# Identification of Material Parameters with LS-OPT®

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## Overview

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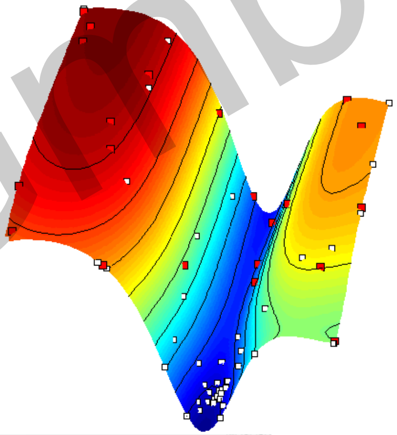
- Introduction
  - *Parameter identification*
- Optimization algorithm
  - *Sequential Response Surface Method*
- Matching of scalar values and curve matching metrics
- *Setup of a parameter identification problem in LS-OPT*
  - *Live demonstration*
- Parameterization of LS-DYNA input curves
  - *Live demonstration*
- Remarks

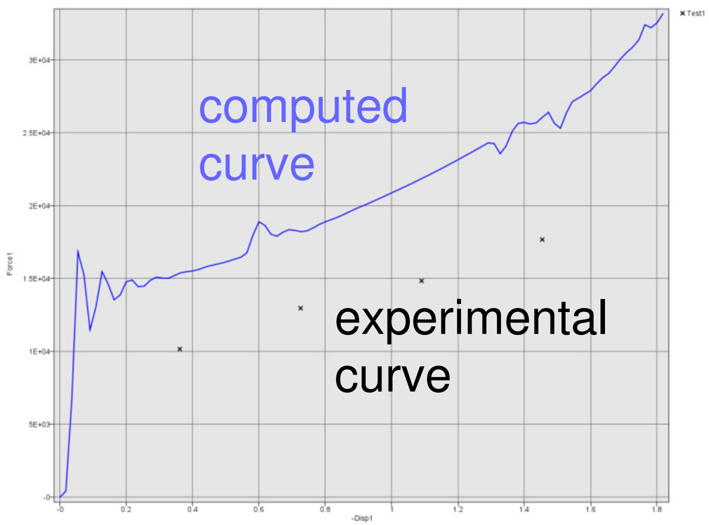
# About LS-OPT

- LS-OPT is a standalone optimization software
  → can be **linked to any simulation code**
  - Interface to LS-DYNA and MSC-Nastran
  - User-defined Interface
- Current production version is LS-OPT 5.1
- LS-OPT Support web page
  → [www.lsoptsupport.com](http://www.lsoptsupport.com)
  - *Download of Executables*
  - *Tutorials*
  - *HowTos / FAQs*
  - *Documents*
  - *....*



