DYNAmore Express

Topology Optimization with LS-TaSC and Parametric Optimization with LS-OPT

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Outline

- Classification of Structural Optimization Techniques
- LS-TaSC
  - Overview
  - New features in Version 2022R1
- LS-OPT
  - Overview
  - New features in Version 2022R1

Classification of Structural Optimization Techniques

- 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
  - a free shape of the outer surface contour is chosen

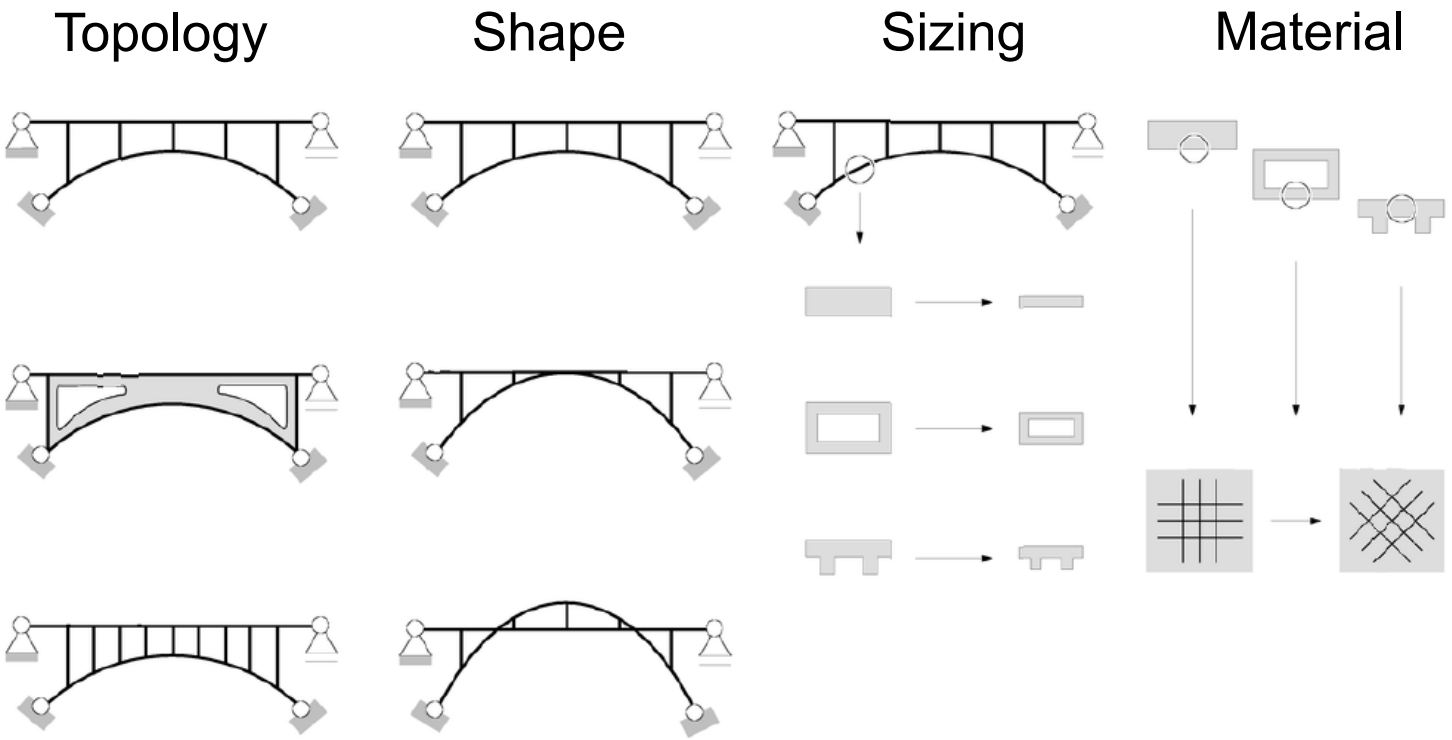
LS-TaSC

- Shape optimization
  - parameterized geometry (e.g. a hole radius) is designed
- Size optimization
  - shell thickness is designed per part basis
- Material optimization
- ...

