15th German LS-DYNA Forum

Identification of Material Parameters with LS-OPT®

Katharina Witowski, Christian Ilg
DYNAmore GmbH

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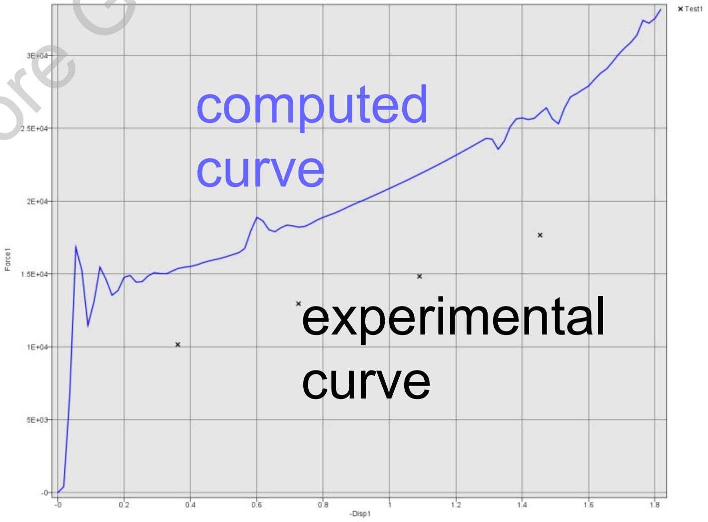
Outline

