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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

DIC data: deformation states

$t = 0$

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

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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
  \[
  \min_T \| \hat{s} X_{\text{Test}} T - X_{\text{FE}} \|
  \]
  - $X_{\text{Test}}$: Test points (subset), $X_{\text{FE}}$: FE model points, $T$: transform, $\hat{s}$: Isotropic scaling
Extraction of Multihistories from simulation

- D3PLOT Interface (LS-OPT 6.0)

Visualization in LSPP
Objective Functions -
Matching of Scalar Values and
Curve Matching Metrics
Matching of scalar values

- Standard Composite Functions
  - Targeted Formulation

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

- \( f_j(x) \): 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

Computed curve: $F(x,z)$

Response Surface constructed for each interpolated matching point

Interpolated test curve $G(z)$

Test results

Residual $e_i$
Partial Curve Mapping

- Suitable for steep or hysteretic curves

\[ \delta T_i = \delta S_i \]

\[ (\xi_i', \eta_i') \]

\[ (\xi_i'', \eta_i'') \]

\[ \delta S_i \]

\[ i = 1, 2, \ldots, m \]

\[ j = 1, 2, \ldots, n \]

\[ (\xi_j', \eta_j') \]

\[ (\xi_j'', \eta_j'') \]

\[ j = 1, 2, \ldots, n \]

\[ j = 9 \]

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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

![Graph showing Dynamic Time Warping](image)
Example
Example

Tensile test

- Material model *MAT_24 → calibration of stress-strain curve
- Modified Hockett-Sherby flow curve formula:
  \[ f(\varepsilon_p) = D + B(1 - e^{-C\varepsilon_p N}) \]
- \( D, B, C \) and \( N \) optimization parameters
Example

- Target data (ARAMIS)
  - x 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 …

- Material Calibration using LS-OPT: A Longest Common Subsequence Method for Matching Curves with Different Length
  *N. Stander*
  Thursday, May 16, 09:20

- A Full-Field Calibration Approach to Identify Failure Parameters of a HS-Steel
  *S. Cavariani*
  Thursday, May 16, 11:05
More Information on the LSTC Product Suite

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  www.lstc.com

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