LS-OPT

→ Parametric optimization

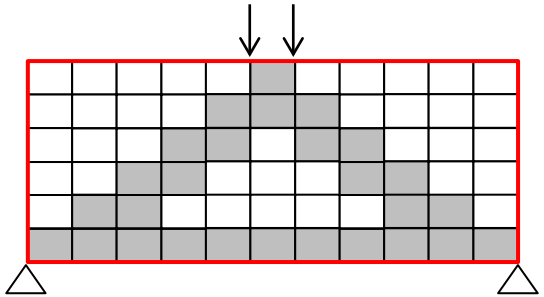
Classification of Structural Optimization Techniques

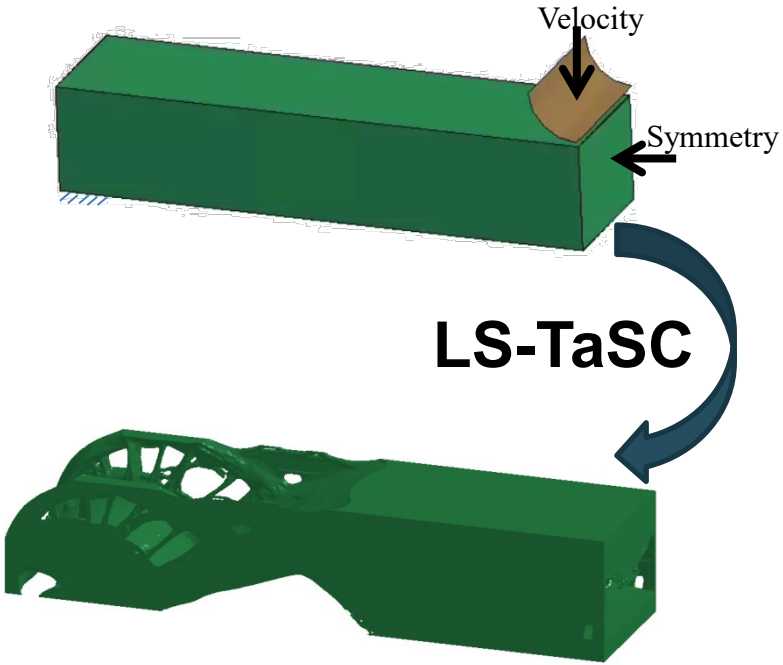


LS-TaSC Overview

Topology Optimization

- Redistribution of material within a given domain

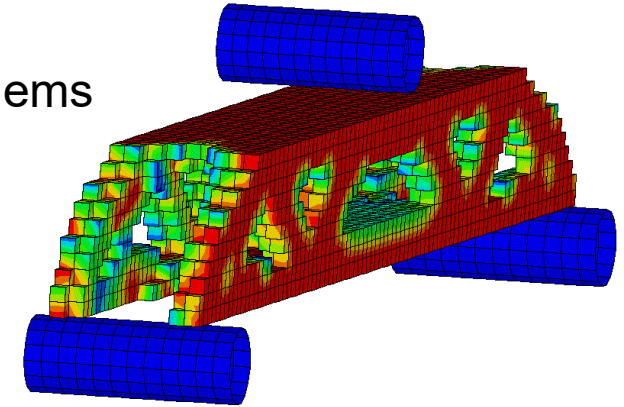


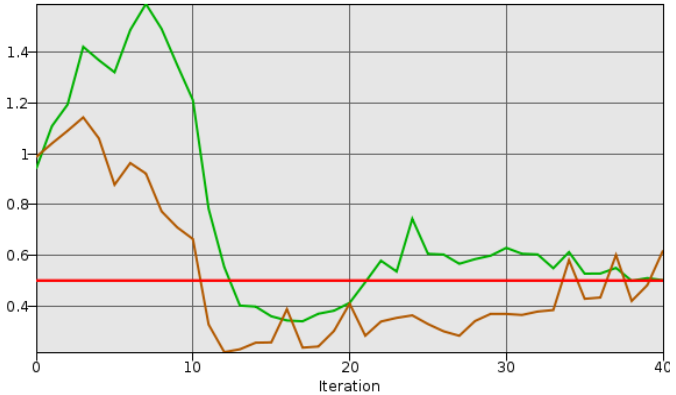


- Design variables
  - Relative density of each element
- Result
  - New material distribution
  - New shape of structure