- 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

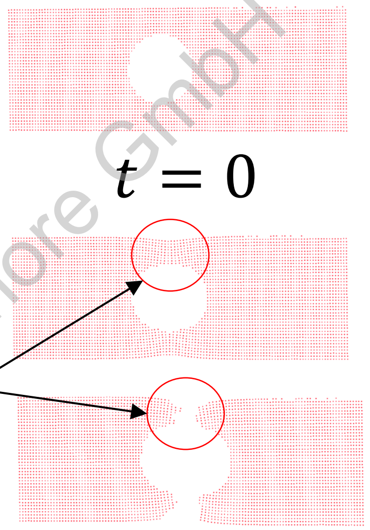


Calibration of material parameters - Standard approach

- 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

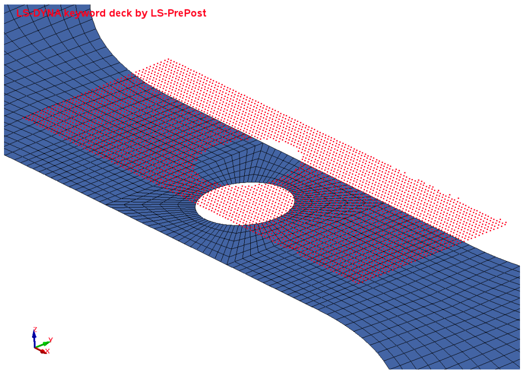
→ Use full-field data

Local deformation



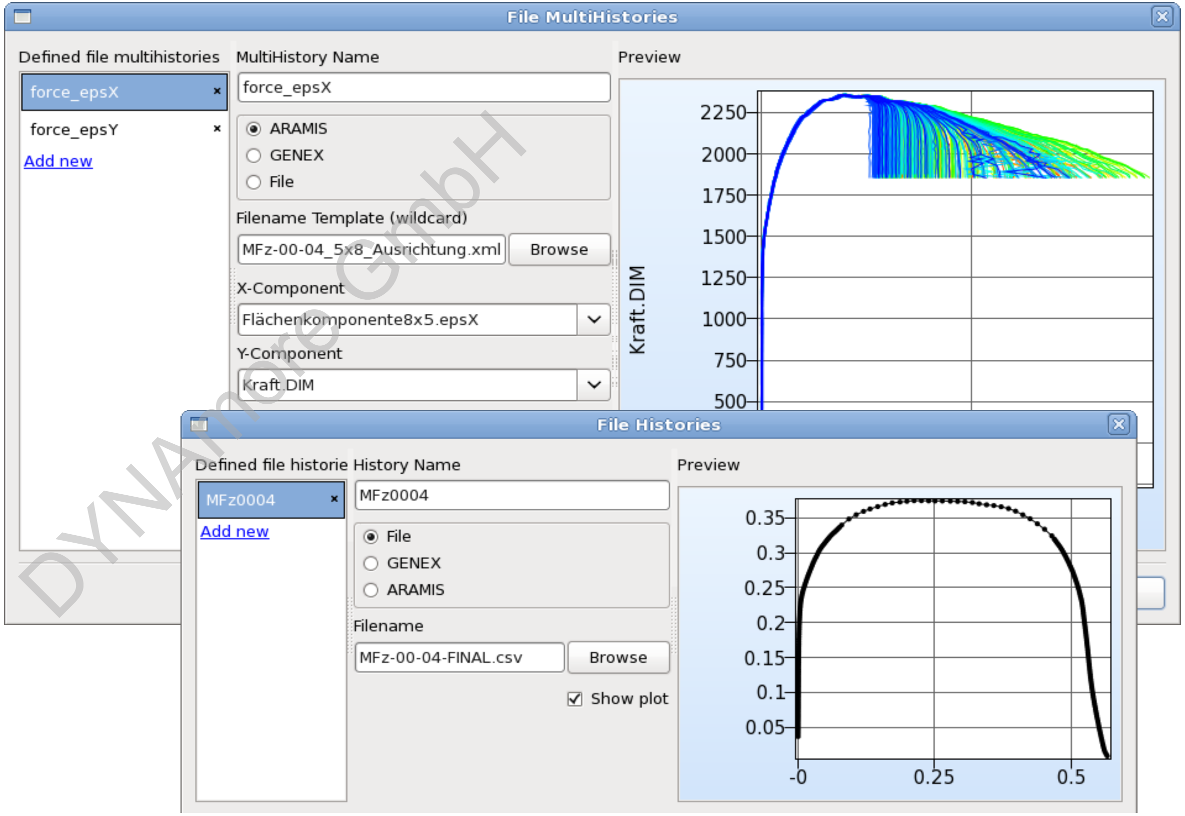
DIC data: deformation states

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

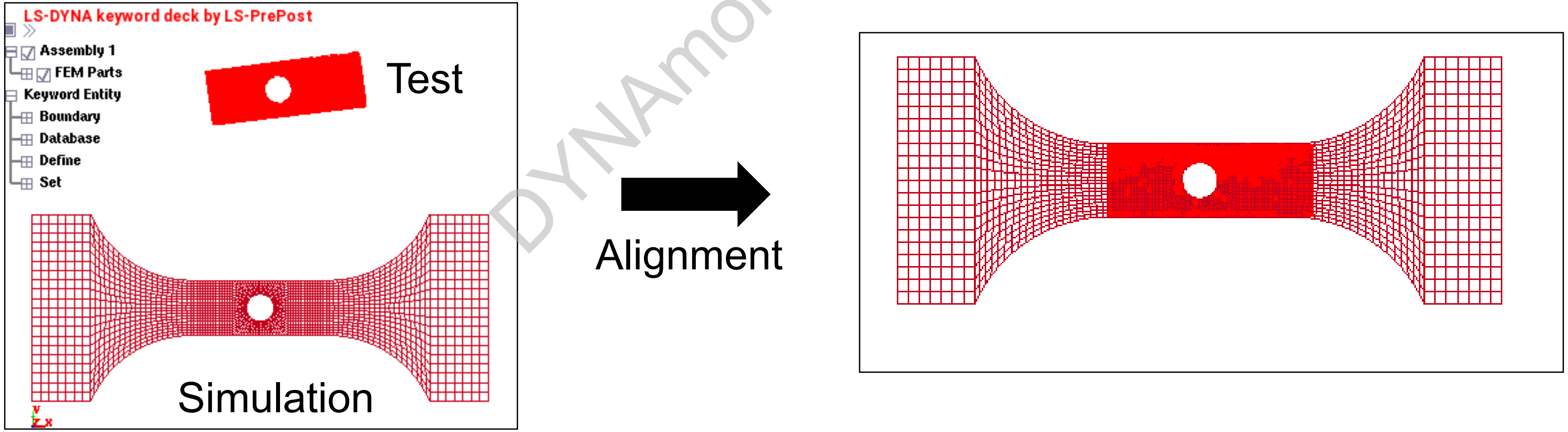


Alignment of test and simulation data

