APPLICATIONS OF SHAPE OPTIMIZATION WITH LS-OPT AND ANSA

[1]Heiner Müllerschön*, [1]Marko Thiele, [2]Wolfram Mühlhuber, [2]Uwe Gerlinger
[1]DYNAmore GmbH, Germany, [2]AUDI AG, Germany

KEYWORDS - Optimization, Morphing, META-Models, Crashworthiness, Process Flow

ABSTRACT - The purpose of this paper is to explore aspects of shape and geometry optimization for nonlinear applications and to propose optimization strategies for such problems.

Different optimization strategies are discussed and pros and cons are compared. The application of the Successive Response Surface Method (SRSM) for optimization of nonlinear applications is demonstrated. This is performed using LS-OPT as optimization software and ANSA as pre-processor for geometry variation. For this ANSA is run in batch mode and is driven by parameterized control files, which interface with the optimization software LS-OPT. By the variation of morphing control parameters or just geometrical translational or rotational operations the design is optimized with respect to shape properties and geometrical configuration. After morphing operations usually automated batch meshing of the considered parts is applied.

The set-up of the process flow and how the several programs interface with each other is also described in the paper.

In addition, a methodology to get a reliable surrogate model using neural networks is introduced. The surrogate model (META-Model or Response Surface Model) approximates the relationship between design parameters and a simulation response and can be used to visualize and explore the design space.

One of the regarded examples treats the optimization of a crash box at AUDI. The procedure of generating an advanced µETA-model to get an approximation of the global design space using neural networks is demonstrated for this example. Furthermore, the visualization of multi-dimensional meta-models in two- and three-dimensional design space is illustrated by using the software D-SPEX. The program D-SPEX interfaces with LS-OPT as an advanced optimization and stochastic post-processor.

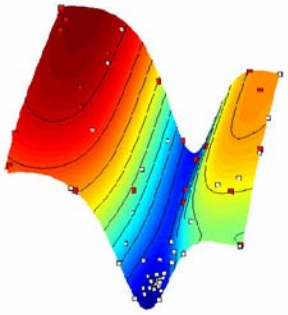
Applications of Shape Optimization with LS-OPT and ANSA

Heiner Müllerschön, Marko Thiele
DYNAmore GmbH, Germany
Wolfram Mühlhuber, Uwe Gerlinger
AUDI AG, Germany

DYNAmore GmbH
Industriestraße 2
70565 Stuttgart
http://www.dynamore.de

Overview

- Introduction
- Methodologies for Optimization in LS-OPT
- Example I
  - *Optimization of a Crash Box*
  - *Conclusions*
- Example II
  - *Sensitivity Study (DOE) for Radiation Analysis*
  - *Conclusions*



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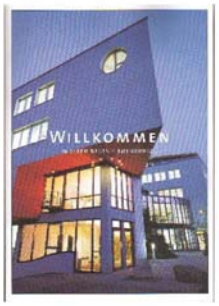
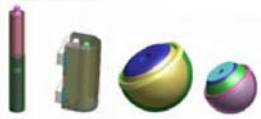
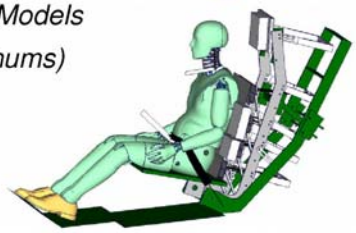
DYNA MORE

→ About DYNAmore

- Distributor of LS-DYNA and related software products in Germany, Austria, Switzerland and other european countries
- Further development and customization in collaboration with LSTC (long term relationship)
- DYNAmore in total 34 People (June 2007)
- LS-DYNA Software Models
  - *Many Dummy Models*
  - *Barrier Models*
  - *Pedestrian Safety Models*
  - *Human Models (Thums)*







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→ Optimization Competence Center at DYNAmore

- Many experience particularly in crashworthiness optimization, reliability and robustness studies, MDO, Meta-Modelling…
- Main optimization customers: Audi, BMW, TAKATA, BASF, ALCAN, Karmann, DOW Automotive

software
- LS-OPT (LSTC)
- Vanderplaats (VR&D) optimization products
- D-SPEX

engineering
- optimization engineering services
- consulting
- benchmarks

seminars
- several training classes
  - *optimization*
  - *robustness/reliability*
  - *parameter ident.*
- informational events

services
- support (phone, on-site)
- software development
- system integration and process flow

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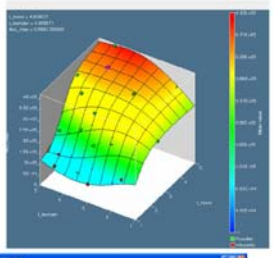
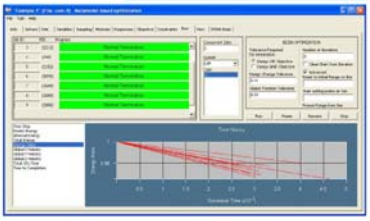
➔ About LS-OPT

