_min_princ_strain L_surf_2nd_princ_strain U_surf_min_princ_strain U_surf_max_princ_strain U_surf_2nd_princ_strain U_surf_min_princ_strain U_surf_max_princ_strain U_surf_effective_strain M_surf_min_princ_strain M_surf_max_princ_strain M_surf_2nd_princ_strain M_surf_min_princ_strain M_surf_max_princ_strain M_surf_effective_strain

Source: ARAMIS Coordinate File

ARAMIS multihistory: force_epsX

FE Interpolation: Nearest node

Distance Tolerance: [input]

Cluster source points

Align test and simulation geometry

align [dropdown] [New alignment] [Open in LSPP]

Parts to be included: All Parts List of parts: x1

visualization in LSPP

Defined transformations

trans_tensile

Transformation Name: trans_tensile

Test: Simulation

Coordinates: Node ID

Test x coord	Test y coord	Test z coord	Node ID
-8.47391	.78577	2.02715	495
17.57689	6.08299	2.38169	1435
-8.19484	-6.23842	2.0367	1925
16.96481	-3.20172	2.38046	2771

Scale factor: 1.0 (default)

alignment

Objective Functions - Matching of Scalar Values and Curve Matching Metrics

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Matching of scalar values

Standard Composite Functions

Targeted Formulation

$$F = \sum_{j=1}^m W_j \left[\frac{f_j(\mathbf{x}) - G_j}{S_j} \right]^2$$

$f_j(\mathbf{x})$: simulation response as function of variable vector \mathbf{x}

G_j : target value

W_j : weighting factor

S_j : normalization factor

Composites

Name for composite: F_damage

Composite function type: Sqrt MSE

Composite components

Entity	Multiplier	Divisor	Target
× intrusion_3	1 (default)	30 (default is 1)	20
× intrusion_4	1 (default)	25 (default is 1)	35

Add new

Responses

- Disp2
- Disp1
- Acc_max
- Mass
- HIC
- intrusion_3
- intrusion_4

Variables

- tbumper
- thood

Cancel OK

Curve Matching Metrics

■ Response (LS-OPT 6.0)

- Matching of histories and multihistories
 - Mean Square Error
 - Partial Curve Mapping
 - Discrete Fréchet
 - Dynamic Time Warping

■ Composite

- Only matching of histories
 - Mean Square Error
 - Partial Curve Mapping

Edit response

Name	Subcase	Multiplier	Offset
Residual		n/a	n/a

Match

Histories

Multihistories

Algorithm

Mean Square Error

Partial Curve Mapping

Discrete Fréchet

Dynamic Time Warping

Target multihistory

test_tensile [Add new file multihistory](#)