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

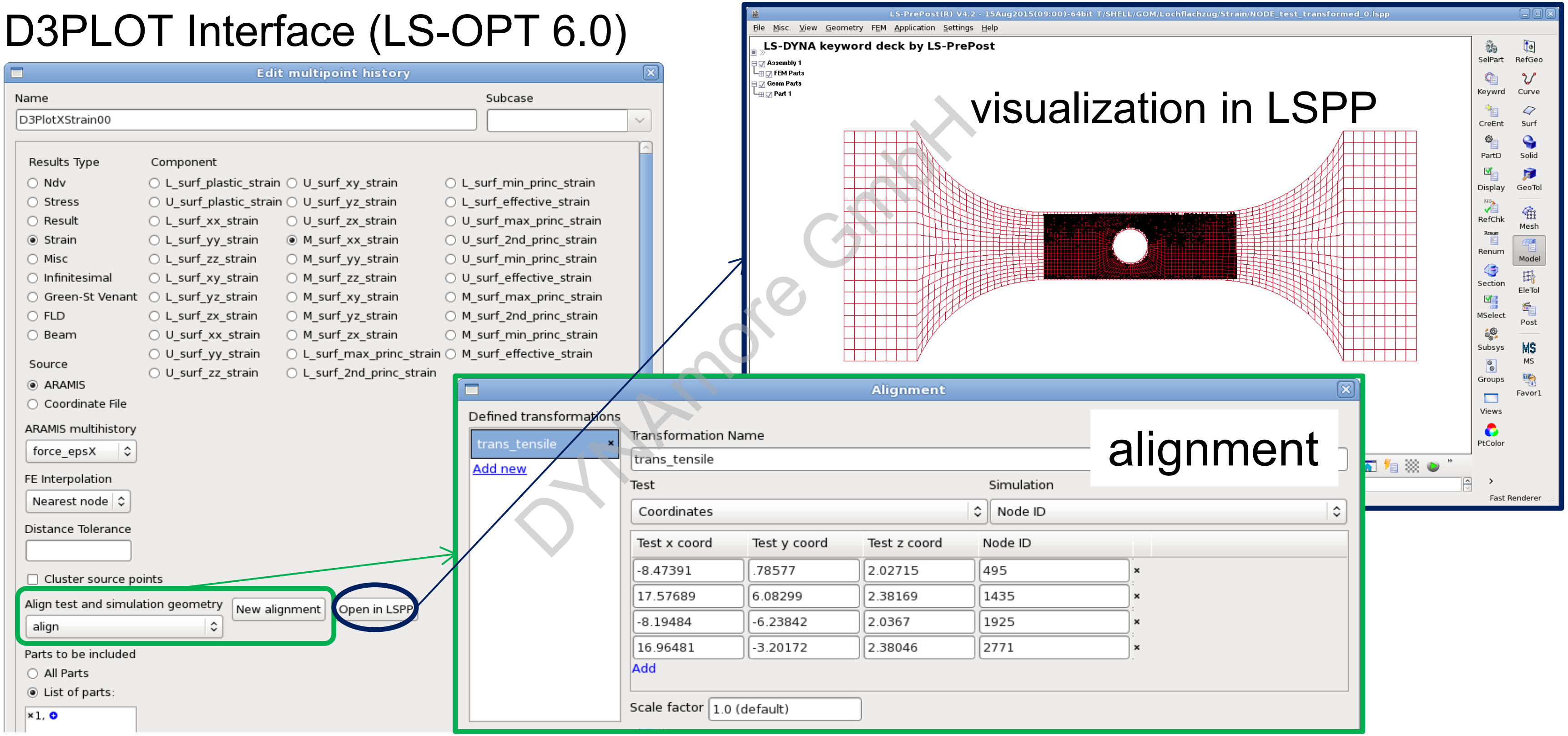
$$\min_{\boldsymbol{T}} \left\| \hat{s} \boldsymbol{X}_{\mathrm{Test}} \boldsymbol{T} - \boldsymbol{X}_{\mathrm{FE}} \right\|$$

  - $\boldsymbol{X}_{\mathrm{Test}}$: Test points (subset), $\boldsymbol{X}_{\mathrm{FE}}$: FE model points, $\boldsymbol{T}$: transform, $\hat{s}$: Isotropic scaling



Extraction of Multihistories from simulation

- D3PLOT Interface (LS-OPT 6.0)