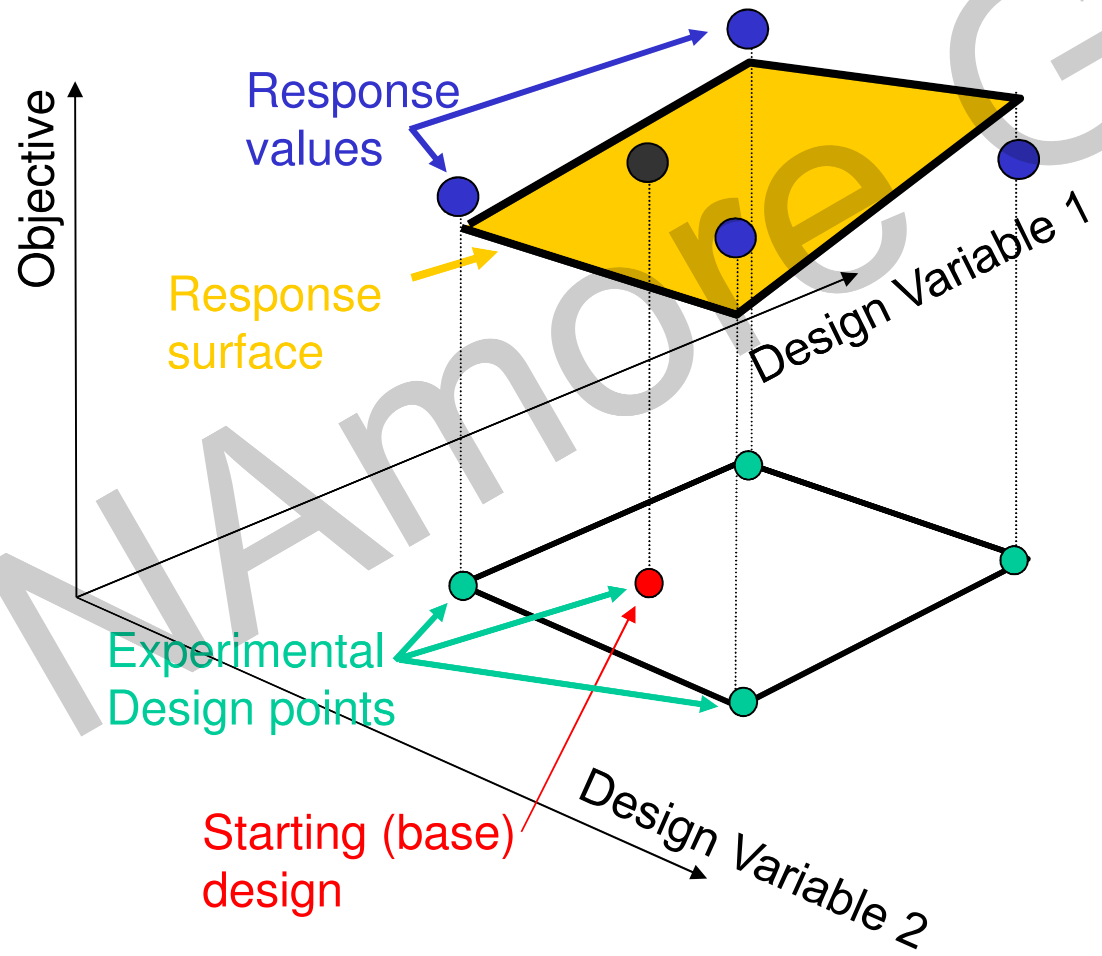
## Parameter identification: Objectives

- 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
- Principle technologies involved:
  - *Optimization algorithm*
  - *Curve Matching metric*