- LS-OPT is a product of LSTC (Livermore Software Technology Corporation)
- LS-OPT can be linked to any simulation code – stand alone optimization software
- Methodologies/Features:
  - *Successive Response Surface Method (SRSM)*
  - *Reliability based design optimization (RBDO)*
  - *Multidisciplinary optimization (MDO)*
  - *Multi-Objective optimization (Pareto)*
  - *Discrete Optimization*
  - *numerical/analytical based sensitivities*
  - *Analysis of Variance (ANOVA)*
  - *Stochastic/Probabilistic Analysis*
  - *Monte Carlo Analysis using Metamodels*
  - …





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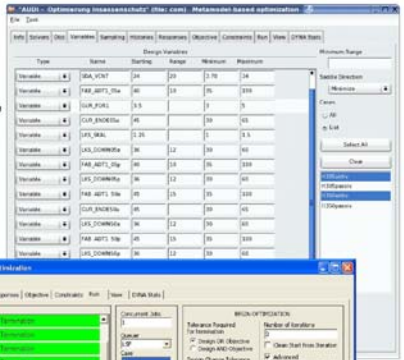
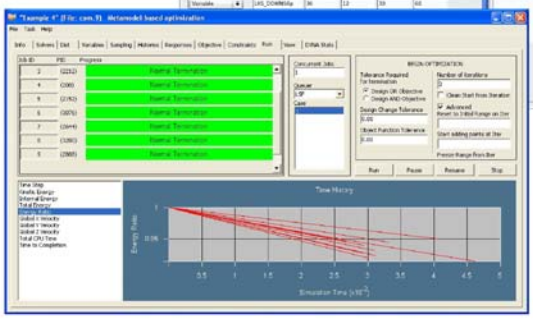
➔ About LS-OPT

- Job Distribution - Interface to Queuing Systems
  - *PBS, LSF, LoadLeveler, AQS, etc.*
- LS-OPT might be used as a "Process Manager"
- Shape Optimization
  - *Interface to SFE-Concept, Hypermesh ANSA, DEP-Morpher*
  - *User-defined interface to any Pre-Processor*
- Parameter Identification Module
- Visualization of Statistical Quantities on the FE-Model





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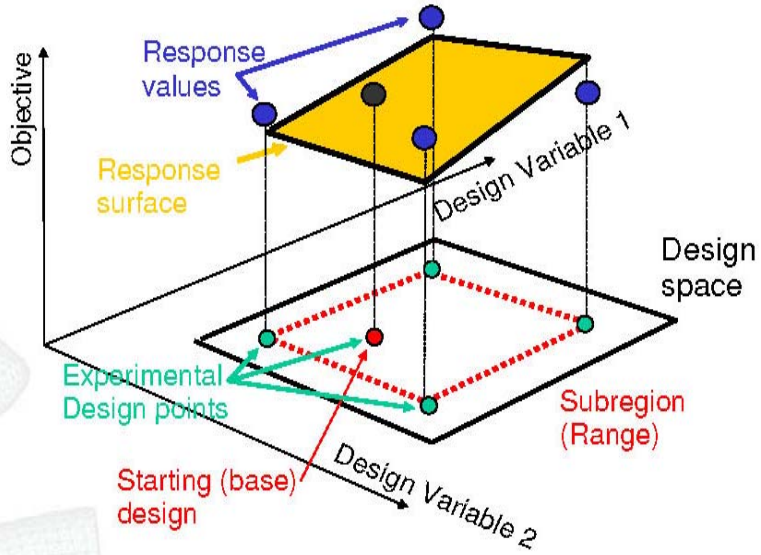
→ Response Surface Methodology - Optimization Process



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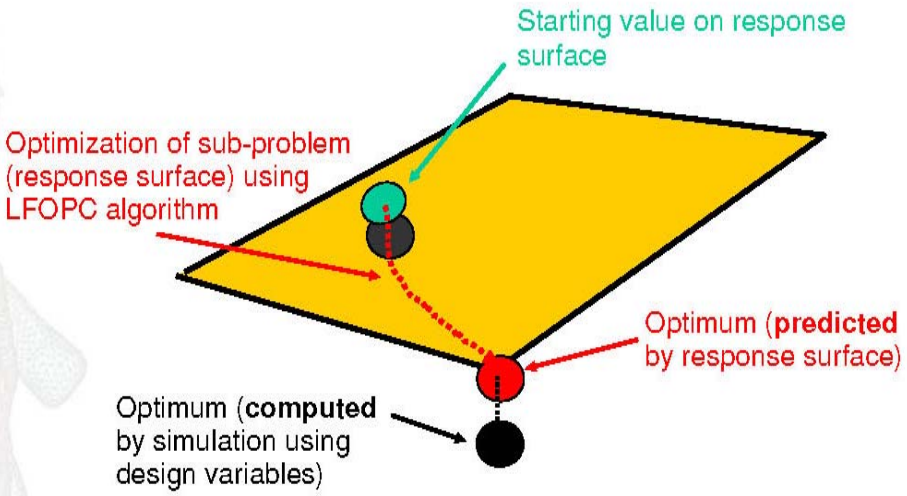
→ Find an Optimum on the Response Surface (one iteration)



