



Optimization with LS-OPT[®] - Overview and new developments in V 5.2

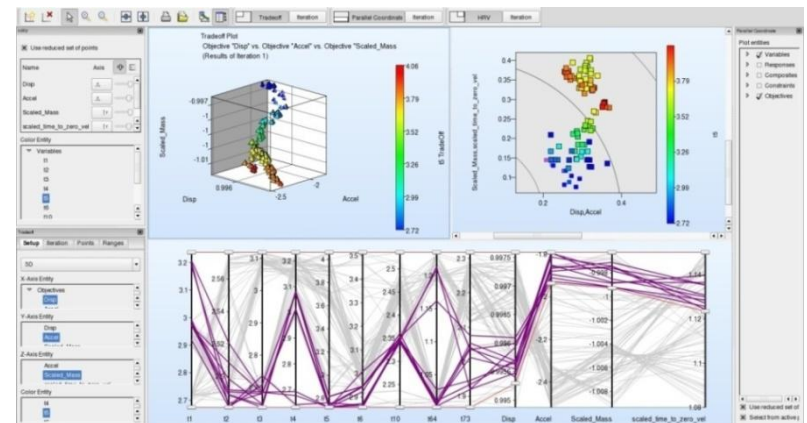
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70565 Stuttgart
<http://www.dynamore.de>



Outline

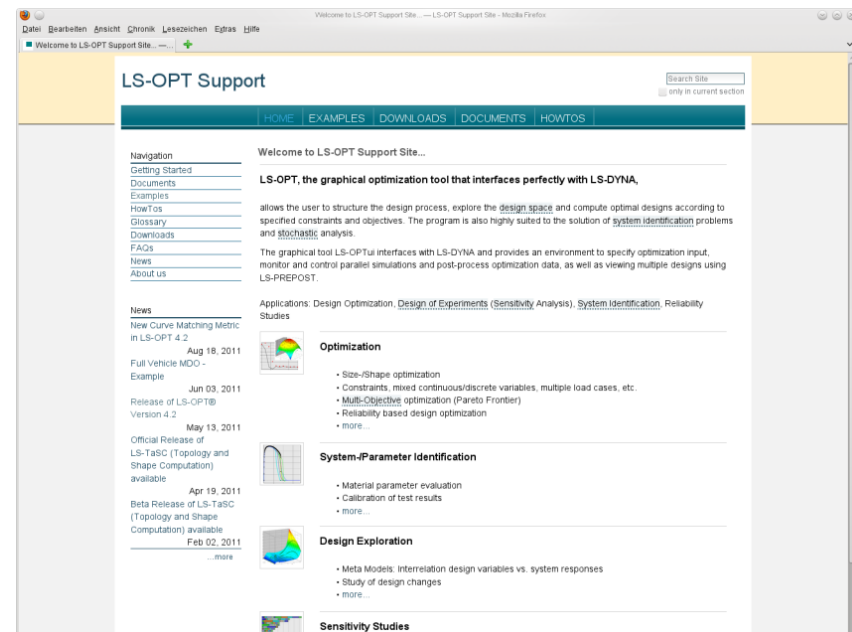
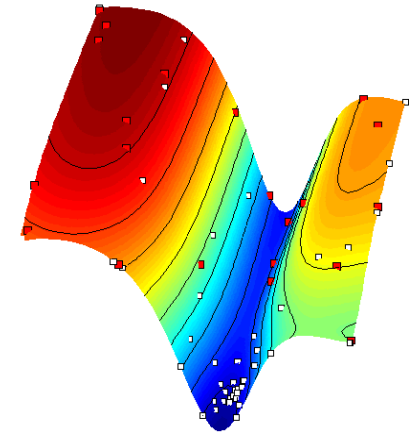
- Overview of methodologies and applications of LS-OPT
 - *DOE/Sensitivity analysis*
 - *Parameter identification*
 - *Shape optimization*
 - *Robustness analysis*
- New developments in LS-OPT 5.2
- Outlook



Introduction

→ About LS-OPT

- LS-OPT is a standalone optimization software
 - can be linked to any simulation code
 - Interface to LS-DYNA, MSC-Nastran, Excel, Matlab
 - User-defined Interface
- Current production version is LS-OPT 5.2
- LS-OPT Support web page
 - www.lsoptsupport.com
 - *Download of Executables*
 - *Tutorials*
 - *HowTos / FAQs*
 - *Documents*
 - *.....*



➔ About LS-OPT – General Aspects

■ Job Distribution - Interface to Queuing Systems

- *PBS, LSF, LoadLeveler, SLURM, AQS, User-defined, etc.*

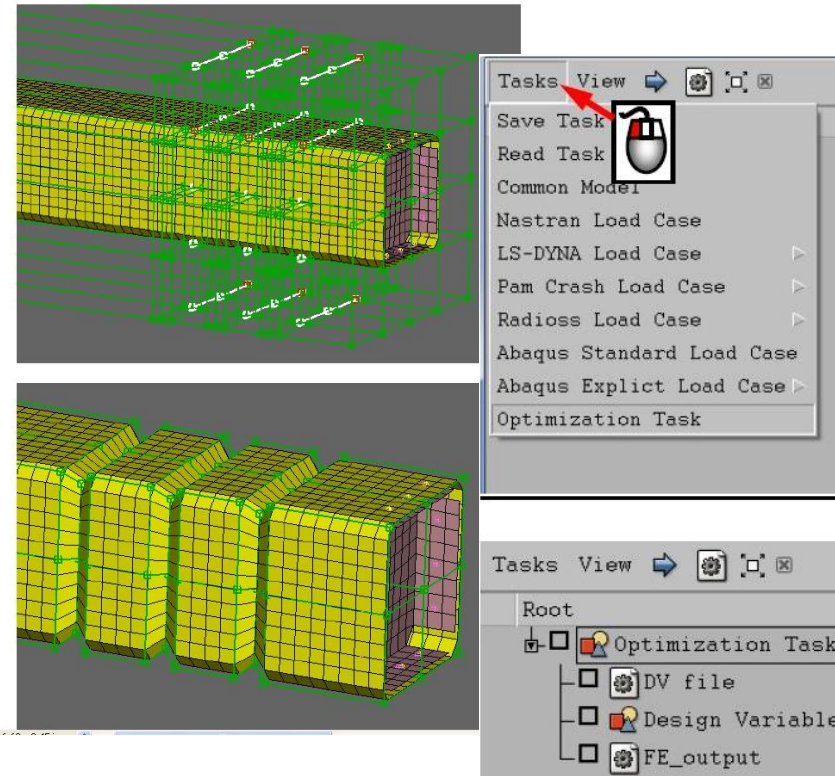
■ LS-OPT might be used as a “Process Manager”

■ Interfaces to Preprocessors (→ Shape Optimization)

- *LS-PrePost, ANSA, HyperMorph, ...*
- *User-defined interface*

■ Interfaces to Postprocessors

- *META Post: Allows extraction of results from any package (Abaqus, NASTRAN, ...) supported by META Post (ANSA package)*
- *User-defined interface*



LS-OPT – Overview Methodologies

■ Response Surface Method (RSM)

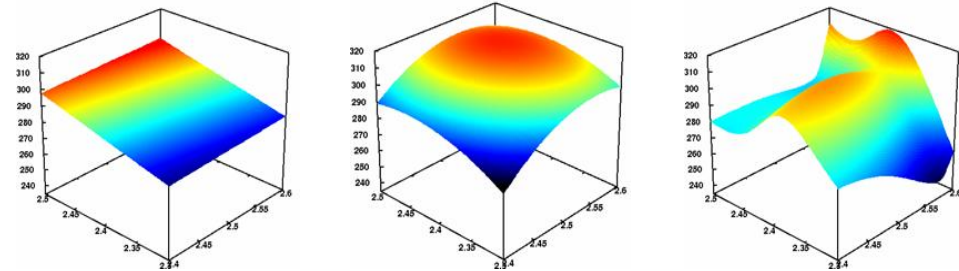
■ *Sequential Response Surface Method (SRSM)*