Computed multihistory

cp_mh_first_principal_strain

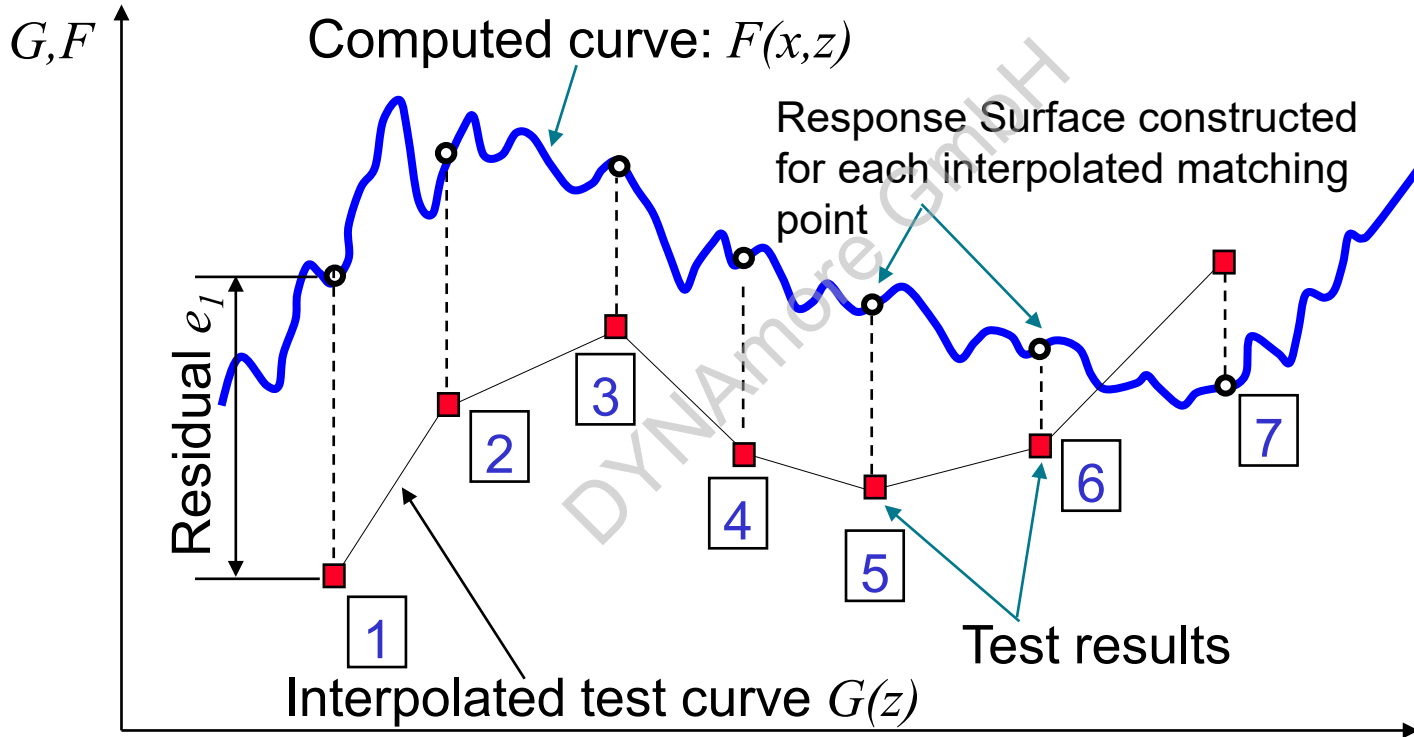
Regression Points

From target curve

Fixed number (equidistant, interpolated)

