Calibration of the GISSMO model using LS-OPT®

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Overview

- Goals
- Background
- Theory of DTW
- Example
- Conclusions
- Recommendations

Goal

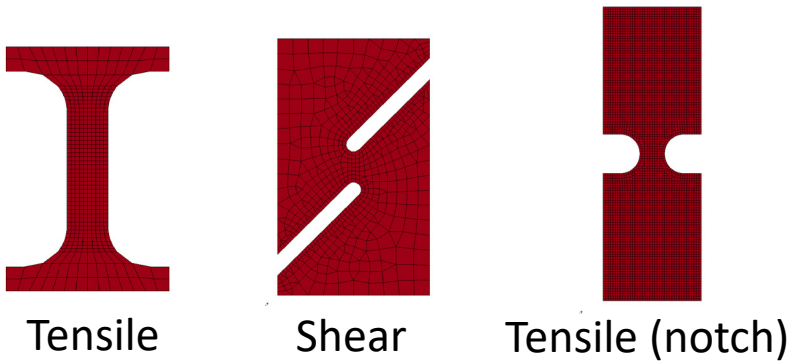
- To demonstrate the ability to calibrate a GISSMO model using 3 test cases
  - Characteristics
    - Computational noise
    - Steep failure curves
- To establish a best practice for GISSMO model characterization using LS-OPT®

Background

- As a result of requests for assistance with GISSMO calibration as well as a demand for supporting DIC as part of the calibration procedure we have recently also added new, more robust, curve similarity measures namely Dynamic Time Warping (1994) and Discrete Fréchet (1906).

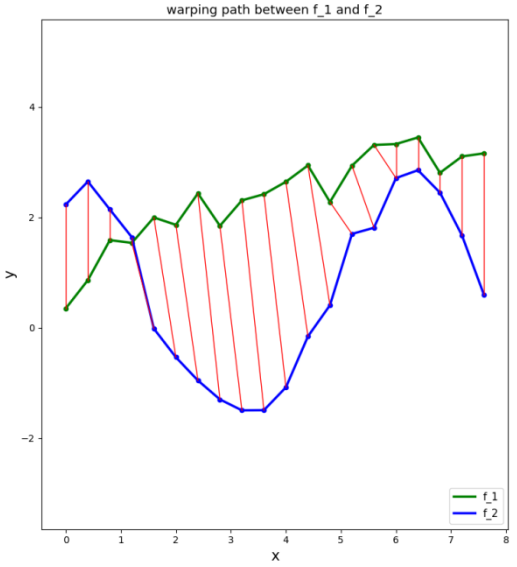
Setup and Example Overview

- Parameters: 7
- Test cases: 3
- Target curve: Synthetic
- Curve Matching
  - Dynamic Time Warping (DTW) (1994)
  - Truncation of Force history at failure load (uses LS-OPT feature)
- Optimization methods
  - SRSM (Sequential Response Surface, local optimizer): 15 iter, 14 sim, 3 cases = *639*
  - GA (Direct Genetic Algorithm, global optimizer): 50 gen, 100 pop., 3 cases = *15000*



Dynamic Time Warping

Curve Similarity Measure

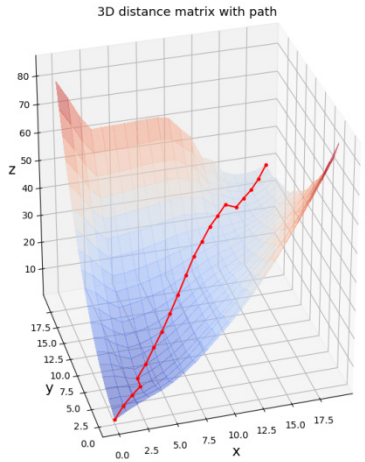


DTW calculates the distance between two data sets, which may vary in time, via its corresponding warping path. This path is the result of the minimum accumulated distance which is necessary to traverse all points in the curves

While the Euclidean distance measure is a strict one-to-one mapping, DTW also allows one-to-many mappings.