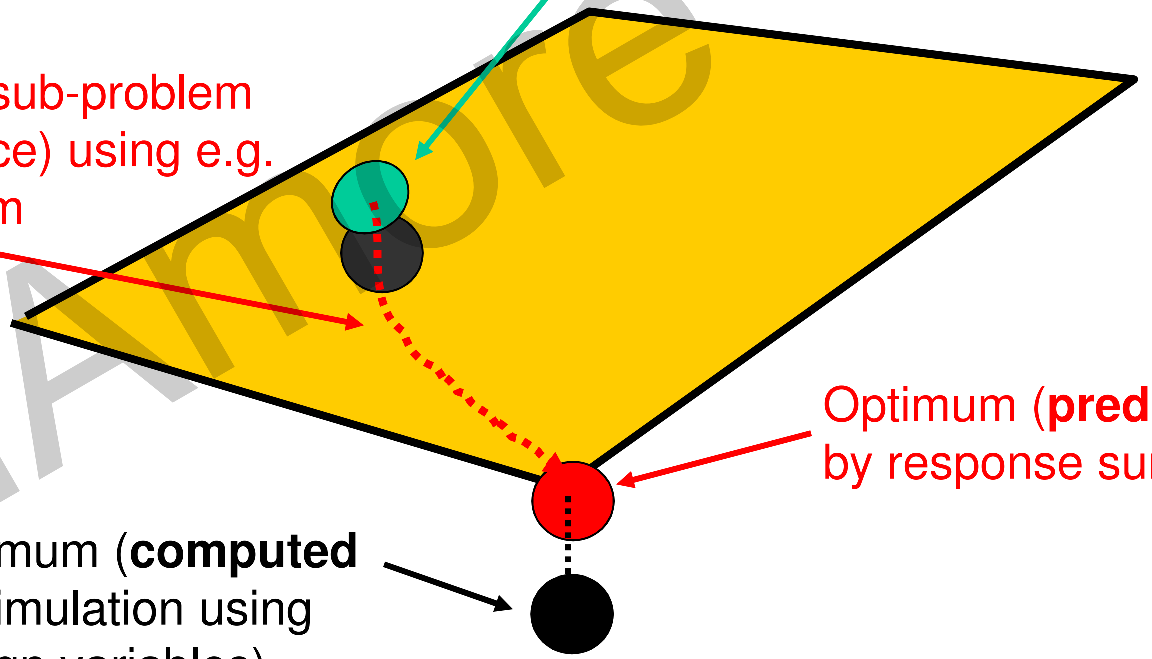


# Optimization Algorithm - Sequential Response Surface Method (SRSM)

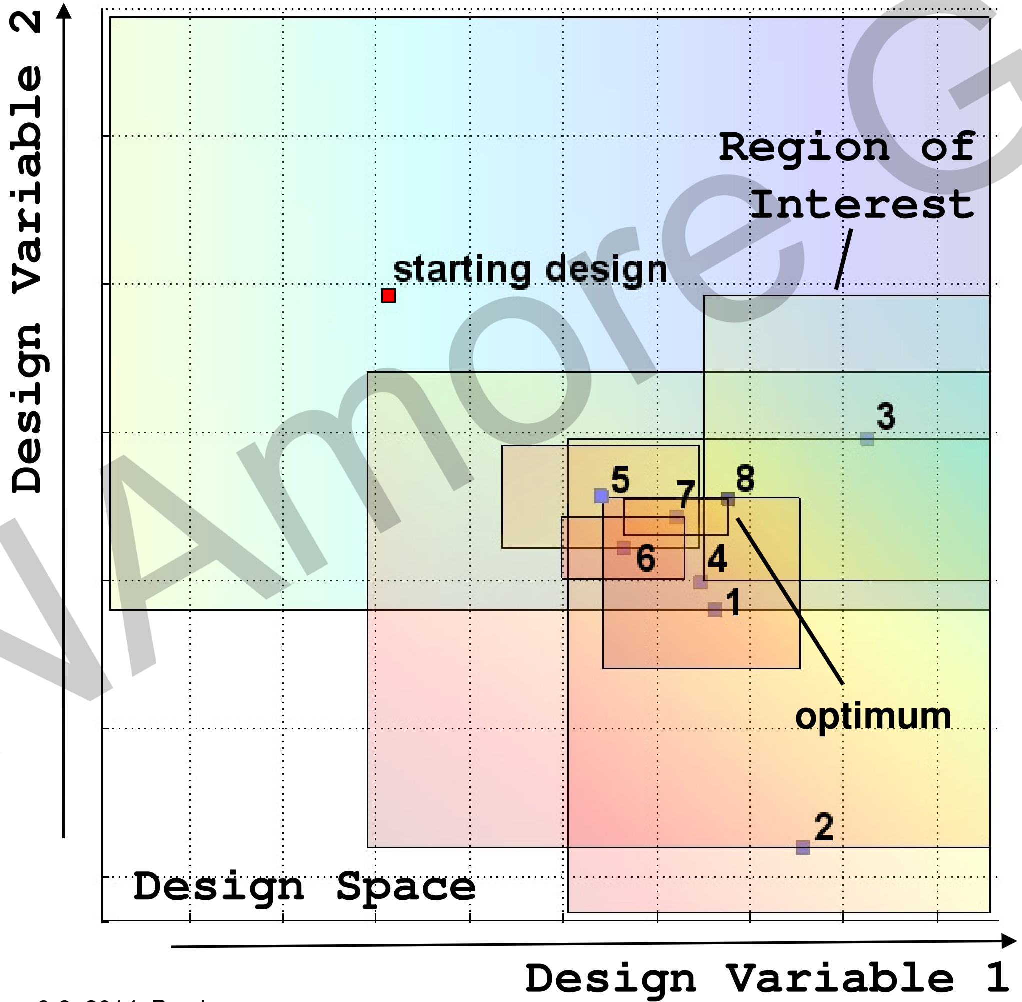
## Response Surface Methodology - Optimization Process



