

New Developments on Identification of Material and System Parameters with LS-OPT[®]

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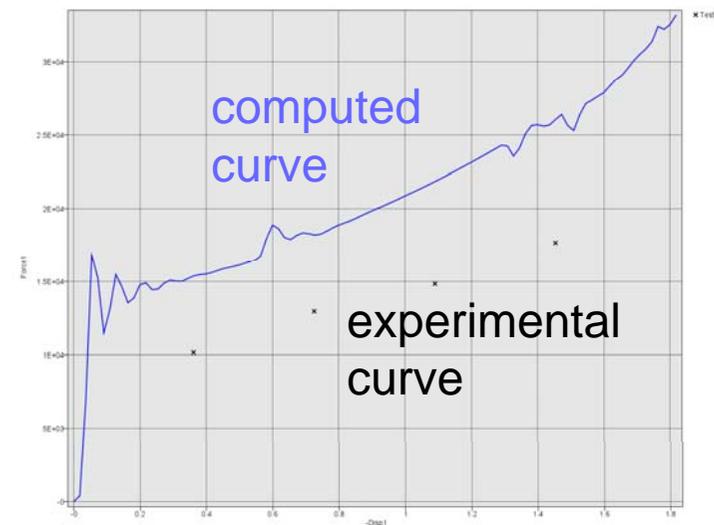


- Introduction: Problem statement
- Example: Current ordinate-based curve matching metric
- Motivation and theory of new curve matching metric
- Examples
- Conclusions

Parameter identification: Objectives

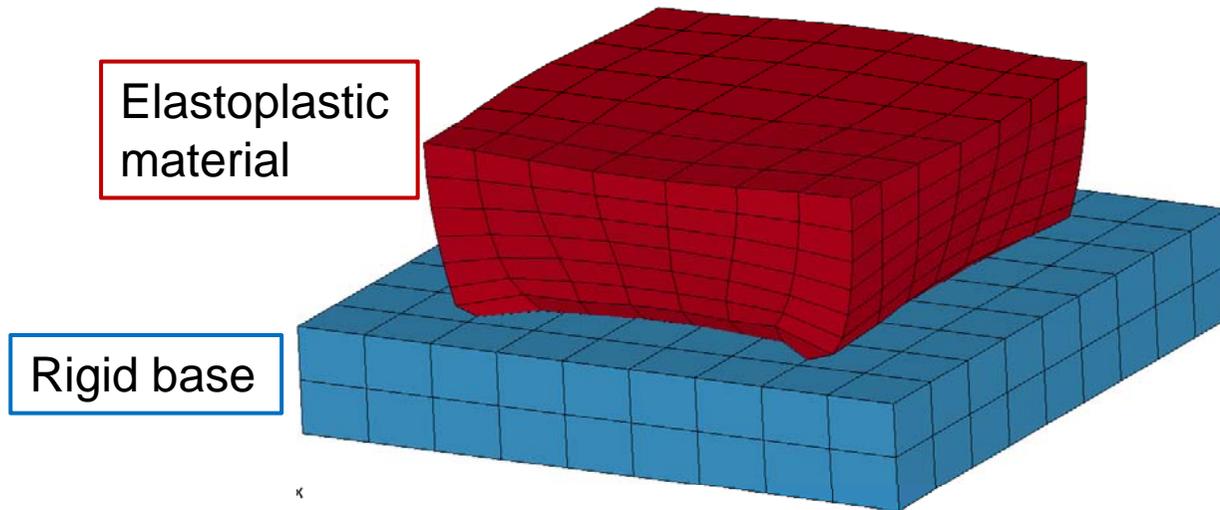


- Parameter Identification problems are non-linear inverse problems solved using optimization
- A computed curve (from LS-DYNA®), dependent on parameters, is matched to an experimental curve
- Optimization provides a calibration of the unknown parameters
- An LS-OPT feature dedicated to Parameter Identification (MeanSqErr) has been available since LS-OPT v3
- Principle technologies involved:
 - *Optimization algorithm*
 - *Curve Matching metric*



Current Ordinate-based Parameter Identification (MeanSqErr) - Example

- Example: Material properties of a foam



Experiment:

Displ	Force
0.36168	10162
0.72562	12964
1.0903	14840
1.4538	17672

*PARAMETER

rYMod,7e5,rYield,15e2

*MAT_PLASTIC_KINEMATIC

```

1  1.0E-3 &YMod  0.3 &Yield  10.0  0.0
0.0  0.0  0.0  0.0
    
```

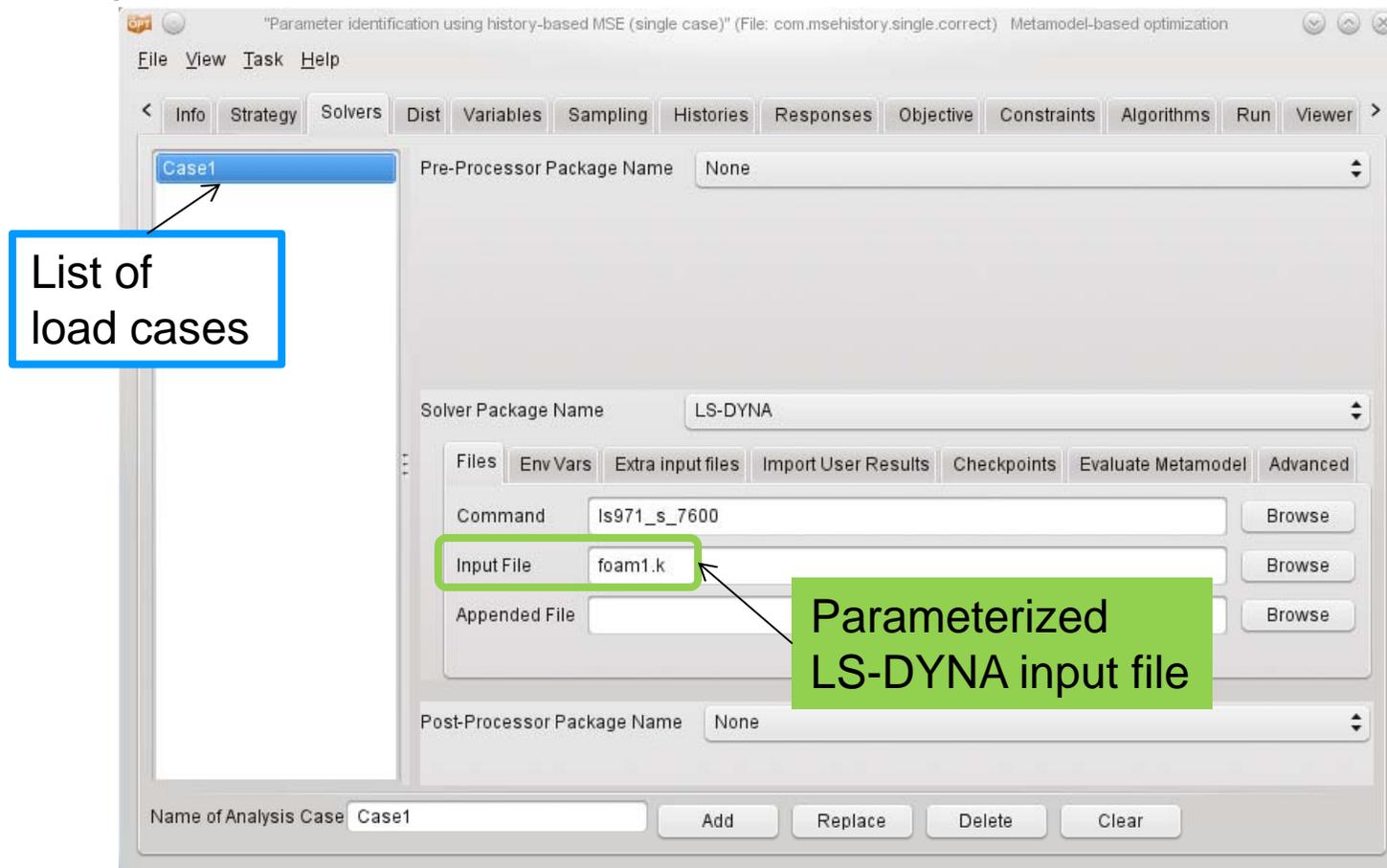
Parameters:

- Young's modulus
- Yield stress

Current Ordinate-based Parameter Identification (MeanSqErr) - Example

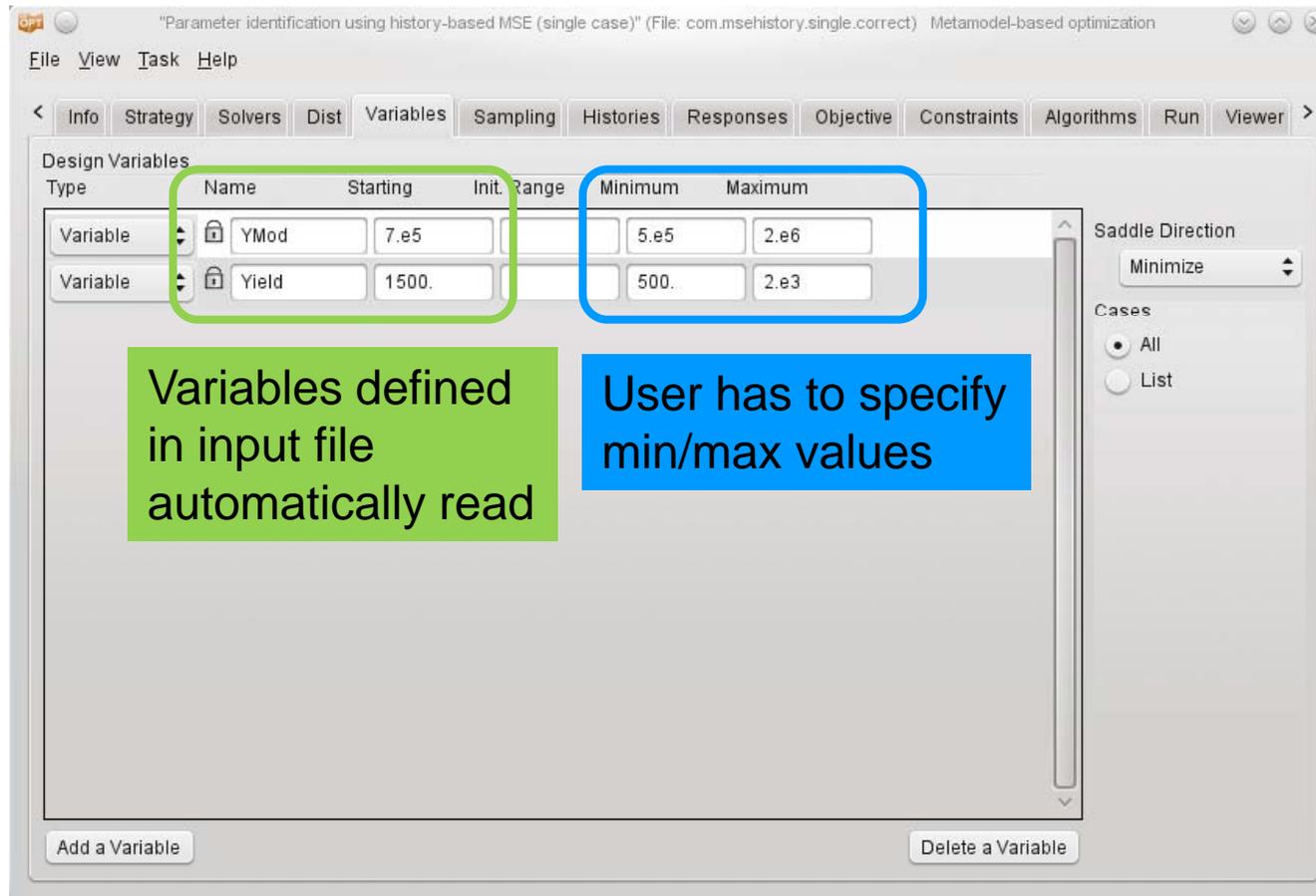


- Setup in LS-OPT GUI – Definition of load cases



Current Ordinate-based Parameter Identification (MeanSqErr) - Example

- Setup in LS-OPT GUI – Definition of variables



The screenshot shows the LS-OPT GUI window titled "Parameter identification using history-based MSE (single case)". The "Variables" tab is active, displaying a table of design variables. Two variables, "YMod" and "Yield", are listed. The "YMod" row has a starting value of 7.e5, a minimum of 5.e5, and a maximum of 2.e6. The "Yield" row has a starting value of 1500., a minimum of 500., and a maximum of 2.e3. A green box highlights the "Name" and "Starting" columns, and a blue box highlights the "Minimum" and "Maximum" columns. A green text box explains that variables are automatically read from the input file, and a blue text box explains that users must specify min/max values.

Type	Name	Starting	Init.	Range	Minimum	Maximum
Variable	YMod	7.e5			5.e5	2.e6
Variable	Yield	1500.			500.	2.e3