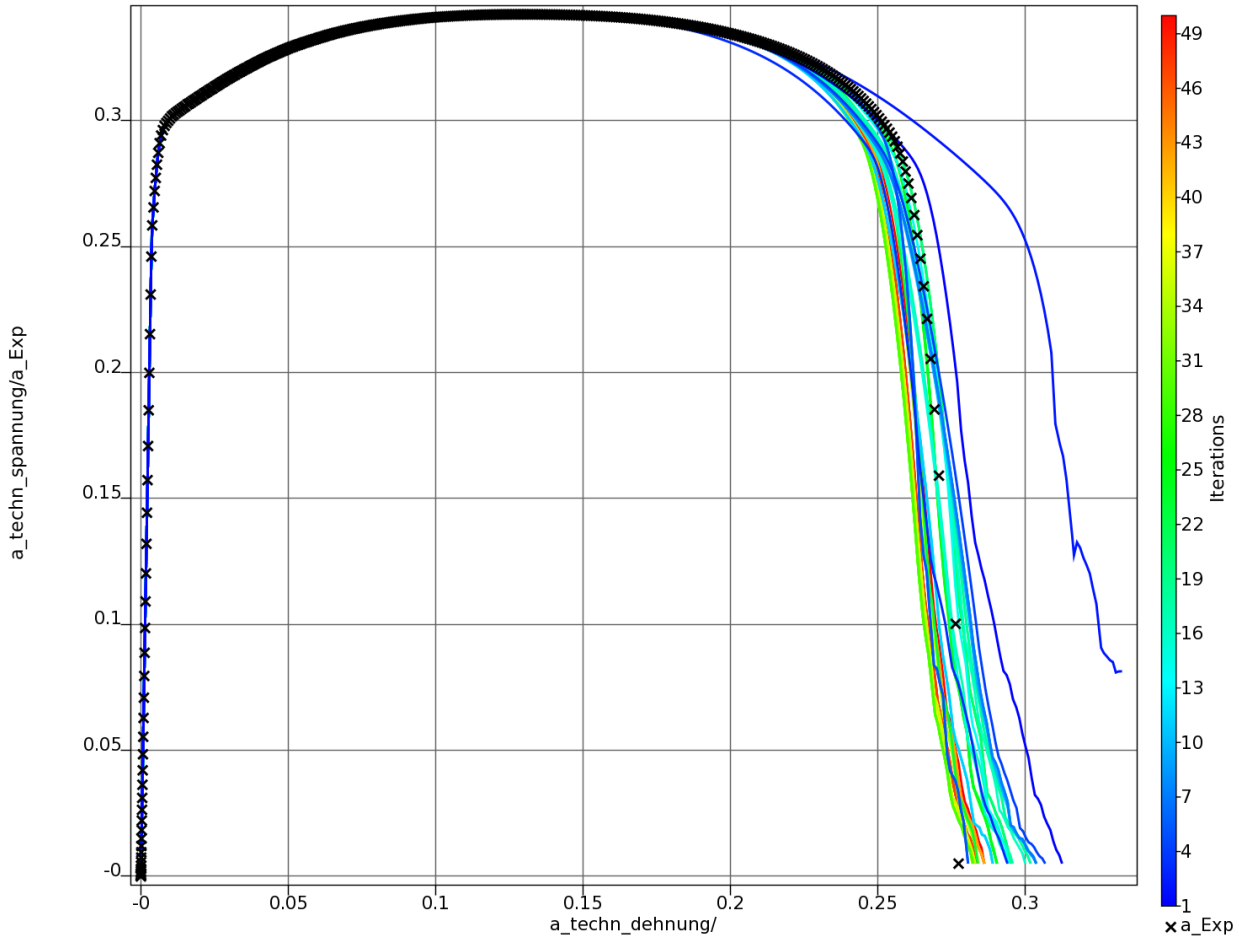
Mathematically,

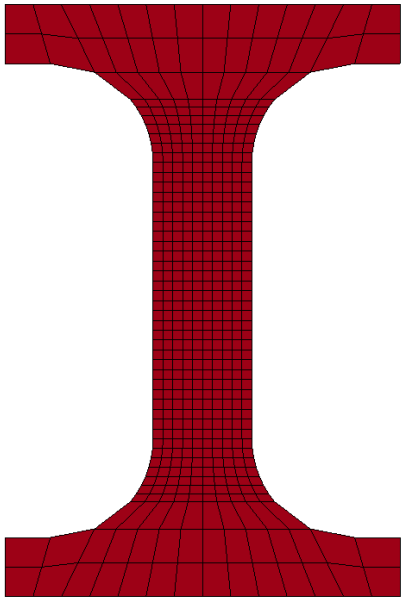
$$DTW(P,Q) = \min_{W} \left\{ \sum_{i=1}^{l} \delta(w_i) \right\}$$



