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Overview and New Features in LS-OPT and LS-TaSC

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Agenda

What‘s coming next

- Introduction
- LS-TaSC
  - Overview
  - Examples
  - New features in Version 2022R1
- LS-OPT
  - Overview
  - Examples
  - New features in Version 2022R1

Introduction

Overview on structural optimization techniques

LS-TaSC

- Topology optimization
  - **Shape, size, and location of gaps** in the defined domain is derived by the optimizer
- Topometry optimization
  - **Shell thickness** is designed per element basis
- Shape optimization
  - Free shape of the **outer surface contour** is chosen

LS-OPT

- Shape optimization
  - **Parameterized geometry** (e. g. a hole radius) is designed
- Size optimization
  - **Shell thickness** is designed per part basis
- **Material-parameter identification**
  → material-parameter optimization

Parameter optimization

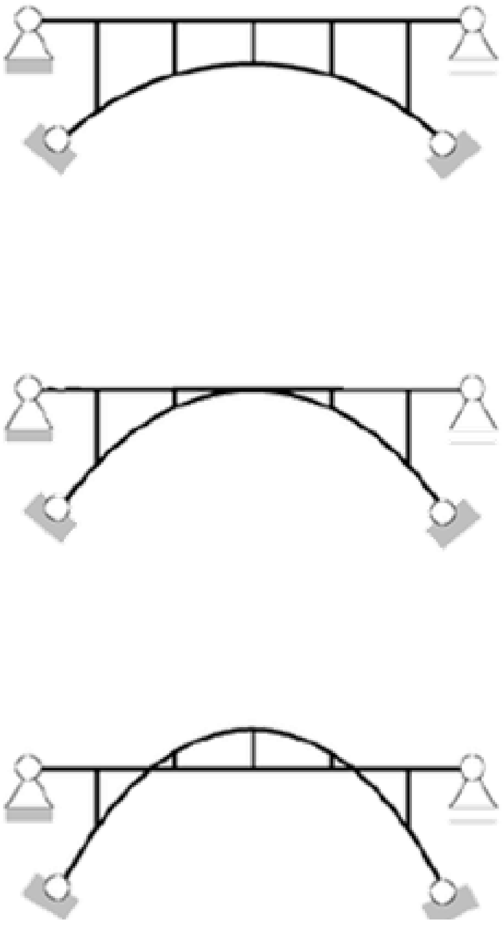
Optimization of a any parameterized model

Introduction

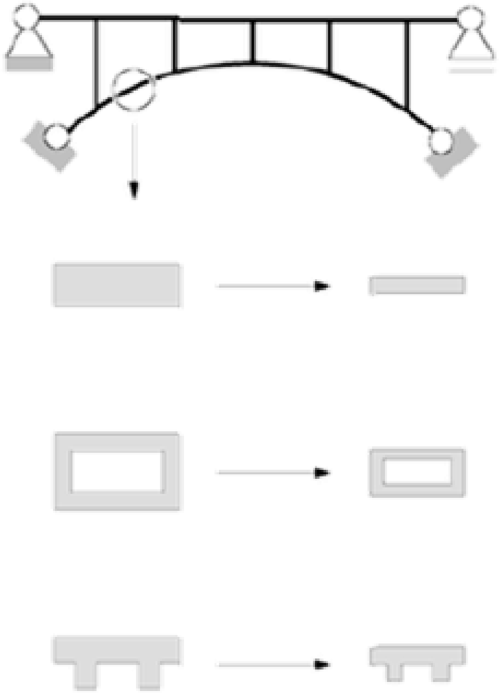
A deeper look on classifications

Topology

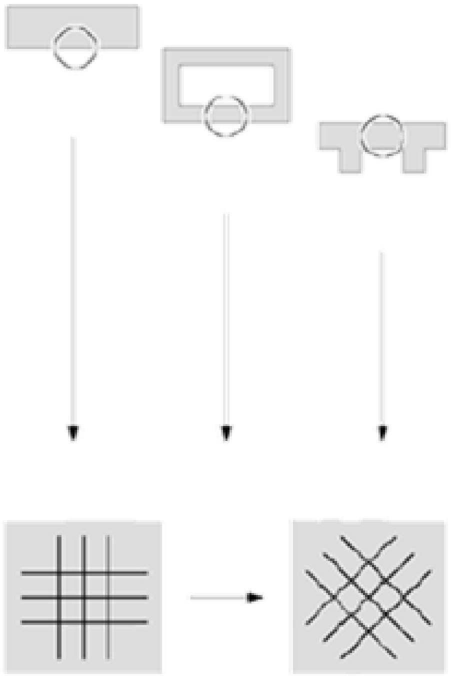
Shape



Sizing



Material



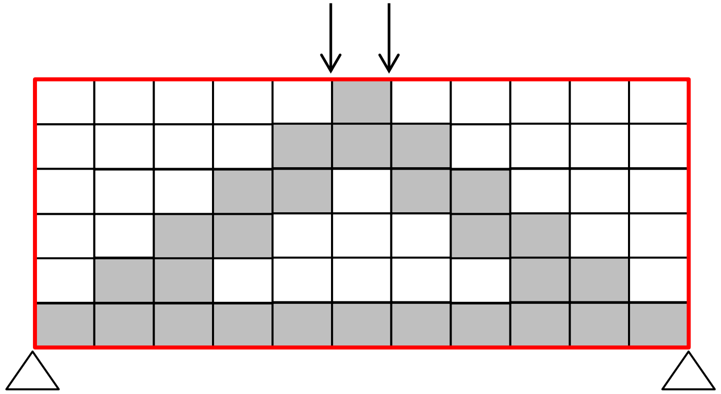
LS-TaSC

Topology, topometry and shape optimization

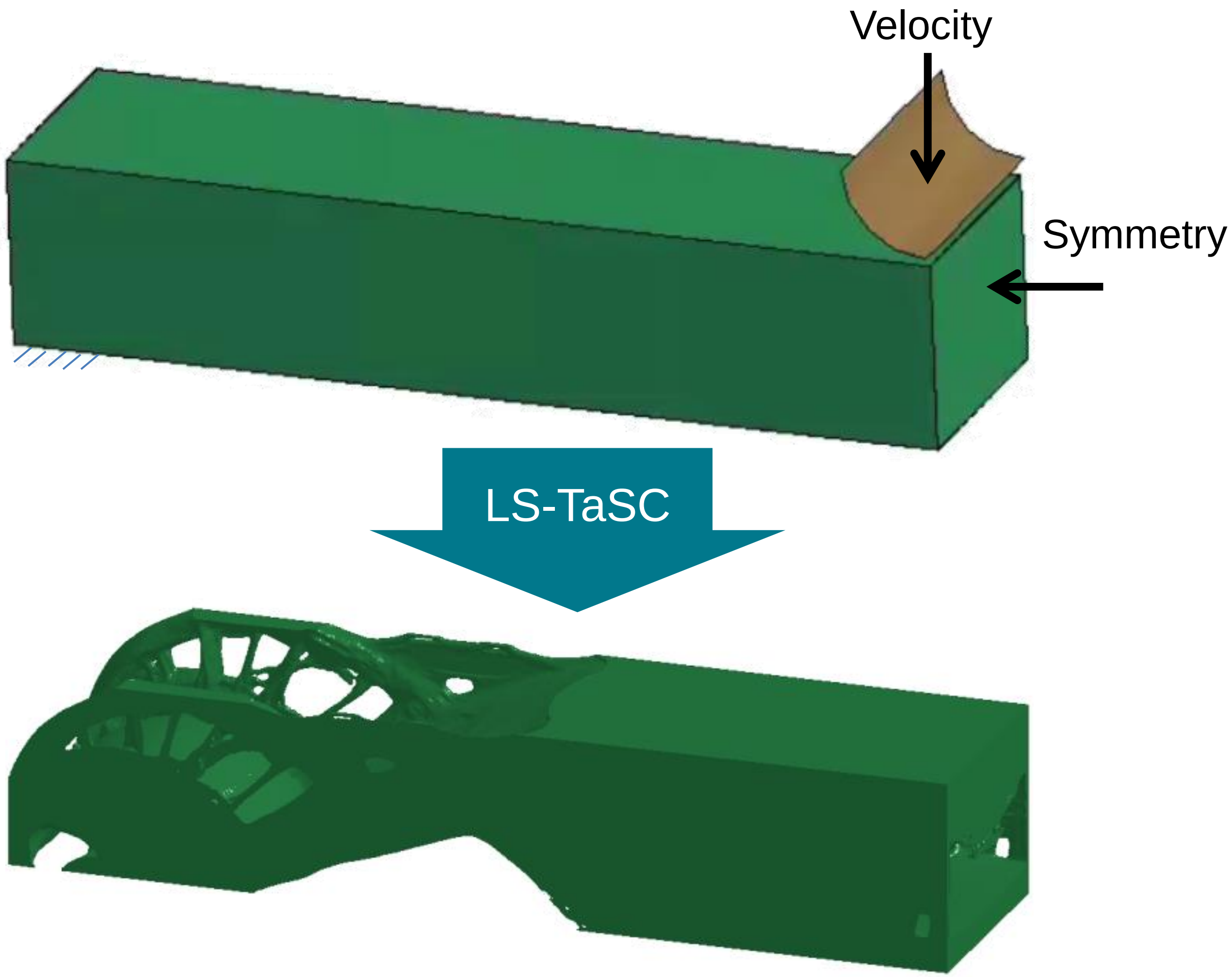
LS-TaSC

Basic idea

- **Redistribution of material** within a given domain



- Design variables
  - **Relative density** of each element
- Result
  - New **material distribution**
  - New **shape of structure**



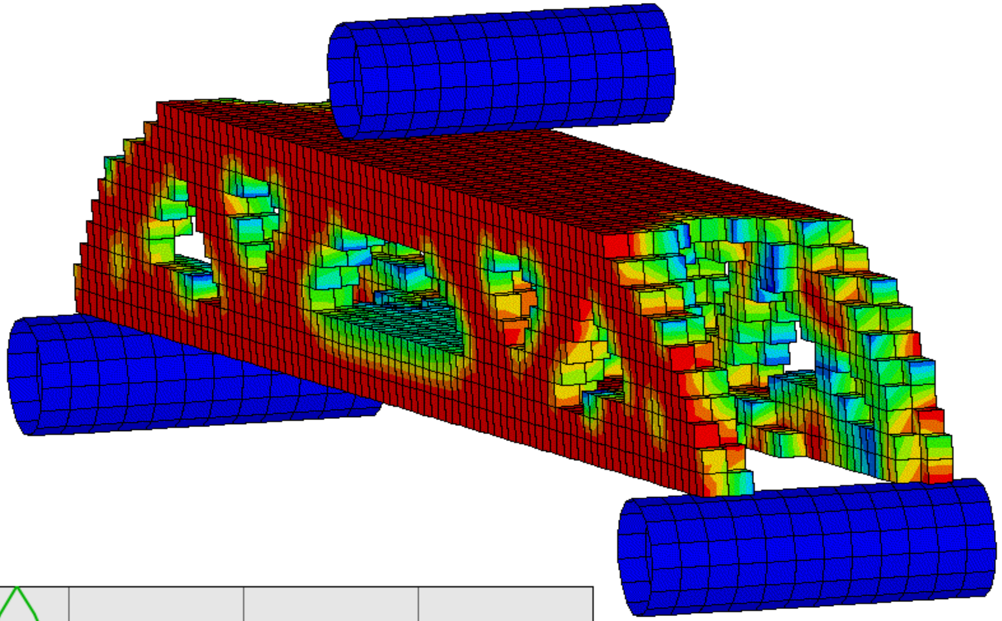
LS-TaSC

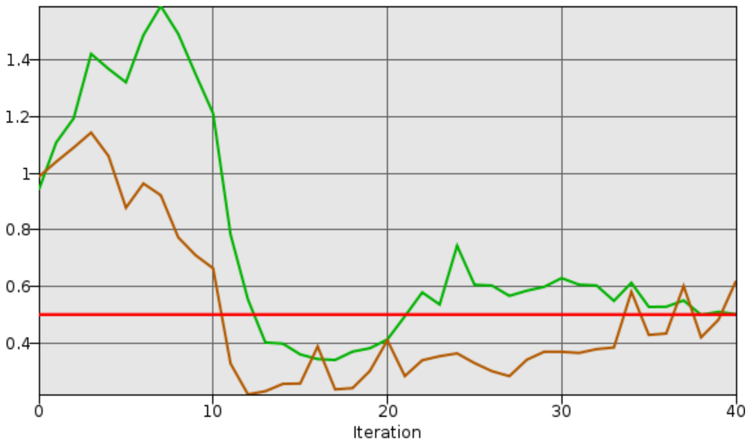
Feature overview

- **Topology and shape optimization of non-linear problems**
  - Dynamic loads
  - Contact conditions
  - Solids and shells

    → **Identify design concepts** for structures analyzed using LS-DYNA (implicit and explicit)
- **Huge LS-DYNA models** (more than 10 million elements)
- **Multiple load cases and disciplines**
- Global **constraint handling**, e. g.
  energy absorption, maximum reaction forces, …