LS-TaSC - General

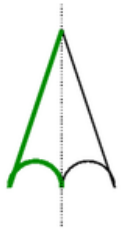
- Topology and shape optimization of non-linear problems
  - Dynamic loads
  - Contact conditions
  - Solids and shells
  - → find a concept design for structures analyzed using LS-DYNA (implicit and explicit)
- Huge LS-DYNA models
  - 10 million elements
- Multiple load cases and disciplines
- Global constraint handling
  - Energy absorption, maximum reaction forces, …
  - → Multi-point optimization and metamodels



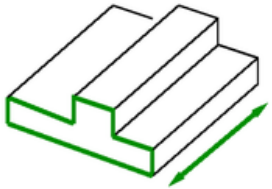


Geometry definitions

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

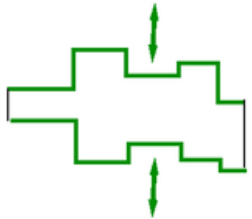


Symmetry

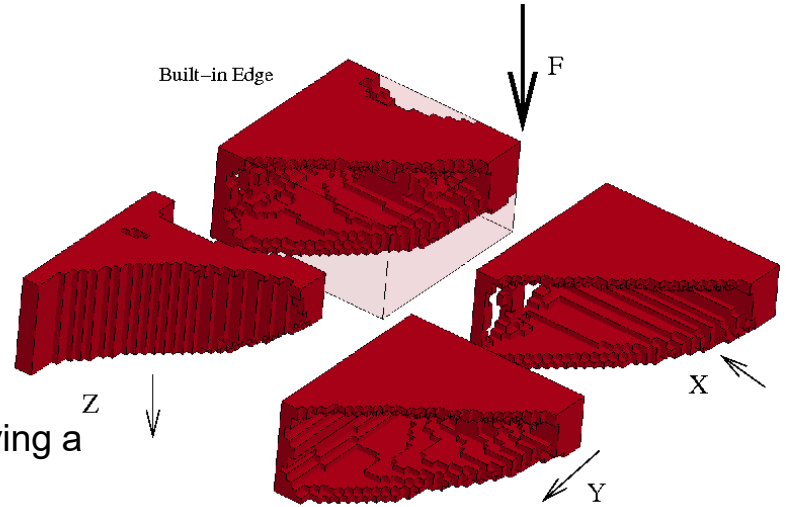


Extrusion

One–sided Casting



Two–sided Casting



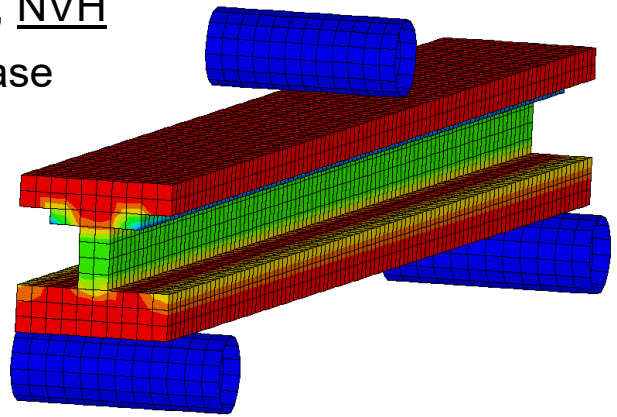
Forging: Two-sided casting preserving a minimum thickness (no holes)

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

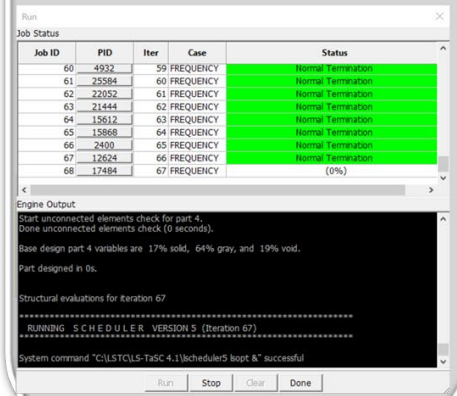
  → maximization of fundamental frequency for NVH load case
- Free Surface Design
  - Objective: Uniform surface stress