Case A: tensile

GA: optimum at each generation

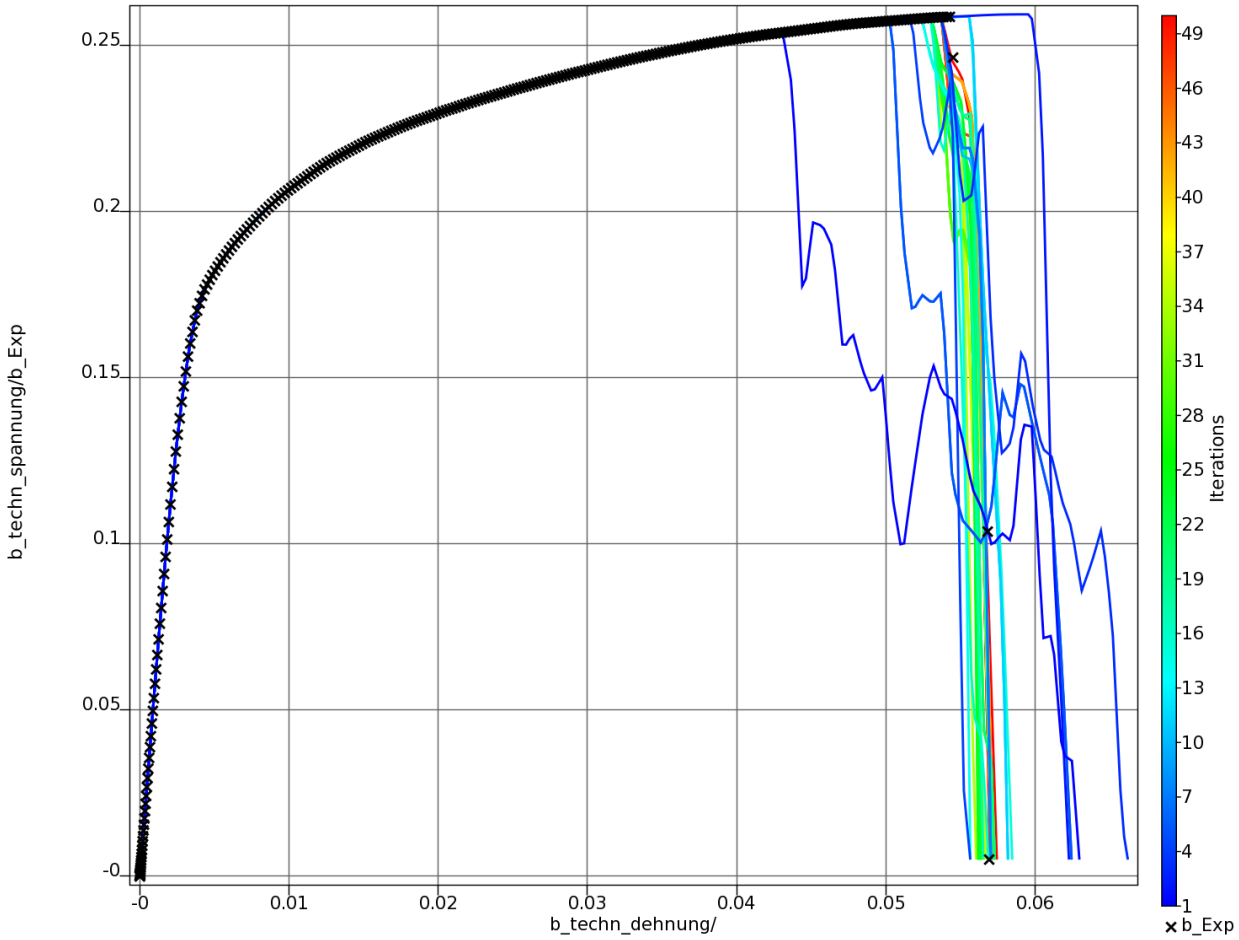


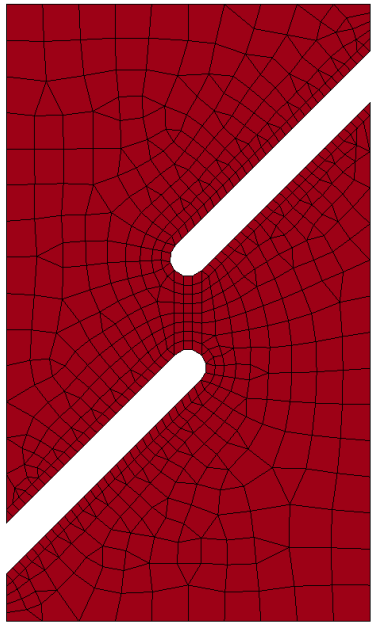


Example by courtesy of DYNAmore GmbH, 2011

Case B: shear

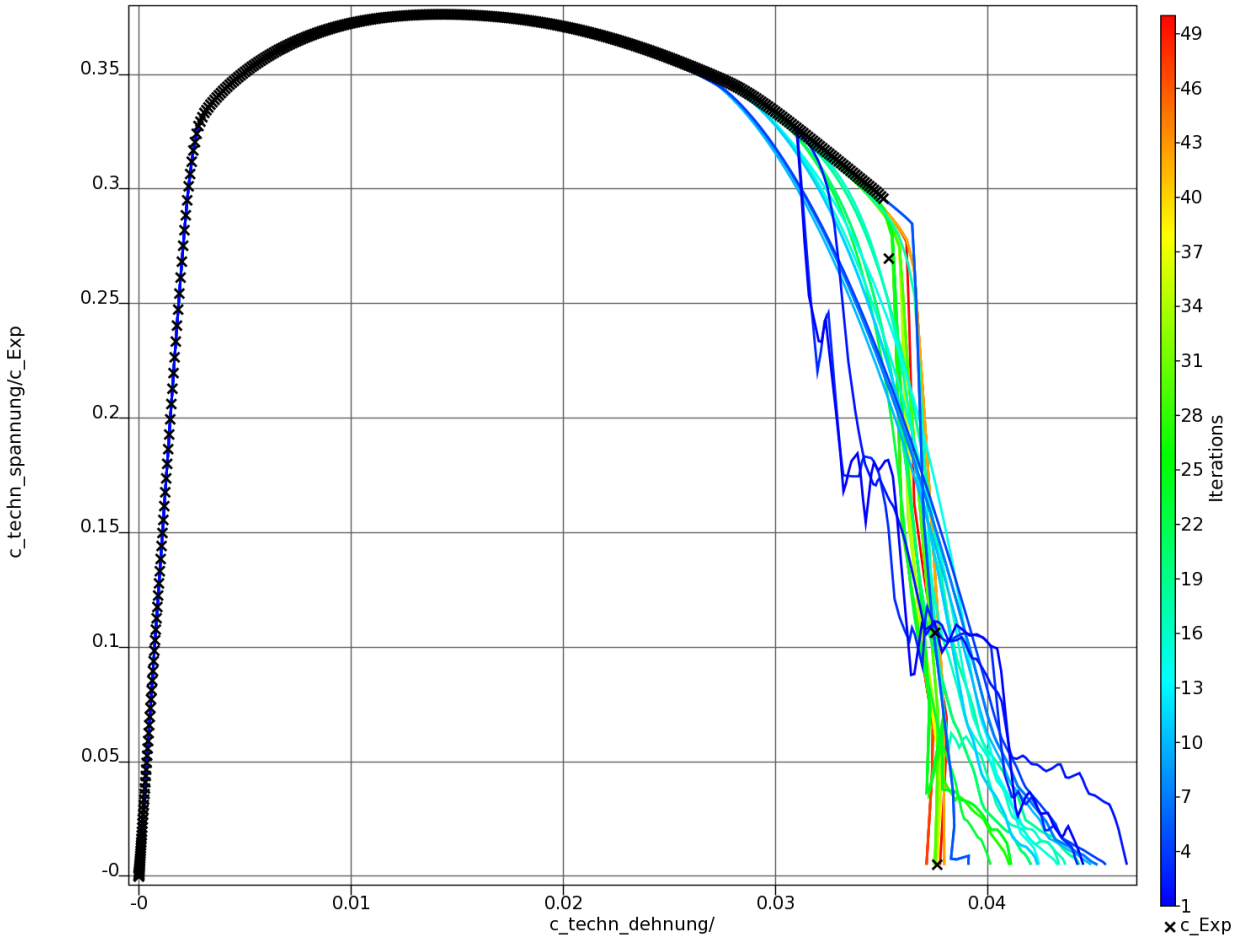
GA : optimum at each generation

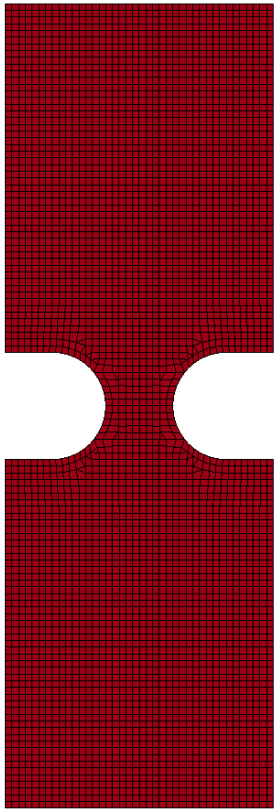




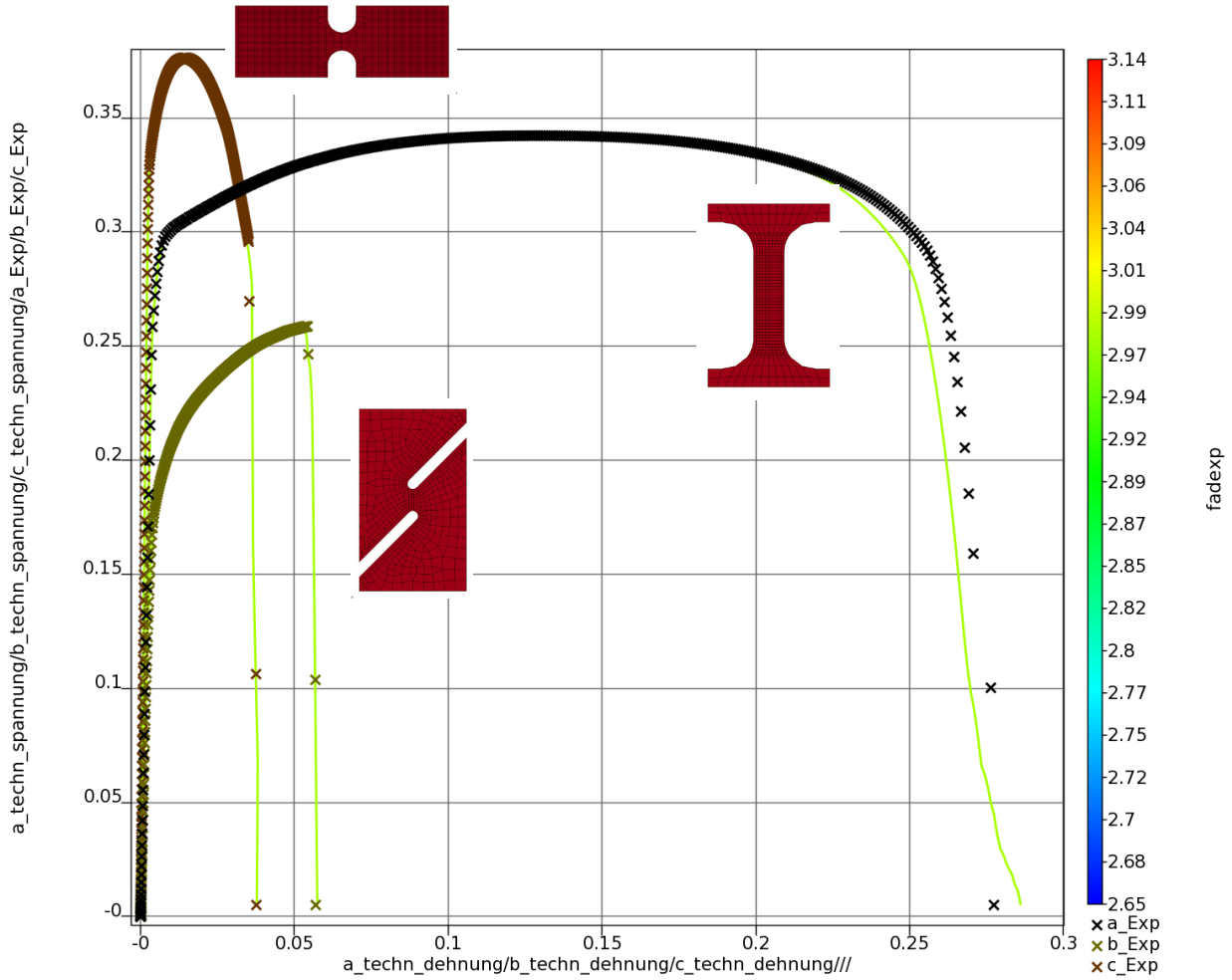
Case C: tensile (notch)