  → **Multi-point optimization and metamodels**

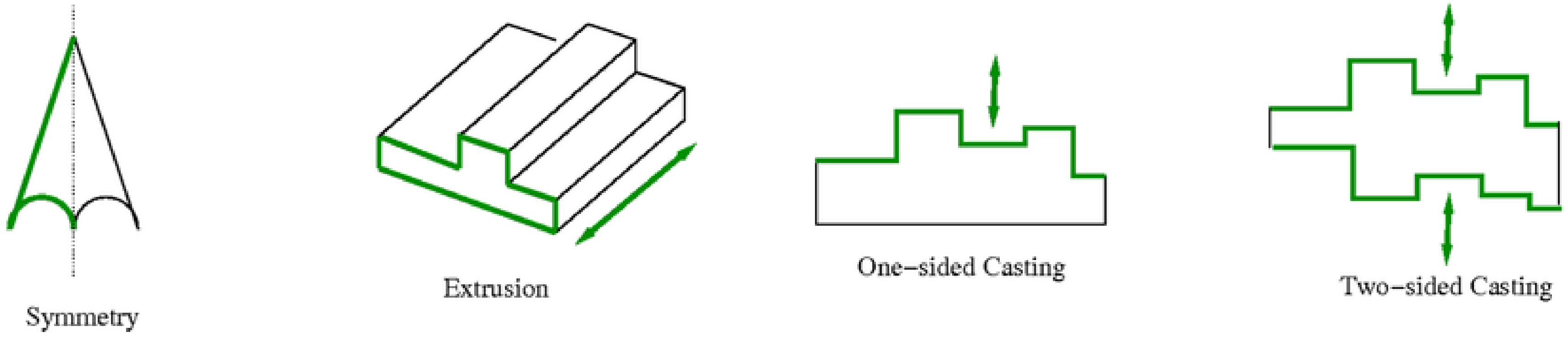


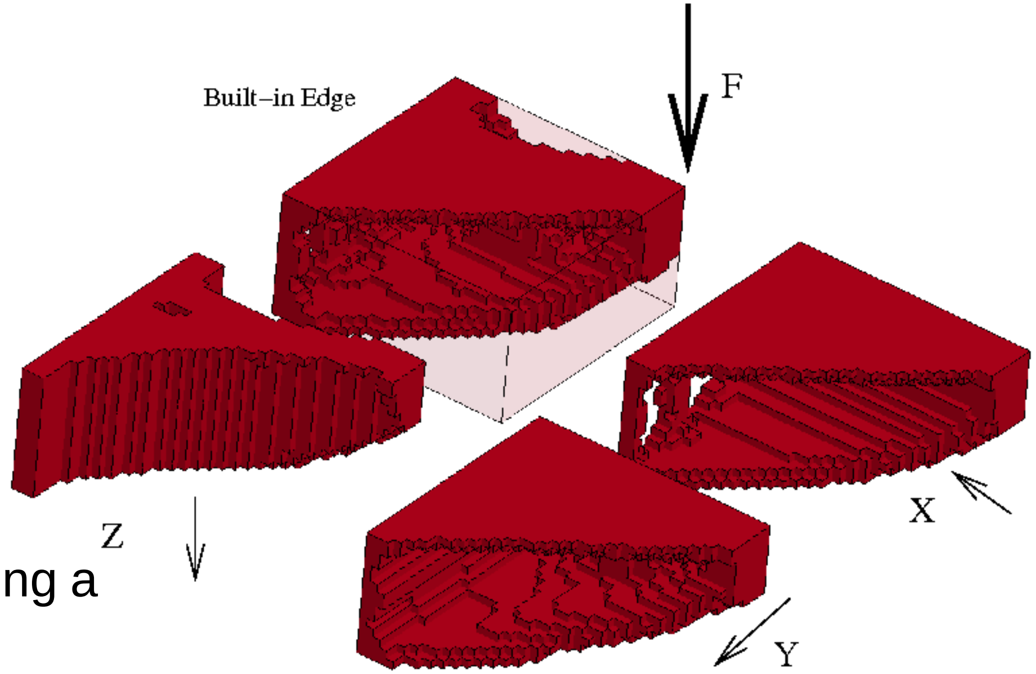


LS-TaSC

Geometry definitions

- Symmetry
- Extrusion
- Casting
  - One sided
  - Two sided
- Forging
  - Two-sided casting
  - Preserving a minimal thickness
- Pattern and cyclic repetition (2022R1)



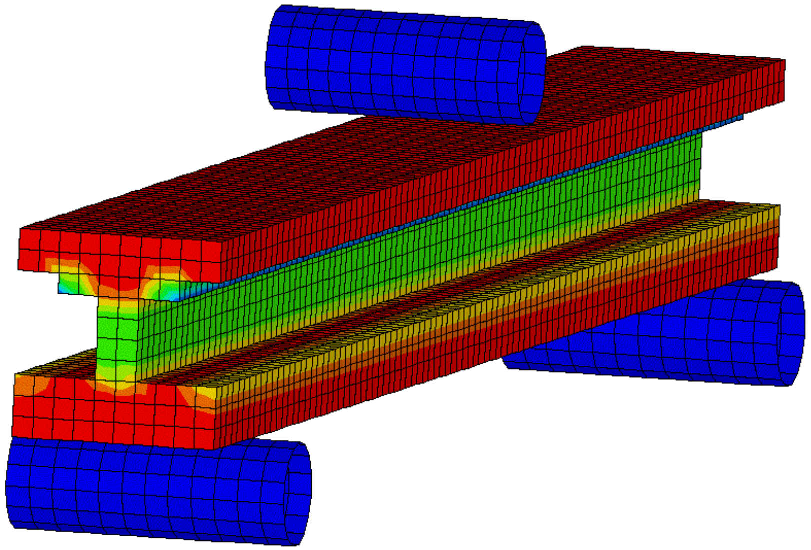


Forging: Two-sided casting preserving a minimum thickness (no holes)

LS-TaSC

Methodologies

- Topology optimization
  - Optimality Criteria for Dynamic Problems
    - Objective: Homogenization of internal energy density (IED)
      → uniform loading of material for given mass
  - Projected Subgradient Method
    - Enables multi-disciplinary optimization: Impact, Static, NVH
      → maximization of fundamental frequency for NVH load case
- Free Surface Design
  - Objective: Uniform surface stress

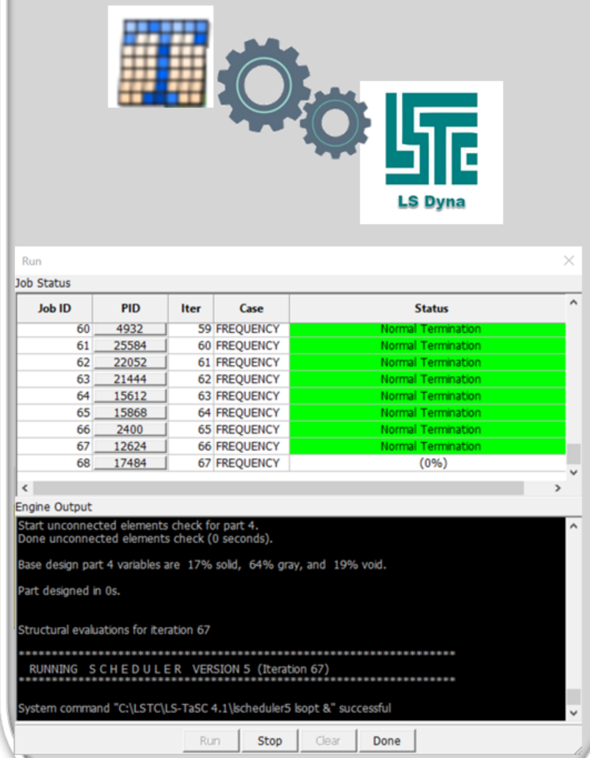


LS-TaSC

Integration

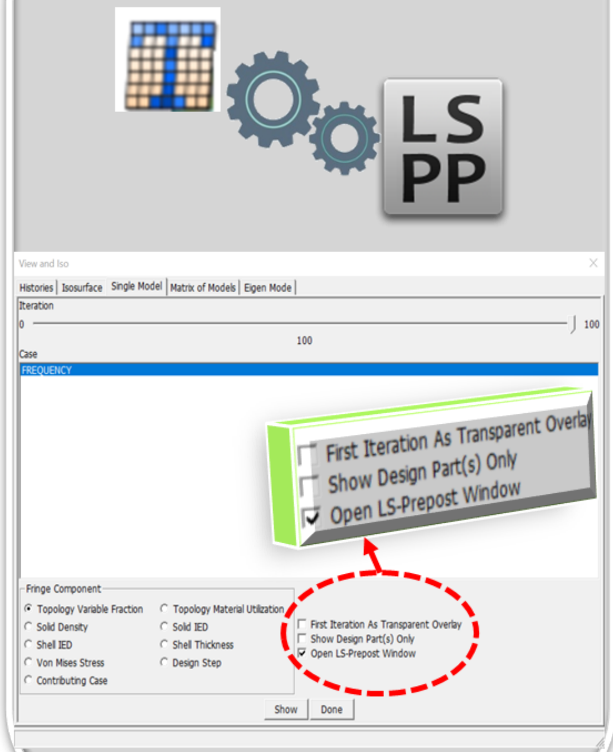
LS-TaSC with LS-DYNA

- no special treatment for nonlinearties



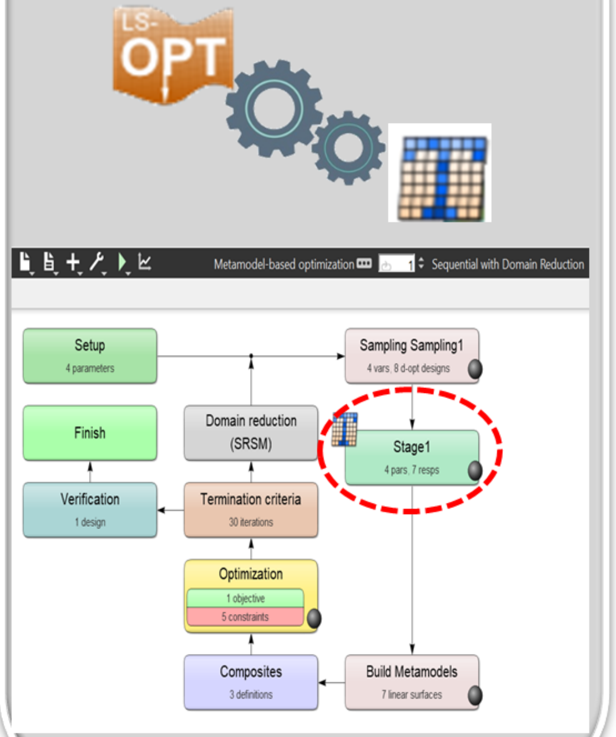
LS-TaSC with LS-PrePost

- results visualization
- model editing



LS-TaSC with LS-Opt

- multilevel and complex design schemes

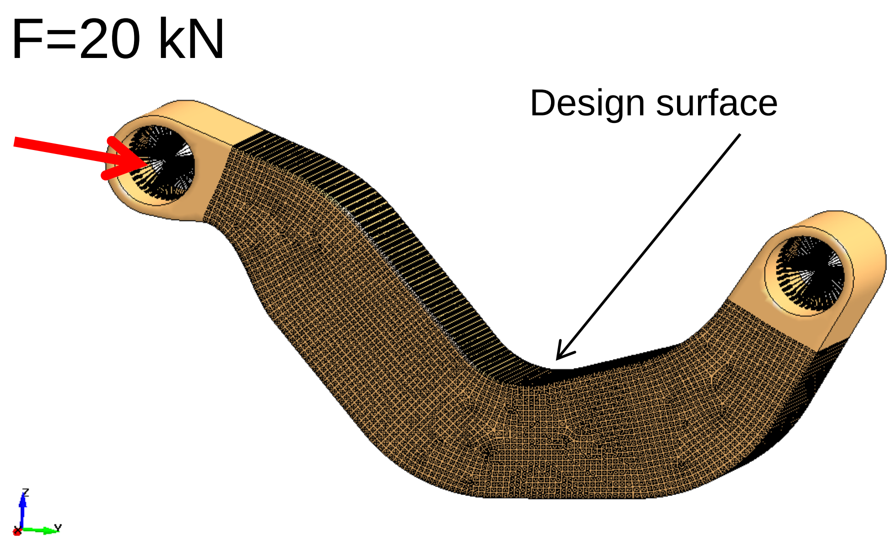


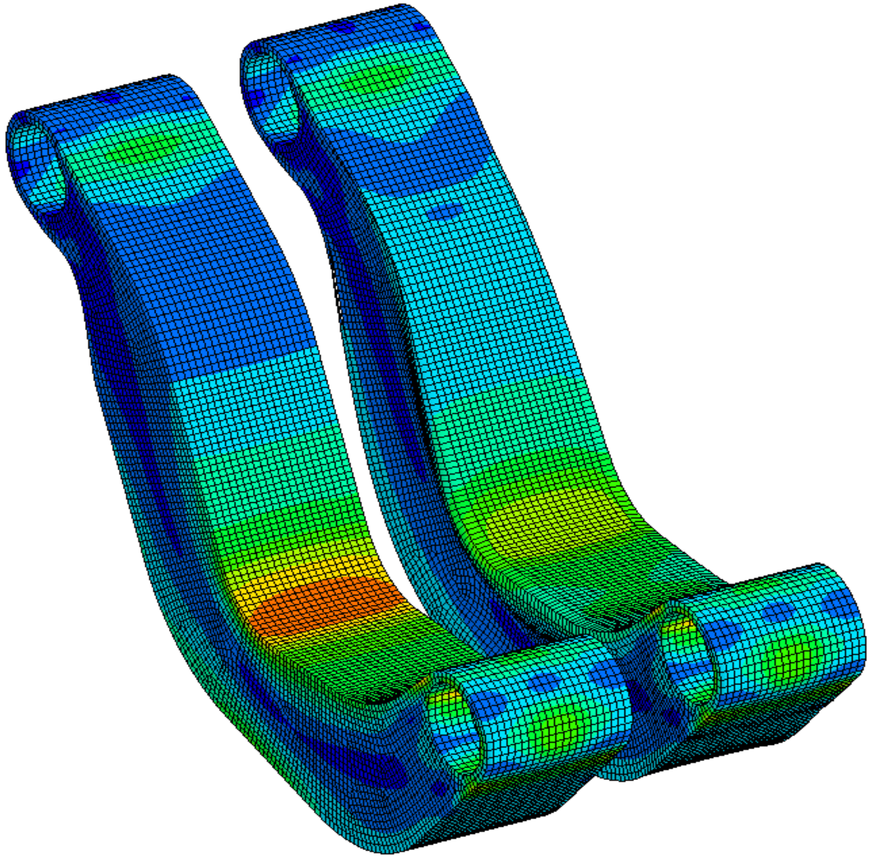
LS-TaSC Examples

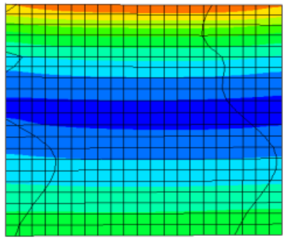
LS-TaSC Examples

Free-surface design

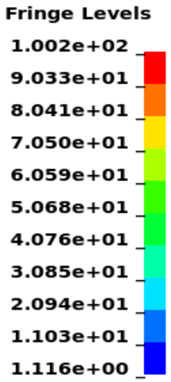
- Objective: uniform surface stress → reduction of stress concentration