→ Metamodels

■ *Polynomials*

■ *Radial Basis Functions*

■ *Feedforward Neural Networks ...*



■ Genetic Algorithm (MOGA->NSGA-II)

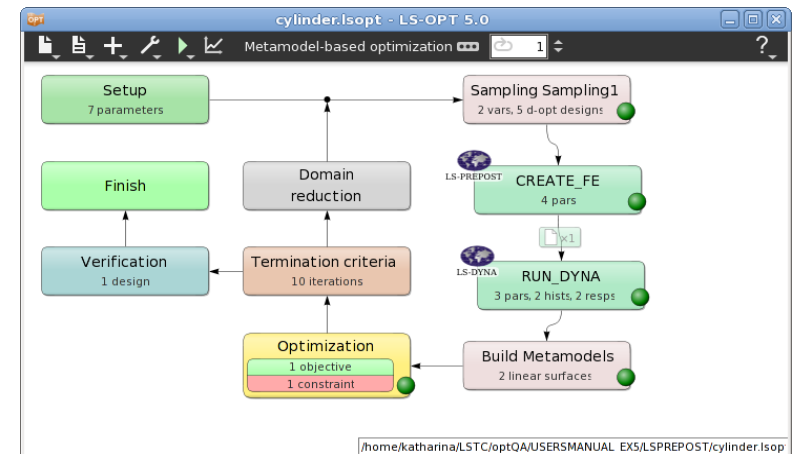
■ *Direct*

■ Metamodel-based

■ Monte Carlo Analysis

■ *Direct*

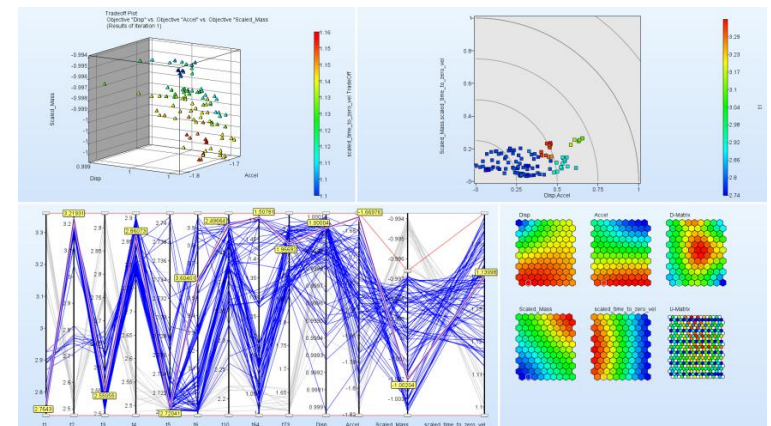
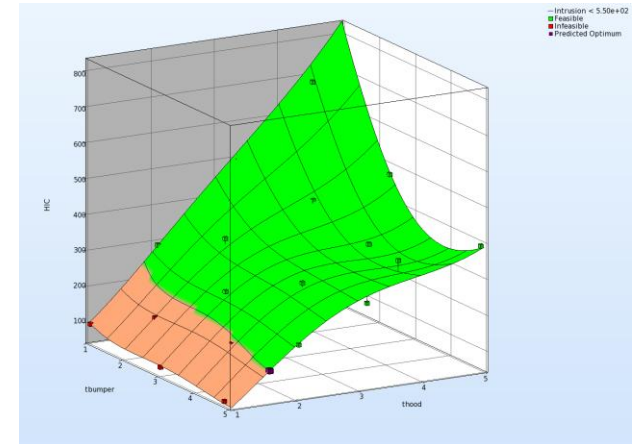
■ Metamodel-based



Applications of LS-OPT

■ Optimization

- *Size-/Shape optimization*
- *Constraints*
- *Mixed continuous/discrete variables*
 - *Specify sets of discrete variables (e.g. sheet thicknesses)*
- *Multiple load cases*
 - *Multi-disciplinary optimization (MDO)*
- *Multi-objective optimization (Pareto Frontier)*
- *Reliability based design optimization*
- *Methodologies*
 - *Meta-model based approaches*
 - *Genetic Algorithms (MOGA->NSGA-II)*

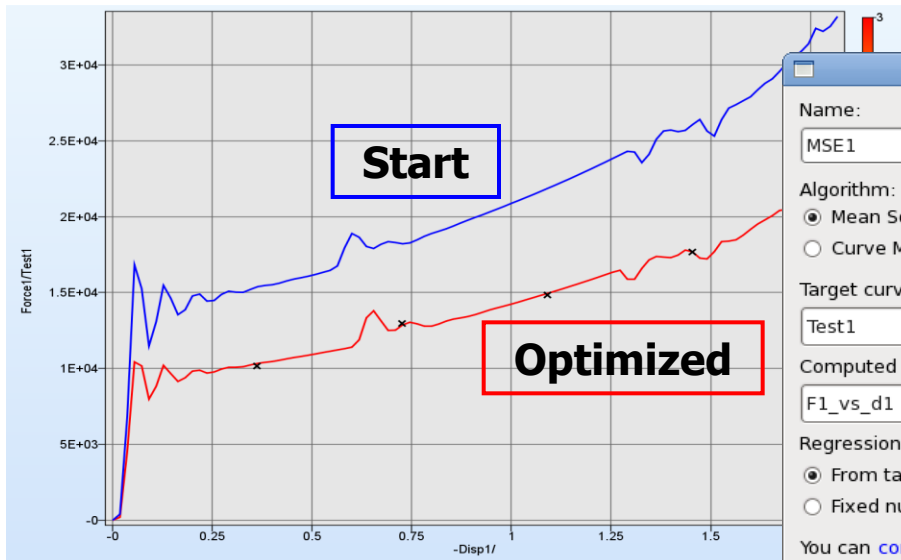


Applications of LS-OPT

■ Parameter/System Identification

- *Calibration of test and simulation curves or scalar values*
- *Visualization of test and simulation curve for comparison*

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



History matching composite

Name:

Algorithm:

Mean Square Error (difference in curve Y values)

Curve Mapping (size of area between curves)

Target curve: add new file history

Computed curve:

Regression points

From target curve

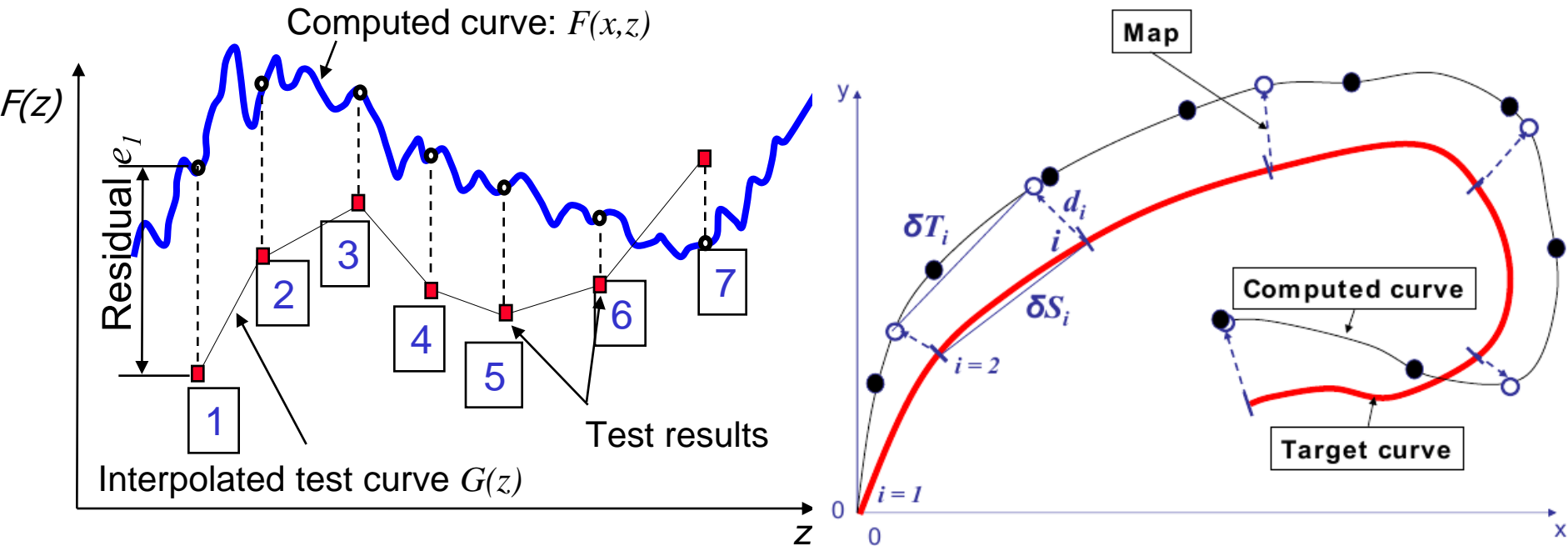
Fixed number (equidistant, interpolated)

You can [convert this composite to an expression](#) for further fine-tuning.