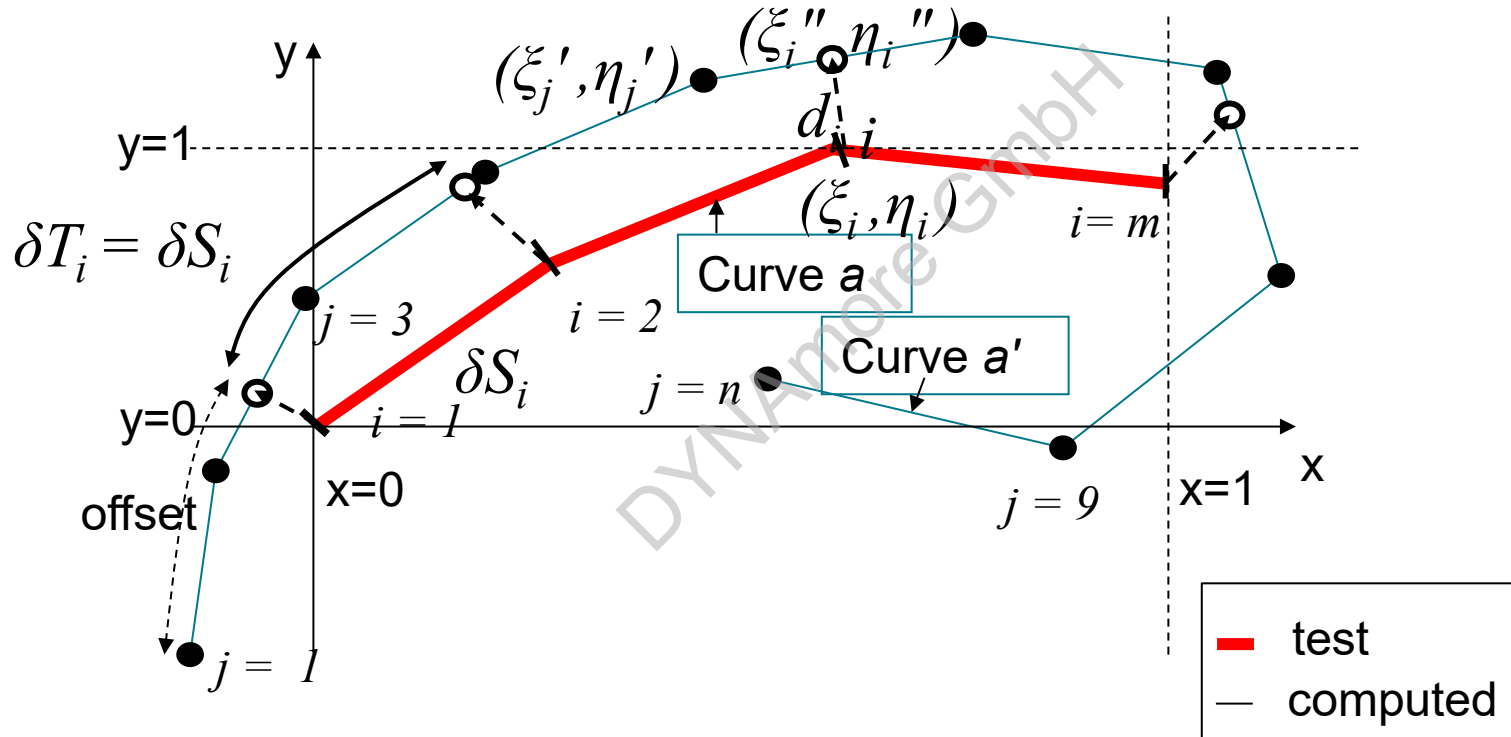
Ordinate-based Curve Matching Metric

■ Mean Square Error



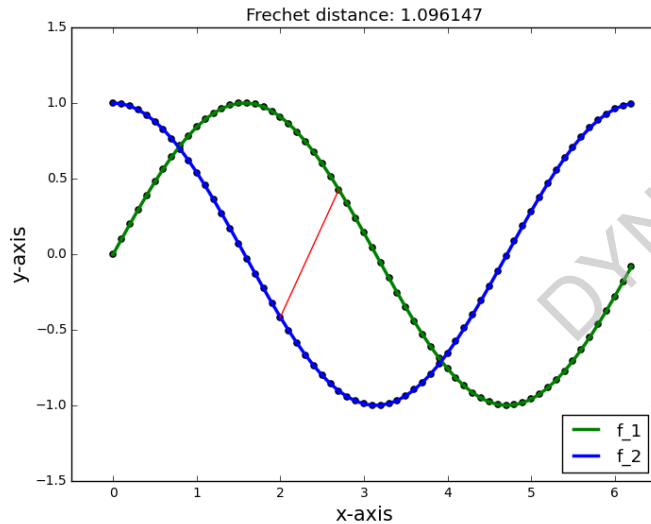
Partial Curve Mapping

- Suitable for steep or hysteretic curves



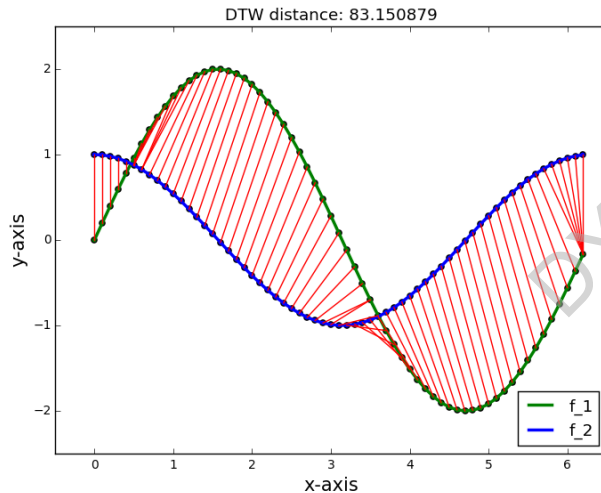
Discrete Fréchet

- Suitable for noisy curves
- Not suitable for partial mapping
- **Minimum of the maximum** of **all possible edge lengths** along a path, which connects all given data points



Dynamic Time Warping

- Suitable for noisy curves
- Not suitable for partial mapping
- **Warping path: minimum accumulated distance** which is necessary to traverse all points in the curves