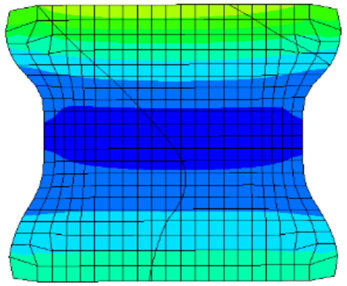






Initial Design



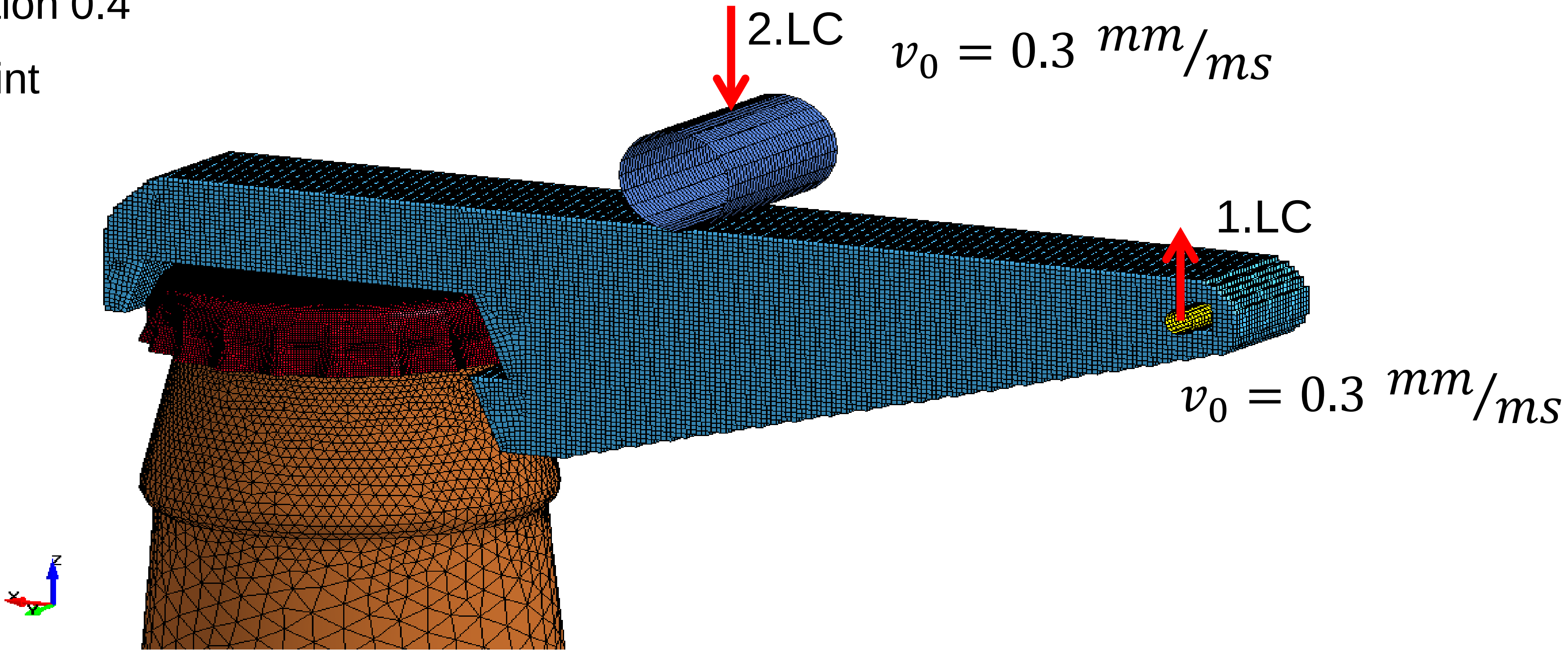


Optimized Design
→ 20% stress reduction

LS-TaSC Examples

Bottle opener

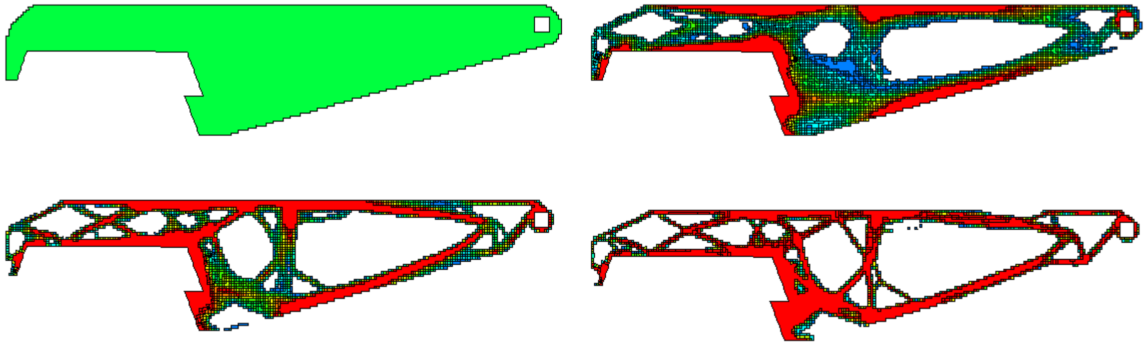
- Starting design and load cases
- Material: plastic
- Desired mass fraction 0.4
- Geometry Constraint
  - Extrusion

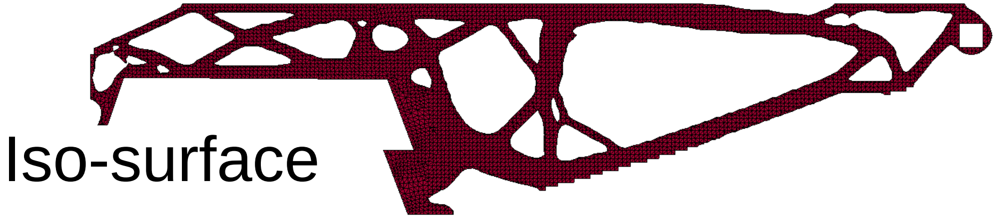


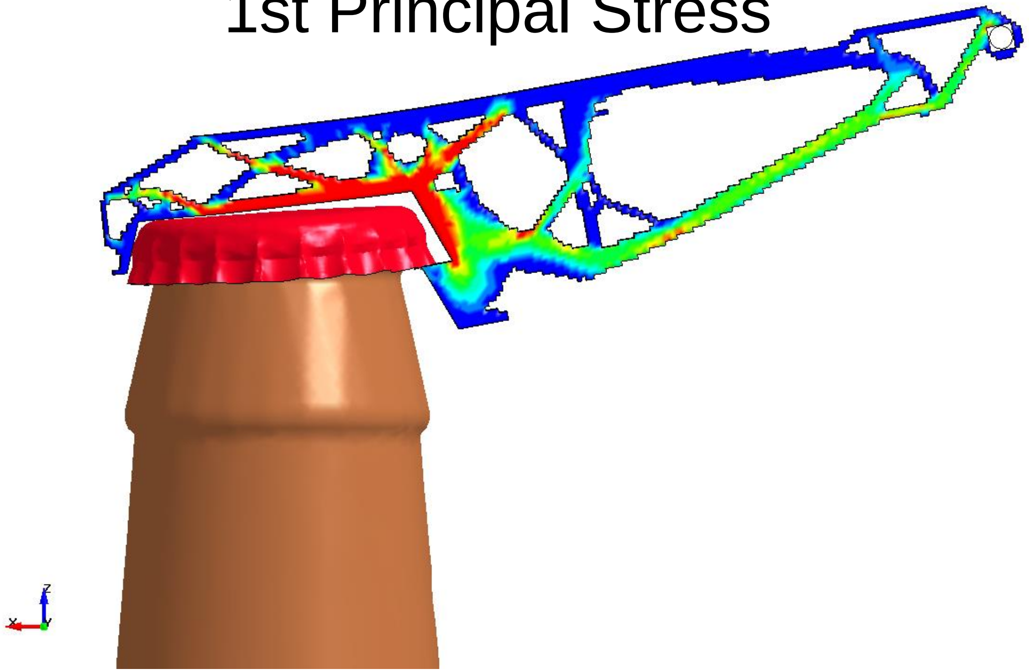
LS-TaSC Examples

Bottle opener

- Results
- From Initial Design to Optimized Structure (density distribution)



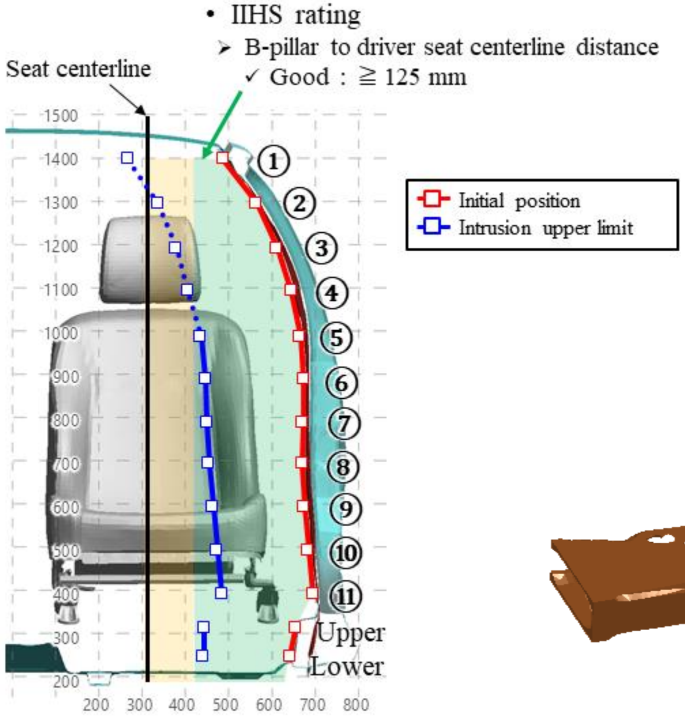


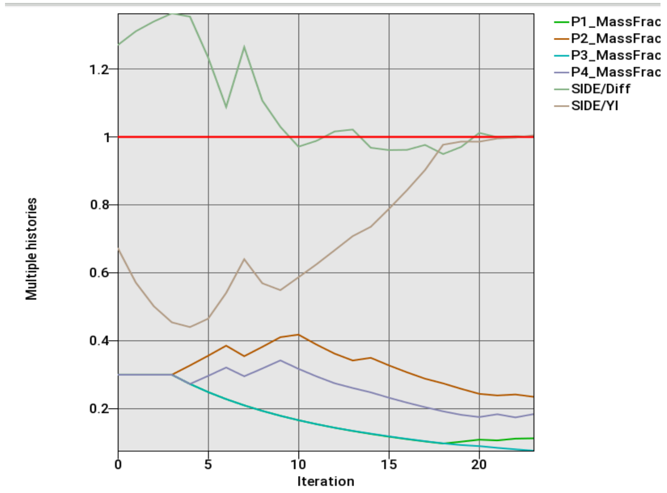


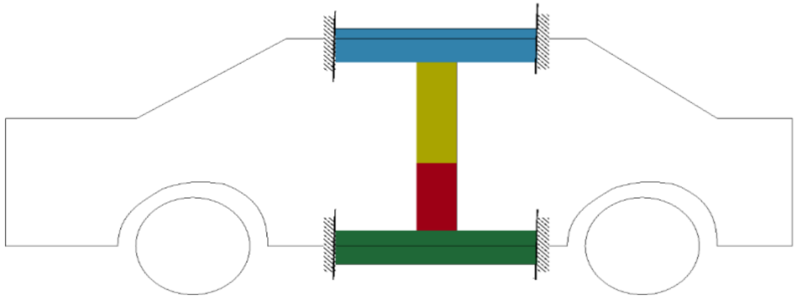
LS-TaSC Examples

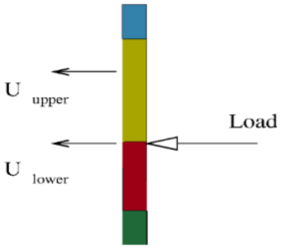
Side Impact

- Simplified B-pillar
  - Objective
    - Stiffest structure
    - satisfy constraints
    - and minimize mass
  - Constraints
    - $-10\,u_{lower} < 1,$
    - $2u_{upper}/u_{lower} < 1$