OK

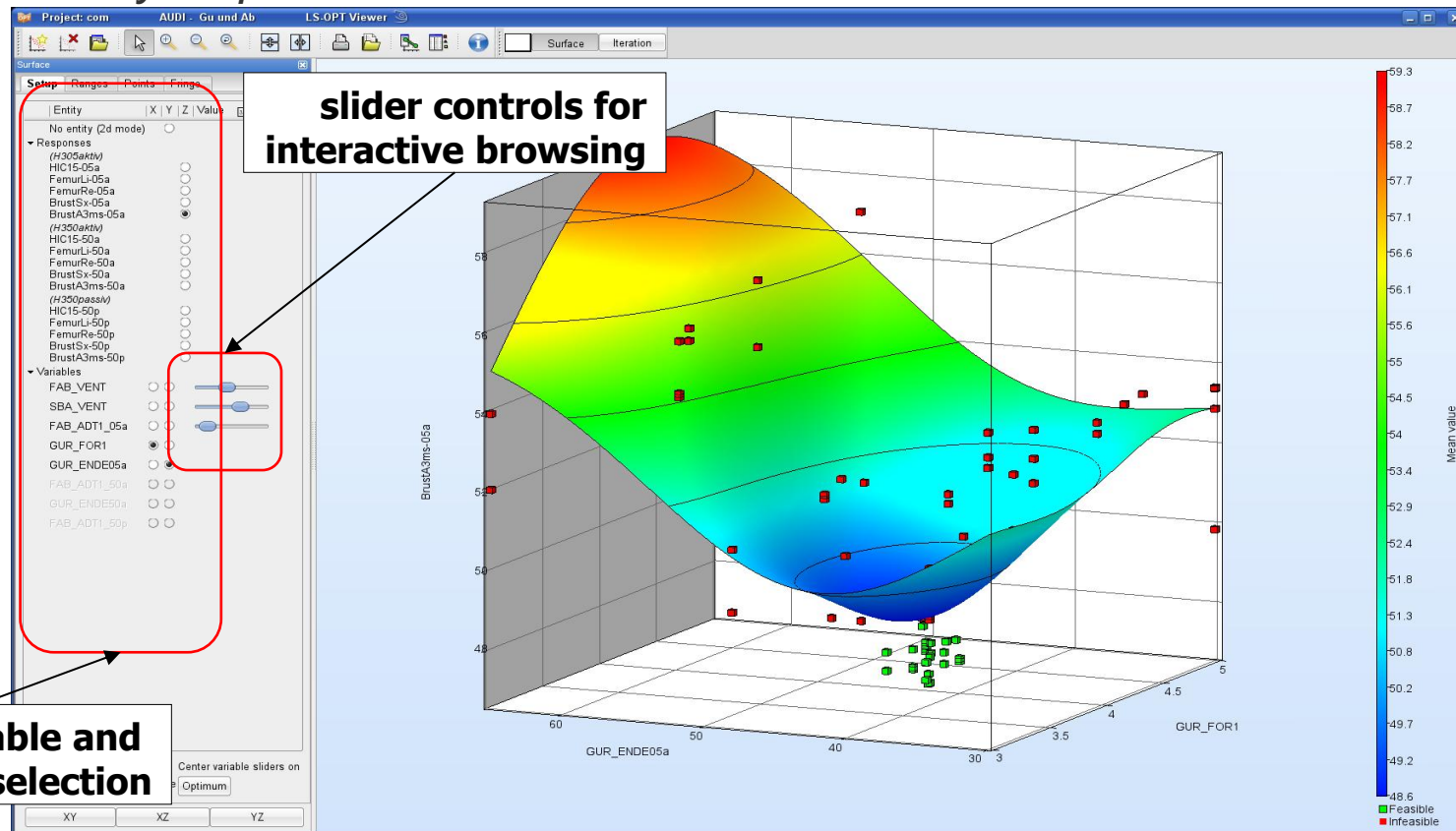
Applications of LS-OPT

Parameter Identification with Test Curves



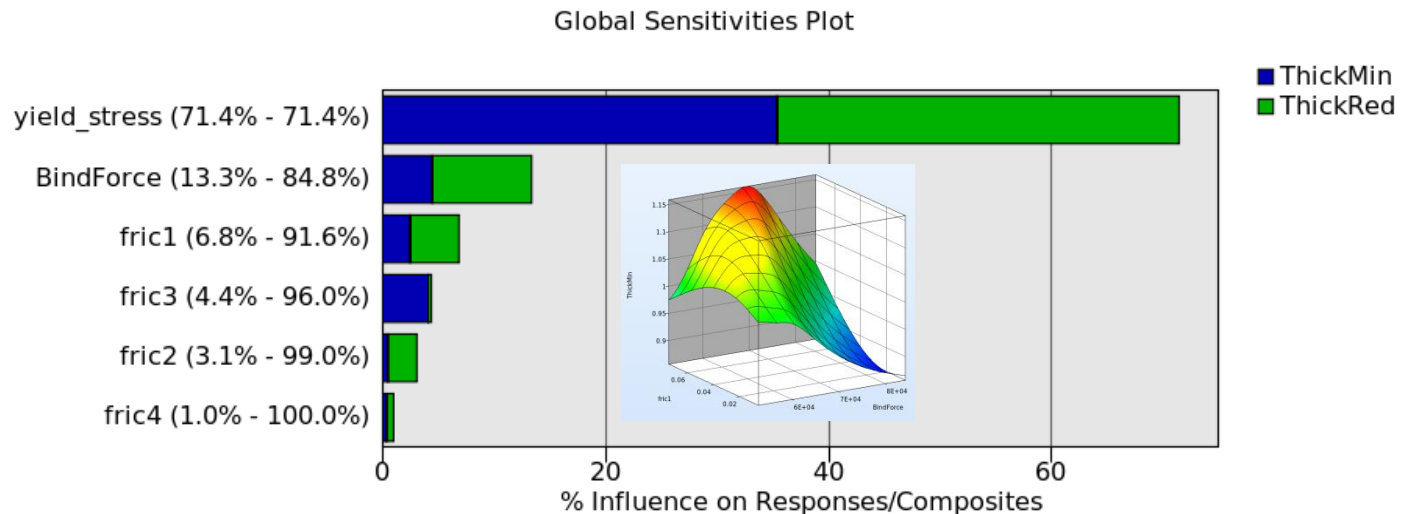
Applications of LS-OPT

- DOE-Studies, Design Exploration
 - *Visualization: 2D/3D sections of the surfaces, 1 or 2 selected variables vs. any response*