GA : optimum at each generation



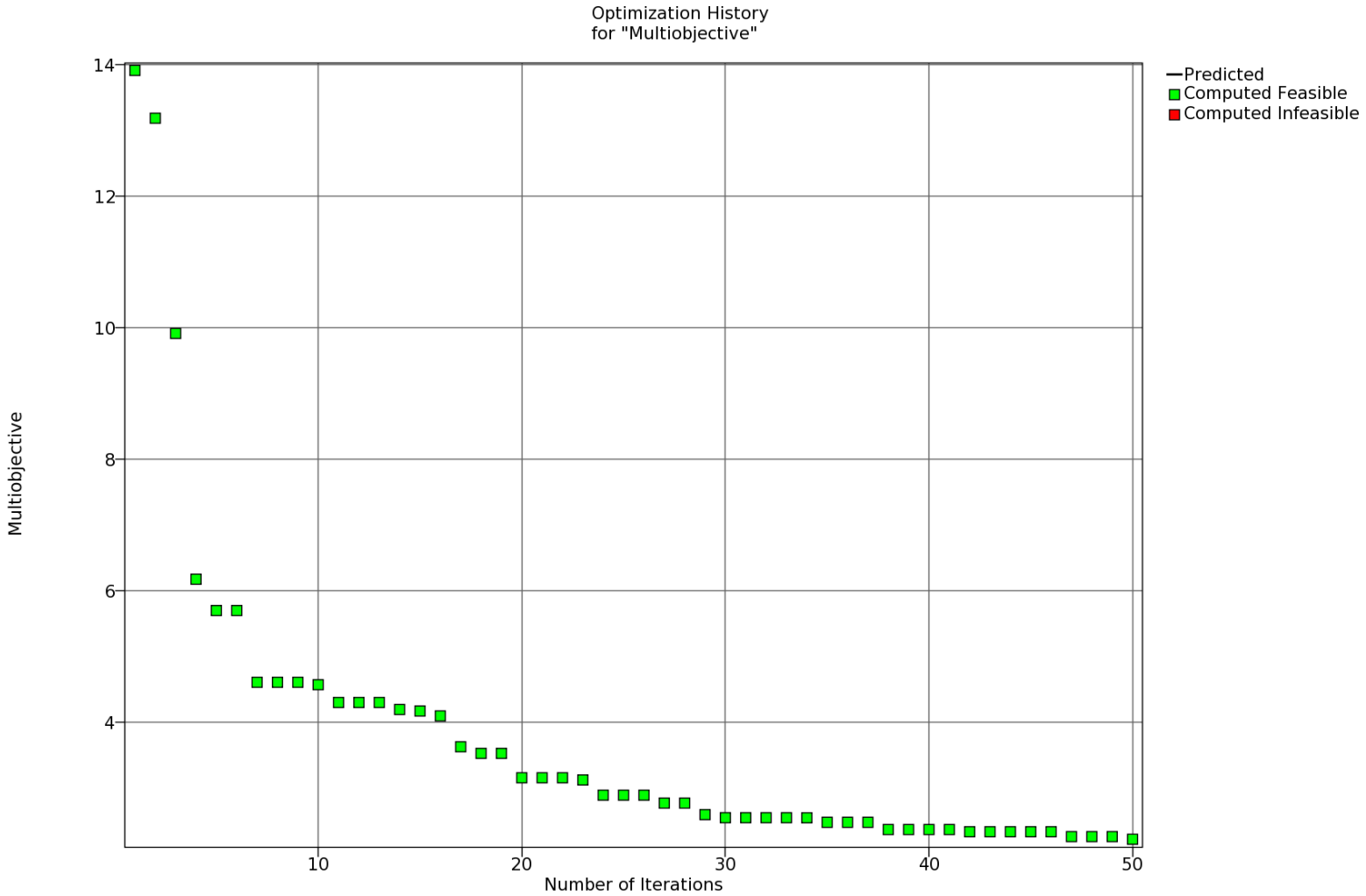


Optimum (GA/DTW)