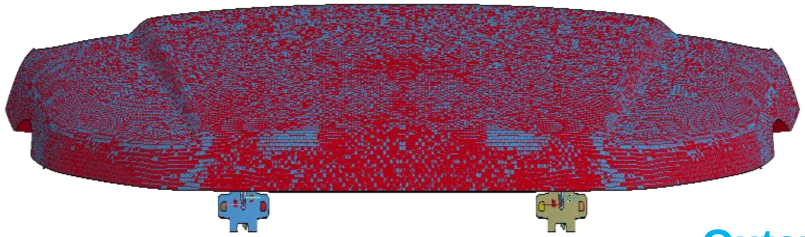


Courtesy of JSOL

LS-TaSC Examples

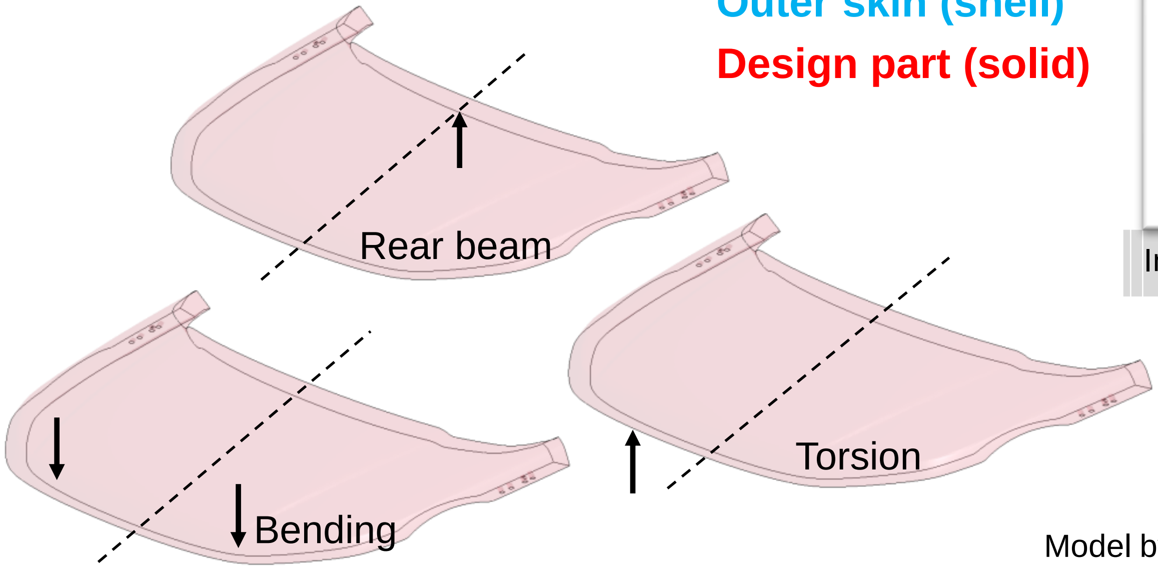
Hood Design

- Objective: Stiffest structure, satisfy constraints and minimize mass
- Constraints: rear beam, bending and torsion displacements



Outer skin (shell)

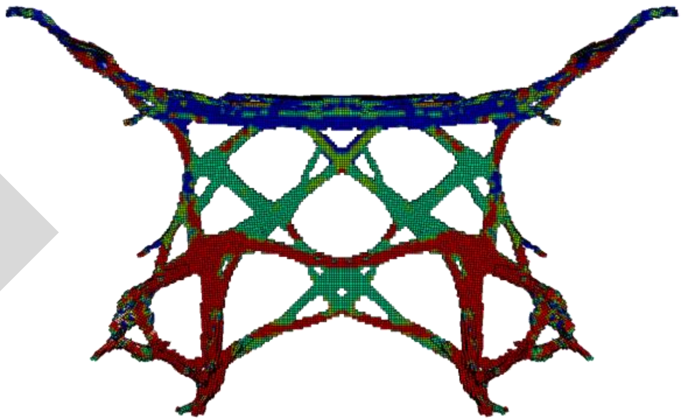
Design part (solid)



Initial Design has very low mass fraction of 0.01.

Model by courtesy of Jaguar Land Rover

Optimum

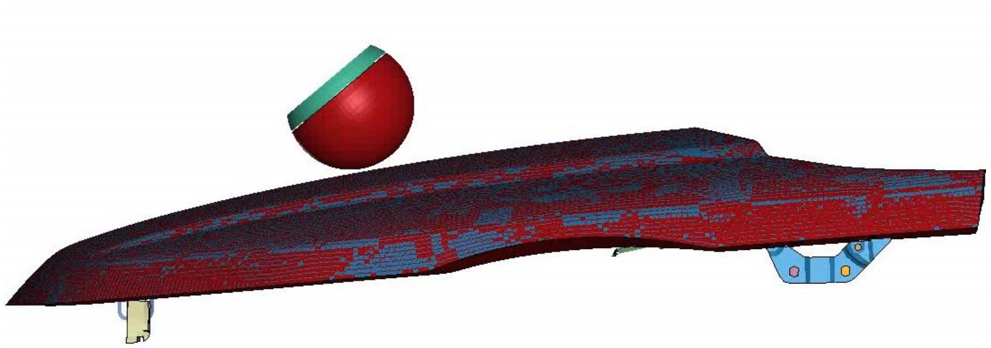


Design Contribution Plot
(Rear beam, torsion, bending)

LS-TaSC Examples

Hood Design

- Multiple objectives to be met
  - Euro NCAP Pedestrian testing protocol composed of many load cases
    → interest in worst-case design methods.
  - NVH
  - Statics
- MDO using topology optimization of solids
- MDO using considering the shell thicknesses
- NVH, impact and statics
  - Constraints such as HIC
    or bounds on eigenmodes
- User-material models allowed for crash
  to cope with fracture

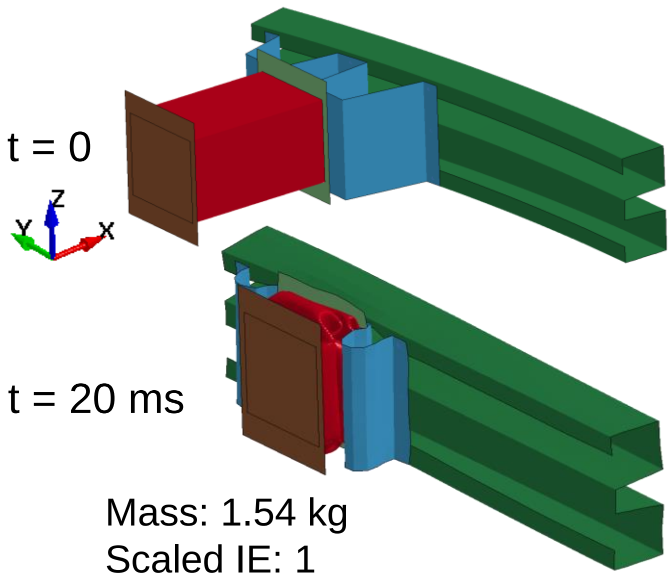


LS-TaSC Examples

Automotive Crash Box

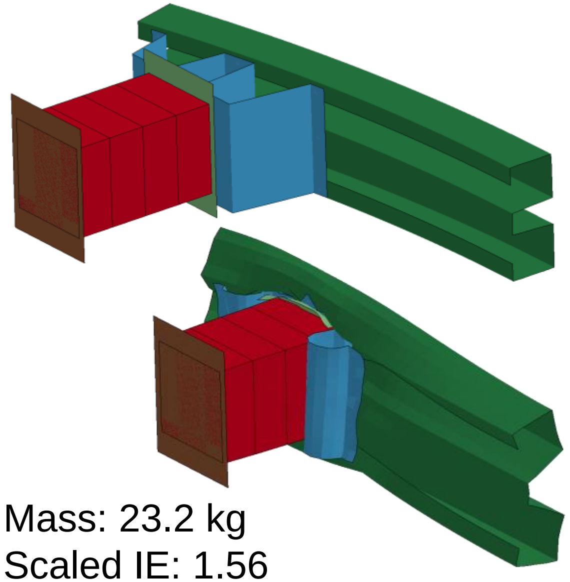
- Crashworthiness and Lightweight Optimization → **minimize mass**
  - Constraints: Scaled max. energy absorption ≥ 1
  - Geometry: solid block split into 4 parts; XY and XZ symmetry

Reference shell structure



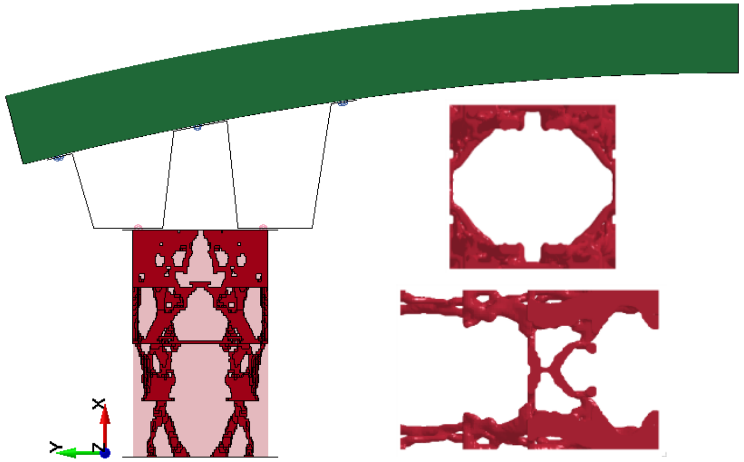
Mass: 1.54 kg
Scaled IE: 1
Scaled Peak Accel: 1

Baseline solid block



Mass: 23.2 kg
Scaled IE: 1.56
Scaled Peak Accel: 0.51

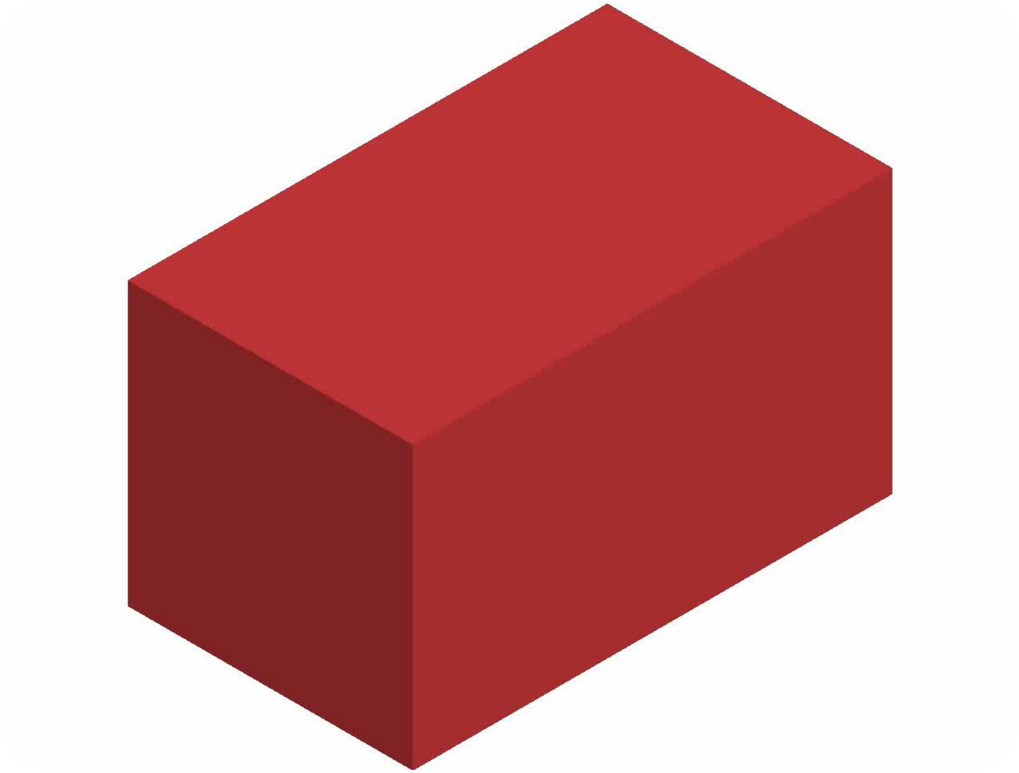
Optimized solid structure

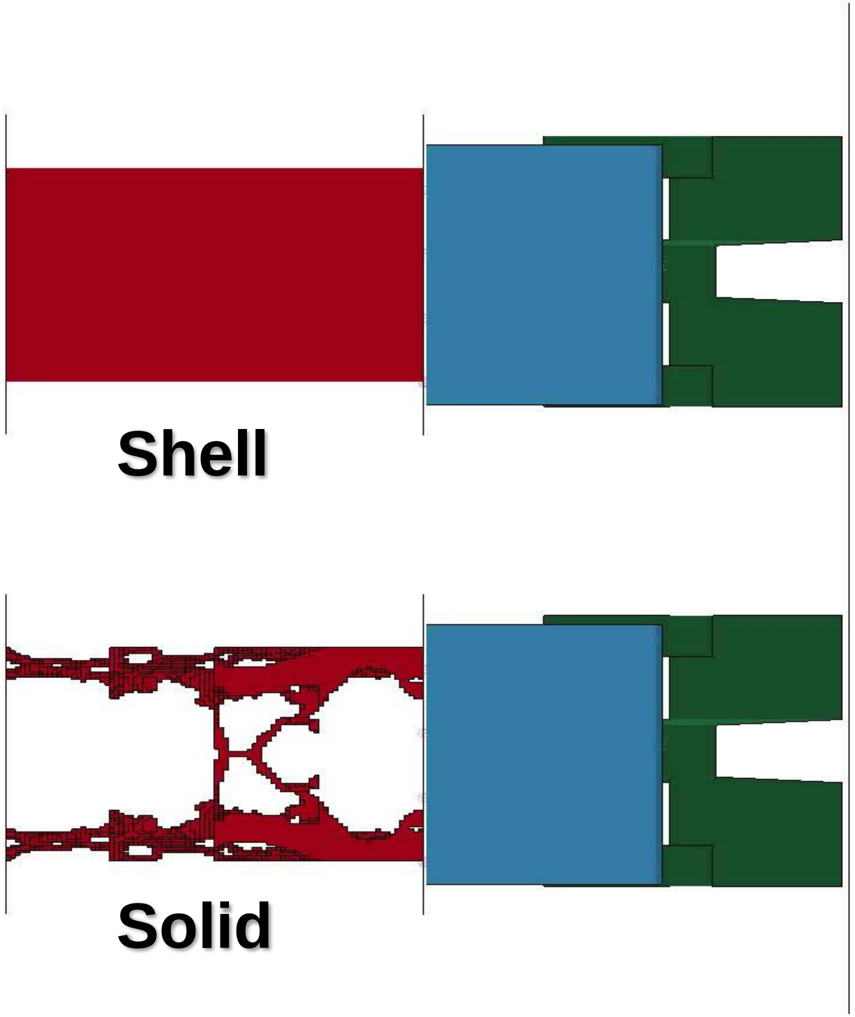


Mass: 1.31 kg (↓15%)
Scaled IE: 1
Scaled Peak Accel: 0.62 (↓38%)