Applications of LS-OPT

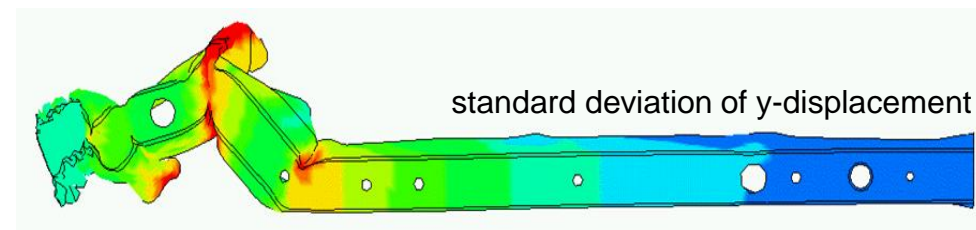
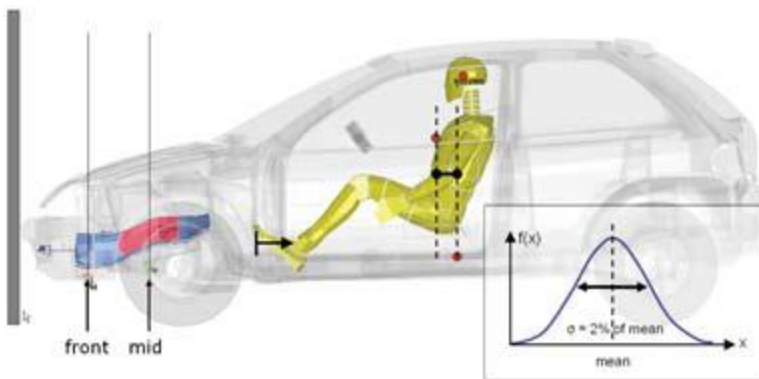
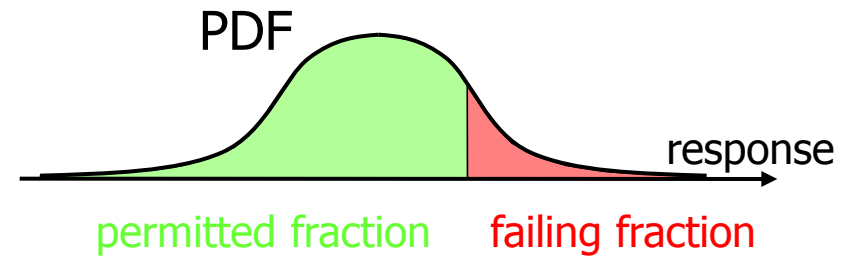
- Sensitivity Studies (ANOVA, Sobol)
 - *Contribution of variables to system performance*
 - *Identification of significant and insignificant variables*
 - *Ranking of importance*



Applications of LS-OPT

- Robustness/Reliability Analysis

- *Consideration of uncertainties*
- *Evaluation of reliability (probability of failure)*
- *Statistics (mean, std, ...)*
- *Correlation analysis*
- *Confidence intervals*
- *Outlier analysis*
- *Fringe statistical results on FE model*





New developments in V 5.2

Integrated Job Progress Window

- Output, progress, job control, post-processing integrated with GUI
 - Unifies platforms (Win/Linux)
- Global progress shown
- Diagnostics:
 - Warnings and errors highlighted

The screenshot shows the 'Metamodel-based optimization' window. At the top, a flowchart illustrates the process: '2 parameters' leads to '2 vars, 5 d-opt designs', which then branches into 'Domain reduction (SRSM)', 'Verification (1 design)', and 'Termination criteria (3 iterations)'. 'Domain reduction (SRSM)' leads to 'Finish', and 'Verification (1 design)' also leads to 'Finish'. 'Termination criteria (3 iterations)' leads to '1' (2 pars, 5 resps), which then leads to 'Domain reduction (SRSM)'. Below the flowchart, a 'Progress' window shows 'Global progress iteration:3' at 37%. A table lists job IDs, components, iterations, and expected iterations, with most jobs showing 'Normal Termination' and one showing 'Running 50%'. On the right, there are buttons for 'View log', 'Open folder', 'LS-OPT', 'Postprocessor', 'Kill', and 'Accelerated kill'.

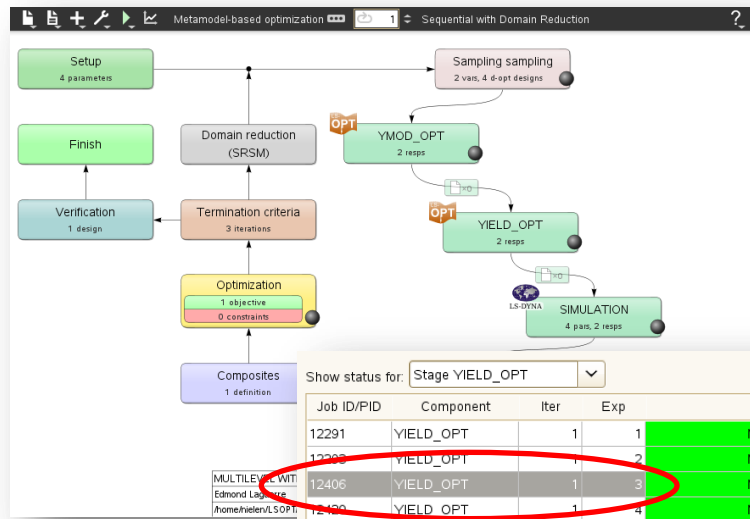
Job ID/PID	Component	iter	Exp	Status
25706	1	1	1	Normal Termination
25709	1	1	2	Normal Termination
25713	1	1	3	Normal Termination
25716	1	1	4	Normal Termination
25720	1	1	5	Normal Termination
25760	1	2	1	Normal Termination
25763	1	2	2	Normal Termination
25766	1	2	3	Normal Termination
25769	1	2	4	Normal Termination
25772	1	2	5	Normal Termination
25814	1	3	1	Normal Termination
25818	1	3	2	Normal Termination
25821	1	3	3	Running 50%
0	1	3	4	Waiting...

The screenshot shows the 'Metamodel-based optimization' window. At the top, a flowchart illustrates the process: 'Setup (2 parameters)' leads to 'Sampling 1 (2 vars, 5 d-opt designs)', which then branches into 'Domain reduction (SRSM)', 'Verification (1 design)', and 'Termination criteria (3 iterations)'. 'Domain reduction (SRSM)' leads to 'Finish', and 'Verification (1 design)' also leads to 'Finish'. 'Termination criteria (3 iterations)' leads to '1' (2 pars, 5 resps), which then leads to 'Domain reduction (SRSM)'. Below the flowchart, a 'Warning' window is open, displaying a log of events. The log shows a remark about point 6 being removed and an error message stating 'All analysis jobs failed' with common causes like 'Wrong name for the executable' and 'Job memory exceeded'.

```

09:13:10 AM REMARK: Point 6 removed (closer than 0.01 tolerance from fixed point 1)
09:13:10 AM
09:13:21 AM
09:13:21 AM
09:13:21 AM ERROR: All analysis jobs failed.
09:13:21 AM Double-click on the red Stage LED.
09:13:21 AM Select a failed run and then "View log" to display the solver log.
09:13:21 AM Common causes are:
09:13:21 AM Wrong name for the executable.
09:13:21 AM Job memory exceeded.
09:13:21 AM
09:13:21 AM
09:13:21 AM
    
```

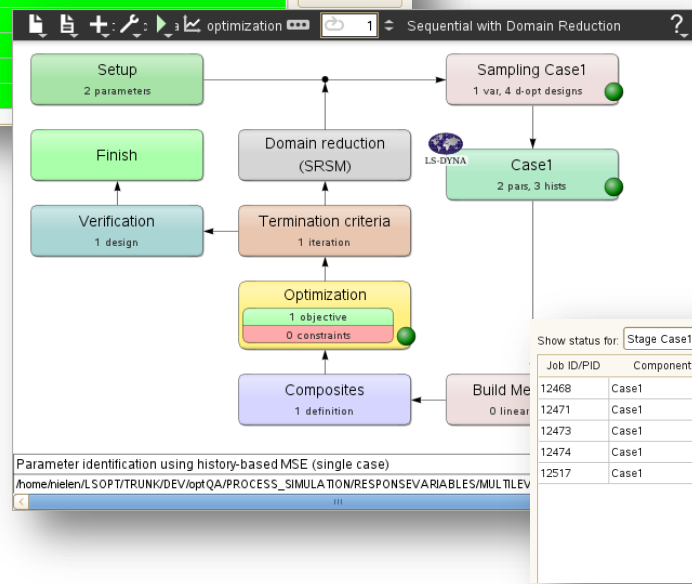

Multilevel Optimization: Navigating the Levels



Outer level

Navigate to ...
using ...