## Find an Optimum on the Response Surface (one iteration)



## Sequential Response Surface Methodology (SRSM)



# Objective Functions - matching of scalar values and curve matching metrics

## 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

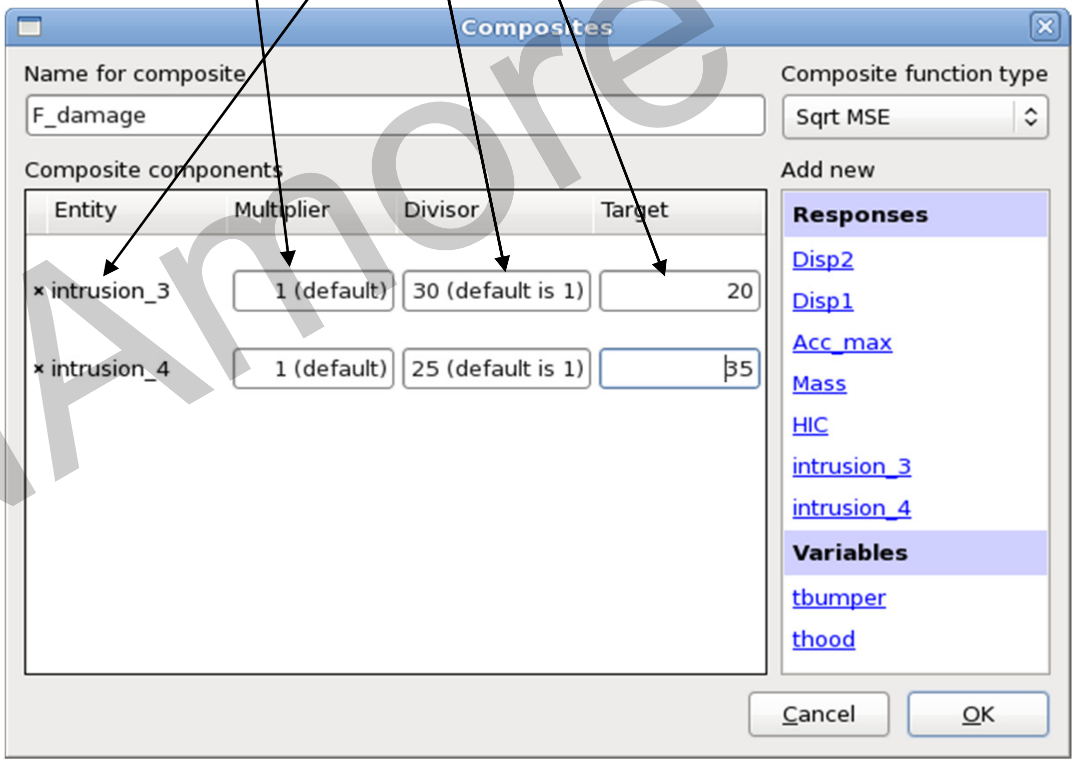
$W_j$ : weighting factor

$s_j$ : normalization factor

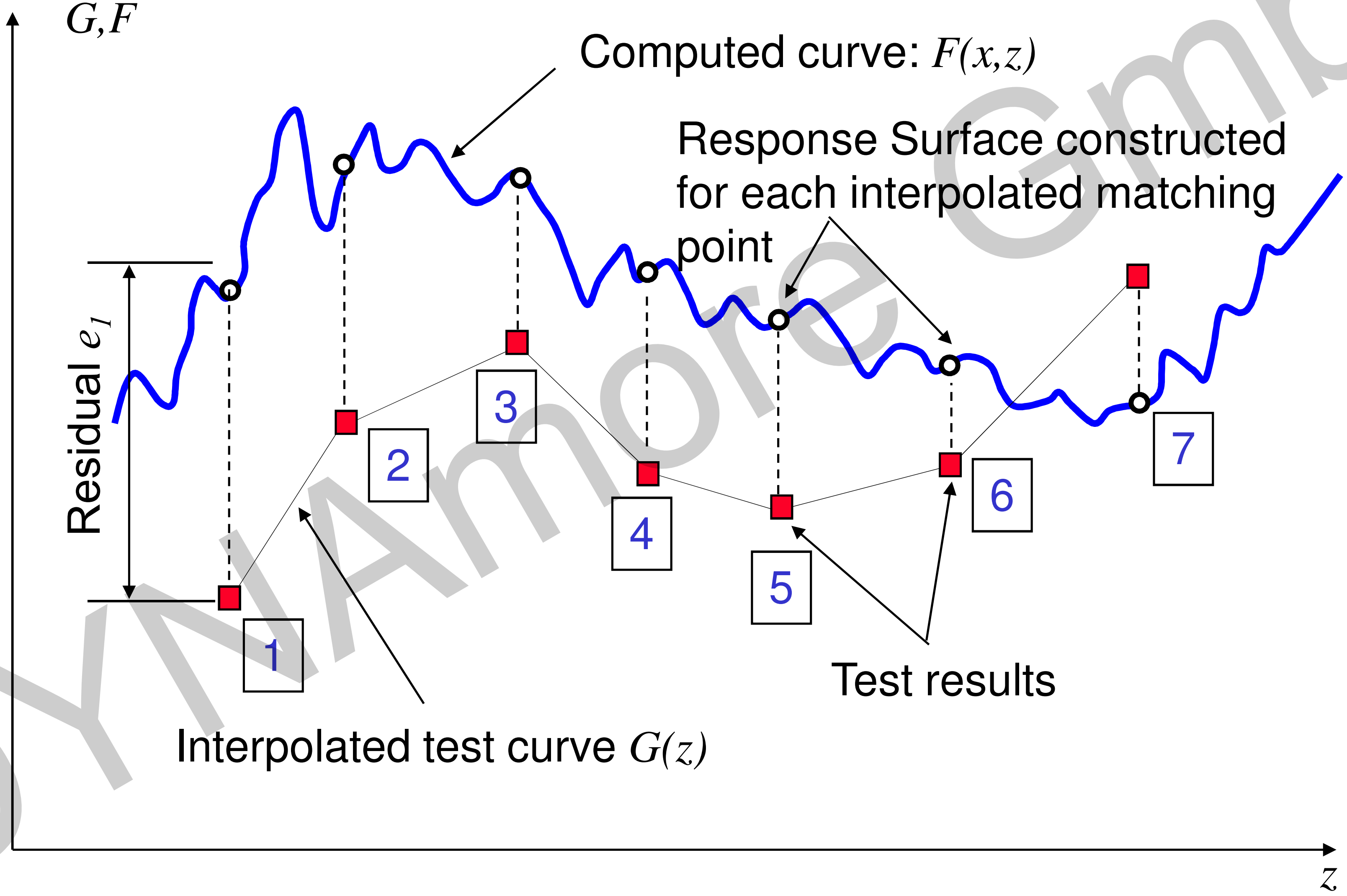