LS-TaSC Examples

Automotive Crash Box



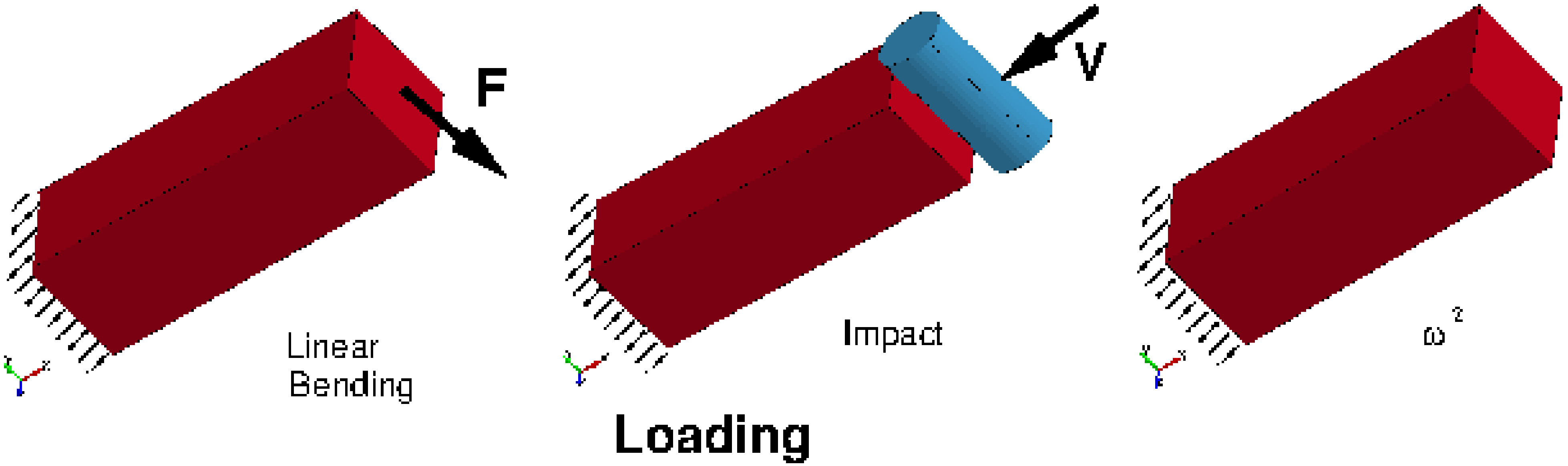


Gandikota I, Yi G, and Roux W,
Crashworthiness and lightweight optimization
of an automotive crash box using LS-TaSC.
FEA Information Engineering Solutions, October 2019

LS-TaSC Examples

Impact, statics, and NVH

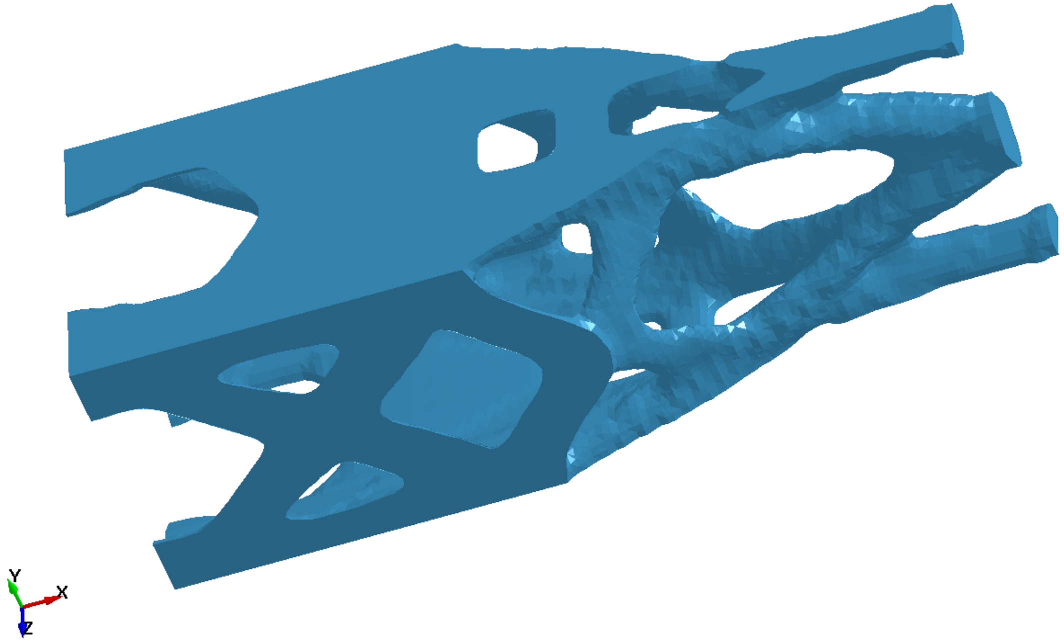
- Multi-disciplinary optimization, 3 load cases
  - Equal weights
- Mass fraction: 0.1



LS-TaSC Examples

Impact, statics, and NVH

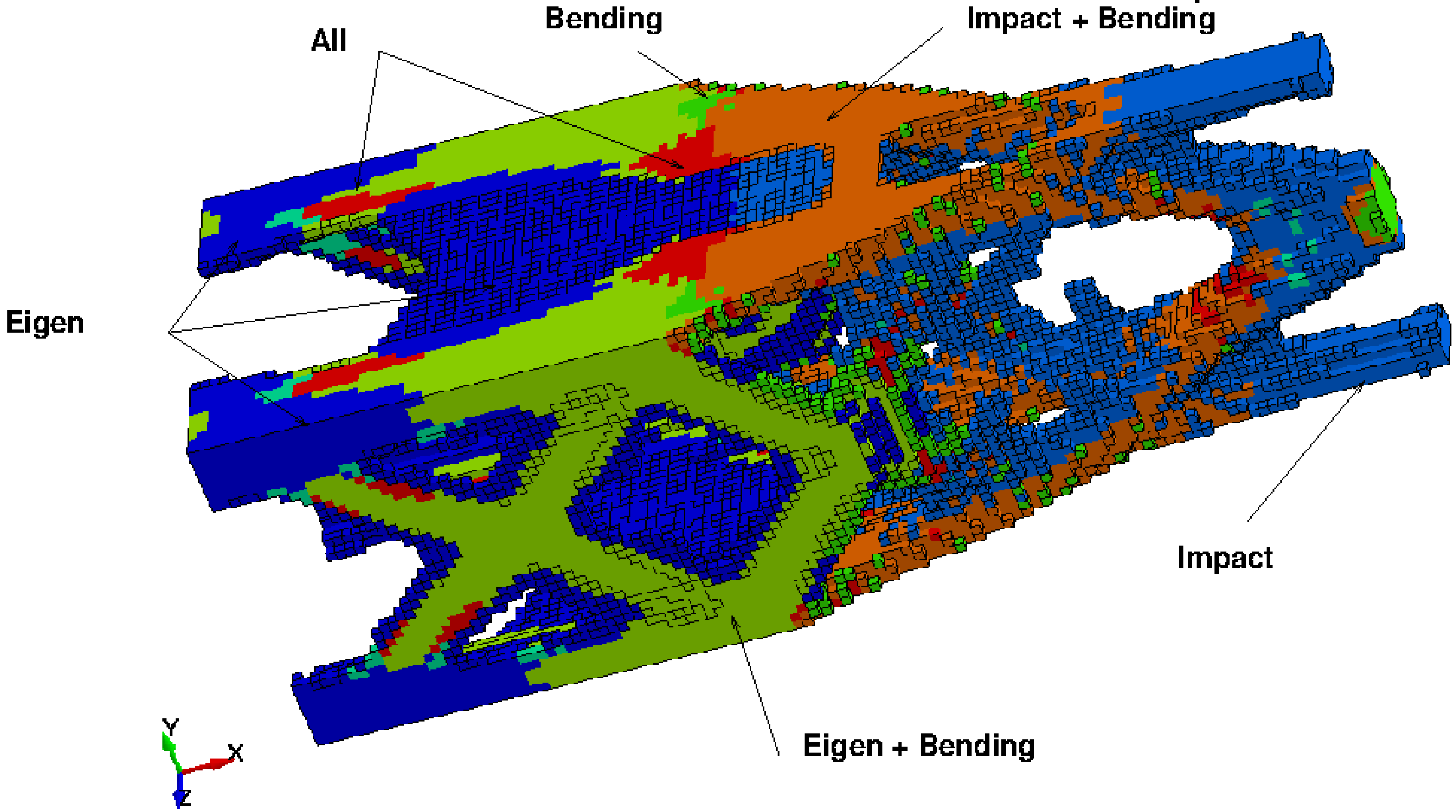
- Results (80 Iterations)
  - Optimal geometry



LS-TaSC Examples

Impact, statics, and NVH

- Results
  - shows which load case contributes the material used in the part



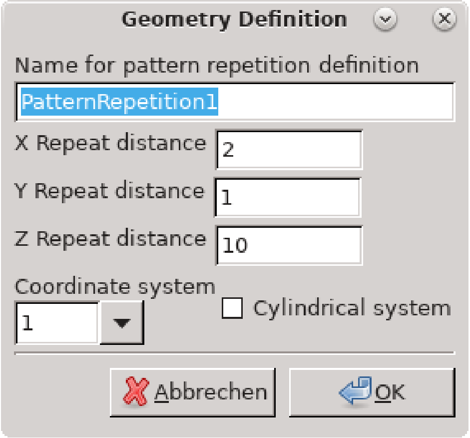
LS-TaSC New Features

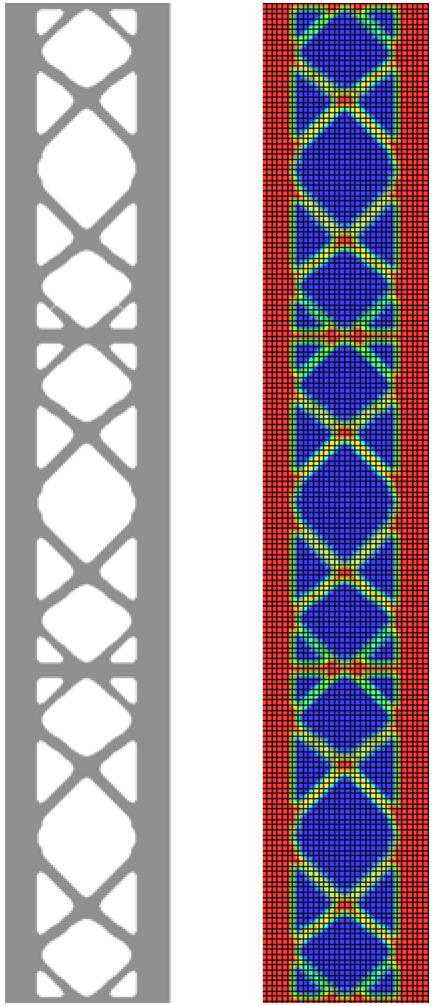
What‘s new

LS-TaSC New Features

What‘s new

- **Improved efficiency** for multi-disciplinary optimization (MDO)
- Support for **STL outputs** of topology design and surface designs
- Support for ***ELEMENT_SOLID_ORTHO** and structures with rubber materials
- Minimum size control of member
- **User subroutines**
  - Design procedures / FE model editing (e. g. adding spot welds) / responses
  - Python versions documented
- Updated to use LS-Reader
- **Repetitive and cyclic symmetry**
- Laundry list of FORD requests
  - Casting definition for shells (required for mega-castings)