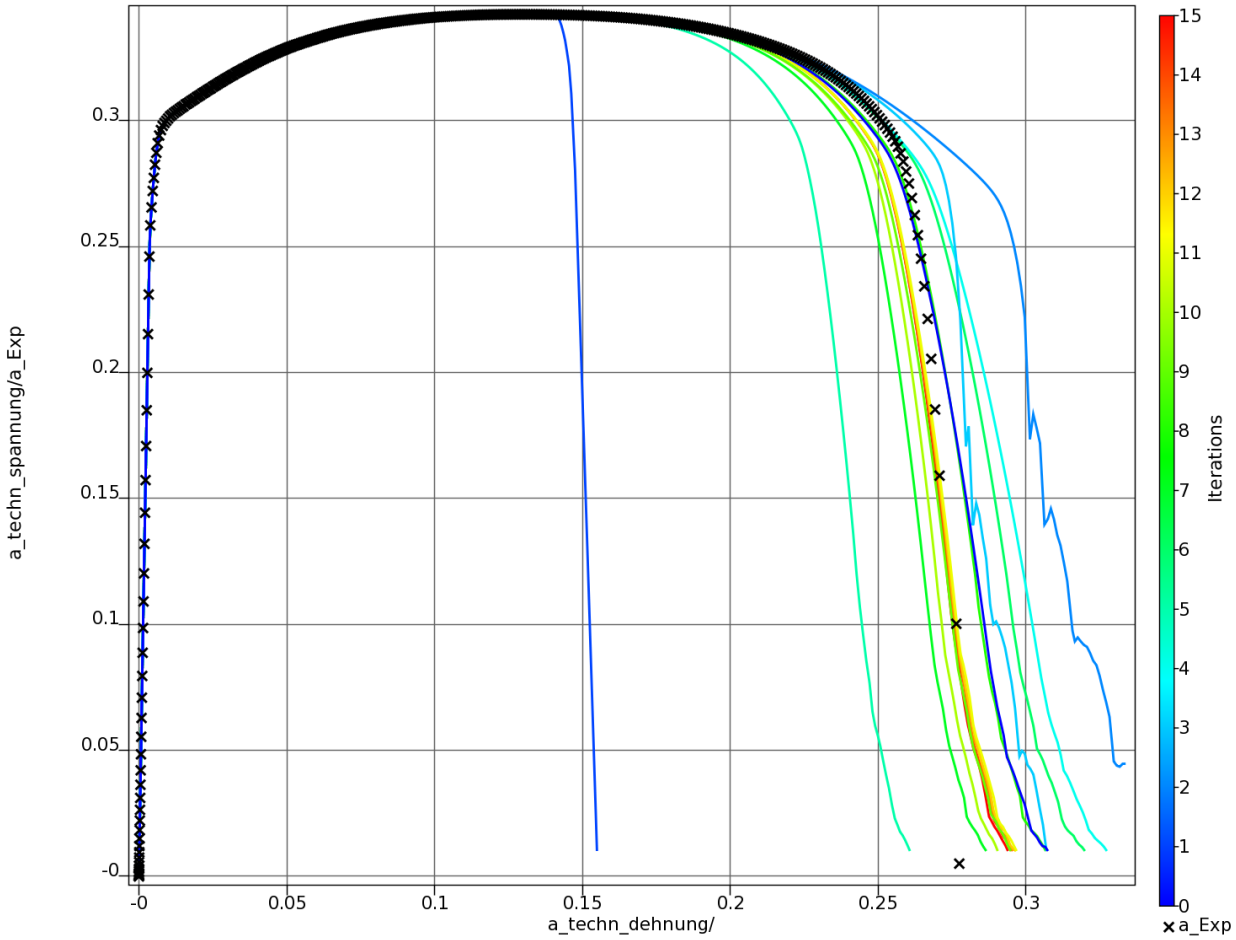
Optimization history

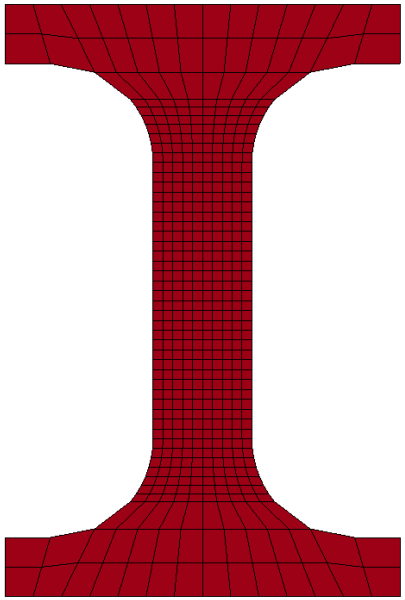
GA, DTW distance measure



Case A: tensile

SRSM: optimum at each iteration

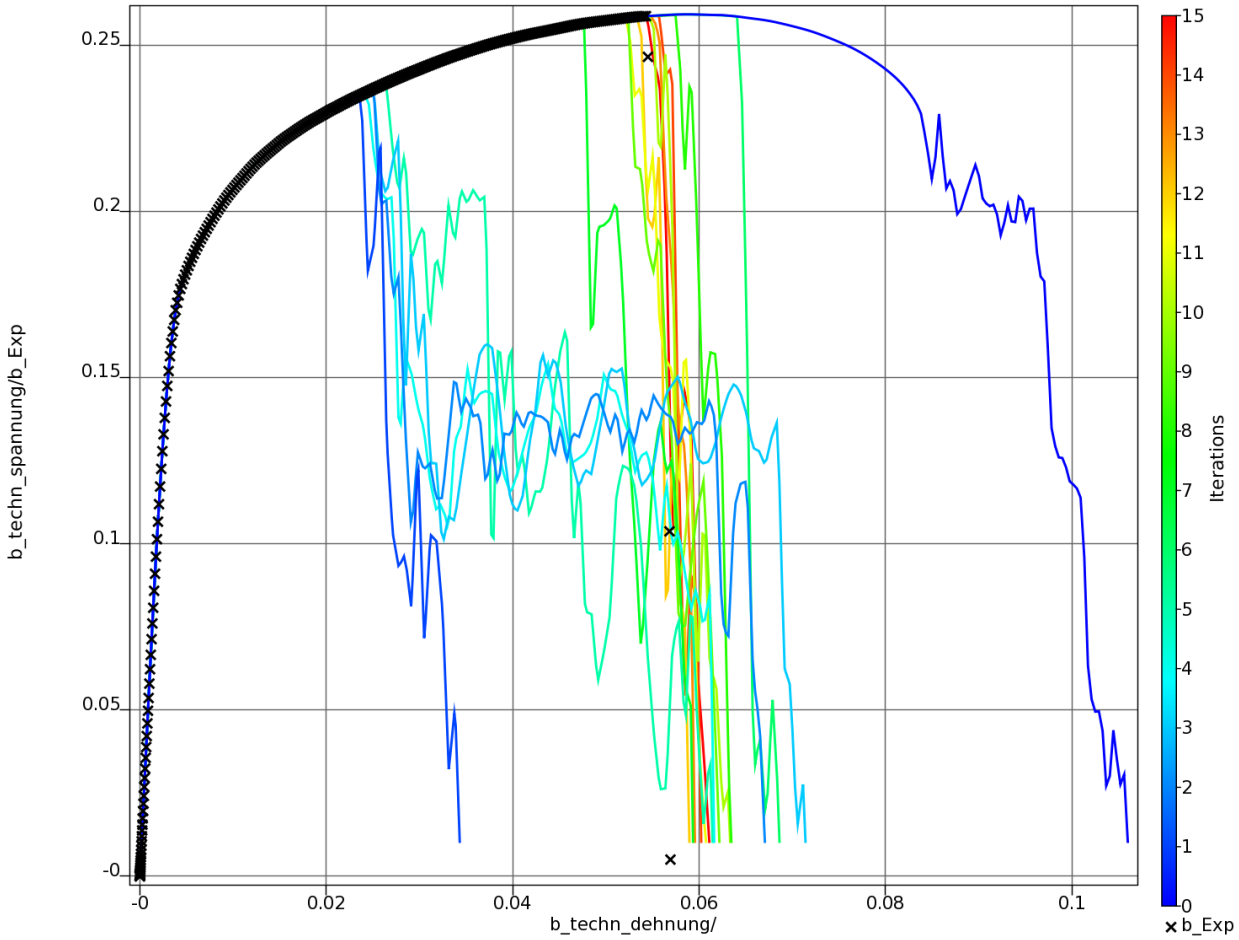


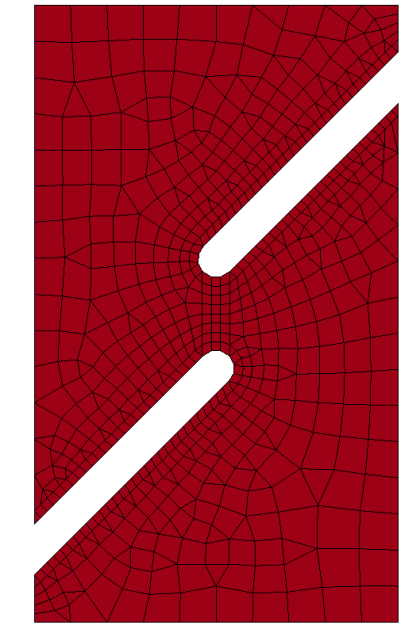