Integration

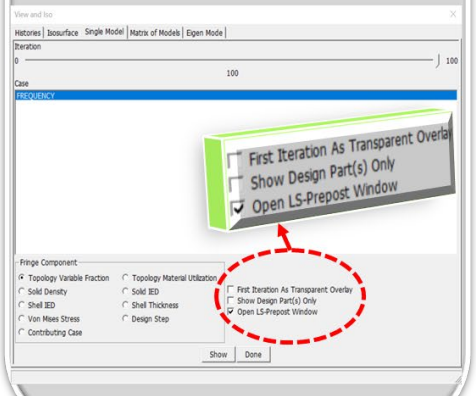
LS-TaSC with LS-DYNA

- no special treatment for nonlinearties



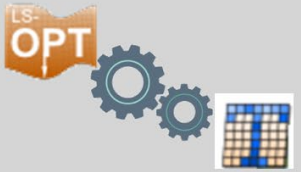
LS-TaSC with LS-PrePost

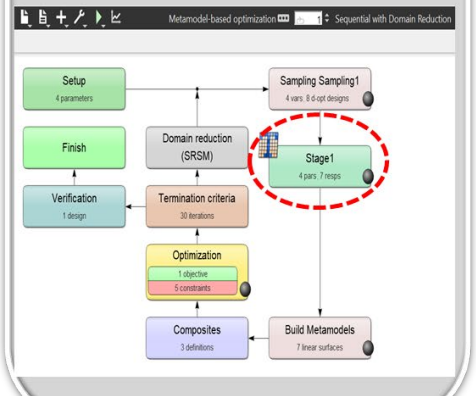
- results visualization
- model editing



LS-TaSC with LS-Opt

- multilevel and complex design schemes



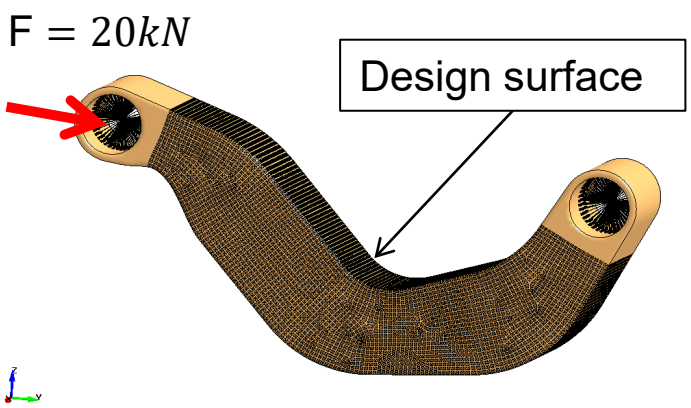


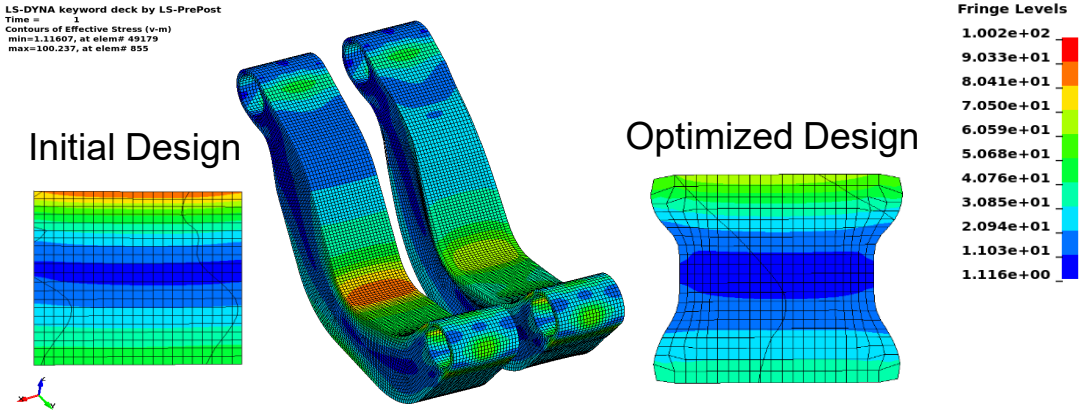
Application Examples