Objective Functions - Matching of Scalar Values and Curve Matching Metrics

Matching of scalar values

- Standard Composite Functions
  - Targeted Formulation

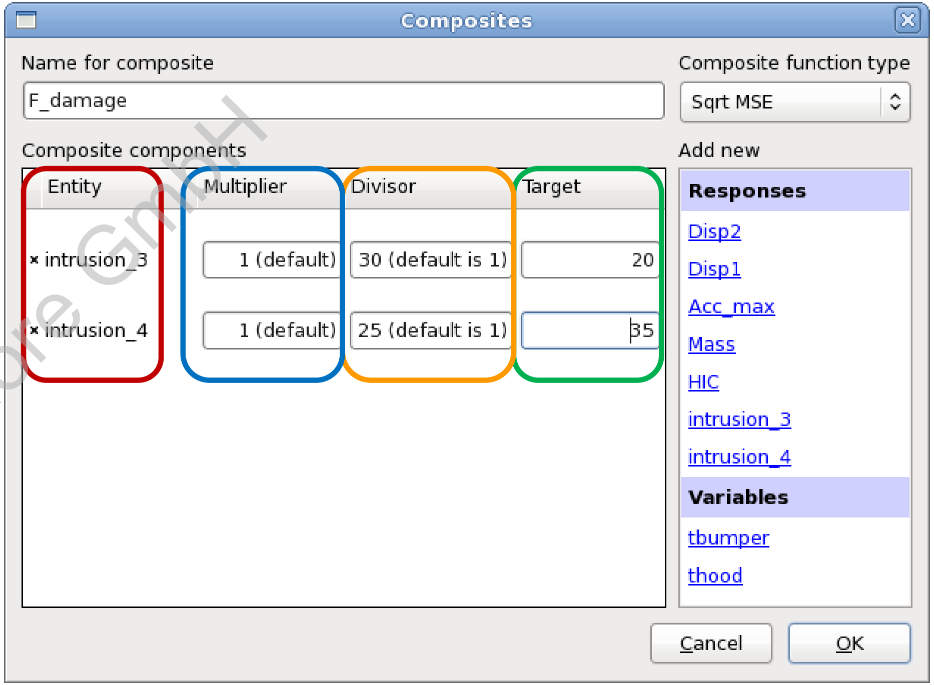
$$F = \sum_{j=1}^{m} W_j \left[\frac{f_j(\mathbf{x}) - G_j}{s_j} \right]^2$$