LS-OPT

Parameter optimization

LS-OPT

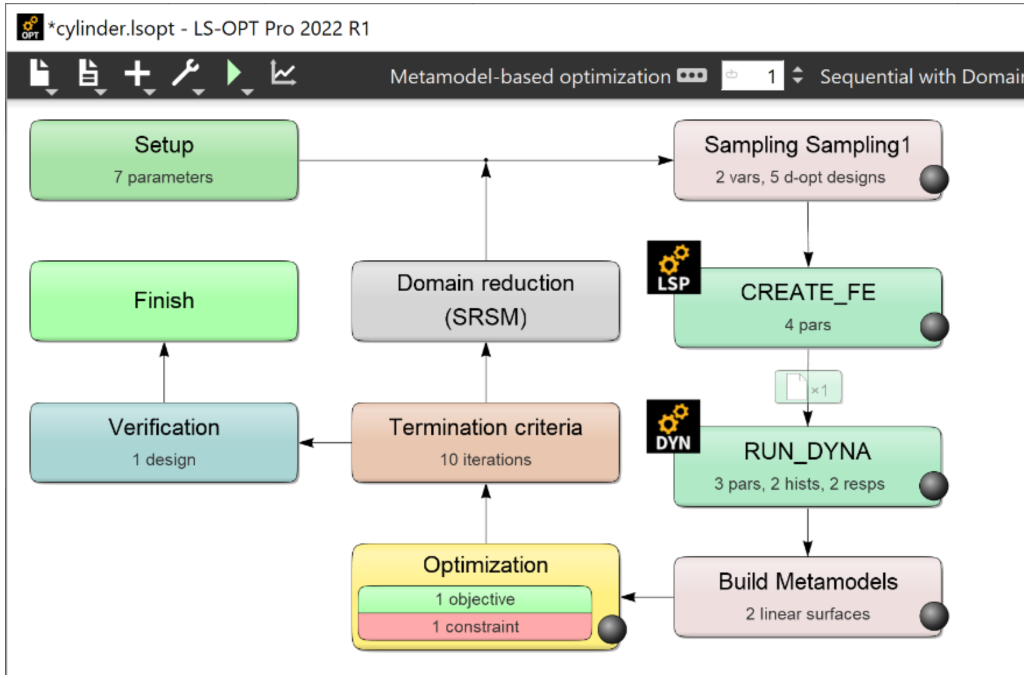
Overview

- LS-OPT is a stand-alone optimization software

  → can be linked to any (simulation) code –

  - Interface to LS-DYNA, Excel, Matlab
  - Interface to LS-PrePost, PRIMER, ANSA, Hypermorph, …
    → **shape optimization**
  - Interface to META Post
    → **result extraction**
  - Interface to LS-OPT, LS-TaSC
    → **nested optimization**
  - User-defined interface
  - Interface to Queuing Systems
    - PBS, LSF, SLURM, AQS, User-defined, …

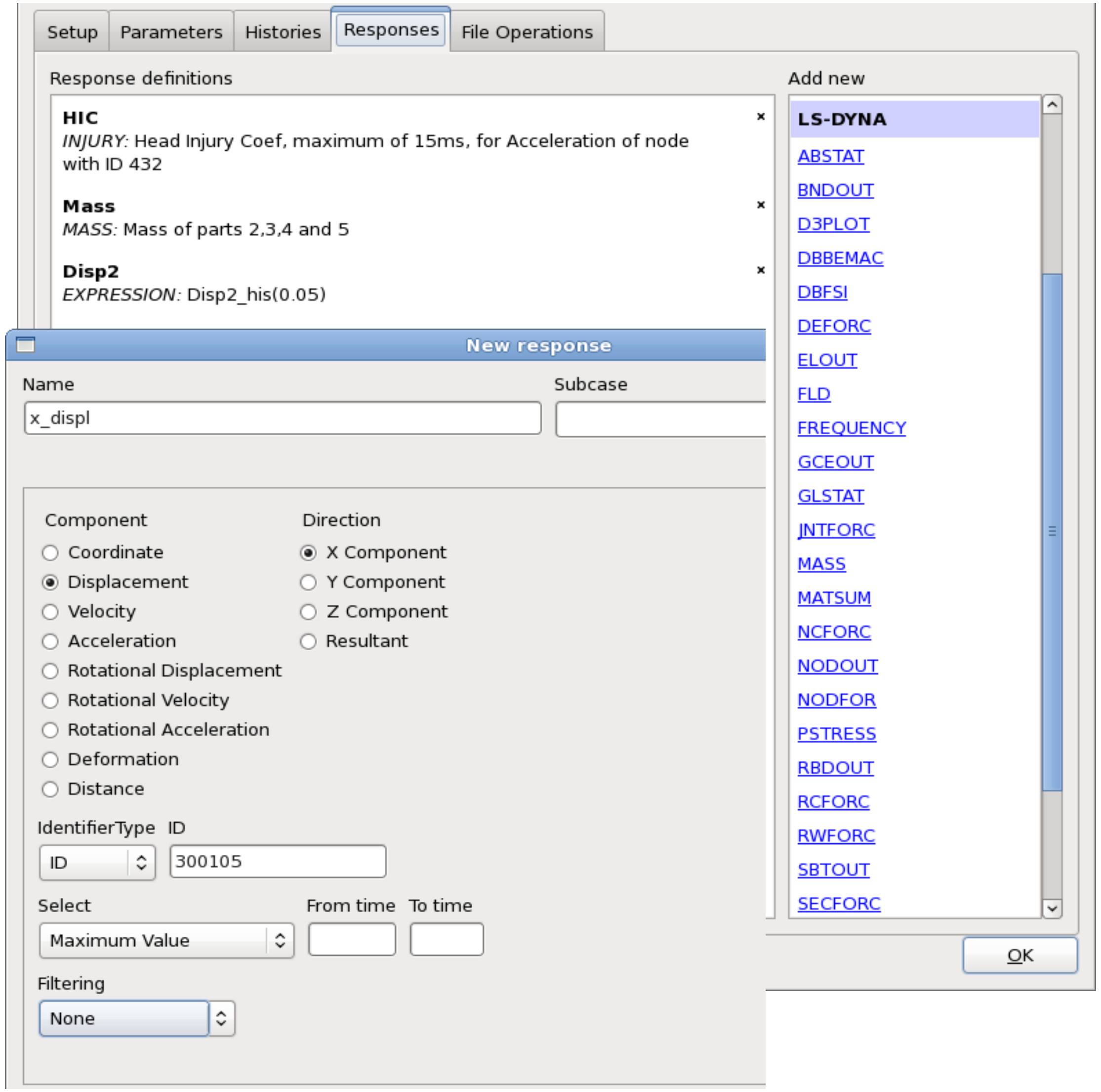
  → **LS-OPT as process manager**



LS-OPT

Overview

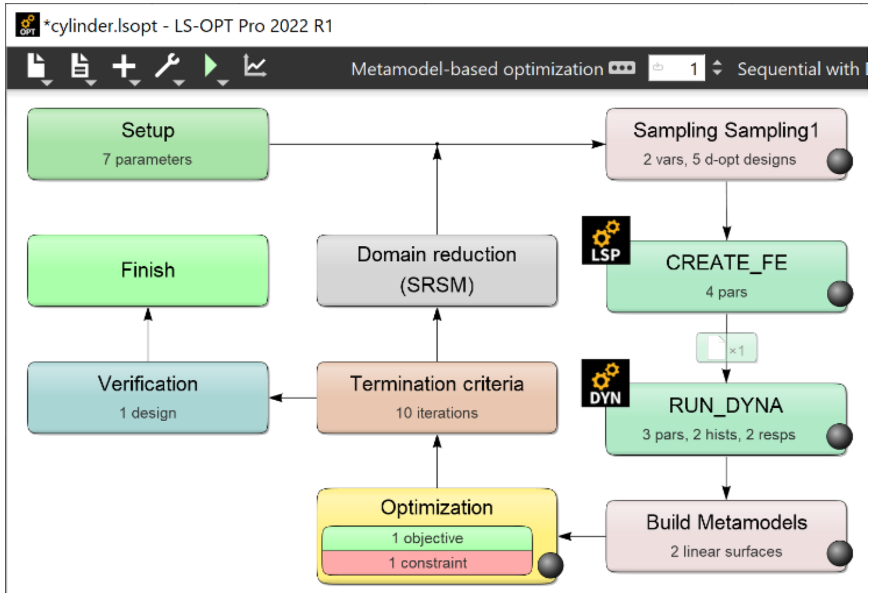
- LS-DYNA integration
  - Importation of design parameters from LS-DYNA keyword files (*PARAMETER)
  - Support of include files (*INCLUDE)
  - Result extraction of most LS-DYNA response types
  - Checking of LS-DYNA keyword files (*DATABASE_)
  - Monitoring of LS-DYNA progress

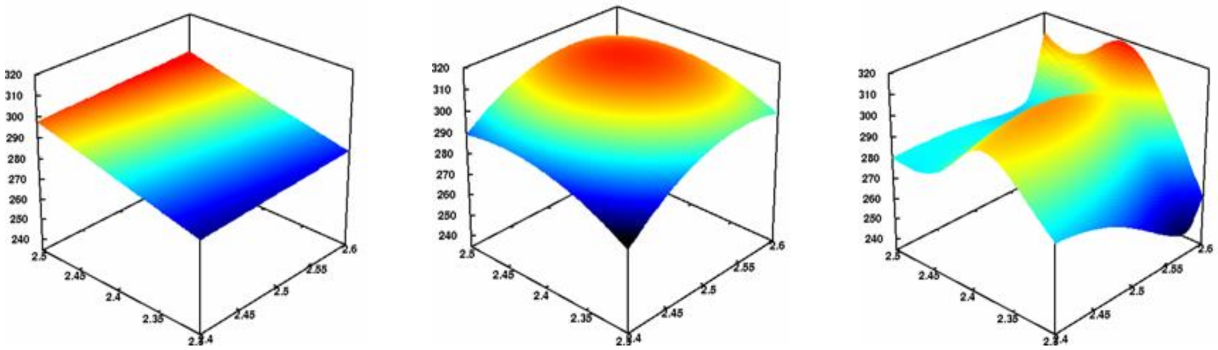


LS-OPT

Methodologies

- (Sequential) Response Surface Method ((S)RSM)
  → Metamodels
  - Polynomials
  - Radial Basis Functions (RBF)
  - Feedforward Neural Networks (FFNN)
- Genetic Algorithm (MOGA->NSGA-II)
  → Multi-objective Optimization
  - Direct and metamodel-based
- Monte Carlo Analysis
  → Robustness Analysis
  - Direct and metamodel-based

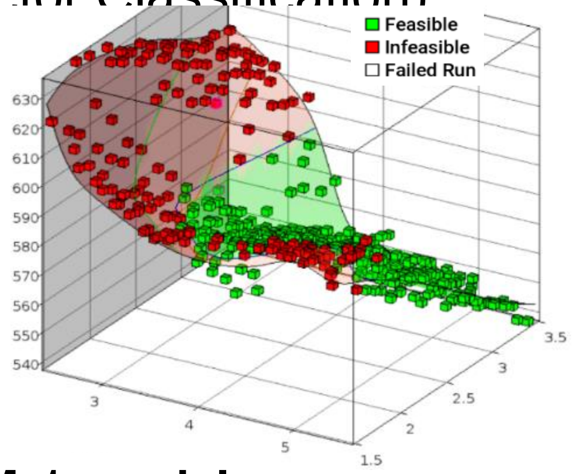




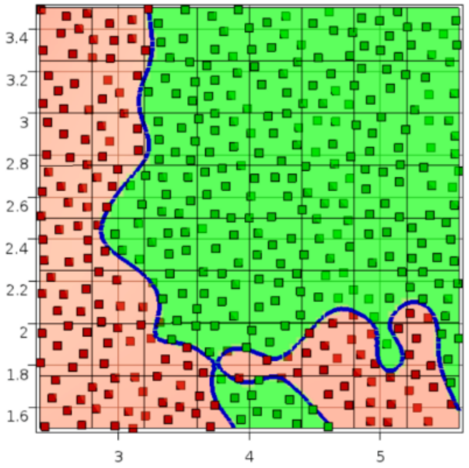
LS-OPT

Methodologies

- Classifiers (Support Vector Classification)



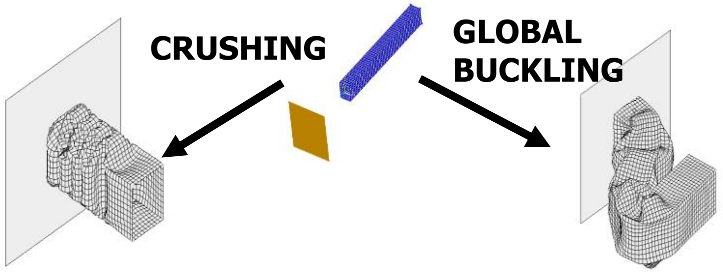
Metamodel
Approximation of response



Classifier
Approximation of constraint boundary
- Design point (variable values)
- Feasibility of each design