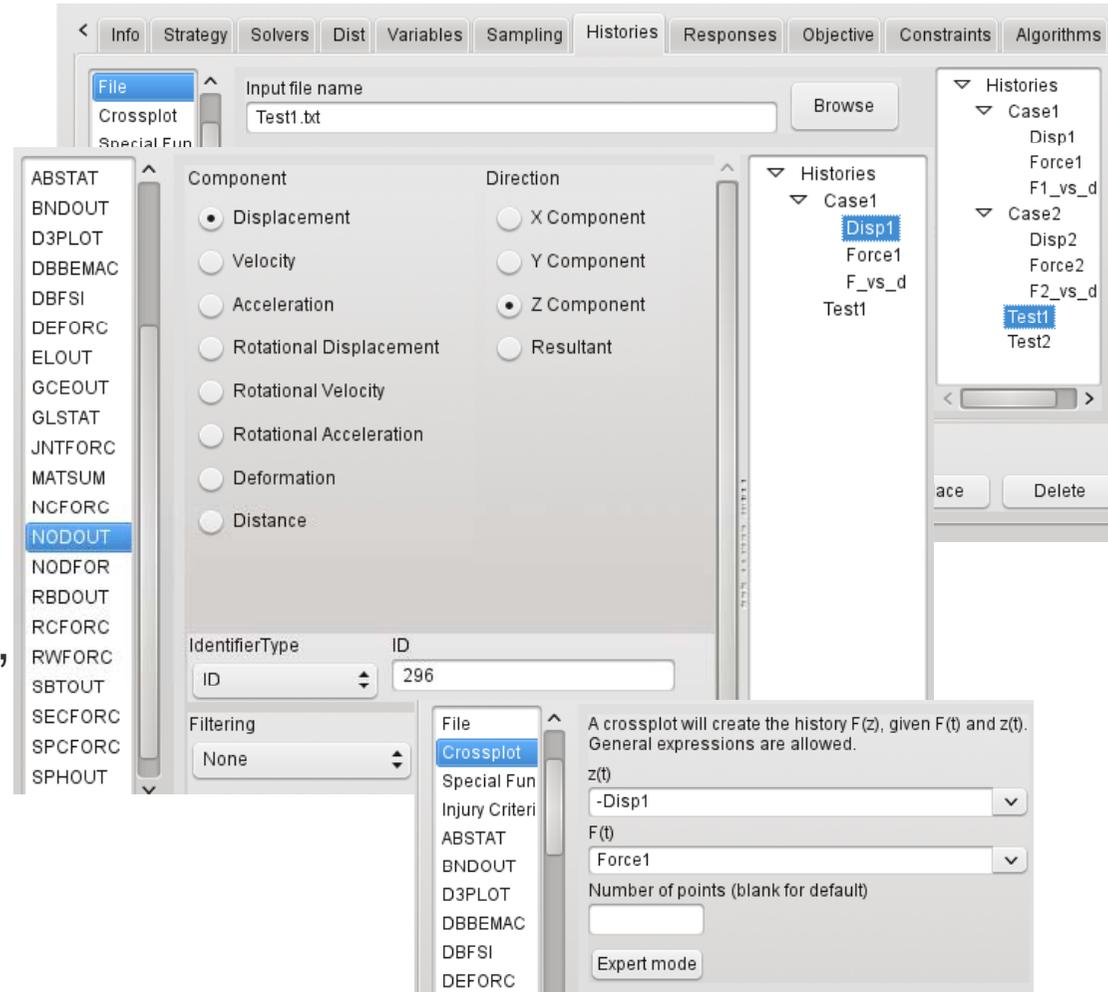
Variables defined in input file automatically read

User has to specify min/max values

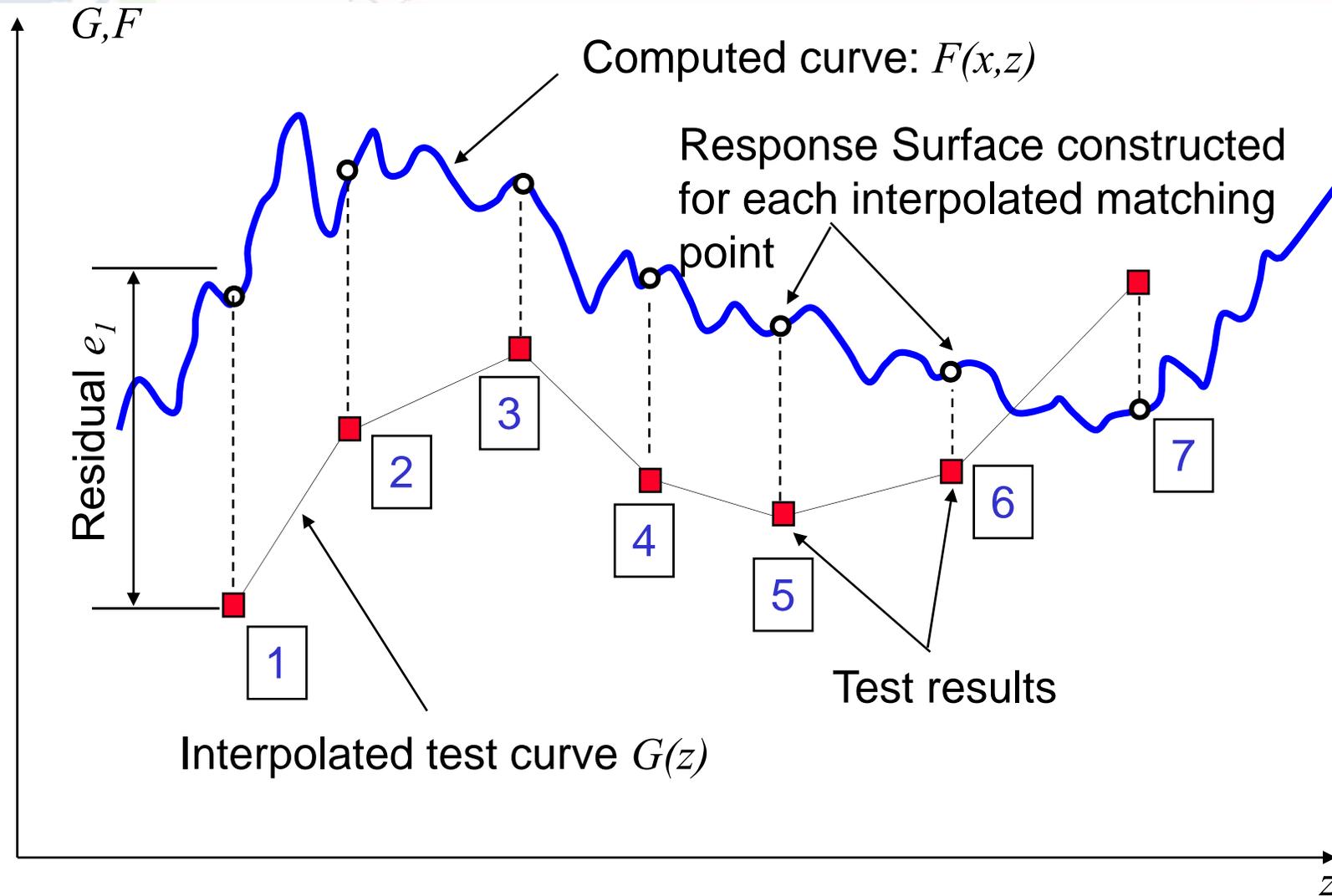
Current Ordinate-based Parameter Identification (MeanSqErr) – Setup in LS-OPT GUI



- Setup in LS-OPT GUI – Definition of test and simulated curves
- Reads test curve files directly
- Interfaces to most LS-DYNA response types
- Crossplots can be defined, e.g. Stress vs. strain, Force vs. deformation ...