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

G_j : target value

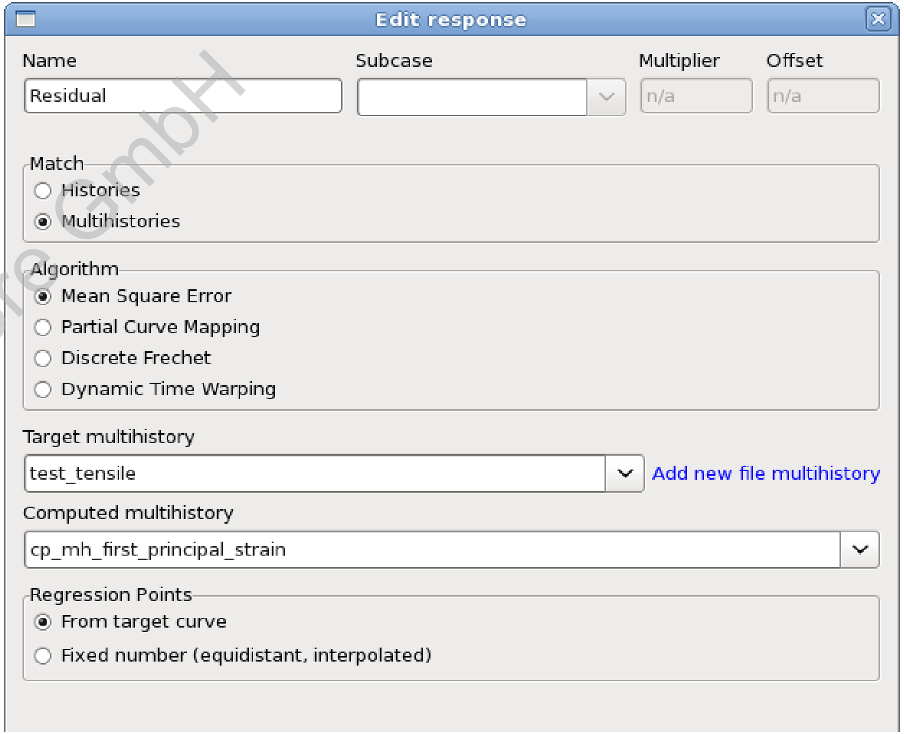
W_j : weighting factor

s_j : normalization factor



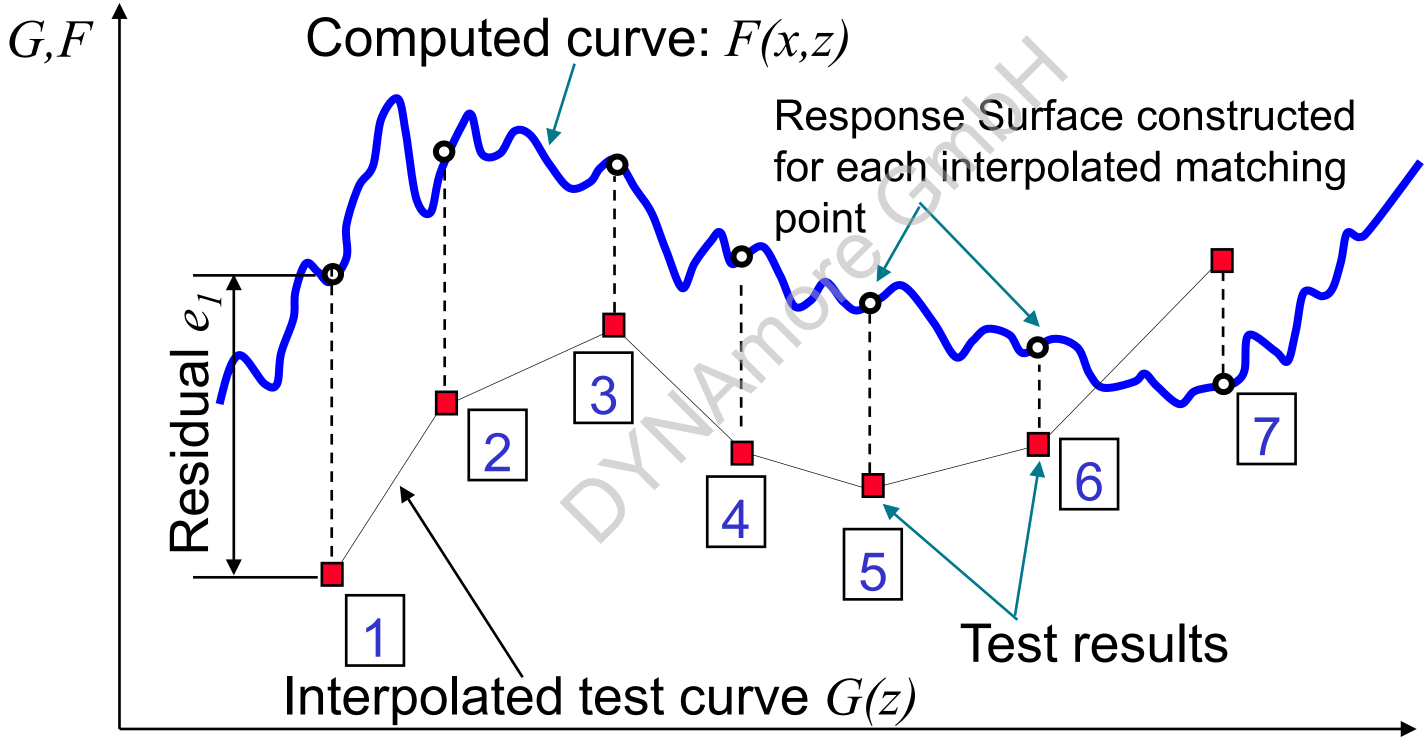
Curve Matching Metrics

- 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



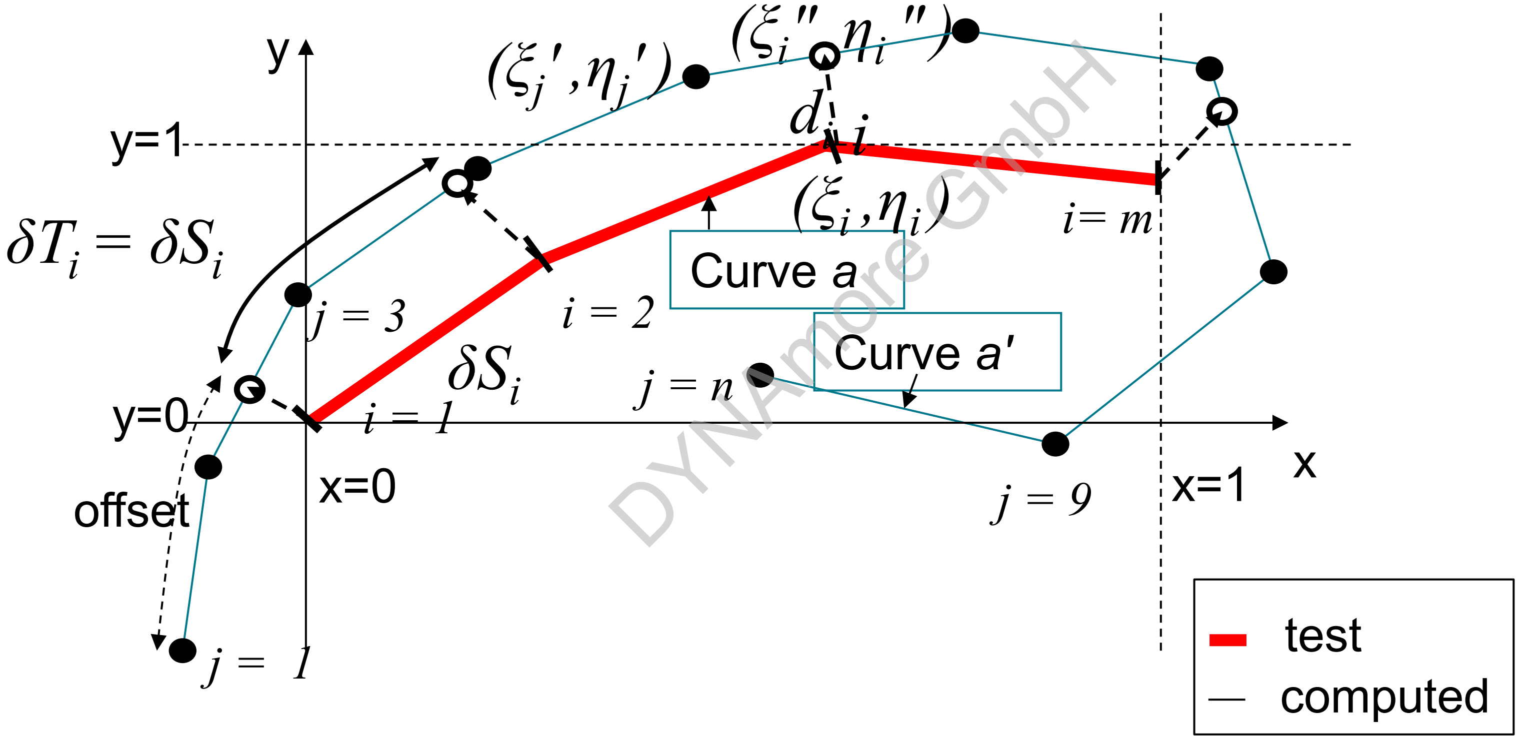
Ordinate-based Curve Matching Metric