Example

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Example

Tensile test

- Material model *MAT_24

→ calibration of stress-strain curve

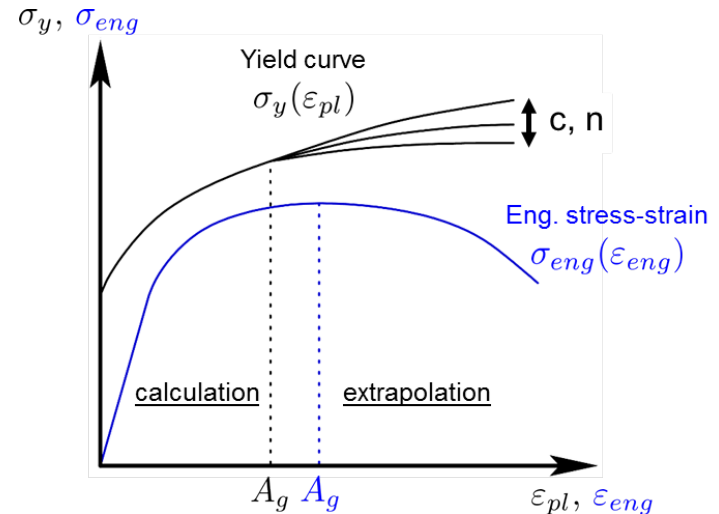
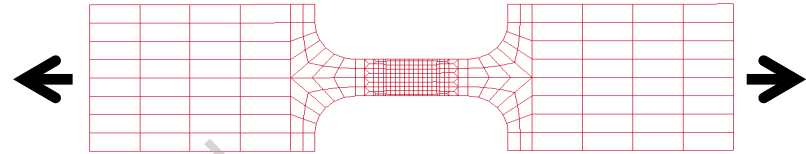
- Hockett-Sherby flow curve formula for extrapolation beyond the point of a uniform strain state:

$$f(\varepsilon_p) = A - B e^{-C \varepsilon_{pl}^N}$$

- C_1 -continuity is assumed at the flow transition

→ A and B

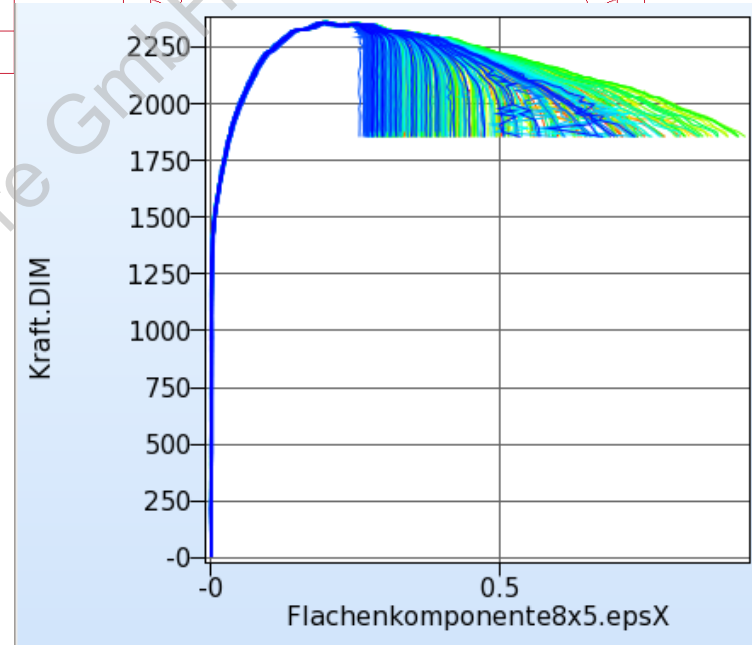
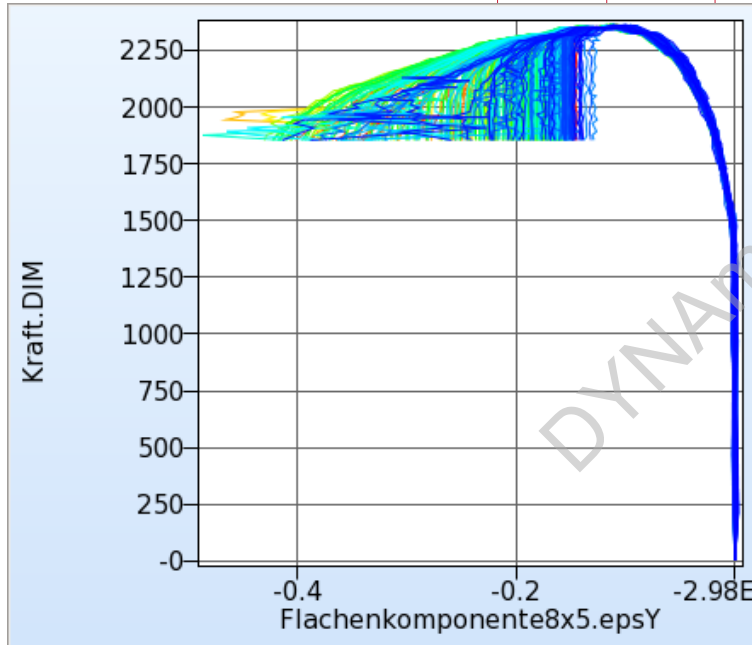
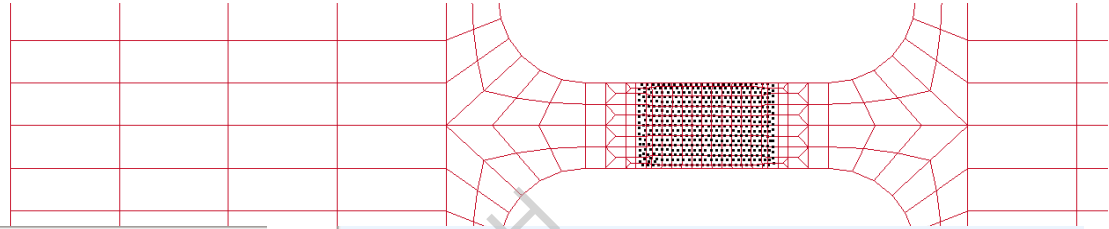
- C and N optimization parameters