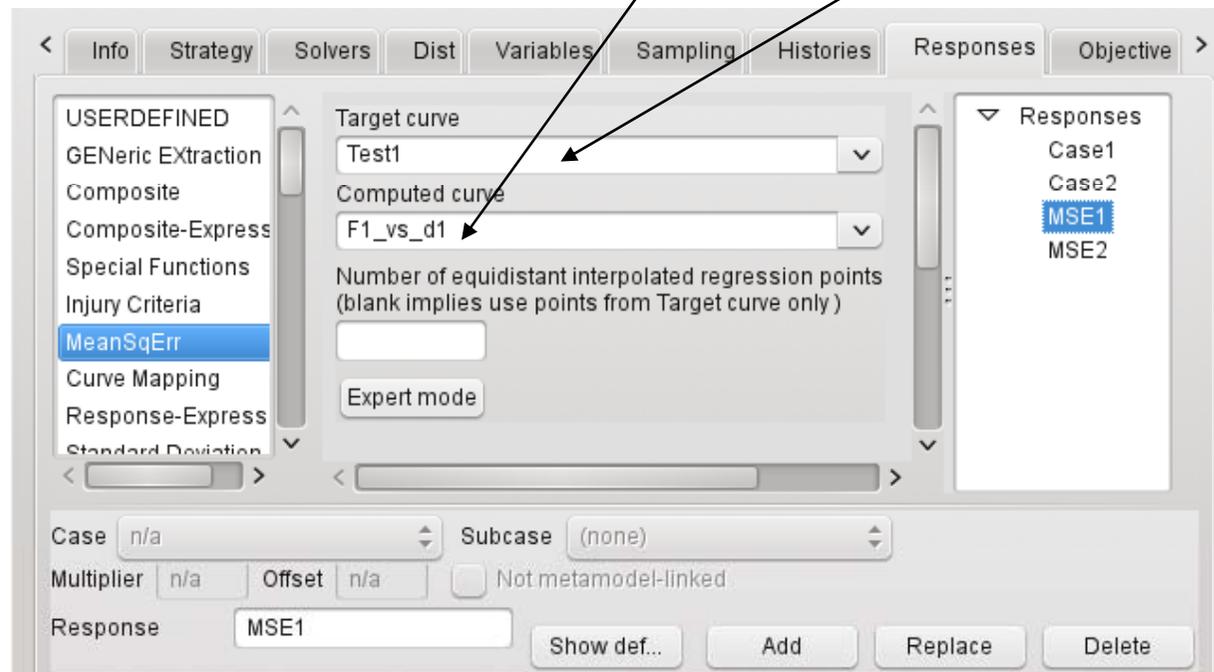
Current Ordinate-based Parameter Identification (MeanSqErr)



Current Ordinate-based Parameter Identification (MeanSqErr) – Setup in LS-OPT GUI

- $$MSE(\mathbf{x}) = \frac{1}{P} \sum_{i=1}^P W_i \left(\frac{F_i(\mathbf{x}) - G_i}{S_i} \right)^2 \rightarrow \min$$

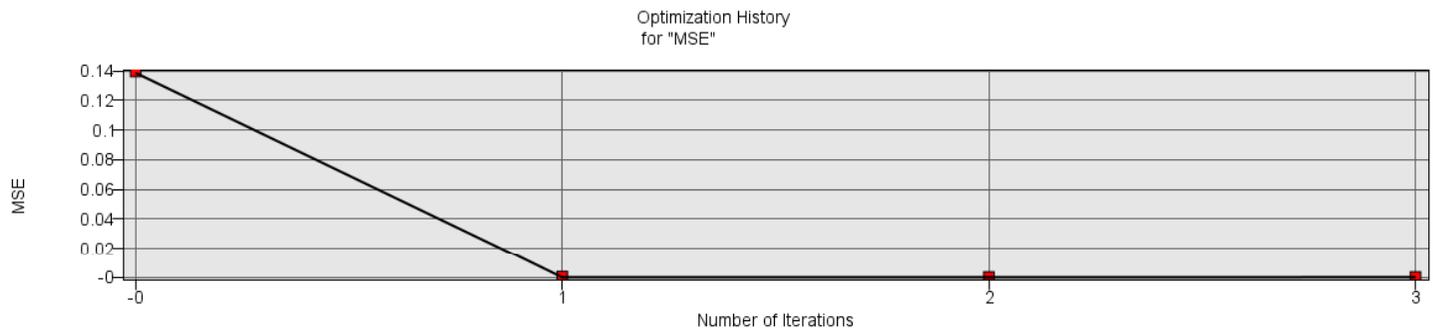
Diagram showing the equation with annotations: $F_i(\mathbf{x})$ is labeled "Simulation curve", G_i is labeled "Test curve", and S_i is labeled "Simulation curve".



- Advanced options: number of points, start point, end points, weighting/scaling options