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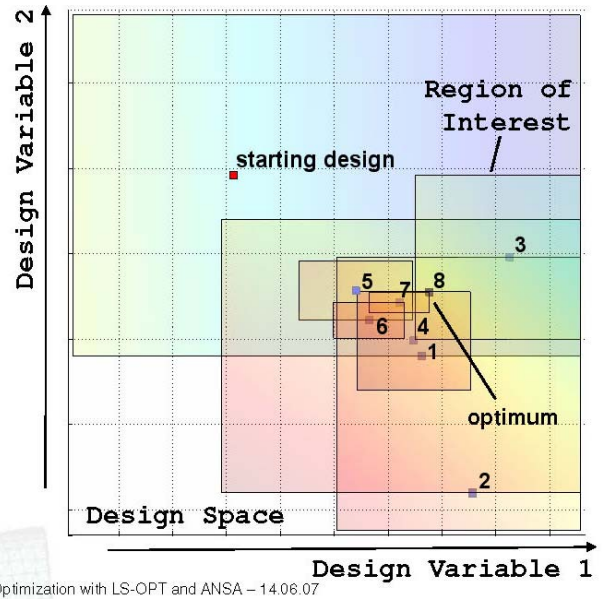
➔ Successive Response Surface Methodology



Methods - Optimization

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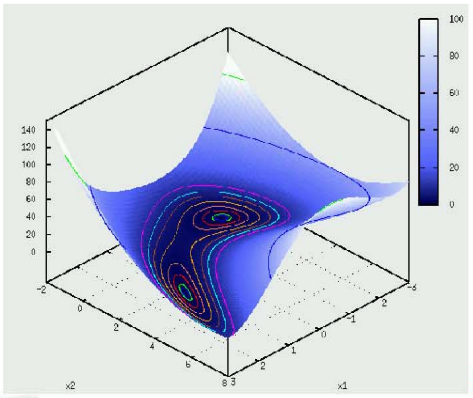
➔ Successive Response Surface Methodology

- Example - 4th order polynomial

$$g(\mathbf{x}) = 4 + \frac{9}{2}x_1 - 4x_2 + x_1^2 + 2x_2^2 - 2x_1x_2 + x_1^4 - 2x_1^2x_2$$



movie

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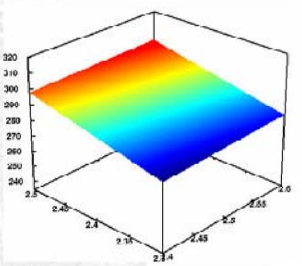
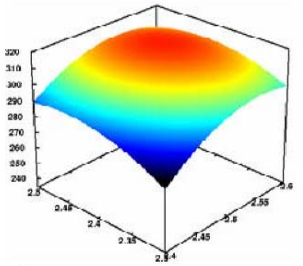
→ Response Surfaces (Meta Models)

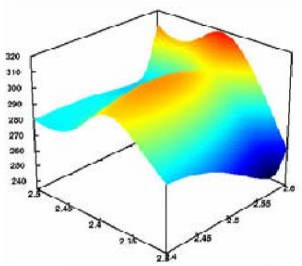
- Linear, Quadratic and Mixed polynomial based
- Neural Network and Kriging for Nonlinear Regression