Example by courtesy of DYNAmore GmbH, 2011

Case B: shear

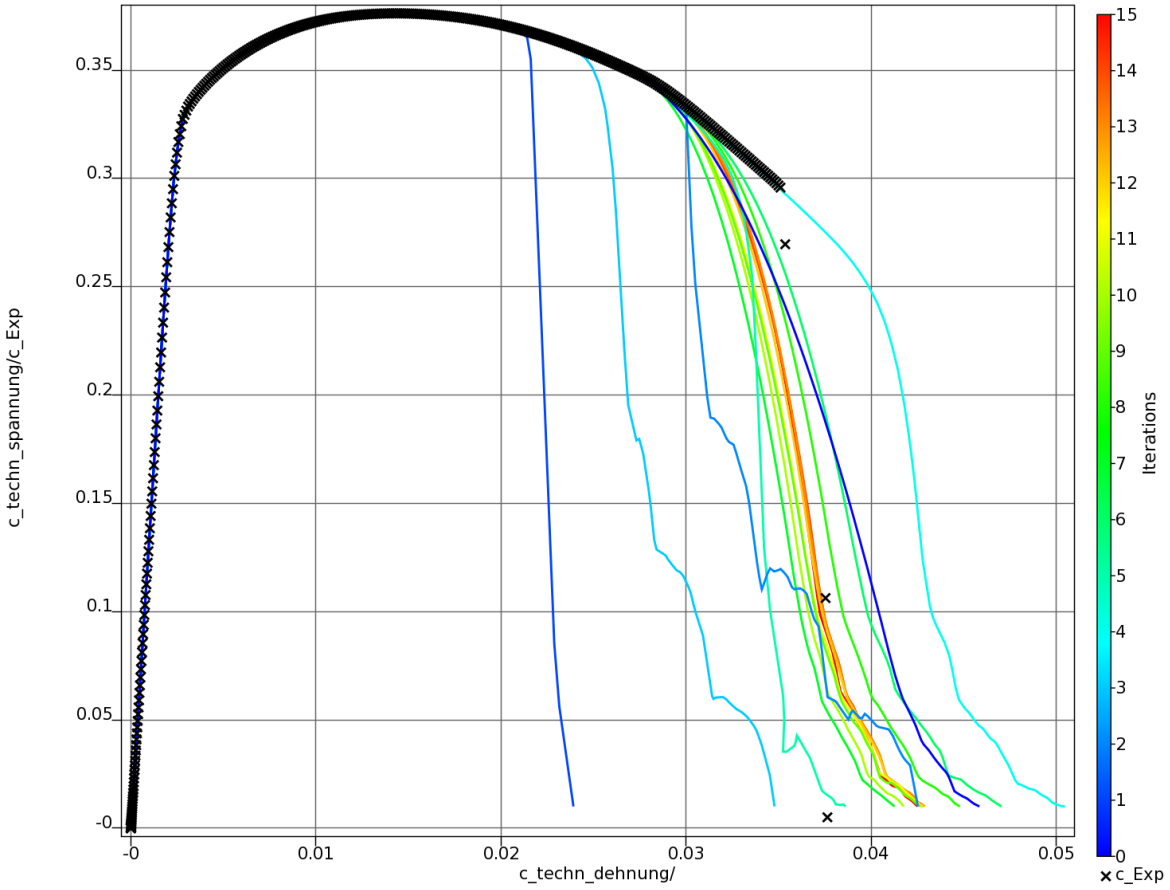
SRSM: optimum at each iteration

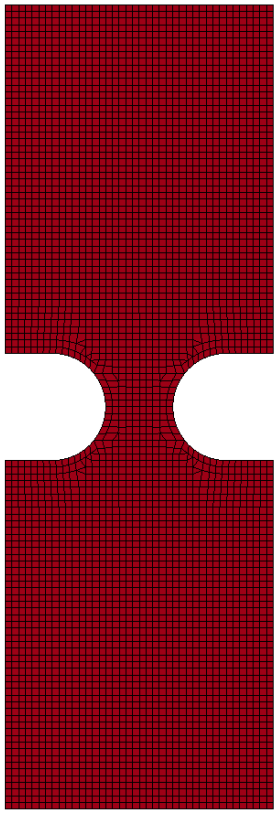




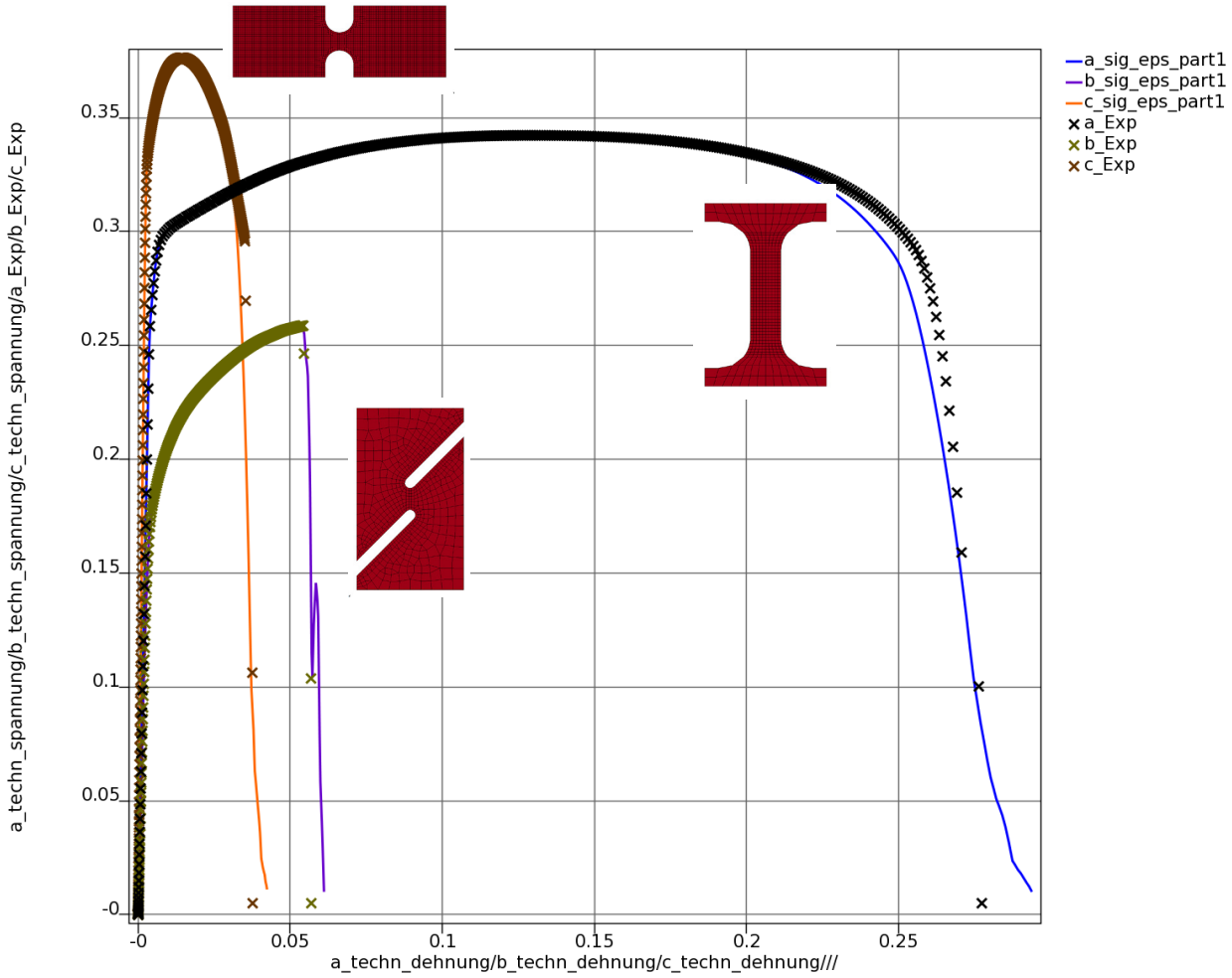
Case C: tensile (notch)