- Discontinuous responses
- Binary responses

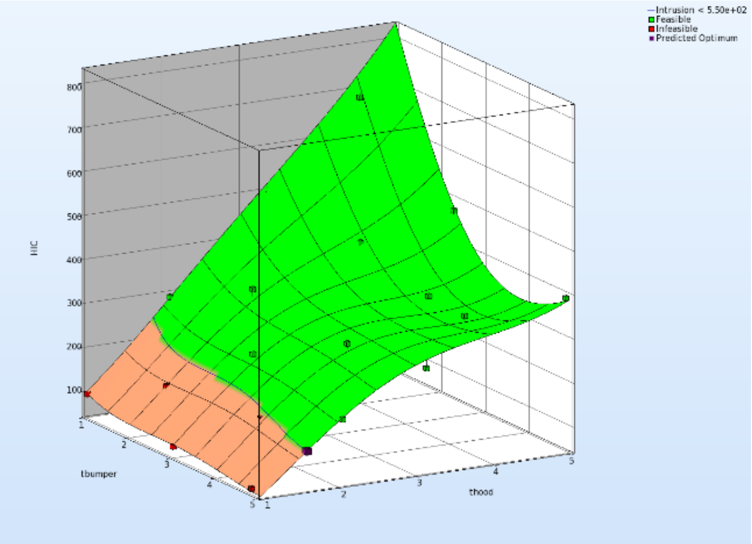
→Constraints for optimization or reliability analysis

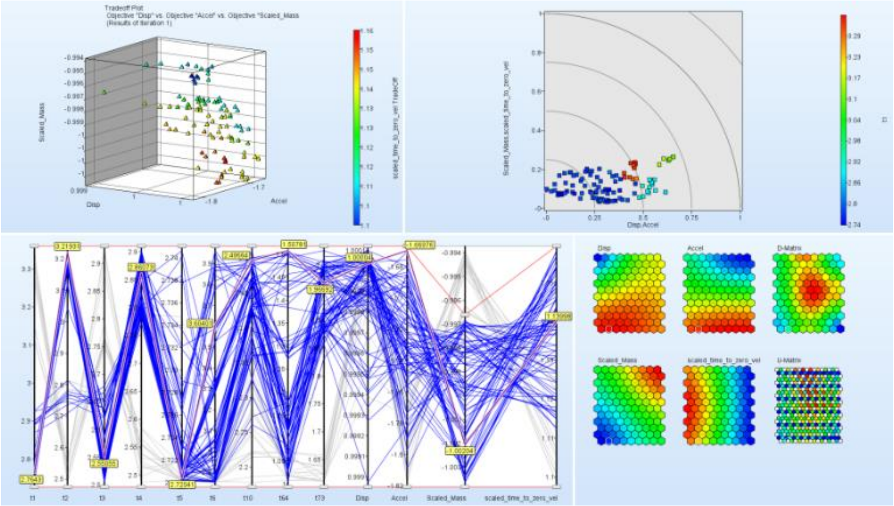


LS-OPT

Application possibilities

- Optimization
  - Size-/Shape optimization
  - Mixed continuous/discrete variables
    - Specify sets of discrete variables (e.g. sheet thicknesses)
  - Parameter/System Identification
  - Multiple load cases
    - Multi-disciplinary Optimization (MDO)
  - Multi-objective optimization (Pareto Frontier)
  - Multi-level optimization
  - Reliability based design optimization
  - Robust parameter design



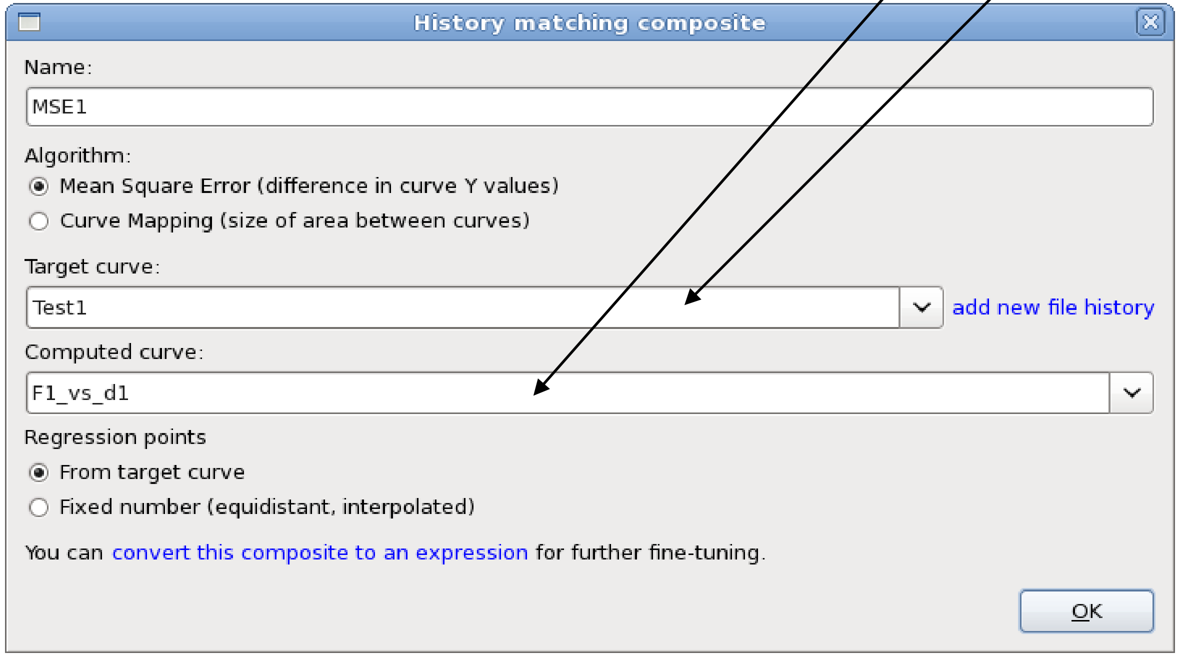


LS-OPT

Application possibilities

- Optimization
  - Parameter/System Identification Module: Calibration of test and simulation curves or scalar values

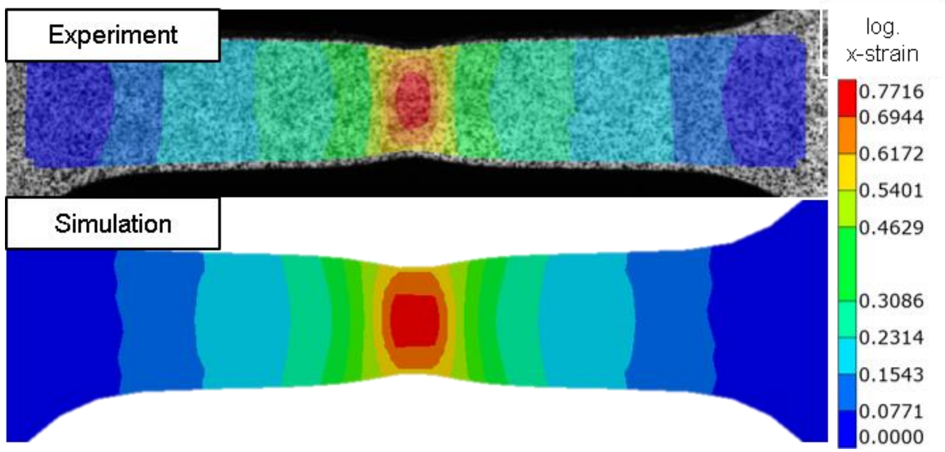
$$\frac{1}{P}\sum_{p=1}^{P} W_i \left(\frac{F_i(\mathbf{x}) - G_i}{s_i} \right)^2$$



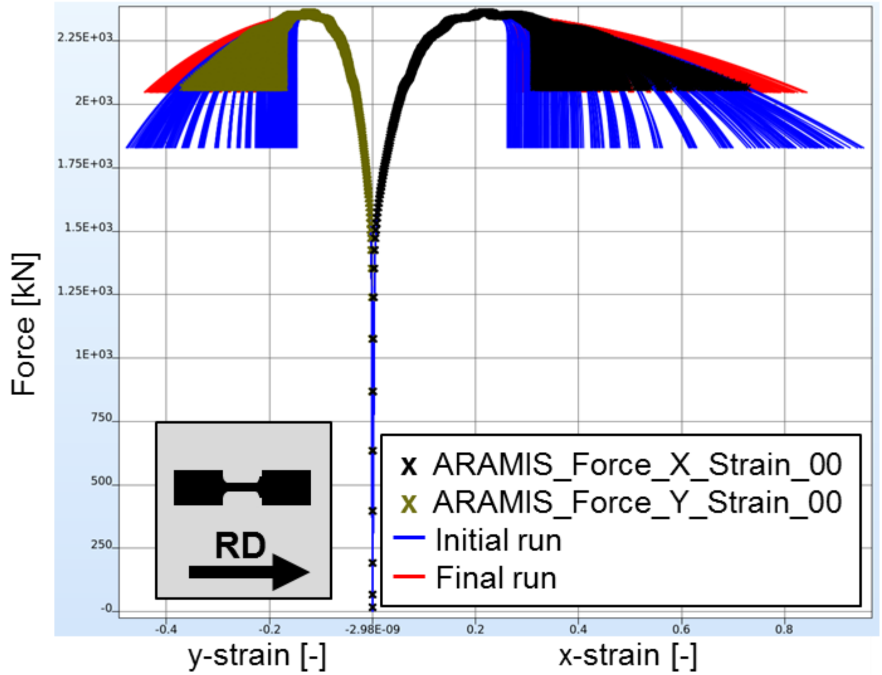
LS-OPT

Application possibilities

- Optimization
  - Full-field calibration
    - parameter identification using DIC data
    - Matching in time and space



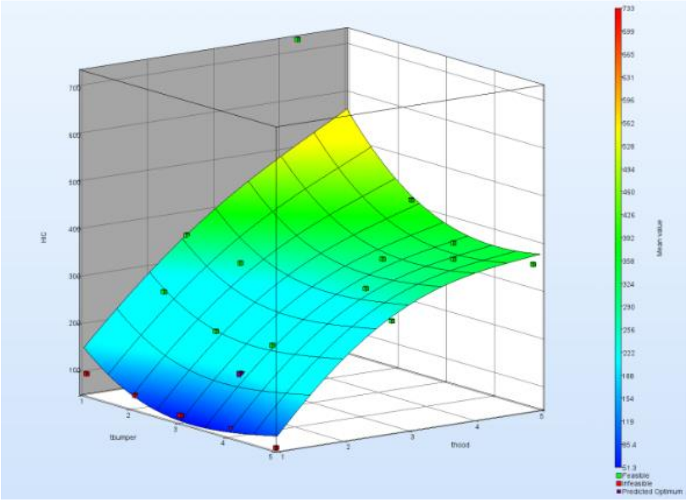
Deformation field of tensile test

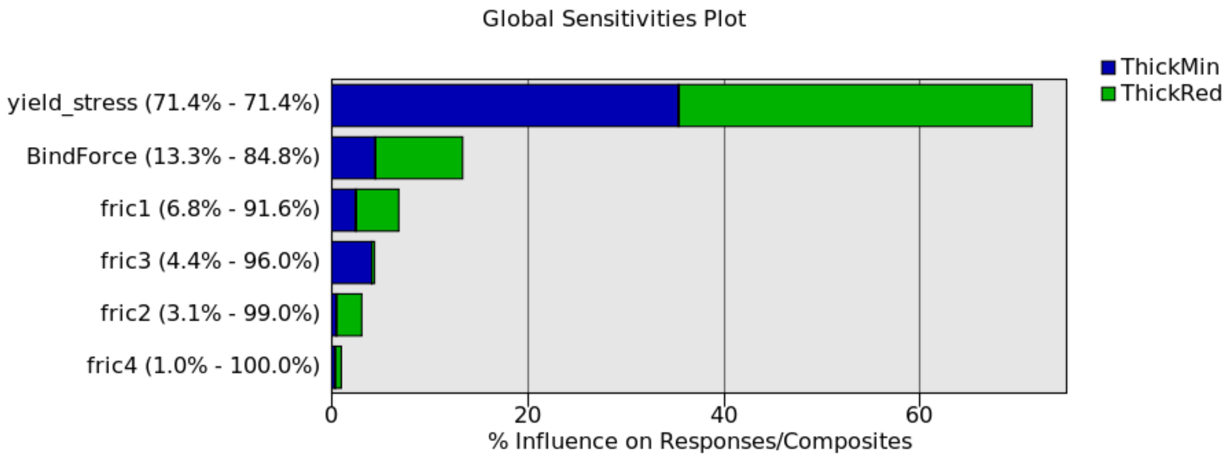


LS-OPT

Application possibilities

- Sensitivity Analysis
  - Design Exploration
  - DOE Studies for Variable Screening (ANOVA, Sobol)
    - *Contribution of variables to system performance*
    - *Identification of significant and insignificant variables*
    - *Ranking of importance*
  - Principal Component Analysis (PCA)