linear polynomial



quadratic polynomial



neural network

Exploring Design Space using D-SPEX

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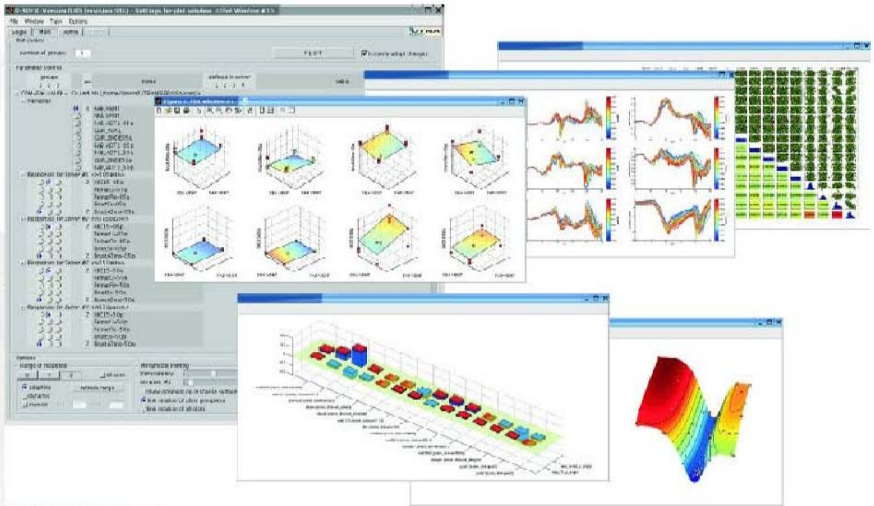
→ D-SPEX Meta-Model Viewer - Exploration of Design Space

- Compare response surfaces, curve plots, ant-hill plots, …



Example I - Optimization

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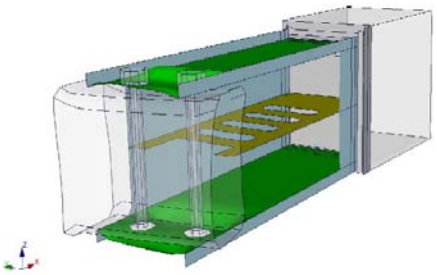
➔ Optimization of a Crash Box

- The objective is to improve the energy absorbtion of a crash box and to reduced the maximum force level
- **Sheet thickness variables** as well as **geometric variables** are considered
- **Test load is 1 m/s** boundary prescribed motion applied by a rigid wall
- Optimization formulation: a maximum load level (contact force) has not to be exceeded (**constraint**) while a maximum of energy has to be absorbed (**objective**)



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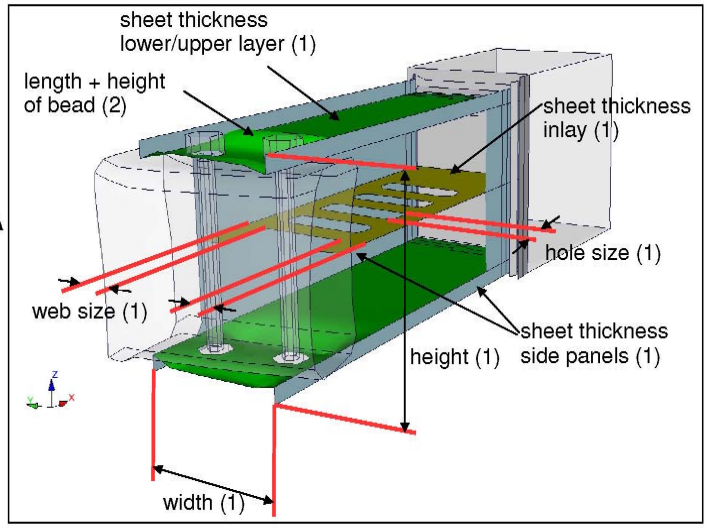
➔ Optimization of a Crash Box

- Total 9 design variables
- Use of Successive Response Surface Method with LS-OPT
- Parameterization by Morphing through ANSA
- In total 240 simulations within 15 iterations



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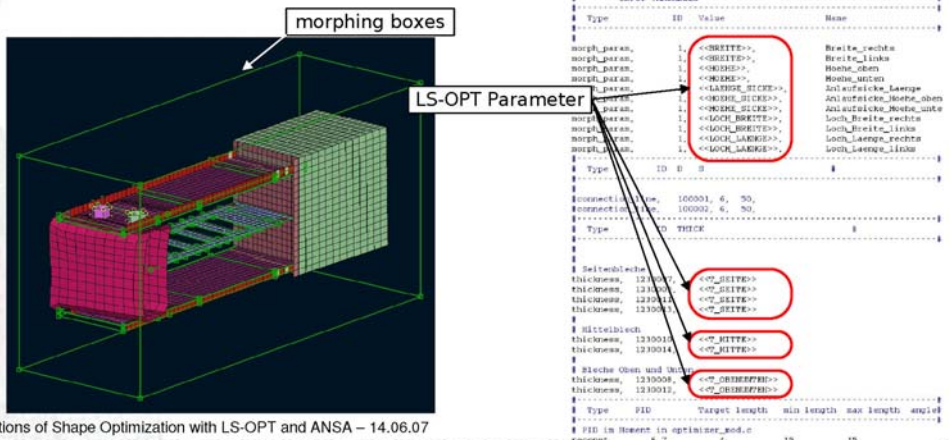
➔ Morphing with ANSA and LS-OPT

- ANSA is specified as Pre-Processor in LS-OPT
- Multiple crash simulation input files are generated automatically through ANSA in batch mode