SRSM: optimum at each iteration



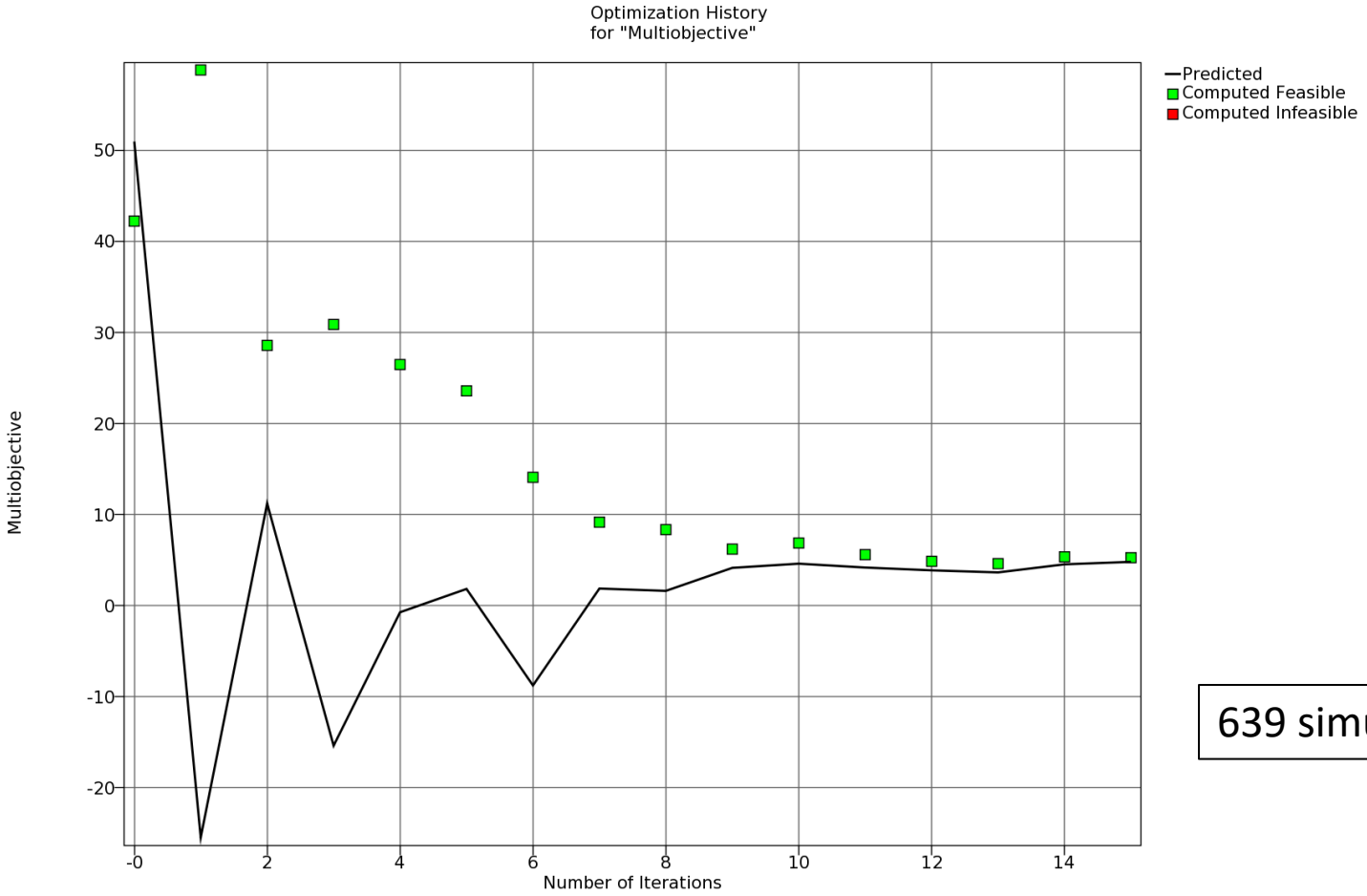


Optimum (SRSM/DTW)