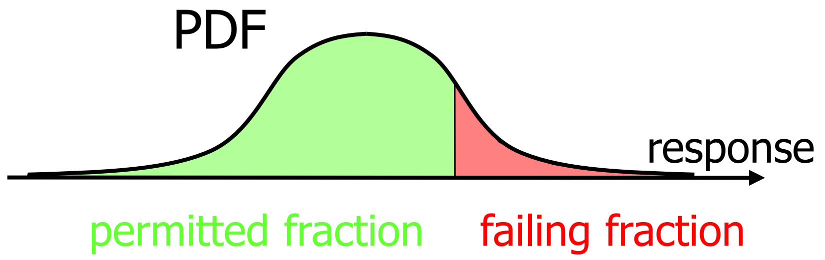


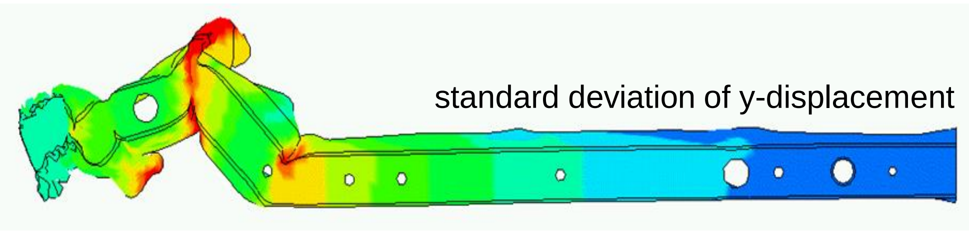


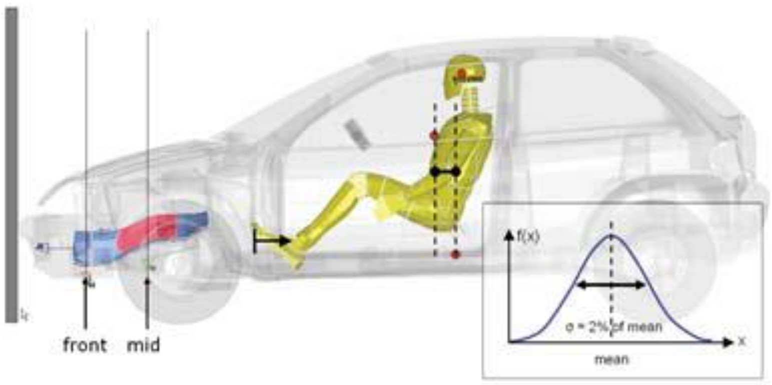
LS-OPT

Application possibilities

- Stochastic/Probabilistic Analysis: Consideration of uncertainties
  - Test of Model Robustness
    - Statistics (mean, standard deviation)
    - Correlation Analysis
  - Reliability (Probability of Failure)
  - Outlier Detection
  - Fringe statistical results on FE model



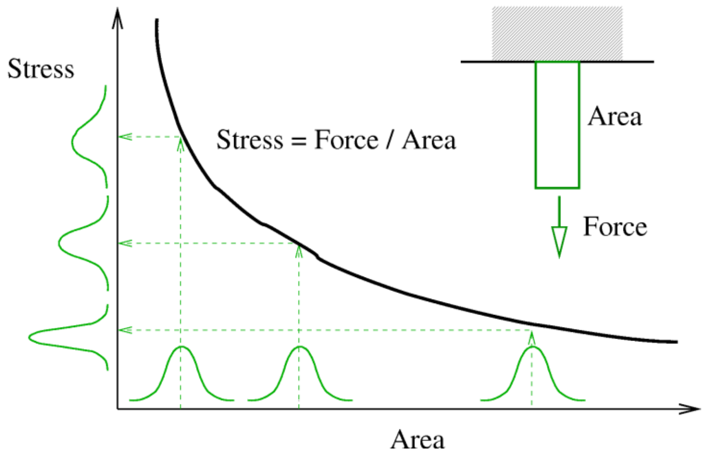


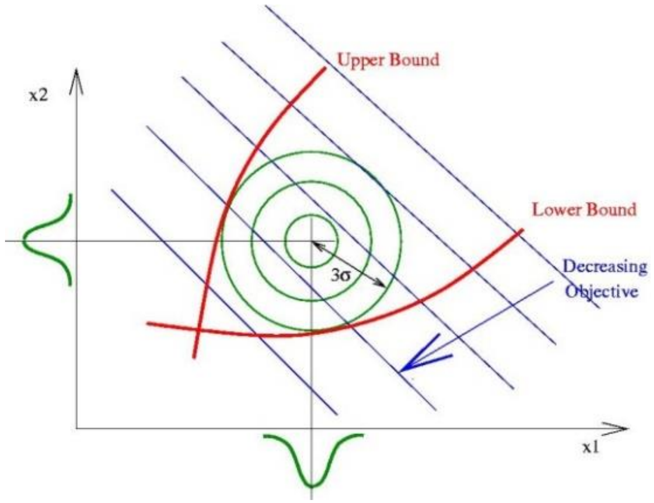


LS-OPT

Application possibilities

- Optimization incorporating uncertainties
  - Robust Parameter Design (RDO)
    - Improve/Maximize the robustness of the optimum
  - Reliability Based Design Optimization (RBDO)
    - Improve failure probability of optimum





- Methodology

LS-OPT New Features

What‘s new

LS-OPT New Features

2022 R1 and onwards

- LS-OPT Pro
  - Version naming will change to **YYYY R1 or R2**
  - The first version of LS-OPT Pro is 2022 R1
    - Released January, 2022
  - LS-OPT Pro part of 3-Tiered licensing system
    - **LS-OPT Pro (Licensed)**
    - optiSLang Premium
    - optiSLang Enterprise

LS-OPT New Features

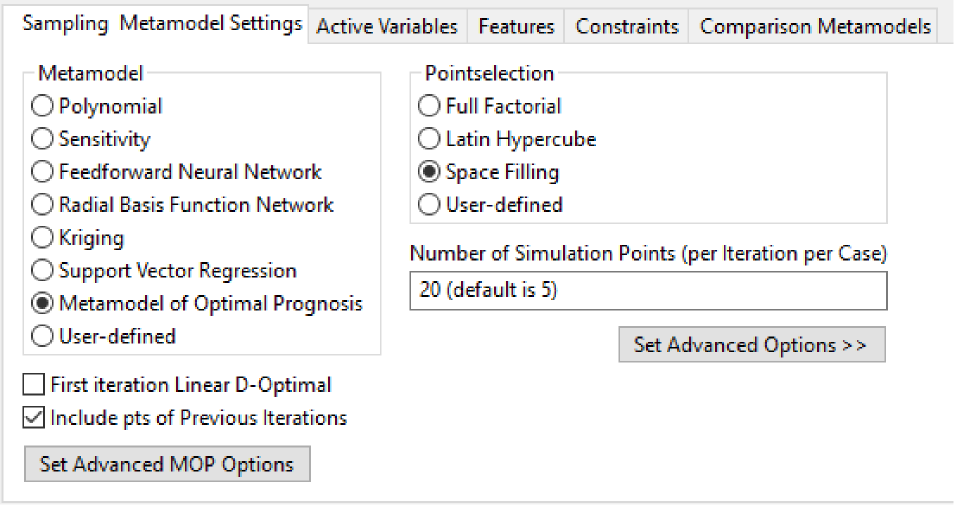
Interaction between LS-OPT and optiSLang

LS-OPT to optiSLang

- LS-DYNA extractor, e. g.
  - Responses and histories
  - Keyword parsing (parameter handling)
  - GUI
  - LS-Reader integration (d3plot)
- LS-OPT Metamodels, e. g.
  - Feed-forward Neural Networks
  - Support Vector Regression
  - Radial Basis Function
  - Kriging

optiSLang to LS-OPT

- Metamodel of Optimal Prognosis (MOP), which automatically selects the best metamodel



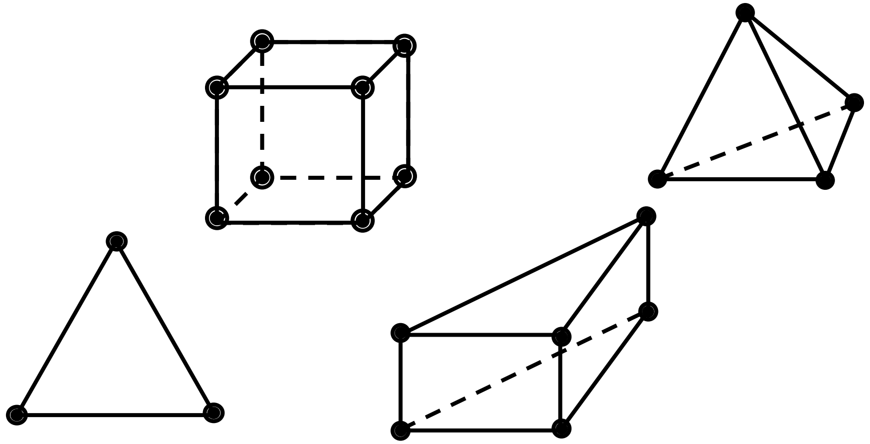
Outlook (scheduled 2023R1)

optiSLang and LS-OPT metamodels as a shared lib

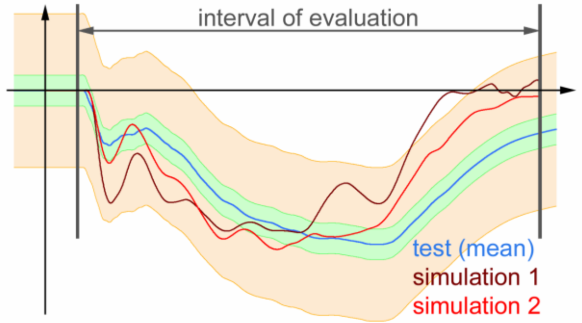
LS-OPT New Features

2022 R1 and onwards

- LS-DYNA® d3plot results extraction: extraction at coordinates
  - Interpolation at exact location for shell and solid elements
    - Shells: Triangles, Quadrilaterals
    - Solids: Tetrahedrons, Pentahedrons, Hexahedrons
  - → e. g. full-field calibration using DIC data

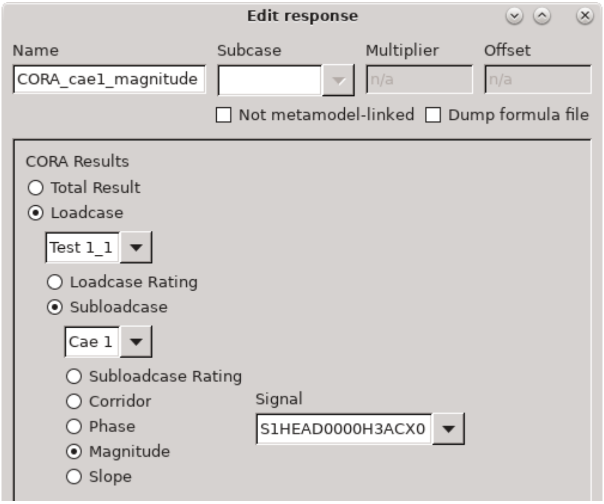


- CORAplus interface
  - pdb - Partnership for Dummy Technology and Biomechanics
  - Calculates level of correlation of time-history signals



Ratings:

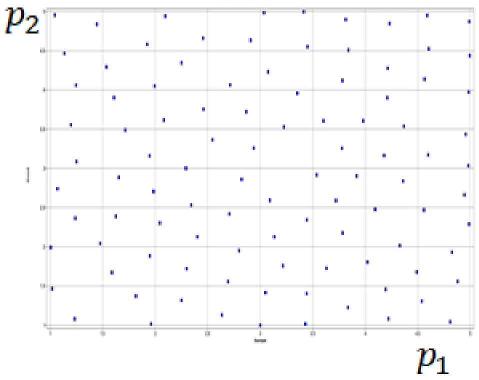
$$C_1 = 0.45$$
$$C_2 = 0.67$$



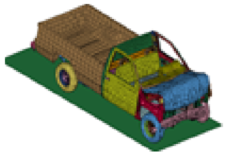
LS-OPT New Features

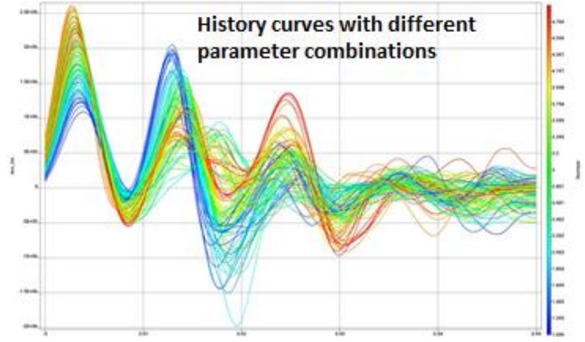
Outlook

- Reduced Order Modelling (ROM)



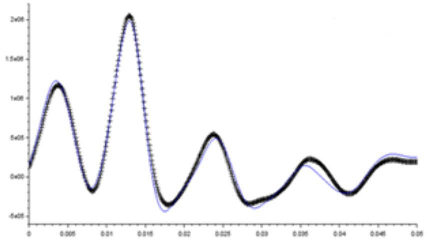
LS-DYNA





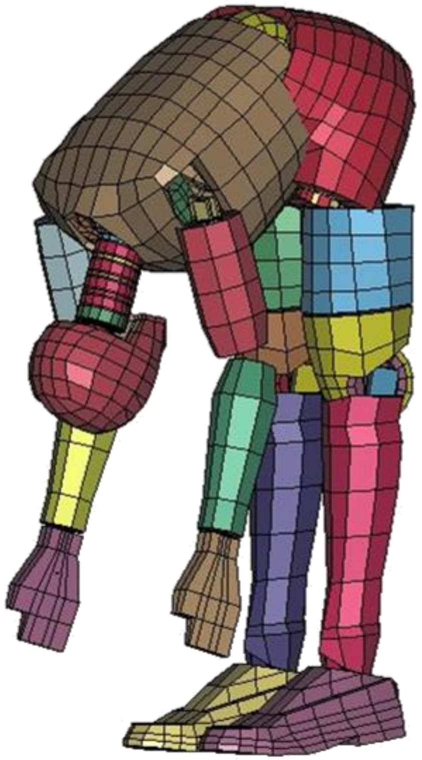
ROM

$$S(p) = \sum_{j=1}^{MS} \hat{\alpha}_j(p) V_j$$



- Improving ROM Accuracy
  - Nonlinearity hampers accuracy – substructure clustering based on nonlinearity (multi-ROM)
  - Improving coefficient prediction accuracy (metamodel selection/adaptive sampling)#
  - Neural Network based field approximation
- Integration into Ansys Twin Builder

Thank You



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