Job ID/PID	Component	Iter	Exp	Status
12468	Case1	1	1	Normal Termination
12471	Case1	1	2	Normal Termination
12473	Case1	1	3	Normal Termination
12474	Case1	1	4	Normal Termination
12517	Case1	2	1	Normal Termination



Inner level

- Controlling *LS-OPT* from *LS-OPT* for multi-level problems, e.g. multi-scale parameter identification, tolerance optimization.

Tolerance Optimization

- Parameters

- 6 thicknesses bounded by tolerance: $t \in U[\bar{t}(1 - \delta_t), \bar{t}(1 + \delta_t)]$
 - 1 relative tolerance (%) parameter: δ_t

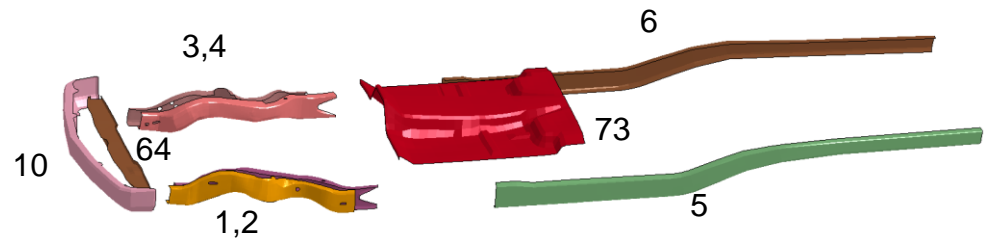
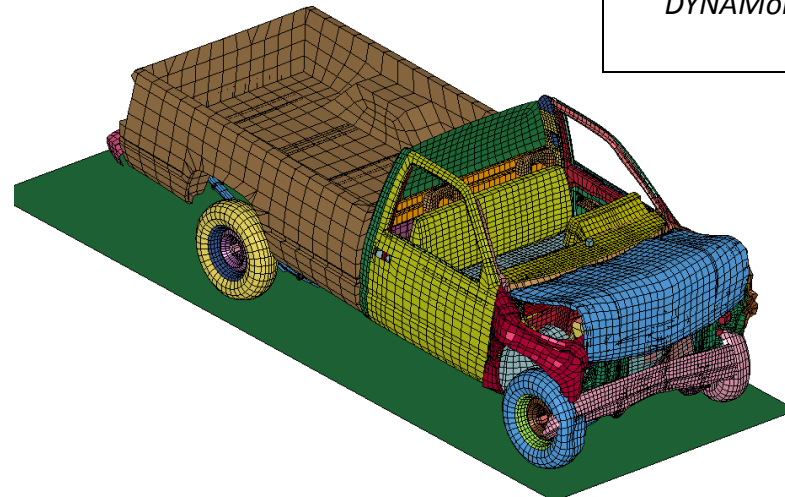
- Objective Functions:

- $\min_{\bar{t}, \delta_t} \text{Mass}(\bar{t})$
 - $\max_{\bar{t}, \delta_t} \delta_t$

- Performance constraints

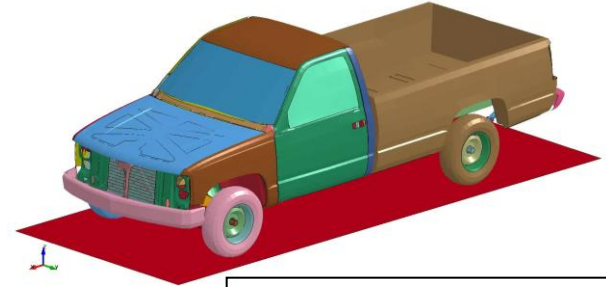
- $P(\text{pulse}_1(\bar{t}) > 1) \leq \varepsilon$
 - $P(\text{pulse}_2(\bar{t}) > 1) \leq \varepsilon$
 - $P(\text{disp}(\bar{t}) > 1) \leq \varepsilon$

Basudhar, A. Tolerance Optimization using LS-OPT, DYNAMore Forum, Bamberg, October 2014



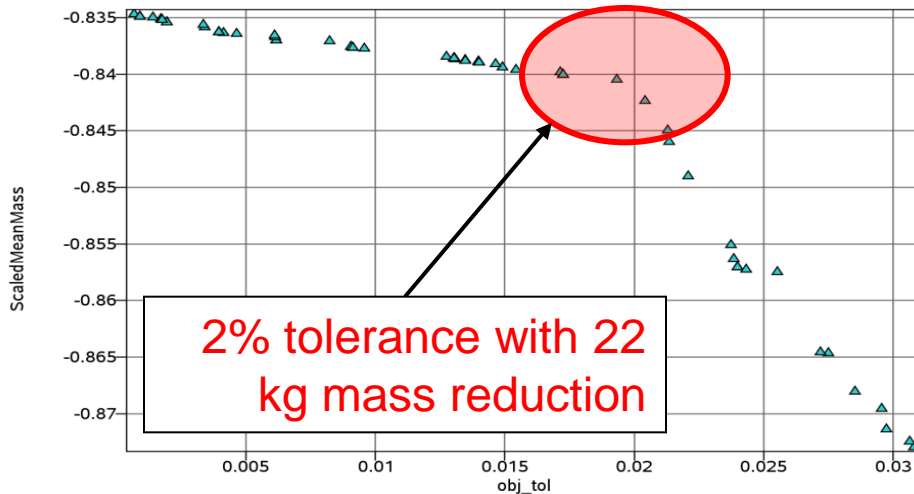
Trading performance and design tolerance

Total vehicle mass: 1800 kg
Mass of optimized parts: 138 kg
Maximum Mass Reduction: 23 kg
Maximum Tolerance: 0.031
with corresponding mass reduction 18 kg



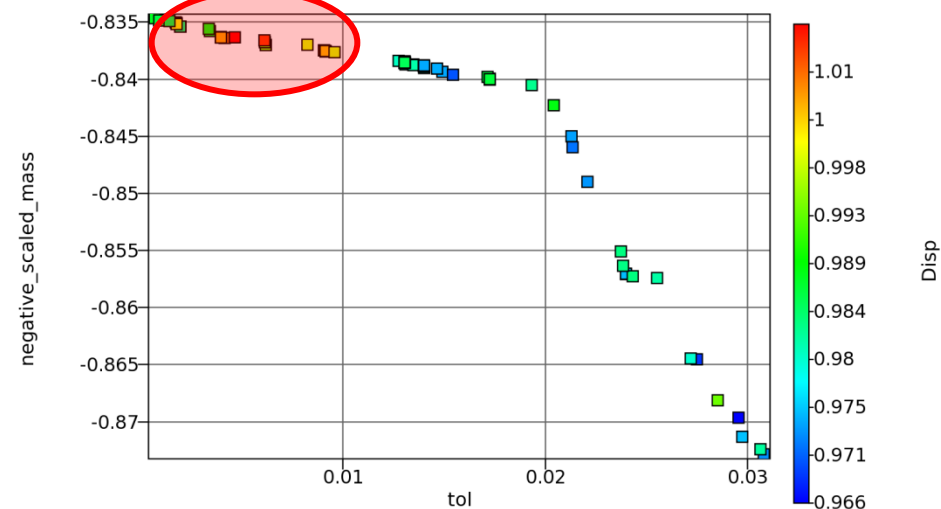
Basudhar, A. Tolerance Optimization using LS-OPT, DYNAMore Forum, Bamberg, October 2014