Example – Free Surface Design

- Objective: uniform surface stress

  → reduction of stress concentration

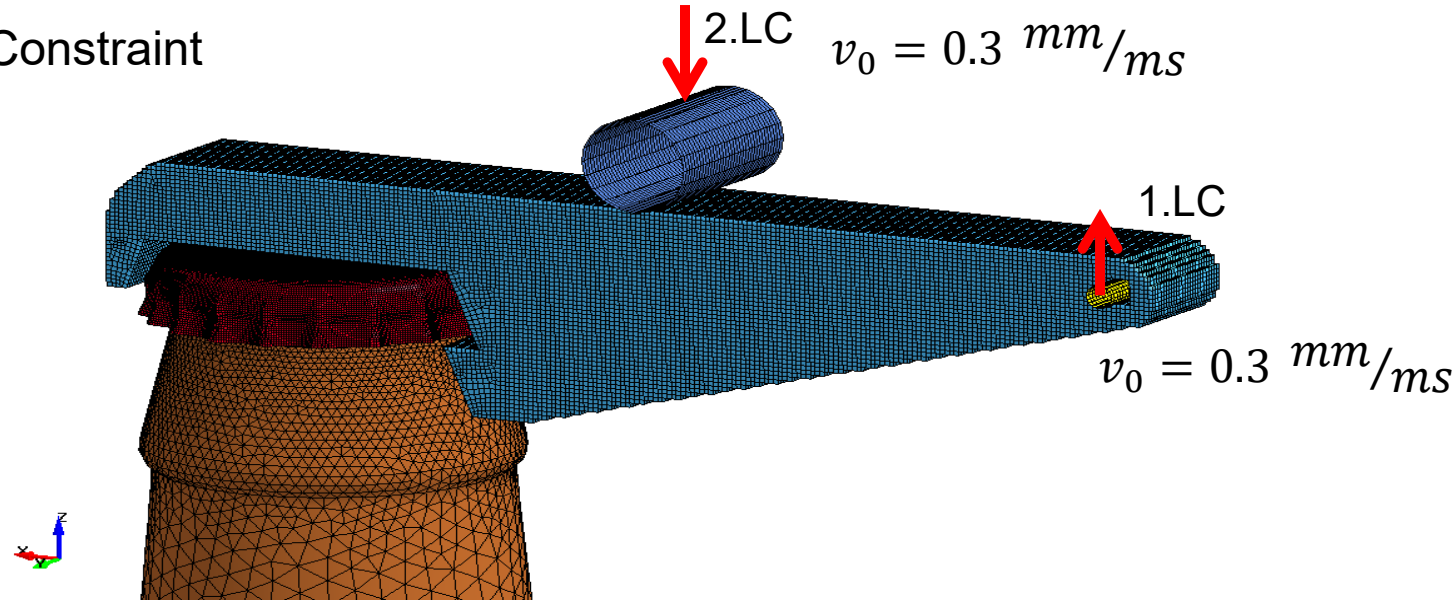




→ 20% stress reduction

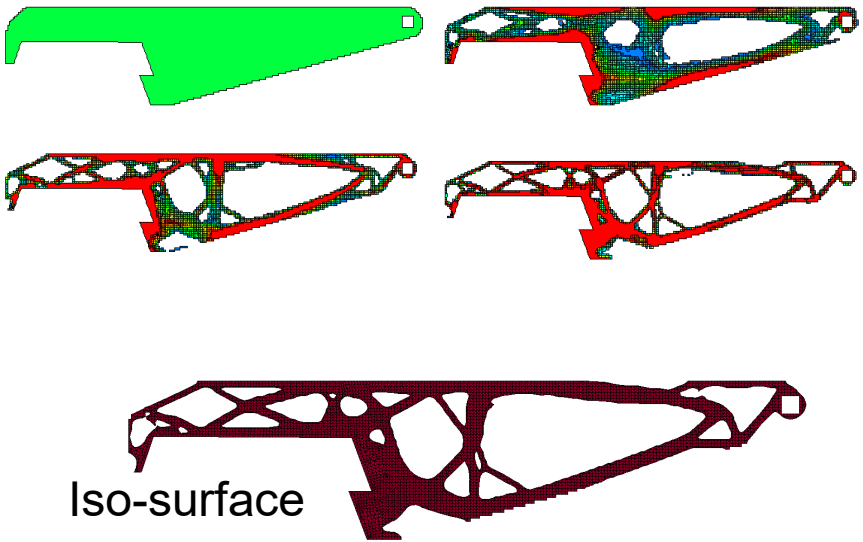
Example – Bottle Opener

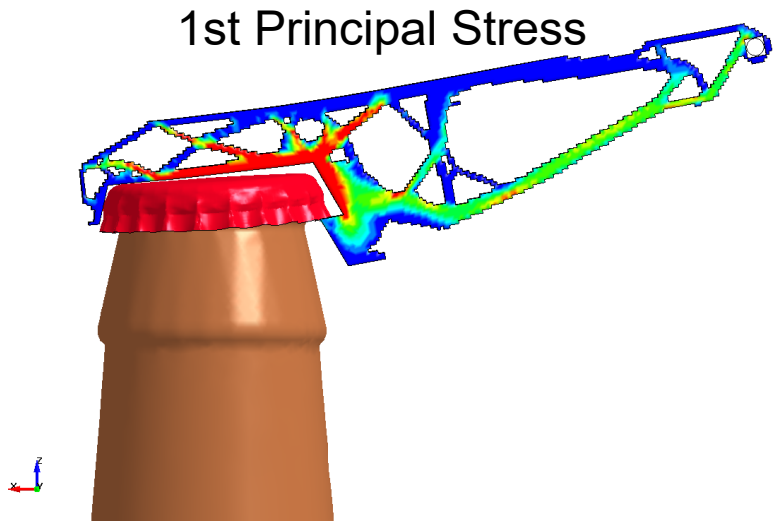
- Starting design and load cases
- Material: plastic
- Desired mass fraction 0.4
- Geometry Constraint
  - Extrusion



Example – Bottle Opener