Example I - Optimization

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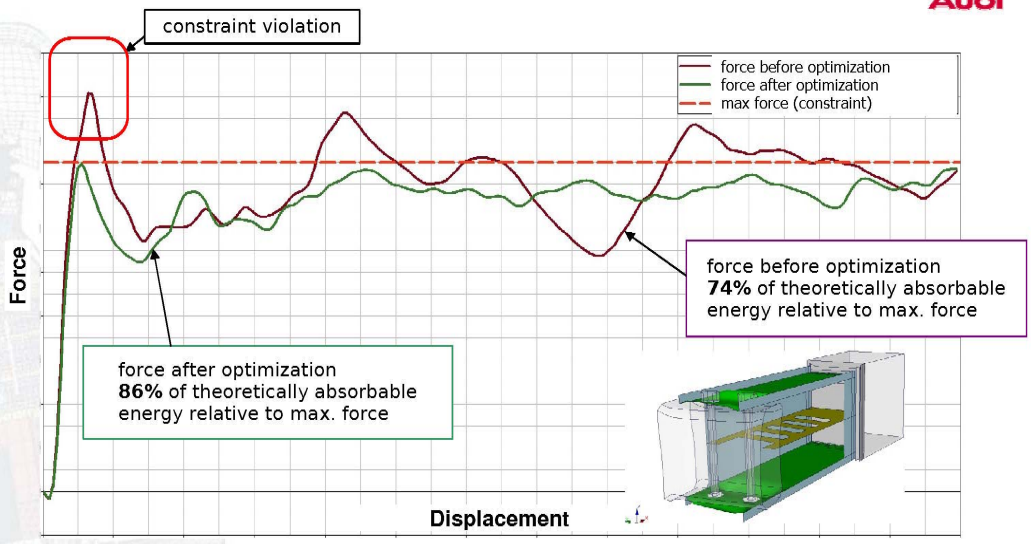
➔ Optimization Result



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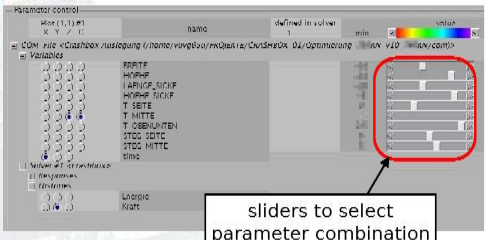
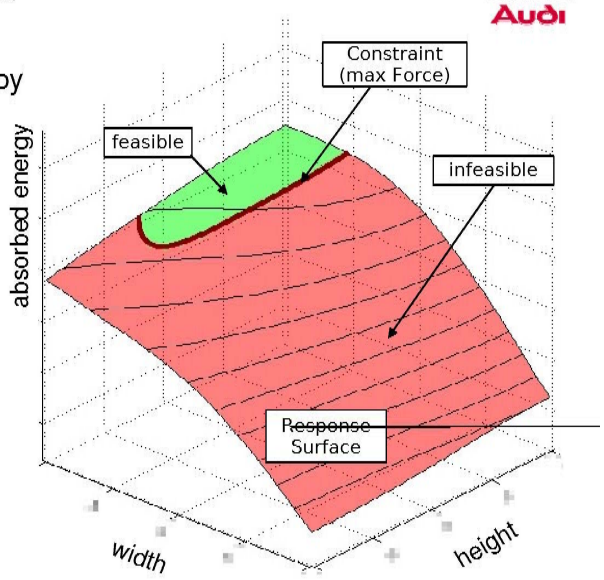
➔ Design Study using D-SPEX

- Visualization of the relationship between variables and responses by means of a response surface
- Can give a deeper understanding of the influences of parameters upon the results





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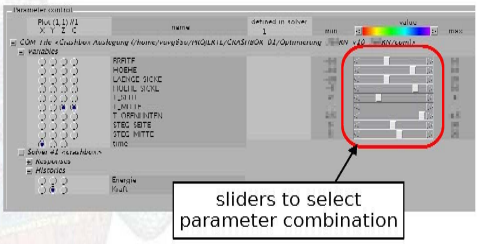
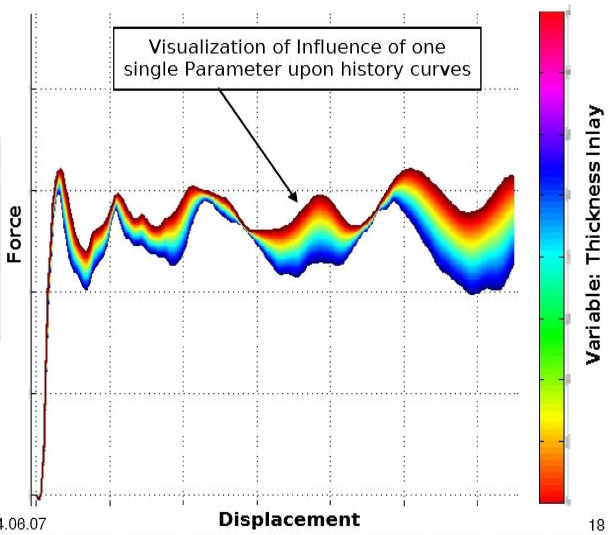
➔ Enhanced Visualization of Simulation results using D-SPEX