Current Ordinate-based Parameter Identification (MeanSqErr) - Example

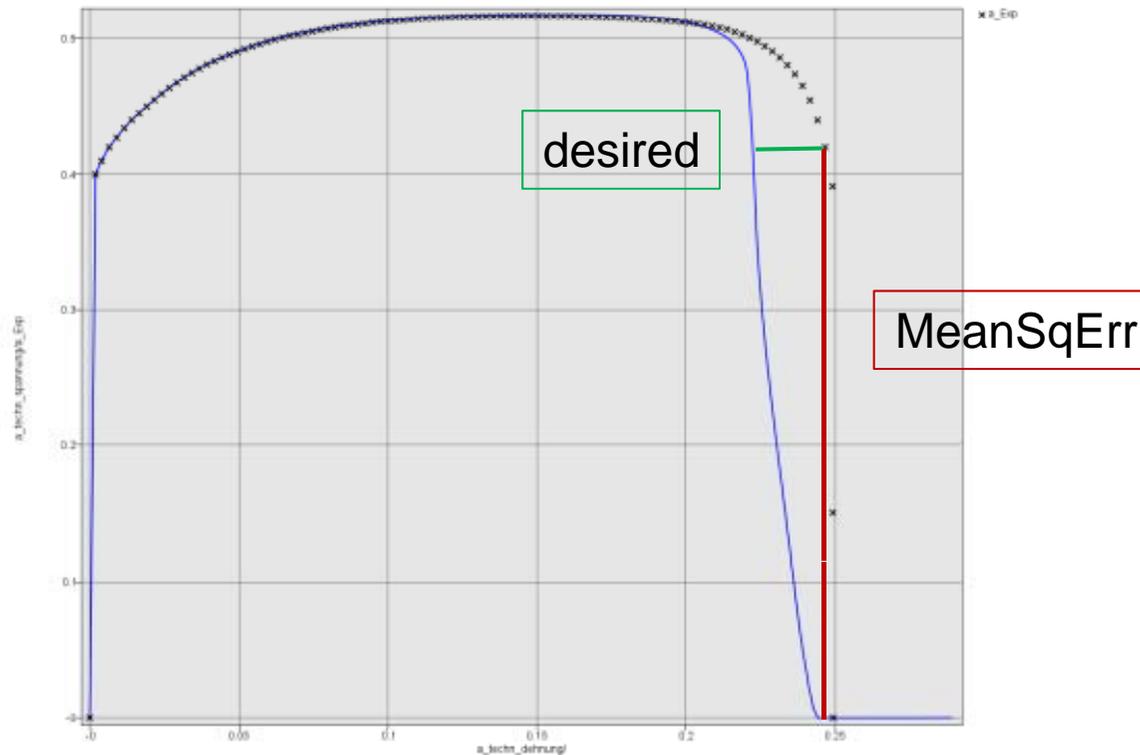
Results



Problems with ordinate-based curve matching

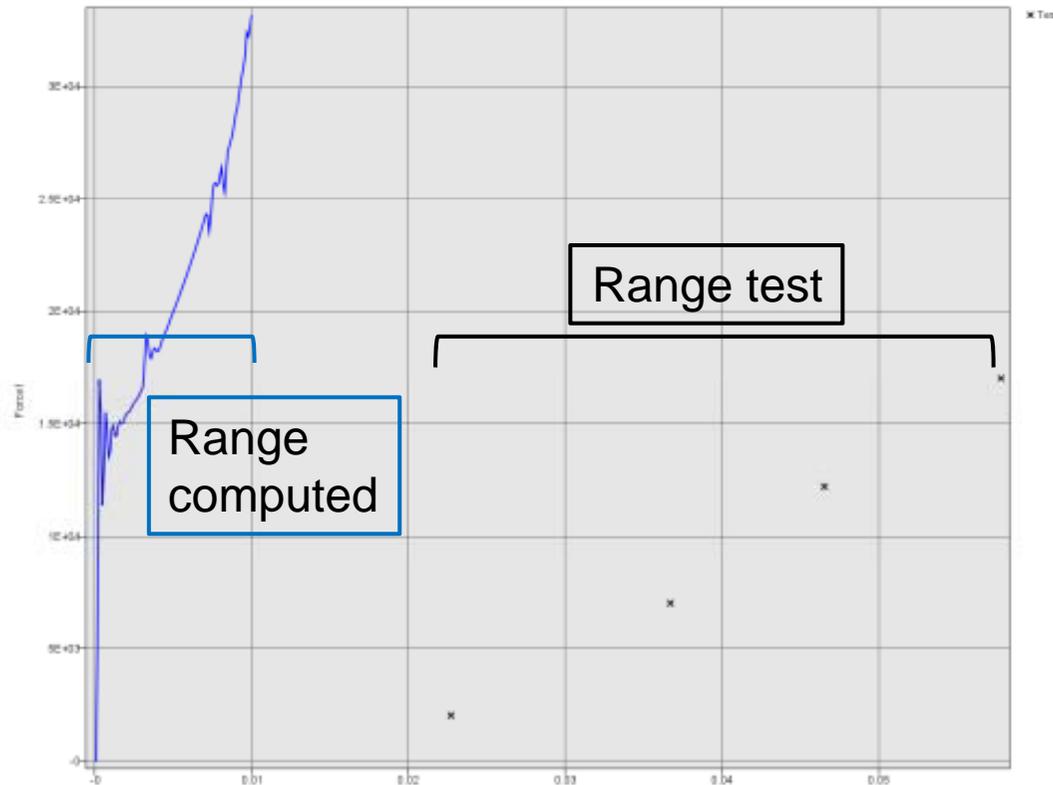


- Steep parts of the response are difficult or impossible to incorporate, e.g. linear elastic range or failure (damage models such as the GISSMO model in LS-DYNA®)



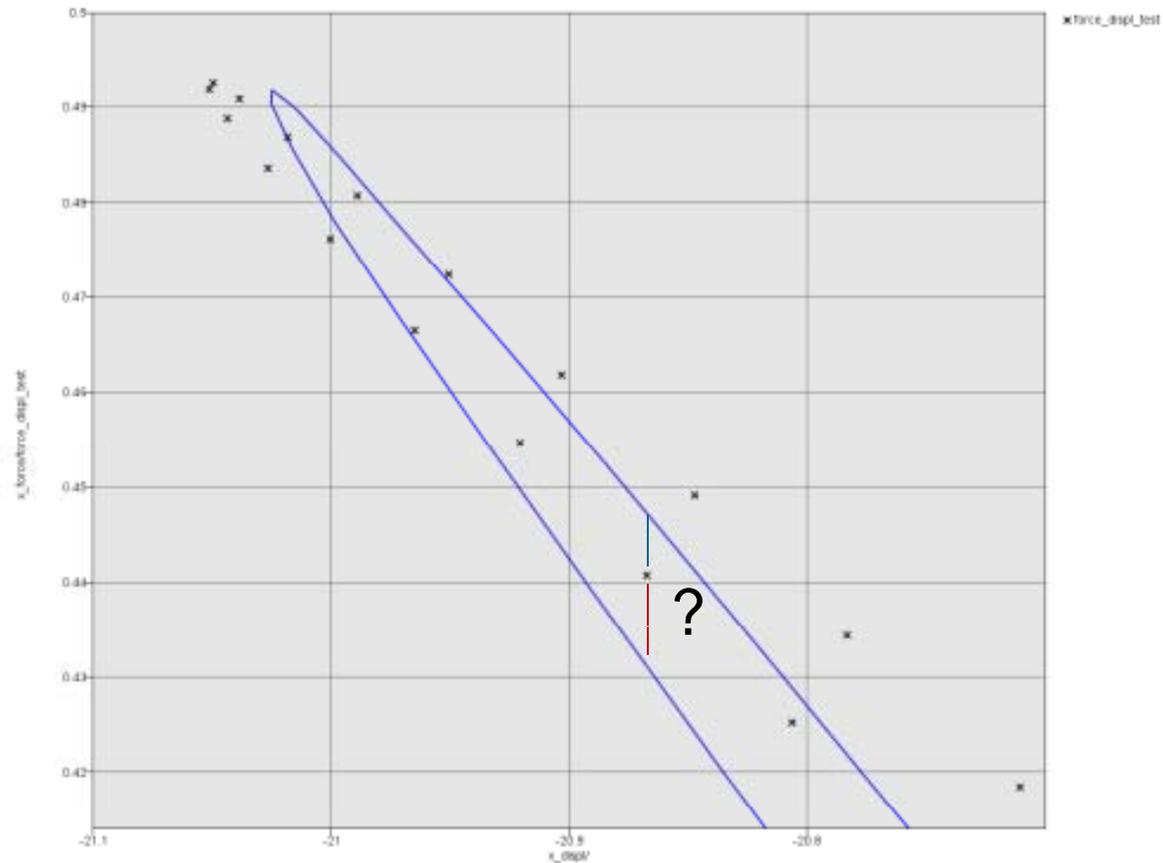
Problems with ordinate-based curve matching

- Ranges of the computed and test curves do not coincide in the abscissa at an interim stage of the optimization resulting in instability



Problems with ordinate-based curve matching

- Hysteretic test curves or springback cannot be matched since the ordinate values are non-unique