- Mean Square Error



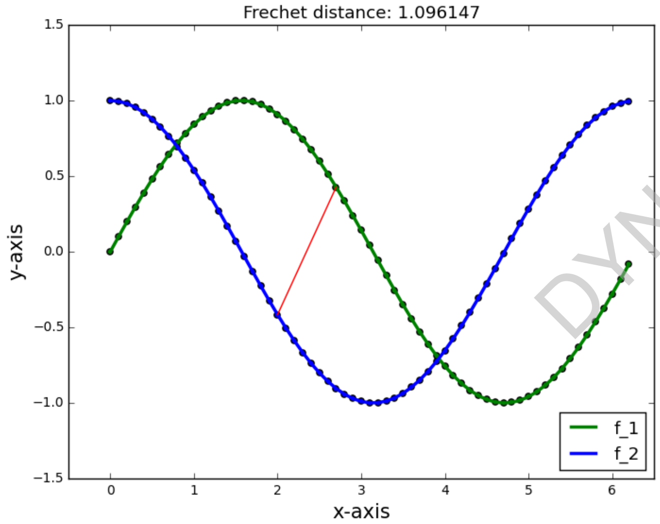
Partial Curve Mapping

- Suitable for steep or hysteretic curves



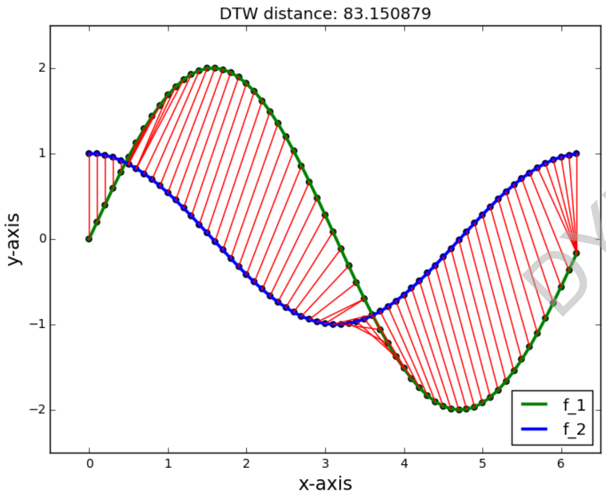
Discrete Fréchet

- 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

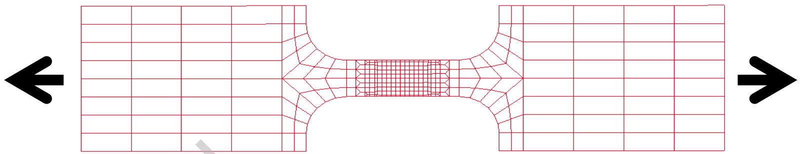
- Suitable for noisy curves
- Not suitable for partial mapping