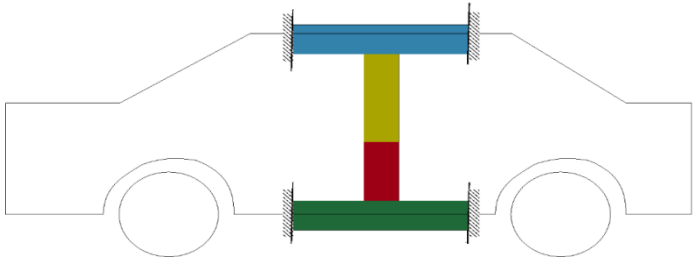
- Results
- From Initial Design to Optimized Structure (density distribution)

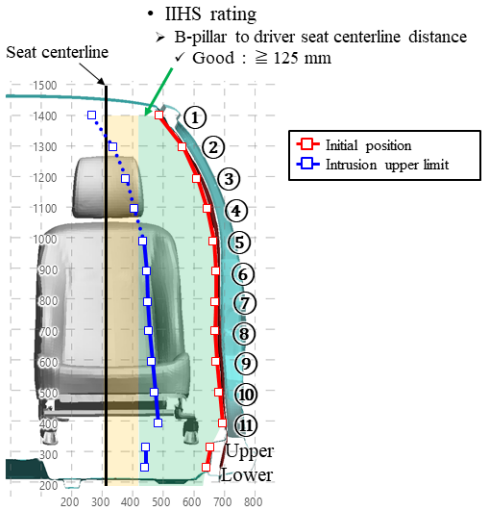


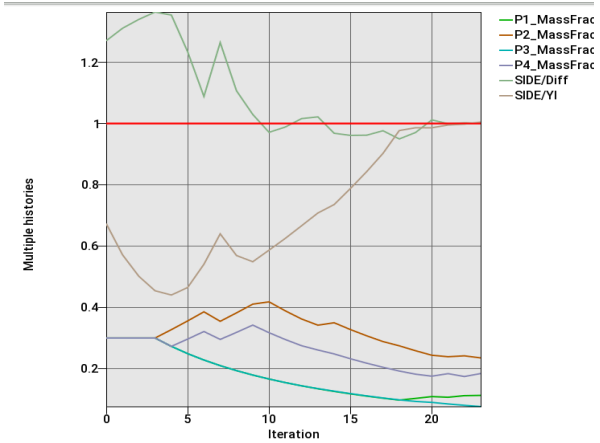


Example – Side Impact

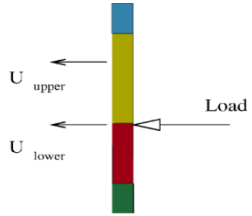
- Simplified B-pillar
  - Objective
    - Stiffest structure
    - satisfy constraints
    - and minimize mass
  - Constraints
    - $-10\,u_{lower} < 1,$
    - $2u_{upper}/u_{lower} < 1$





