12th European LS-DYNA Conference

Identification of Material Parameters with LS-OPT®

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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



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

	File MultiHi	istories
Defined file multihistories	MultiHistory Name	Preview
force_epsX ×	force_epsX	2250
force_epsY ×	ARAMIS	2230
Add new	○ GENEX ○ File	2000
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	Y-Component	⊻ 750-
	Kratt.DIM	500-
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		0.25
	Filename	0.2
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		low plot 0.1-
		0.05
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Alignment of test and simulation data

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

$$\min_{T} \| \hat{s} X_{\mathsf{Test}} T - X_{\mathsf{FE}} \|$$

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





Extraction of Multihistories from simulation

D3PLOT Interface (LS-OPT 6.0)

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Objective Functions -Matching of Scalar Values and Curve Matching Metrics



Matching of scalar values

- Standard Composite Functions
 - Targeted Formulation



- $f_{i}(\mathbf{X})$: simulation response as function of variable vector **x** G_i : target value
- W_i :
 - weighting factor
- normalization factor S_i :





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		\sim	n/a	n/a
Match				
Multibistories				
Algorithm				
Mean Square Error				
 Partial Curve Mapping 				
 Discrete Frechet 				
 Dynamic Time Warping 				
Target multihistory				
test_tensile		~	Add new file	e multihistory
Computed multihistory				
cp_mh_first_principal_strain				~
Regression Points				
 From target curve 				
O Fixed number (equidistant, inte	rpolated)			



Ordinate-based Curve Matching Metric





Partial Curve Mapping





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
 - \rightarrow calibration of stress-strain curve
- Modified Hockett-Sherby flow curve formula: $f(\varepsilon_p) = D + B(1 - e^{-C\varepsilon_{pl}^N})$
 - 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 <u>appropriate</u> analytical function for parameterization of LS-DYNA input curves
- Ranges for parameters?
 - \rightarrow 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

- Livermore Software Technology Corp. (LSTC) www.lstc.com
- LS-DYNA
 - Support / Tutorials / Examples / FAQ www.dynasupport.com
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Thank you for your attention!