Tradeoff Plot
Objective "obj_tol" vs. Objective "ScaledMeanMass"
(Results of Iteration 50)



Exploration

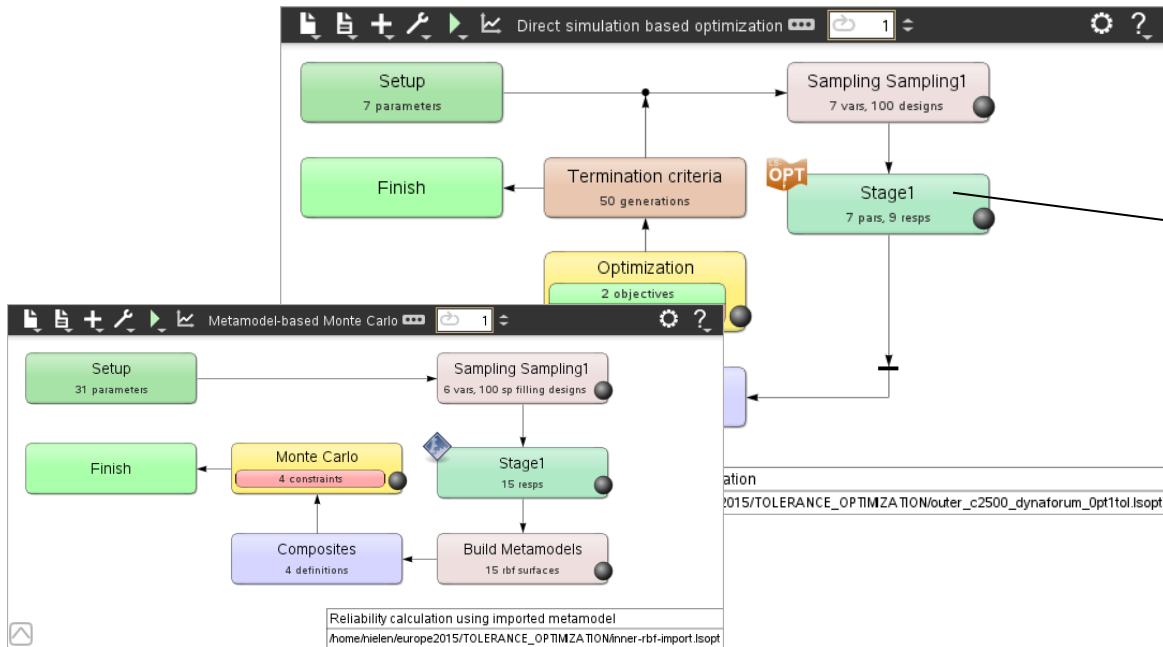
Scatter Plot
Variable "tol" vs. Composite "negative_scaled_mass"
(Results of Iteration 1)



Validation

Tolerance Optimization using Statistics Interface

- Example was done using a multi-level setup: *Optimization* cycles over *Metamodel-based Monte Carlo*
- Automated import of existing metamodel can be done
- Reliability Statistics interface extracts probability of failure
- Future implementation simplified to single level



Name	Subcase	Multiplier	Offset
Pf_scaled_stage2_pulse		n/a	n/a

Not metamodel-linked Dump formula file

Component	Iteration
Global	<input type="radio"/> Last iteration
Variables	<input checked="" type="radio"/> Iteration: 1
Dependents	
Responses	
Composite responses	
Objectives	
Constraints	
Disp	<input type="radio"/> Number of samples
scaled_stage1_pulse	<input type="radio"/> Mean
scaled_stage2_pulse	<input type="radio"/> Standard deviation
scaled_mass	<input checked="" type="radio"/> P[Resp>UB]
	<input type="radio"/> Number of samples > LB
	<input type="radio"/> Number of samples < UB

Transfer responses/histories to input files

YModRV
 Response →
 Variable ←

Parameter Setup Stage Matrix Sampling Matrix Resources Features

YModRV
 YieldRV
 tbumper
 thood

Legend:
 [Icon] - Parameter found in file(s) (hover mouse above to see filename(s))
 [Icon] - Parameter manually added
 [Icon] - Parameter linked to a response

OK

Parameter Setup Stage Matrix Sampling Matrix Resources Features

Show advanced options

Type	Name	Starting	Minimum	Maximum	Delete
Response Variable	YModRV	YMod_OPT_EXPR			
Response Variable	YieldRV	Yield_OPT_EXPR			
Continuous	tbumper		3	1	5
Continuous	thood		1	1	5

- **Response:** Substitute a response of a parent stage in a downstream input file
- **History:** Create LS-DYNA *DEFINE_CURVE to use as *INCLUDE file down stream

Settings: FE Postprocessors & Text Viewer

Path to executables

LS-PREPOST
 Use default (LS-PREPOST v2)
 Custom path:

Text-file viewer
 Use default (genex)
 Custom path:

User-defined postprocessors:

Name	Path	Delete
LSPPP_4	/home/nielen/bin/lsprepost	<input type="button" value="Browse"/> x
LSPPP_2	/home/nielen/LSOPT_EXE/lsprepost	<input type="button" value="Browse"/> x

[Add](#)

- Browse LS-PrePost executables
- Third Party FE post-processor
- Third Party text viewer

2 Sequential with Domain Reduction

g 1
designs

Show status for: All

Global progress Iteration: 2 100 %

Job ID/PID	Component	Iter	Exp	Status
25038	1	1	1	Normal Termination
25040	1	1	2	Normal Termination
25043	1	1	3	Normal Termination
25044	1	1	4	Normal Termination
25047	1	1	5	Normal Termination
25072	1	2	1	Normal Termination

Tools

LS-PrePost

LSPPP_2

LSPPP_4

Post-processing: Comparison Metamodels

- Define any number of metamodel configurations for comparison
- LS-OPT creates metamodels in addition to main metamodel

Sampling & Metamodel Settings Active Variables Features Constraints Comparison Metamodels

Name	Active	Overwrite	Delete	Type
Polynomial_quad	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Edit ×	Polynomial
Kriging	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Edit ×	Kriging
FFNN_6	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Edit ×	FFNN_6
RBF_Gaussian	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Edit ×	RBF_Gaussian
SVR	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Edit ×	SVR