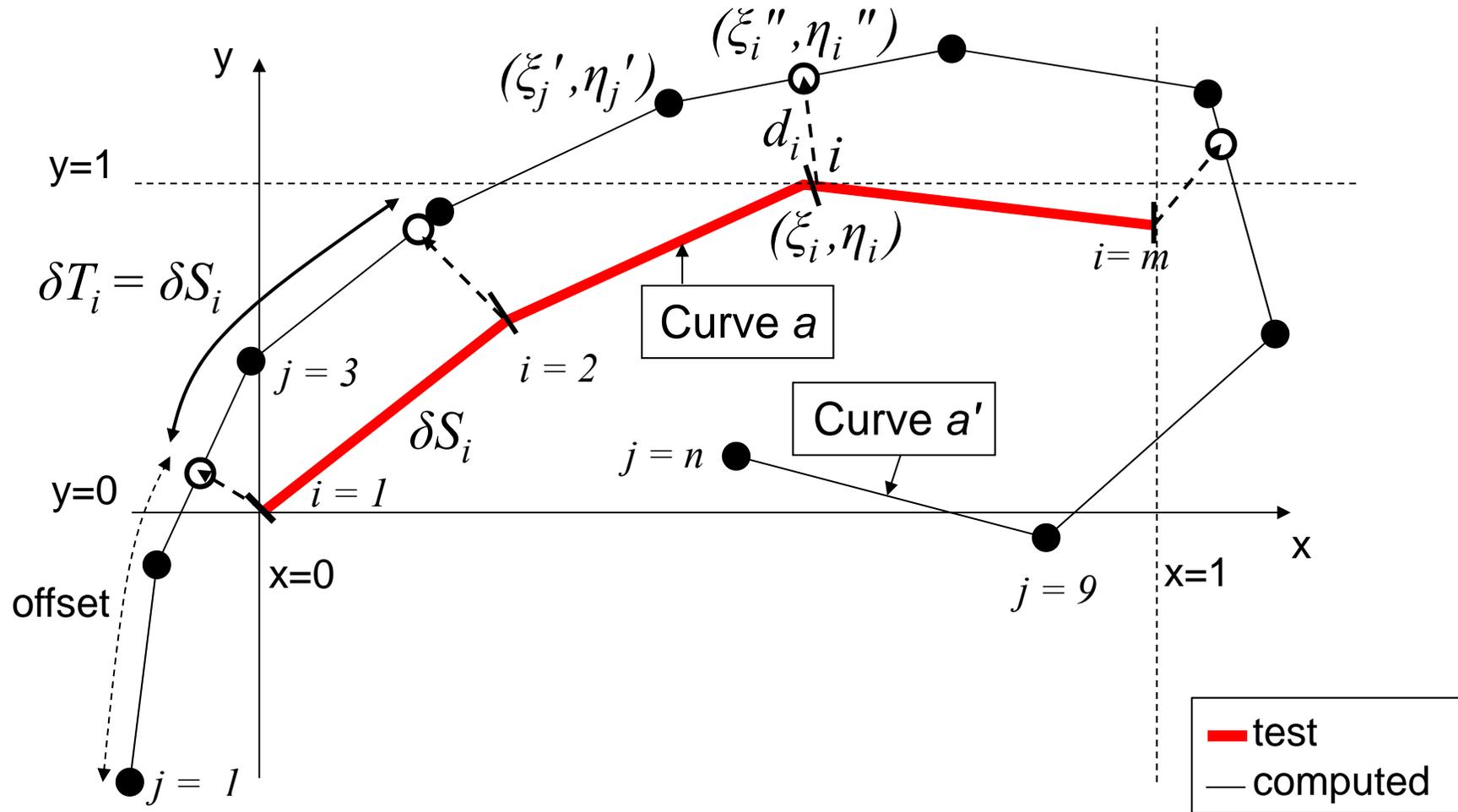
Problems with ordinate-based curve matching



- Partial matching is not robust, i.e. where only a part of the test curve or a part of the computed curve is available

→ Requires Curve Mapping

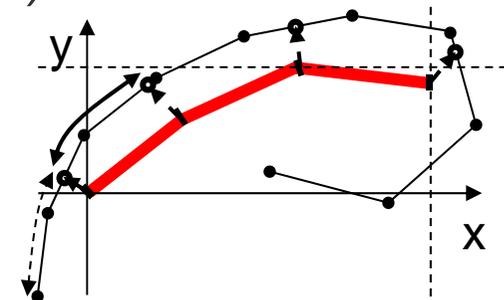
Partial Curve Mapping



Partial Curve Mapping algorithm



- Normalize the curves to the test (experimental) curve
 - *Avoids problems with different magnitudes for abscissa and ordinate*
 - *Unit independent*
- Map the short curve onto the long curve so that the lengths are equal (mild filtering of curves by user is recommended)
- The distance is defined by the area between the short curve and the mapping
- Optimize the offset to find the smallest distance between the curves
- Implemented into LS-OPT as *CurveMapSegment (“testcurve”, “computed_curve”)*



Optimization



- Metamodel-based, sequential
- Metamodel constructed at each time step to produce a virtual history at an arbitrary design point (similar to ordinate-based metric)
- Optimization convergence is ensured through sequential improvement (classical Sequential Response Surface Method)
- Avoids any additional nonlinearities due to the curve matching metric

LS-OPT 4.2 Interface for Curve Mapping



Imported experimental curve in 2-column format

A screenshot of the LS-OPT 4.2 software interface. The 'Responses' tab is active, showing a list of response types on the left, including 'Curve Mapping'. The 'Target curve' dropdown is set to 'Test2' and the 'Computed curve' dropdown is set to 'F2_vs_d2'. A red arrow points from the text box above to the 'Test2' dropdown. Below the dropdowns, there are fields for 'Case' (n/a), 'Subcase' (none), 'Multiplier' (n/a), and 'Offset' (n/a). The 'Response Name' field is set to 'CurveMap_2'. At the bottom right of the interface are buttons for 'Show def...', 'Add', 'Replace', and 'Delete'. A red arrow points from the text box below to the 'F2_vs_d2' dropdown.

Computed history/crossplot

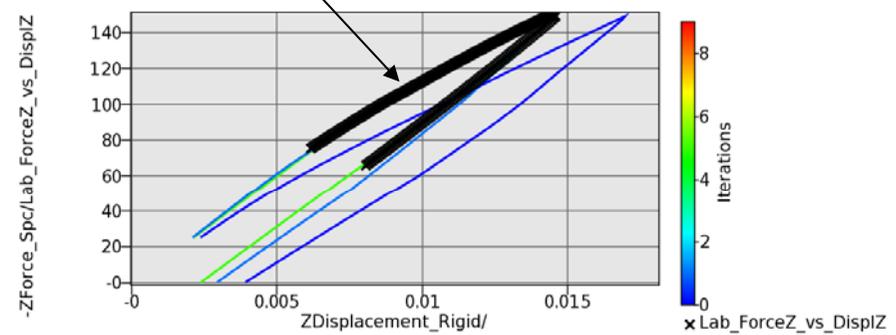
Partial Curve Mapping: Hysteresis examples