- Utilizing response surfaces to approximate curves for specific parameter combination





Conclusions

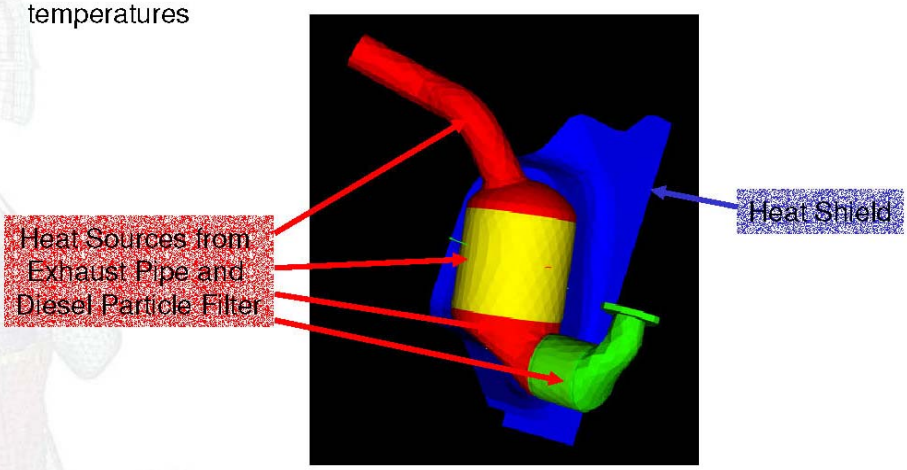
➔ Conclusions

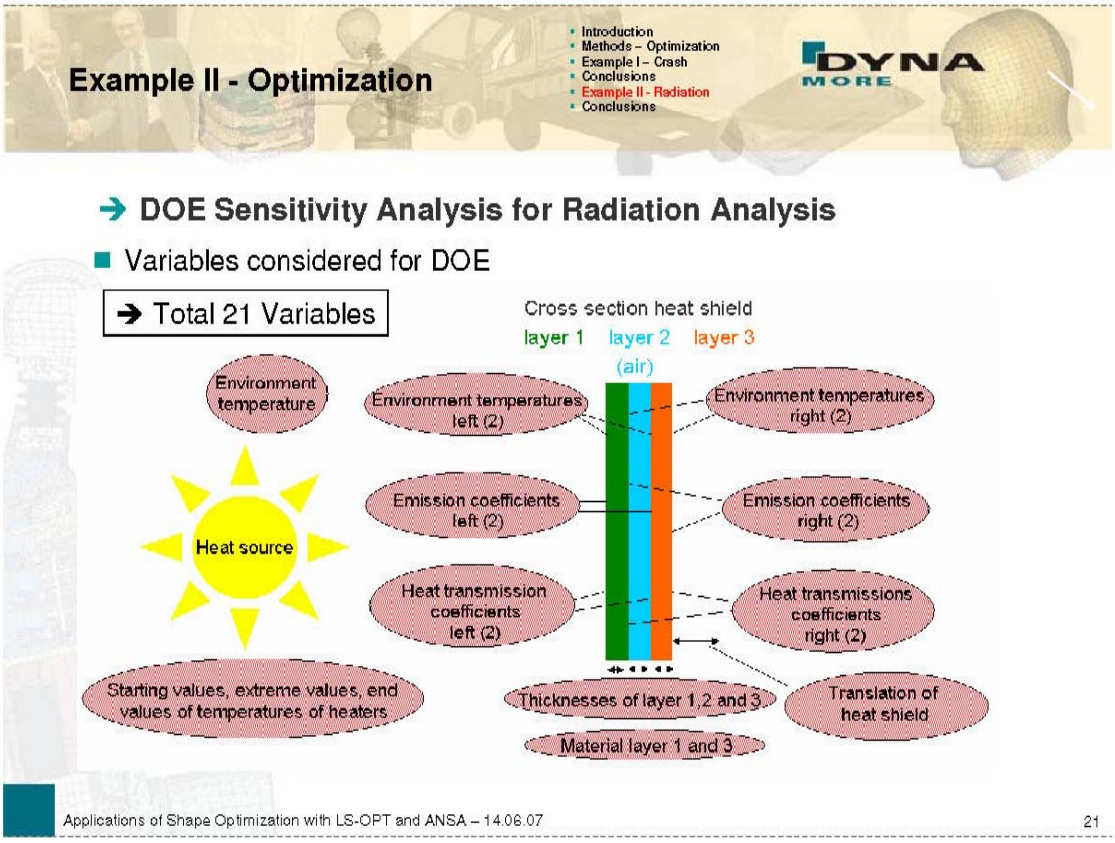
- LS-OPT is a suitable tool for crash box optimization
- Numerical optimization achieved better design and can save manpower in the design process of a crash box
- Morphing capabilities of ANSA are essential in order to realize geometric parameterization
- Visualization of results with D-SPEX can give you a deeper understanding of the influences of parameters upon the results