All active All overwrite

Name
FFNN_6

Active

Overwrite

Metamodel

Polynomial

Feedforward Neural Network

Radial Basis Function Network

Kriging

Support Vector Regression

Parallel Builder

Set Efficiency Options Reset

Number of Hidden Nodes in the Network

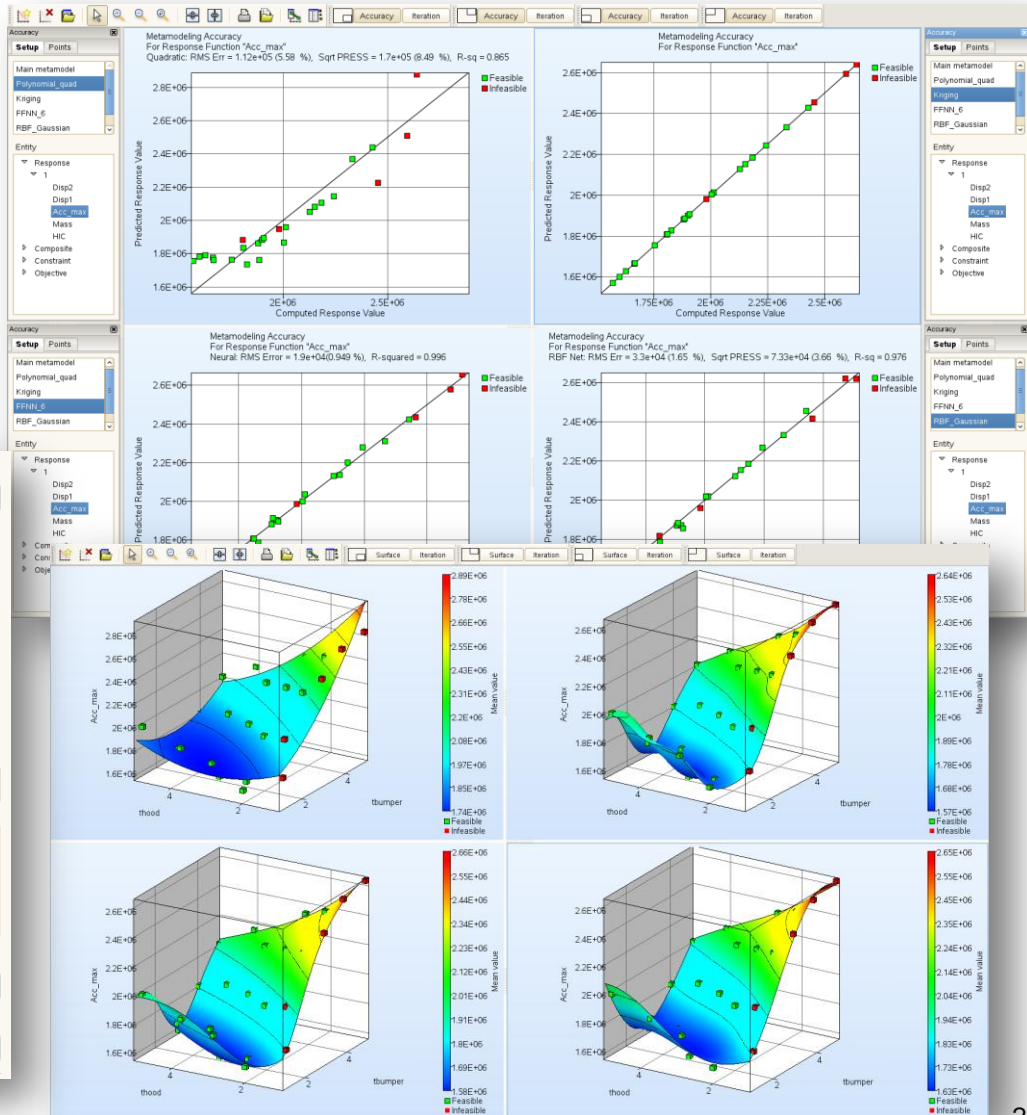
1 2 3 4 5 6 7

8 9 10

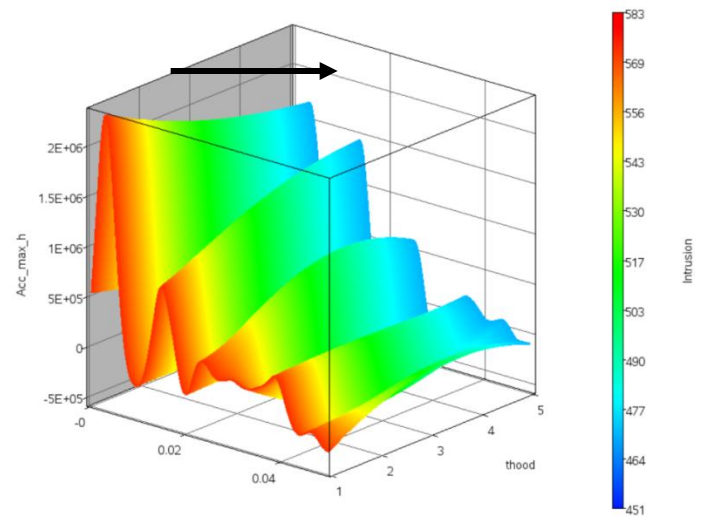
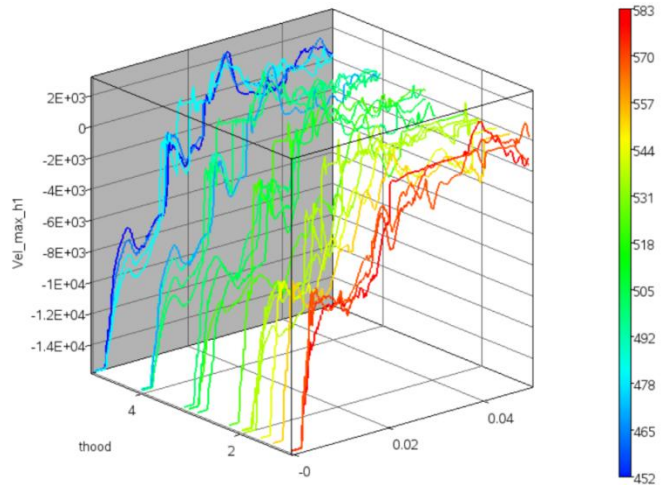
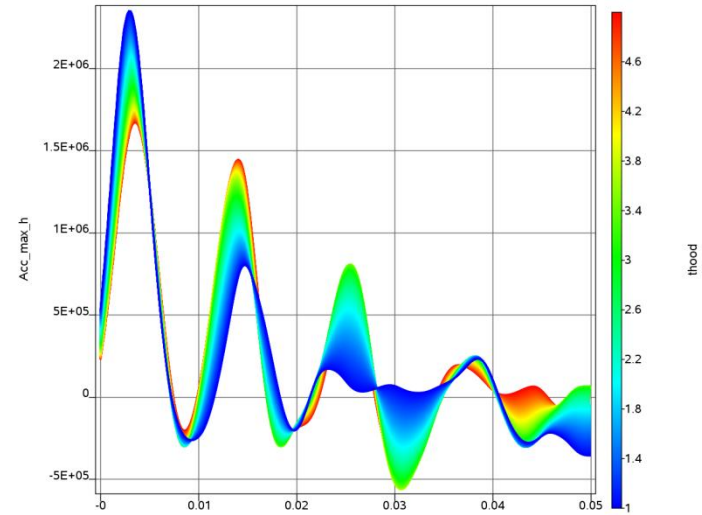
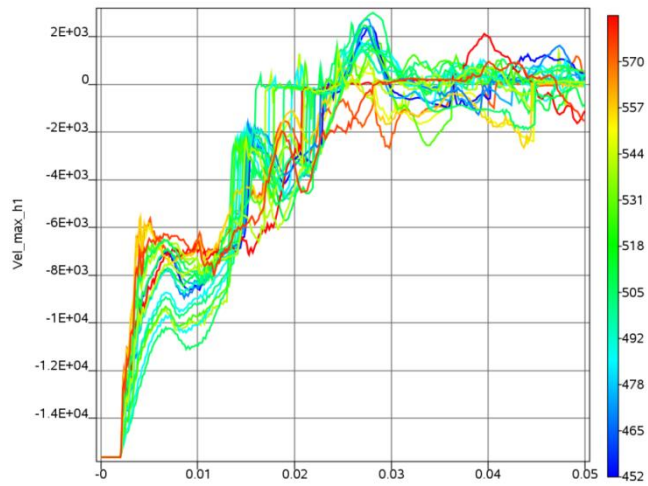
Default = Lin-1-2-3-4-5

Number of Committee Members
9 (default)