Problem data

- 4 parameters
- Loading & unloading in one curve
- Partial experimental curve

Curve Match vs. Iteration number

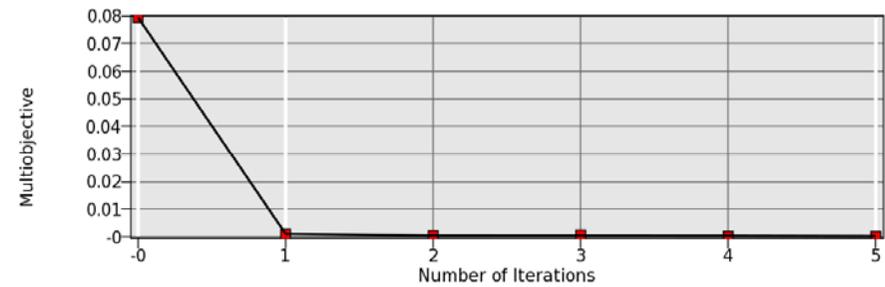
Experimental curve



Results

- Converges in 2 iterations (17 simulations)

Optimization History for "Multiobjective"



Courtesy TRW

Optimization history of Discrepancy

Partial Curve Mapping: Hysteresis examples

Problem data

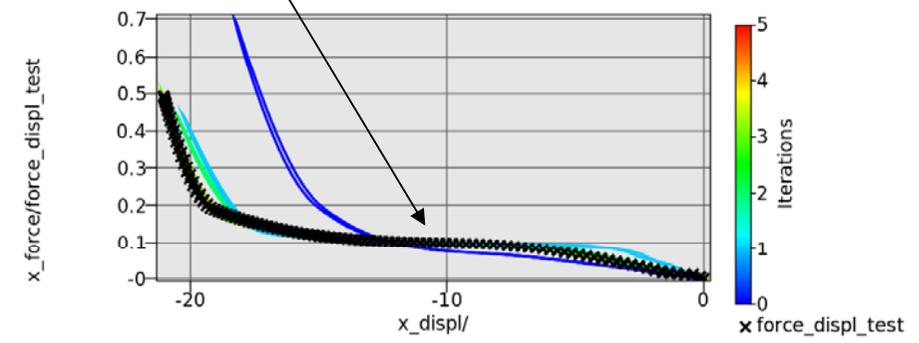
- 5 parameters
- Loading & Unloading in one curve

Results

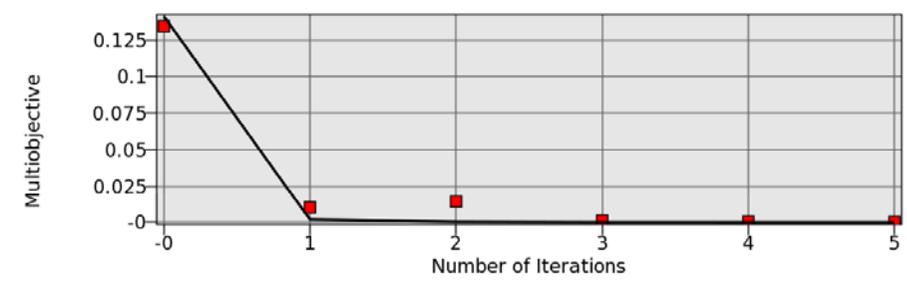
- Converges in 3 iterations (31 simulations)

Curve Match vs. Iteration number

Experimental curve



Optimization History for "Multiobjective"



Optimization history of Discrepancy

Example: GISSMO Material Model (LS-DYNA)



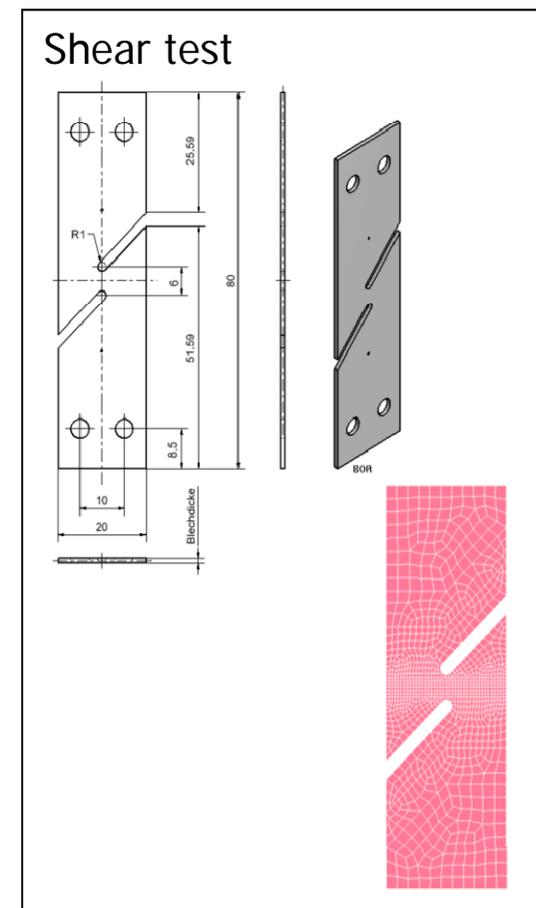
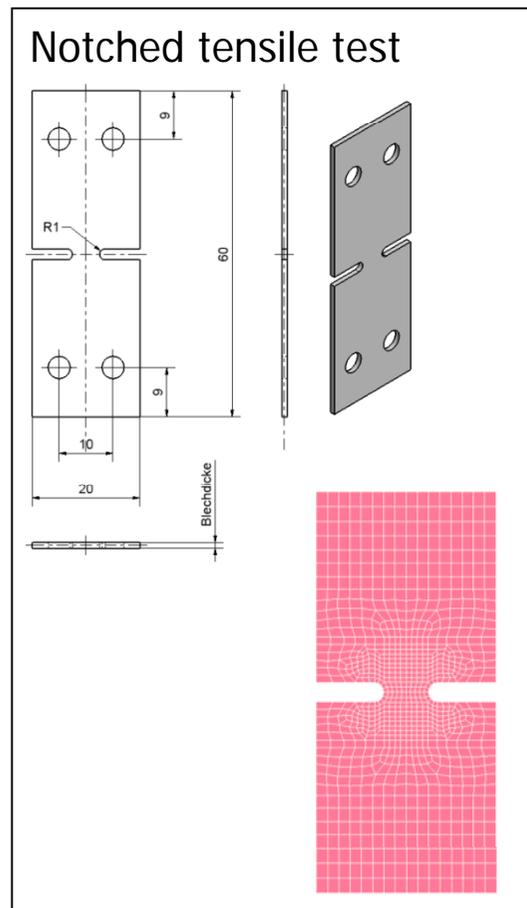
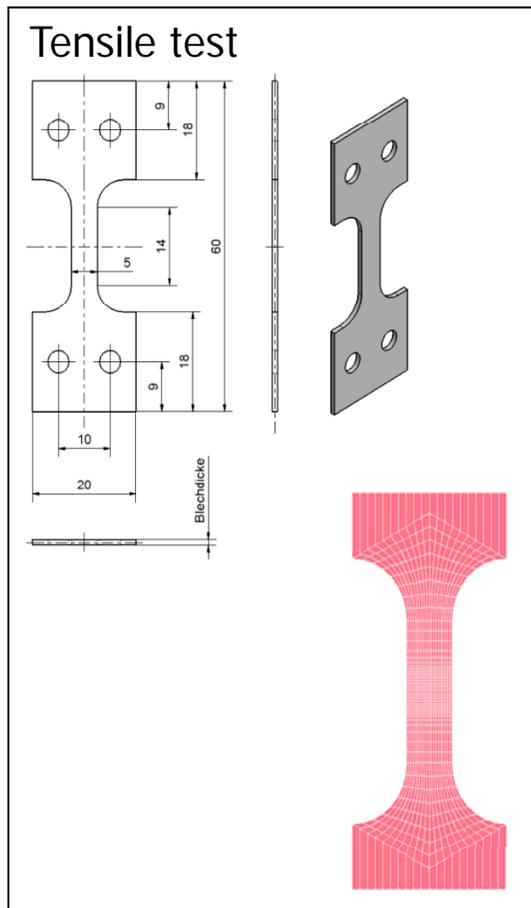
- GISSMO (Neukamm, Feucht, Haufe)* is a material model available in LS-DYNA
- Damage model for use in both stamping and crash simulations
- Experiments used to calibrate GISSMO are often characterized by a steep failure curve. Springback could be present
- Example has 3 test cases and 7 unknown parameters. Typically tensile and shear tests