# Matching of scalar values

- **Targeted Formulation**

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



# Ordinate-based Curve Matching Metric (MeanSqErr)



# Ordinate-based Curve Matching Metric (MeanSqErr)

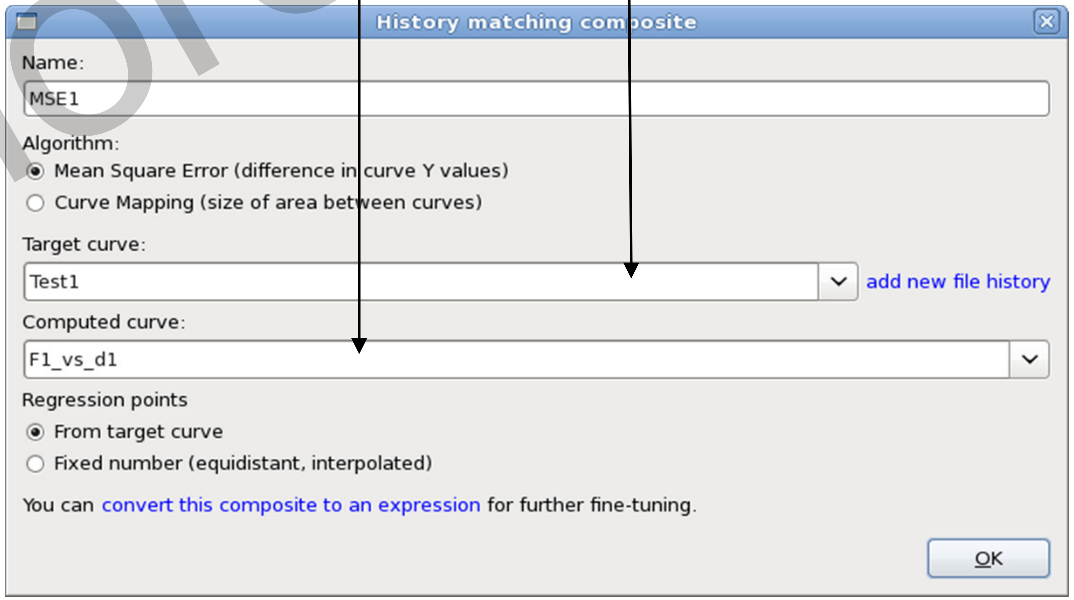
- **Easy set-up in LS-OPT GUI**

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