Optimization history

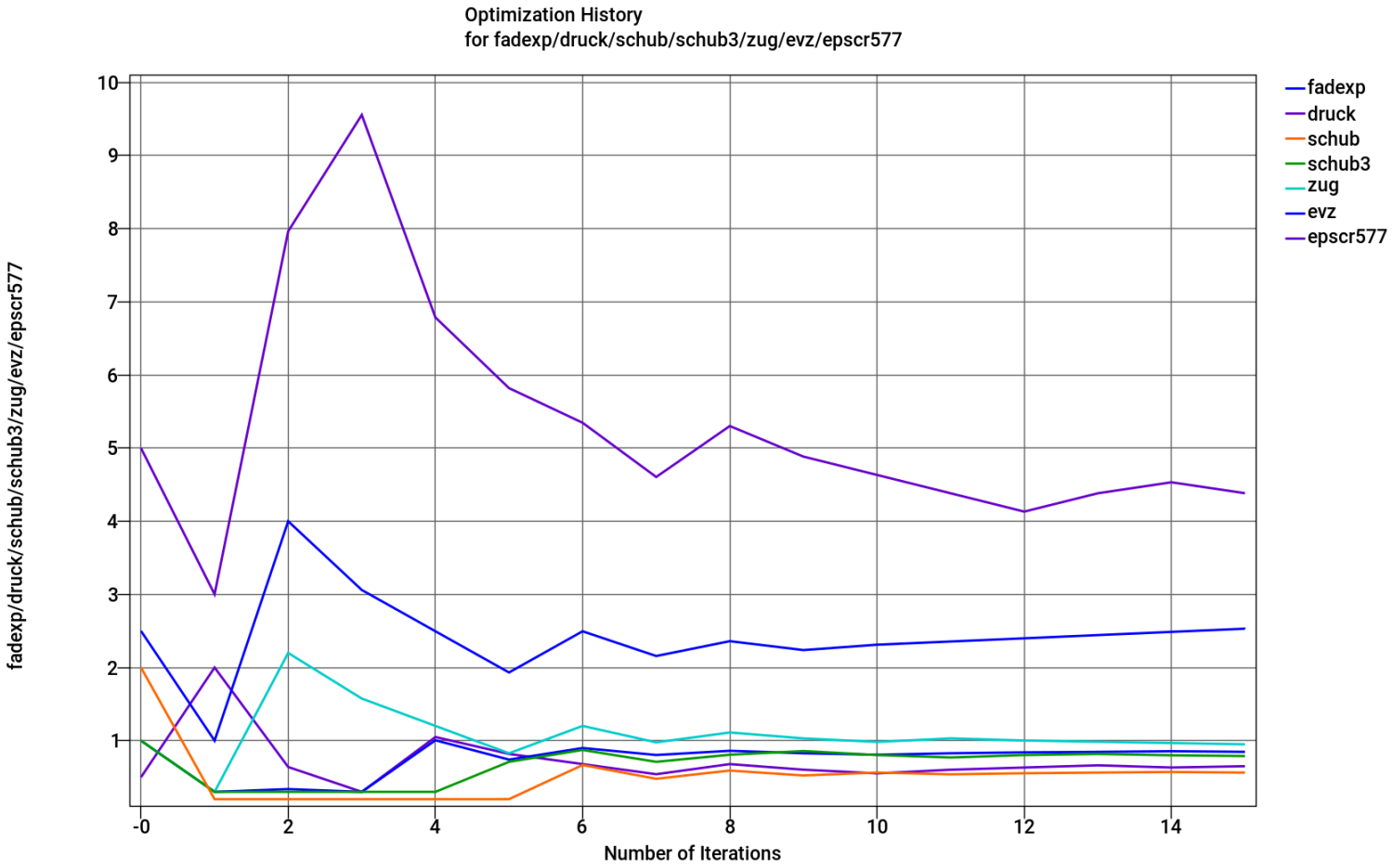
SRSM, DTW distance measure



639 simulations

Variable history

SRSM, DTW distance



Optimal Parameters
GA vs. SRSM

	Direct GA	SRSM
Variable		
fadexp	2.9734	2.531
druck	5.12825	4.38299
schub	0.574127	0.563313
schub3	0.435389	0.78979
zug	0.832831	0.950223
evz	0.805032	0.846885
epscr577	0.991622	0.650799
DTW residuals		
a_curve	*1.38378*	*1.17036*
b_curve	*0.429781*	*2.34613*
c_curve	*0.409606*	*1.75659*
Multi-objective	***2.22317***	***5.27307***

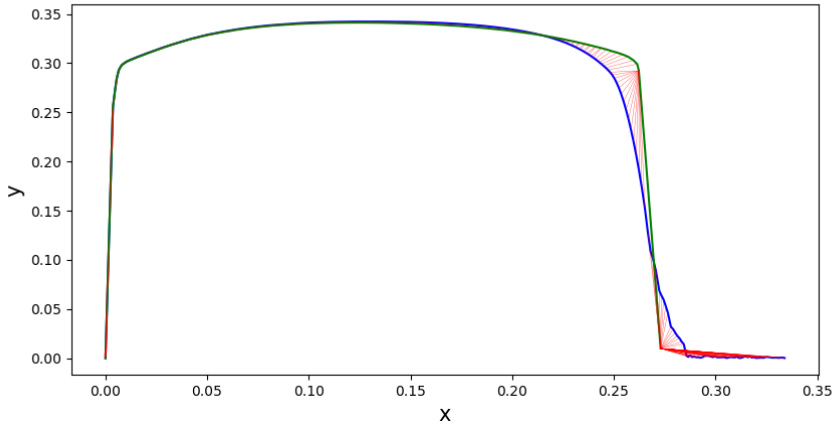
Remarks

- DTW copes well with *noise* displayed by GISSMO behavior
- DTW requires *Force curve truncation*, using an LS-OPT feature, to avoid oscillation beyond fracture
- DTW easier to use than PCM (Partial Curve Mapping)
  - PCM *fails with noise*, requiring a filter which is not robust
- SRSM (Response Surface) performance compares well with GA (639 vs. 15,000 = *4.3%*), despite
  - being a local optimizer
  - having a global convergence deficiency
- Current availability: v6.0 beta

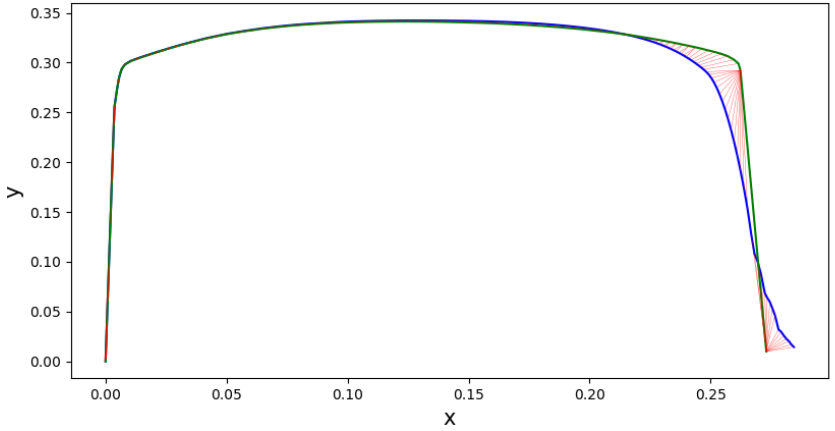
GISSMO calibration Recommendations

- Select Dynamic Time Warping as a similarity measure
- Distribute the experimental points uniformly by specifying a number of interpolation points instead of the default
- Truncate the computational force curve F at failure.
  - This value should be the same as the F value of the last point in the test curve.
  - DTW requires that the simulated and experimental curves have the same length (or as close as possible), otherwise it may focus on the protruding line segment, and yield a misleading value. (See figures in the Addendum, “DTW: Truncation of the curve”).
- Optimizer:
  - Select SRSM for speed *or*
  - Select Direct GA for global optimality (at roughly $20 \times$ the cost)

DTW: Truncation of the curve



DTW Distance value *5.3*



Remove the noise on the simulated blue curve at the end. Now the DTW Distance value is *3.4*