Example II - Optimization

➔ DOE Sensitivity Analysis for Radiation Analysis

- Problem Description: Heat shield to protect environment from high temperatures

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DOE Sensitivity Analysis for Radiation Analysis
Variables considered for DOE
Total 21 Variables
Cross section heat shield
layer 1
layer 2
layer 3
(air)
Environment temperature
Environment temperatures left (2)
Environment temperatures right (2)
Heat source
Emission coefficients left (2)
Emission coefficients right (2)
Heat transmission coefficients left (2)
Heat transmissions coefficients right (2)
Starting values, extreme values, end values of temperatures of heaters
Thicknesses of layer 1,2 and 3
Translation of heat shield
Material layer 1 and 3
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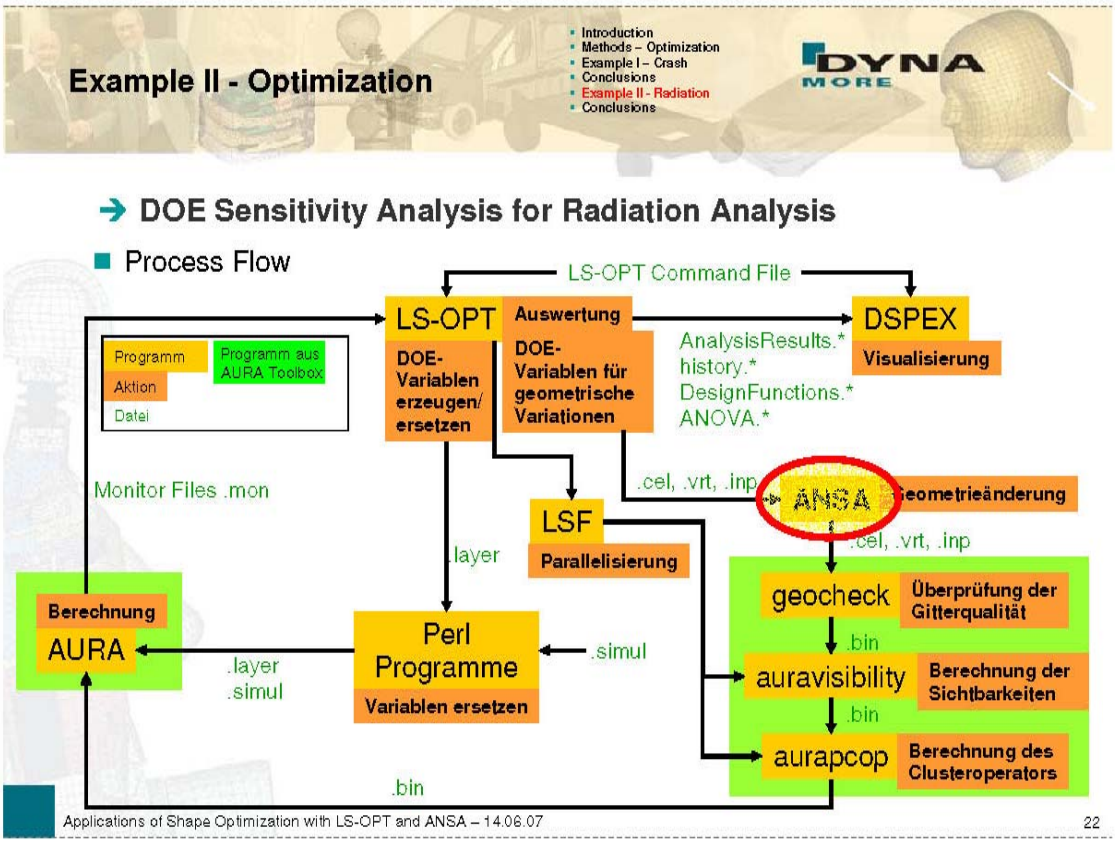
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LS-OPT
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DOE-Variablen für geometrische Variationen
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Visualisierung
AnalysisResults.*
history.*
DesignFunctions.*
ANOVA.*
Programm
Aktion
Datei
Programm aus AURA Toolbox
Monitor Files .mon
.cel, .vrt, .inp
ANSA
Geometrieänderung
LSF
Parallelisierung
.layer
.cel, .vrt, .inp
geocheck
Überprüfung der Gitterqualität
.bin
auravisibility
Berechnung der Sichtbarkeiten
.bin
aurapcop
Berechnung des Clusteroperators
Berechnung
AURA
.layer
.simul
Perl Programme
Variablen ersetzen
.simul
.bin
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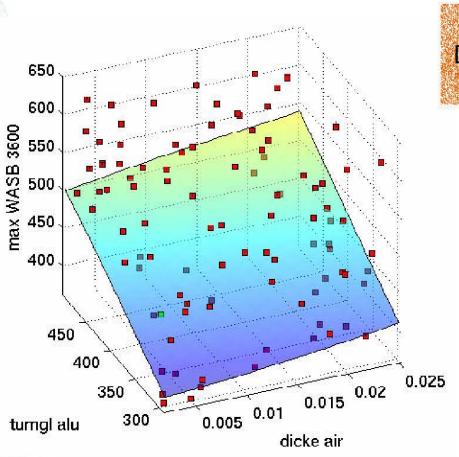
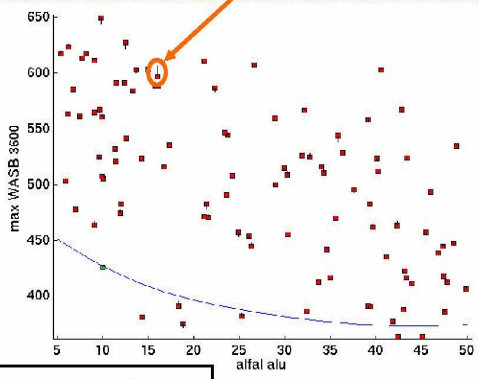
➔ DOE Sensitivity Analysis for Radiation Analysis