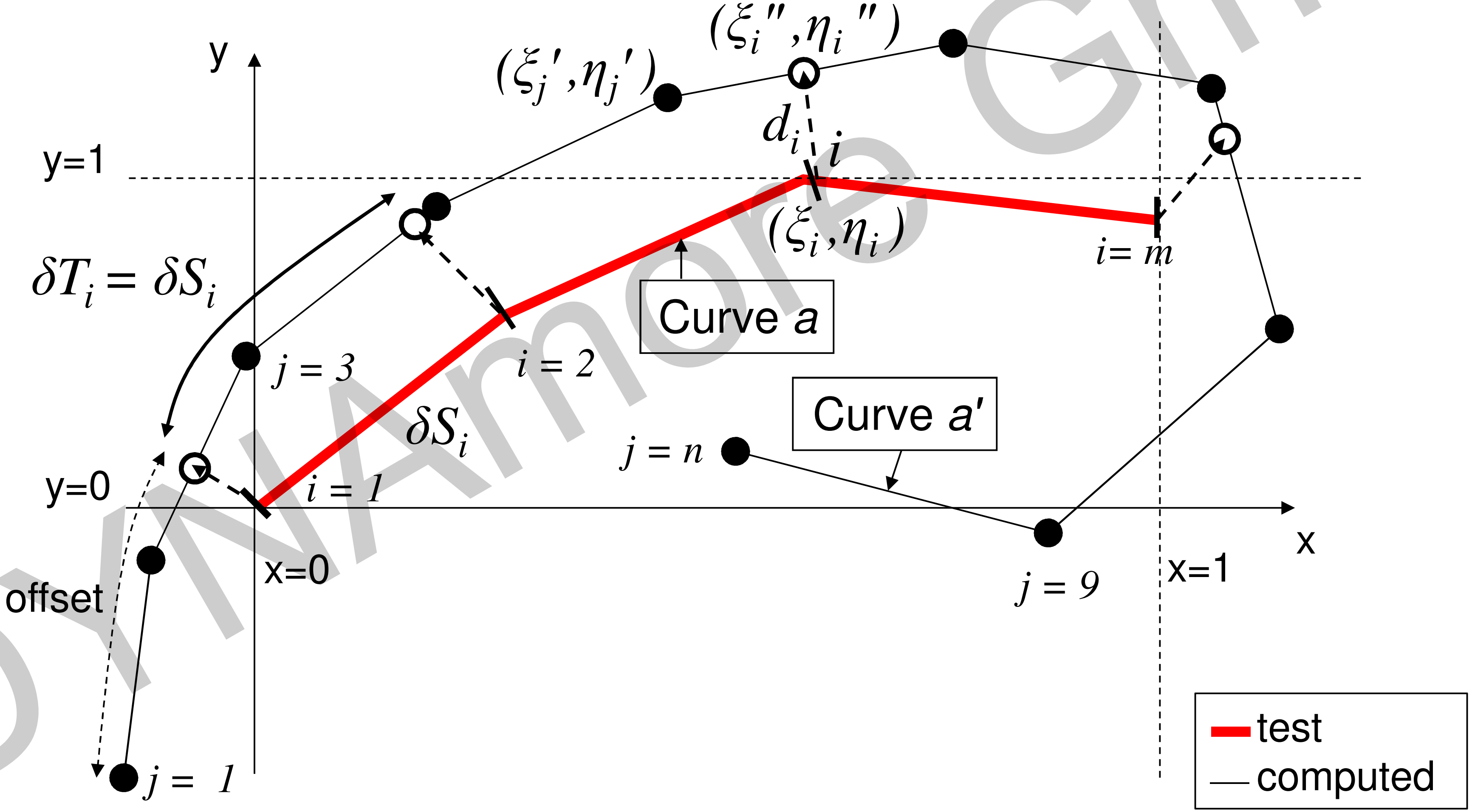
Test curve

Simulation curve

- Reads test curve files directly
- Options:
  - *number of points,*
  - *start point, end points,*
  - *weighting/scaling options*
- Crossplots can be defined, e.g. Stress vs. strain, Force vs. deformation …



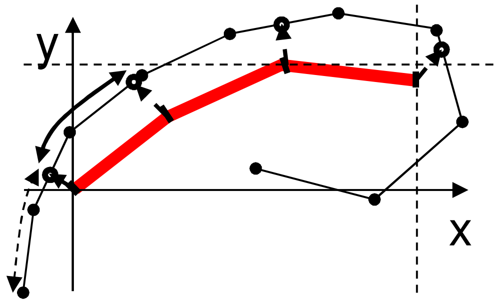
- **Partial Curve Mapping (steep or hysteretic curves)**