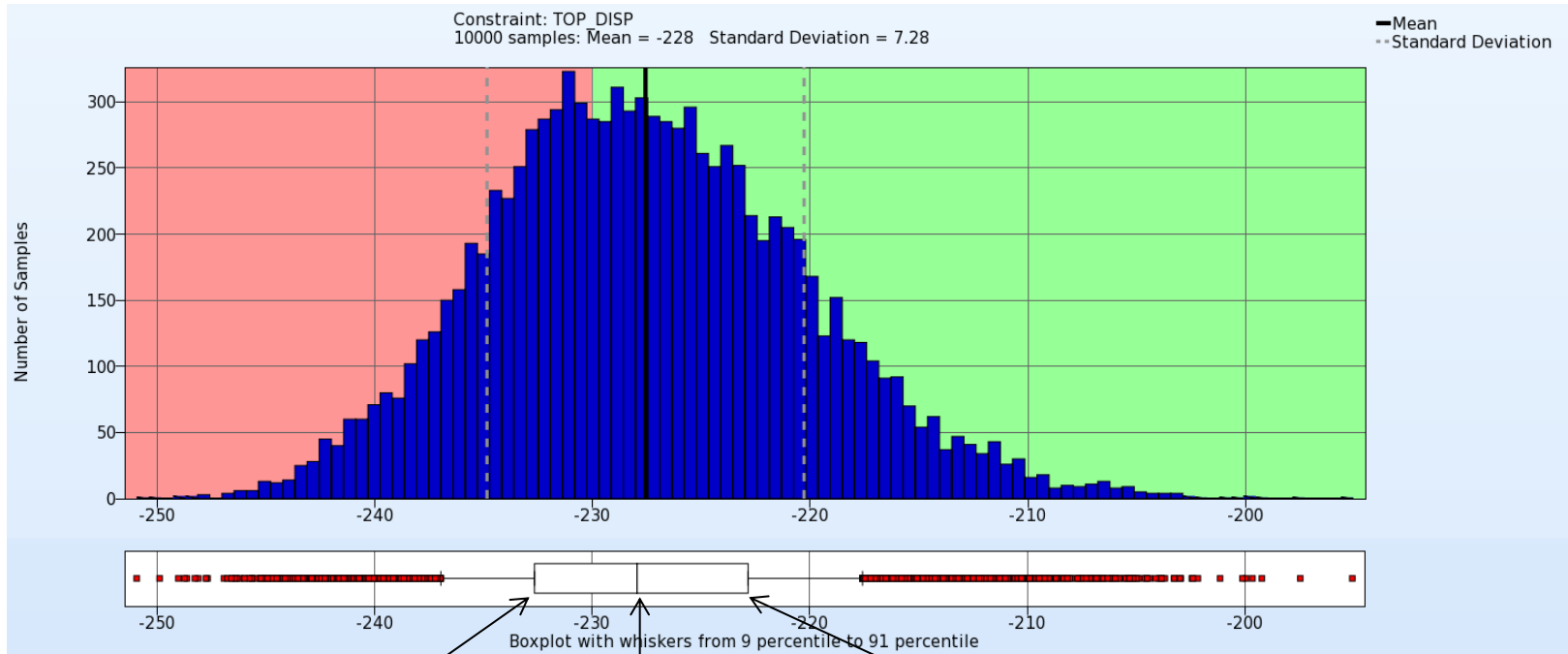
Half Number of Discarded Nets
2 (default)



3D history display (simulation & predicted)



Reliability Statistics: Boxplot



■ Whisker types:

- *Min/max*
- *Interquartile range*
- *Standard Deviation*
- *9%/91%*

1. Quartile

Median

3. Quartile

Other Features

- Matlab interface
 - *Recognizes and substitutes design variables in Matlab input*
- Encryption
 - *Encrypt LS-OPT input file*
- Metamodel import
 - *Import and apply to optimization or Monte Carlo analysis. Currently used in tolerance optimization.*
- Parallel extraction repair
- Parallel mode tracking
- Improvement of efficiency of curve mapping
- Additional feature to GenEx for extraction of history data
- Response file option
- GUI support for Abnormal Termination options
- Image of flow chart can be saved

Current and Future Development

- Classification (Basudhar)

- *Decision surfaces for instability in design*
- *Multi-objective optimization*
- *Material design optimization*

- Tables

- *Integration of tables, plots and simulations*
- *Filters, statistics, highlighting, sorting, categories, visualization*

- Digital Imaging Correlation

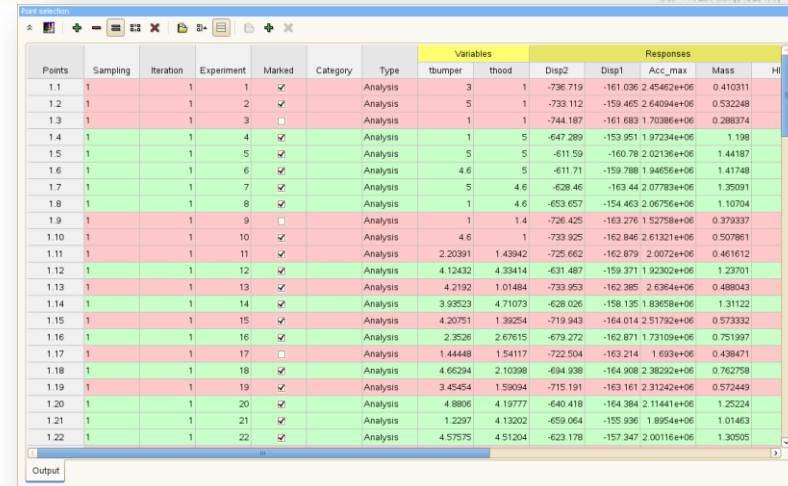
- *Material calibration using DIC spatial/temporal test results*

- Integrated Computational Materials Engineering

- *Multi-scale Material Modeling and Identification*
- *Integration of material design into structural design*

- Reliability

- *Accuracy: small probabilities. Sequential Adaptive Reliability Analysis*



Points	Sampling	Iteration	Experiment	Marked	Category	Type	Variables		Responses				
							tbumper	thood	Disp2	Disp1	Acc_max	Mass	Hi
1.1	1	1	1	✓		Analysis	3	1	-736.719	-161.036	2.45462e+06	0.410311	
1.2	1	1	2	✓		Analysis	5	1	-733.112	-159.465	2.64094e+06	0.532248	
1.3	1	1	3	✓		Analysis	1	1	-744.187	-161.683	1.70386e+06	0.288374	
1.4	1	1	4	✓		Analysis	1	5	-647.289	-153.951	1.97234e+06	1.139	
1.5	1	1	5	✓		Analysis	5	5	-611.59	-160.78	2.02136e+06	1.44187	
1.6	1	1	6	✓		Analysis	4	5	-611.71	-159.788	1.94656e+06	1.41748	
1.7	1	1	7	✓		Analysis	5	4	-628.46	-163.44	2.07783e+06	1.35091	
1.8	1	1	8	✓		Analysis	1	4	-653.657	-154.463	2.06756e+06	1.10704	
1.9	1	1	9	✓		Analysis	1	1	-726.425	-163.276	1.52758e+06	0.379337	
1.10	1	1	10	✓		Analysis	4	6	-733.925	-162.846	2.61321e+06	0.507861	
1.11	1	1	11	✓		Analysis	2.20391	1.43942	-725.662	-162.879	2.0072e+06	0.461612	
1.12	1	1	12	✓		Analysis	4.12432	4.33414	-631.487	-159.371	1.92302e+06	1.23701	
1.13	1	1	13	✓		Analysis	4.2192	1.01484	-733.953	-162.385	2.6364e+06	0.488043	
1.14	1	1	14	✓		Analysis	3.93523	4.71073	-628.026	-158.135	1.83658e+06	1.31122	
1.15	1	1	15	✓		Analysis	4.20751	1.39254	-719.943	-164.014	2.51792e+06	0.573332	
1.16	1	1	16	✓		Analysis	2.3526	2.67615	-679.272	-162.871	1.73109e+06	0.751997	
1.17	1	1	17	✓		Analysis	1.44448	1.54117	-722.504	-163.214	1.693e+06	0.438471	
1.18	1	1	18	✓		Analysis	4.66294	2.10398	-694.938	-164.908	2.38292e+06	0.762758	
1.19	1	1	19	✓		Analysis	3.45454	1.59094	-715.191	-163.161	2.31242e+06	0.572449	
1.20	1	1	20	✓		Analysis	4.8806	4.19777	-640.418	-164.384	2.11441e+06	1.25224	
1.21	1	1	21	✓		Analysis	1.2297	4.13202	-659.064	-155.936	1.8954e+06	1.01463	
1.22	1	1	22	✓		Analysis	4.57575	4.51204	-623.178	-157.347	2.00116e+06	1.30505	