*Neukamm, F., Feucht, M., Haufe, A. Consistent damage modeling in the Process Chain of Forming to Crashworthiness Simulations. *Proceedings of the 7th LS-DYNA Anwenderforum, Bamberg, 2008.*

Example: GISSMO Material Model (LS-DYNA)



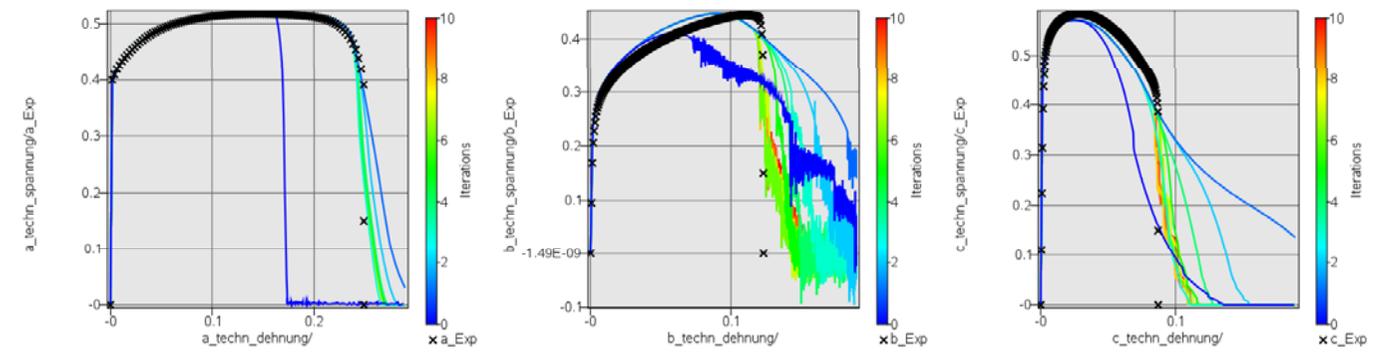
- Experimental test program for calibration



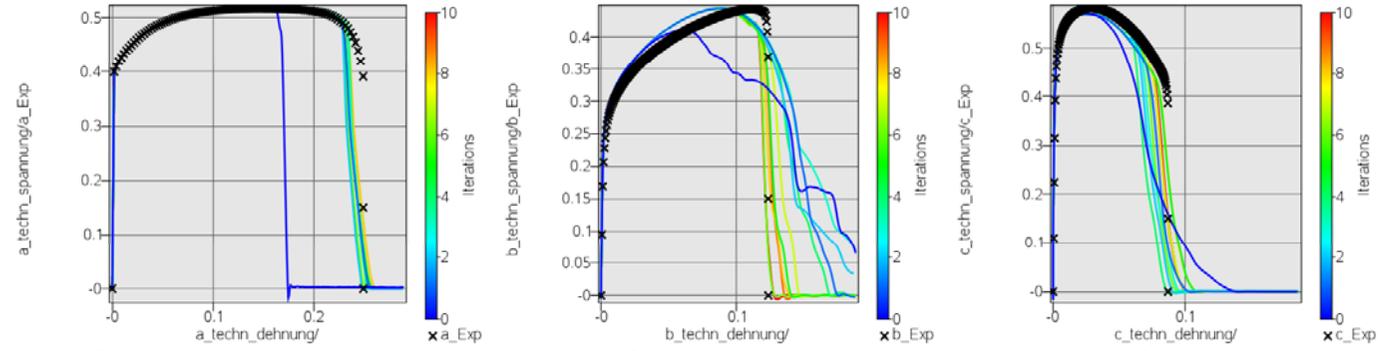
Example : GISSMO Material Model (LS-DYNA)



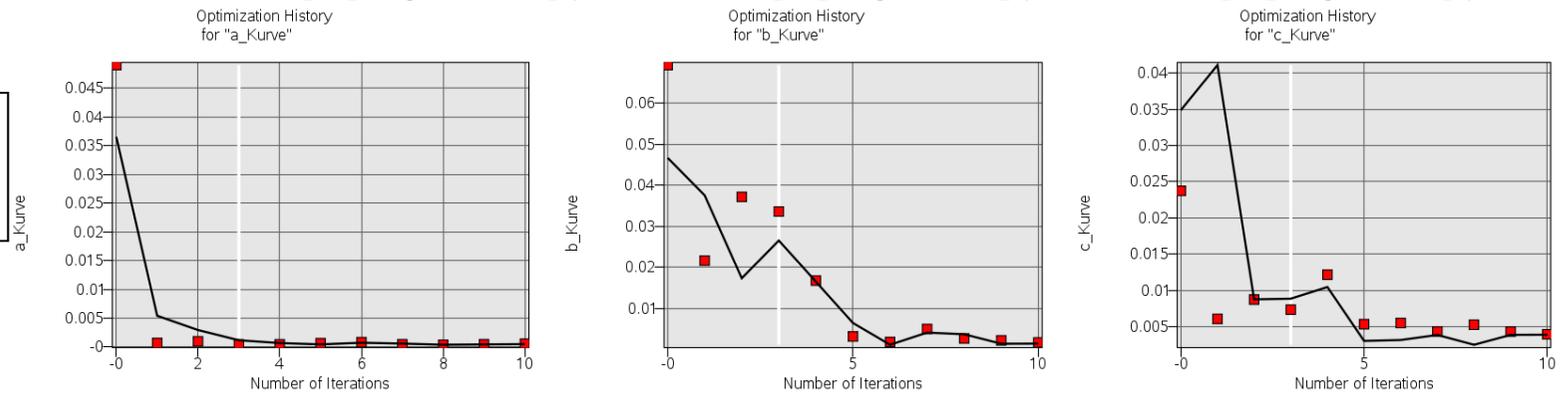
MeanSqErr



CurveMap



Mismatch History



Conclusions

- Partial Curve Mapping allows the identification of hysteretic curves
- Short/long test curves of computed curves can be handled
- Both the ordinate and the abscissa are incorporated
- Curve normalization ensures that the result is independent of the chosen measurement units
- LS-OPT input specification is very simple

Curve mapping is available in *LS-OPT Version 4.2*