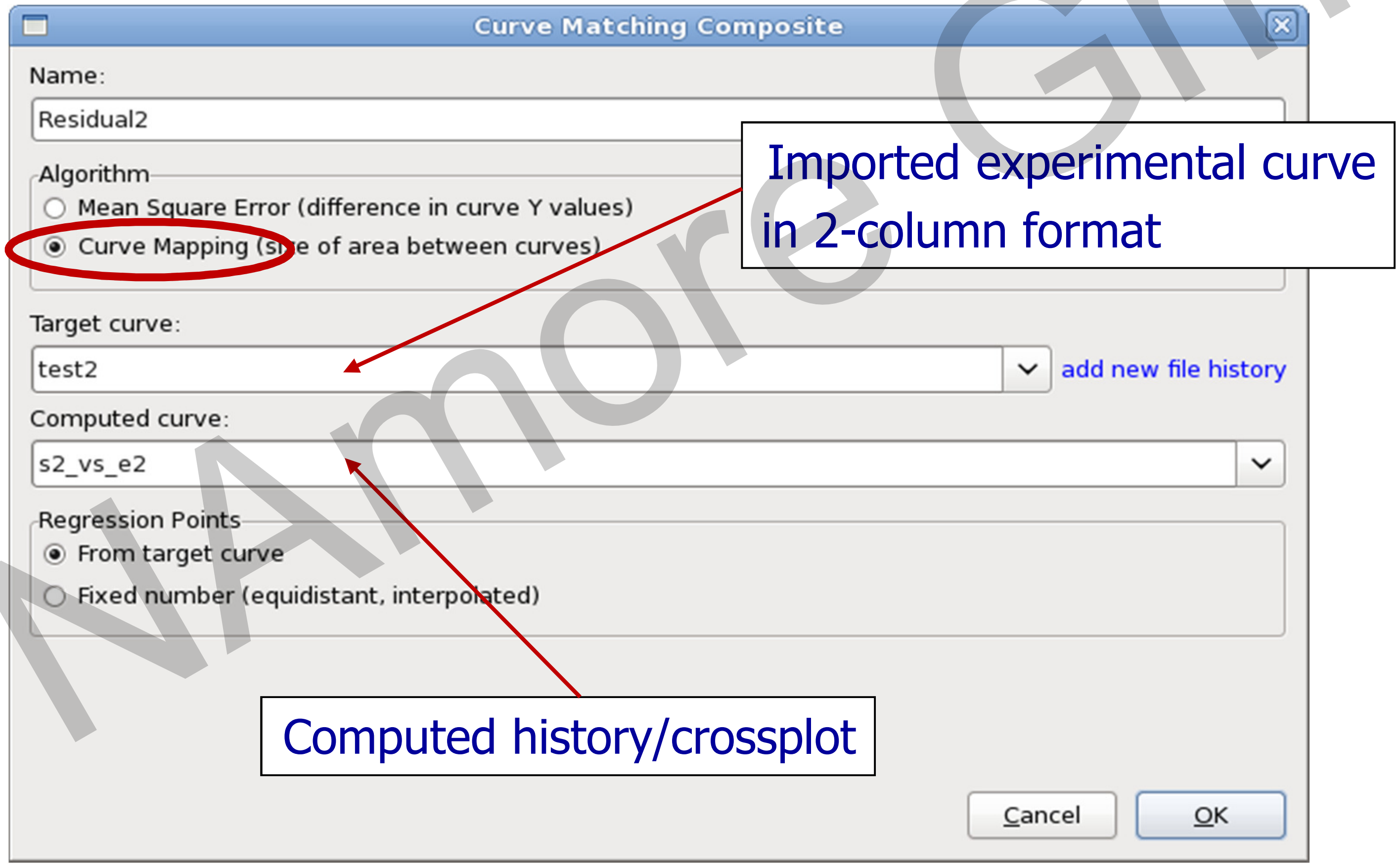
# Partial Curve Mapping

**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



## Interface for Curve Mapping

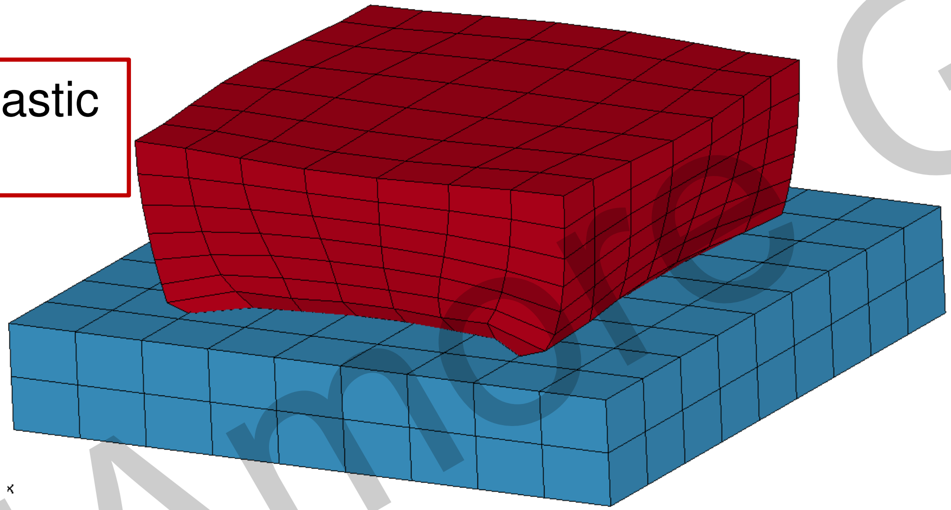


# Setup of a parameter identification problem in LS-OPT - Example

- Example: Material properties of a foam

Elastoplastic material

Rigid base



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

# Live Demonstration

# Parameterization of LS-DYNA input curves

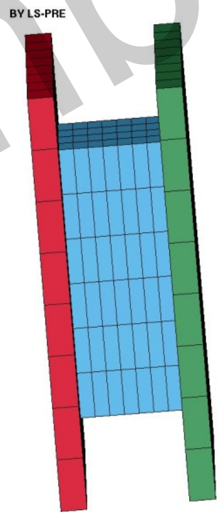
# Parameterization of LS-DYNA input curves

- Material properties of Confor Blue Foam CF45©
- Material model *MAT_FU_CHANG_FOAM

```
*MAT_FU_CHANG_FOAM_TITLE
MAT FU CHANG FOAM (Confor blue)
$#     mid        ro         e        ed        tc      fail      damp      tbid
         2 1.0720E-7  0.150000     0.000     0.000     0.000   0.00500         7
$#  bvflag     sflag     rflag     tflag      pvid      sraf       ref        nu
  1.000000  1.000000  1.000000