Example

- Target data (ARAMIS)

- x and y strains



Live Demonstration

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Remarks

- Make sure to evaluate exactly the same entities from simulation and test (filtering, ...)
- The result can never be better than the (material-) model
- Use appropriate analytical function for parameterization of LS-DYNA input curves
- Ranges for parameters?
→ increase if optimal value is bound and result not good enough (if parameter is sensitive!)
- Additional objective functions like max value, time of failure, ... might improve the results
- Multiple load cases: objectives might be in conflict

More Information ...

- Full-Field Material Calibration using LS-OPT

N. Stander

Tuesday, October 16, 17:50, Room 2

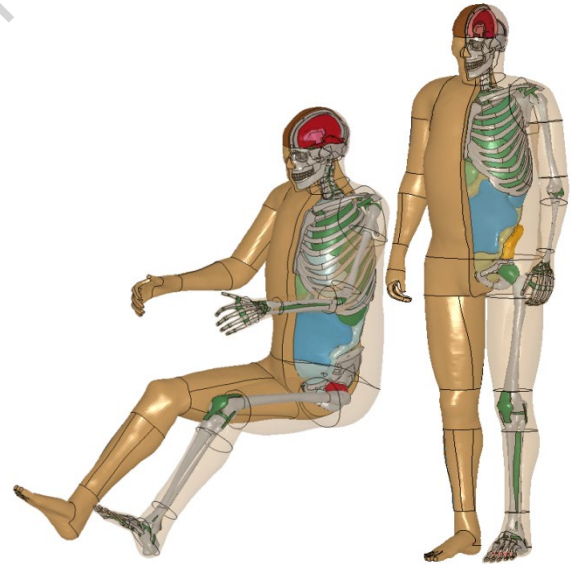
- Parameter Identification of the *MAT_36 Material Model using Full-Field Calibration

C. Ilg

Tuesday, October 16, 18:10, Room 2

More Information on the LSTC Product Suite

- Livermore Software Technology Corp. (LSTC)
www.lstc.com
- LS-DYNA
 - Support / Tutorials / Examples / FAQ
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