- Visualization of DOE results



Residual
Distance Analysis Point <–> Response Surface
➔ Quality Indicator



Cross-Sections through 21-dimensional Variable Space

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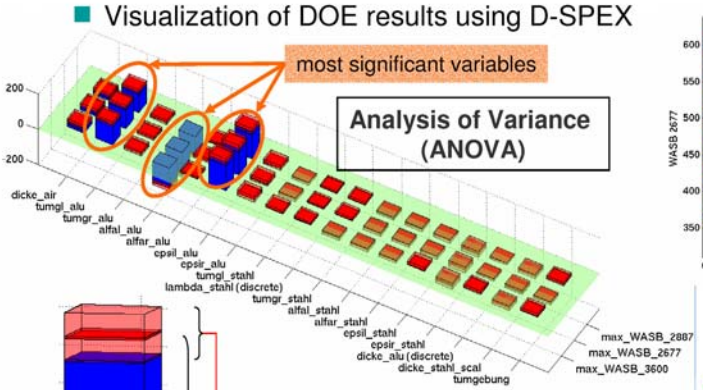
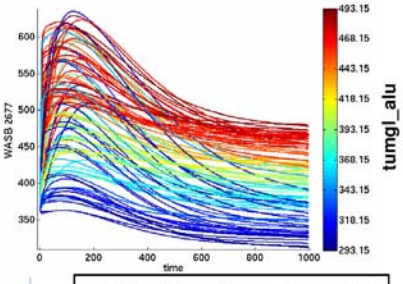
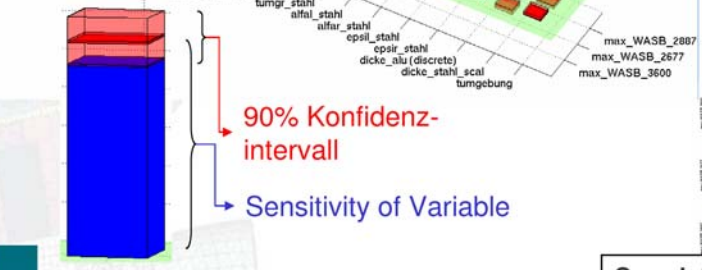
➔ DOE Sensitivity Analysis for Radiation Analysis

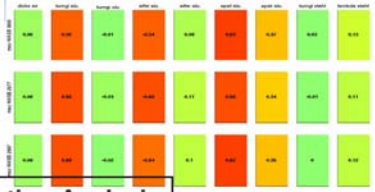
- Visualization of DOE results using D-SPEX





Curve Variation Analysis





Correlation Analysis

Conclusions

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➔ Conclusions

- Meta-Modelling capabilities of LS-OPT are utilized successfully for a sensitivity analysis of a heat radiation problem
- Screening of significant and insignificant variables is performed
- Problem: High dimensional design variable space (21-dim.)
- D-SPEX is a helpful tool to explore the multi-dimensional variable space

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Thanks for your attention!