$#      d0        n0        n1        n2        n3        c0        c1        c2
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
$#      c3        c4        c5       aij       sij      minr      maxr     shape
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

- Strain rate dependent material

```
*DEFINE_TABLE_TITLE
Dehnraten Table
$#    tbid
         7
$#              value        lcid
```



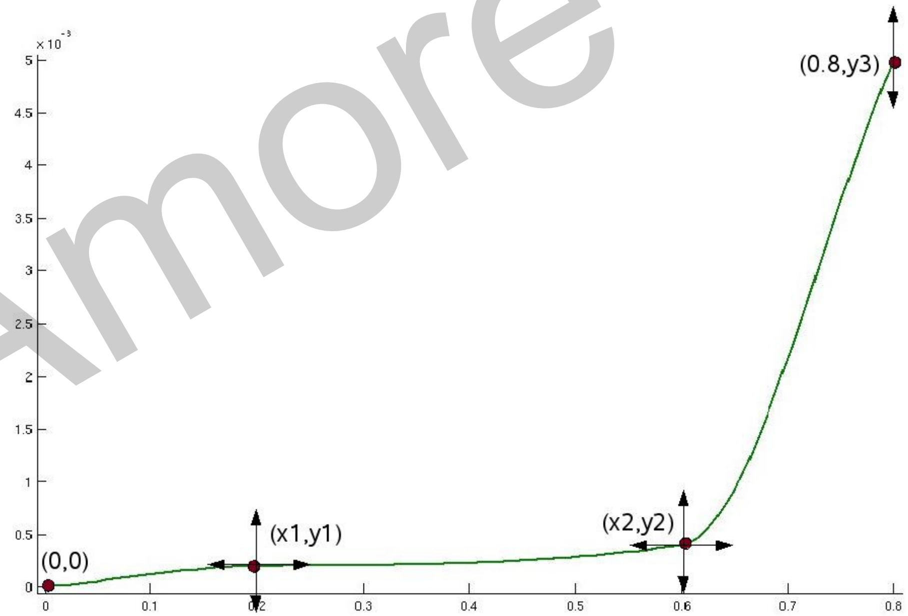

- Use LS-OPT to determine stress vs. strain curves

```
*DEFINE_CURVE
$Dehnrate für 1 1/s
$     LCID      SIDR      SCLA      SCLO      OFFA
         1         0       1.0  1.000000
$                 a1                  o1
```

?

# Parameterization of LS-DYNA input curves

- User-defined preprocessor (Python, Perl, …) that generates LS-DYNA include file containing the curve
- Parameterized analytical function
  - *spline, polynomial, exponential function, …*



# 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