- Warping path: minimum accumulated distance which is necessary to traverse all points in the curves



Example

Example

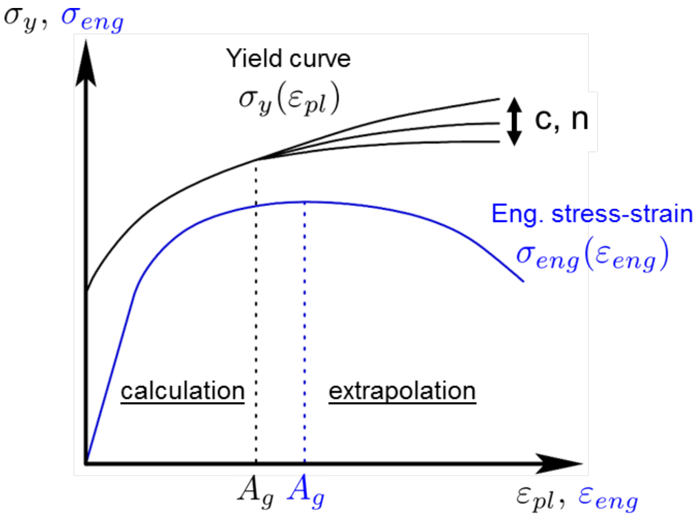
Tensile test



- Material model *MAT_24
  → calibration of stress-strain curve
- Hockett-Sherby flow curve formula for extrapolation beyond the point of a uniform strain state:

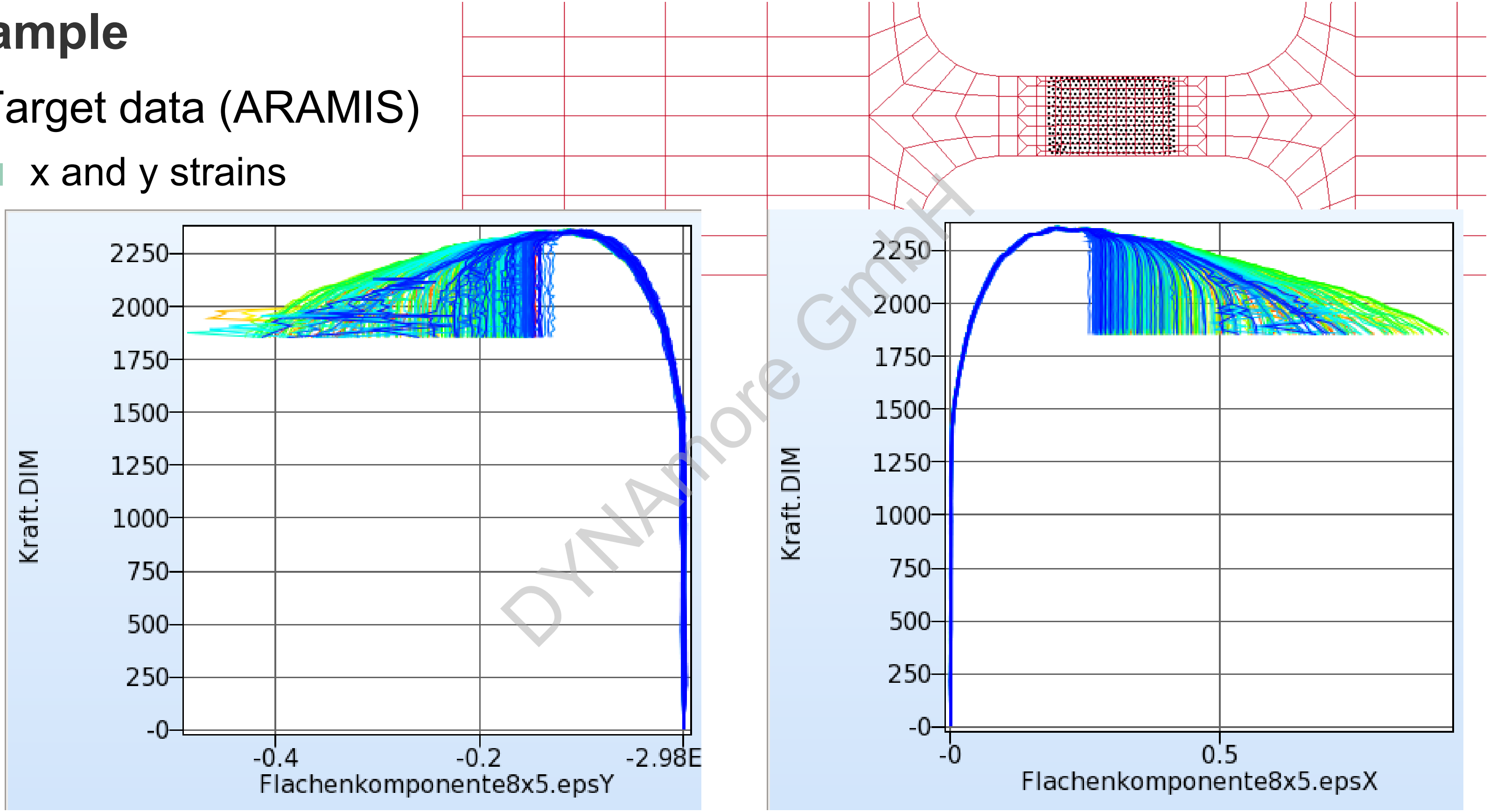
  $$f(\varepsilon_p) = A - Be^{-C\varepsilon_{pl}^N}$$

- 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

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
    www.dynasupport.com
  - More Examples
    www.dynaexamples.com
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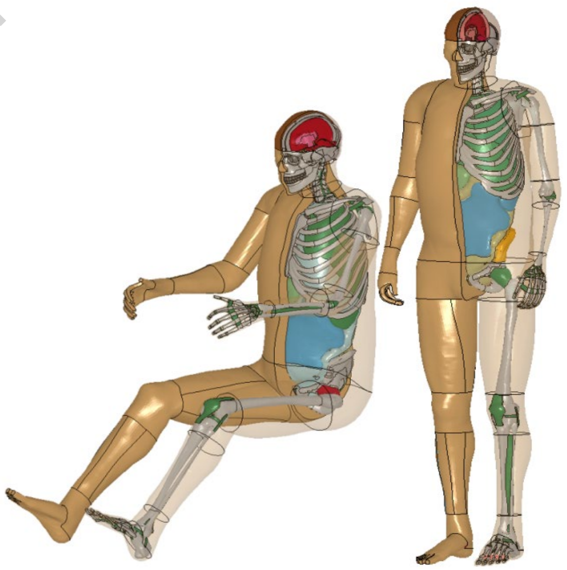

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