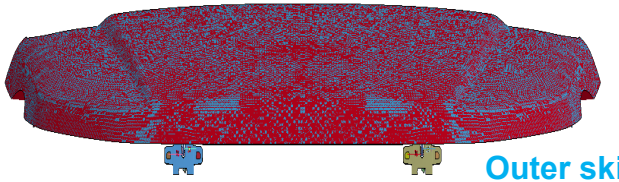


Problem statement by courtesy of JSOL



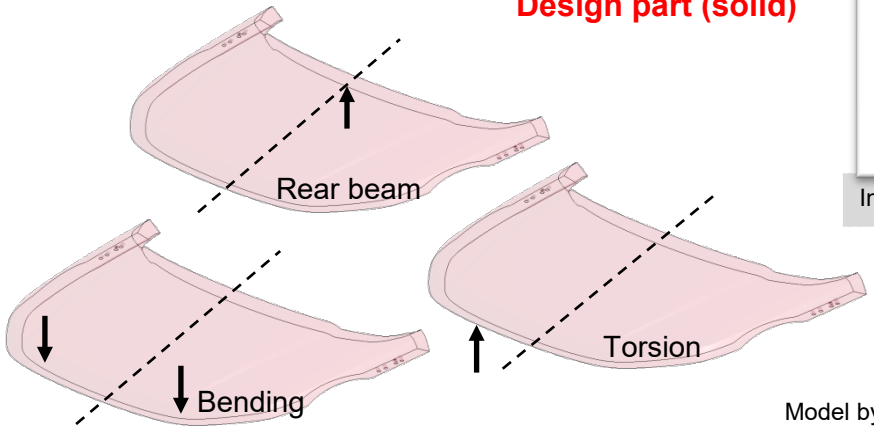
Example – Hood Design

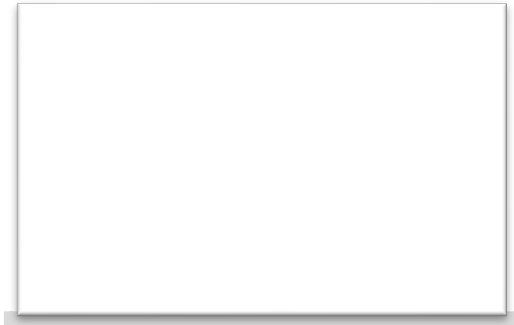
- Objective: Stiffest structure, satisfy constraints and minimize mass
- Constraints: rear beam, bending and torsion displacements



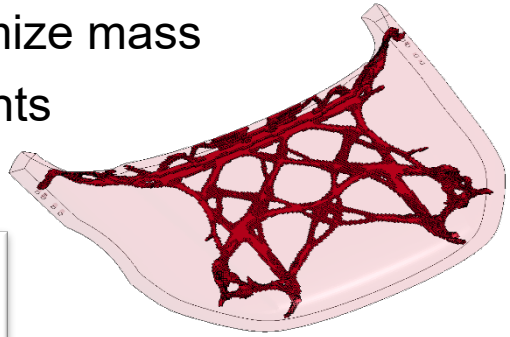
Outer skin (shell)

Design part (solid)

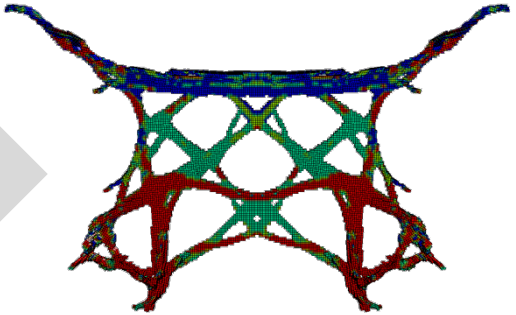




Initial Design has very low mass fraction of 0.01.



Optimum



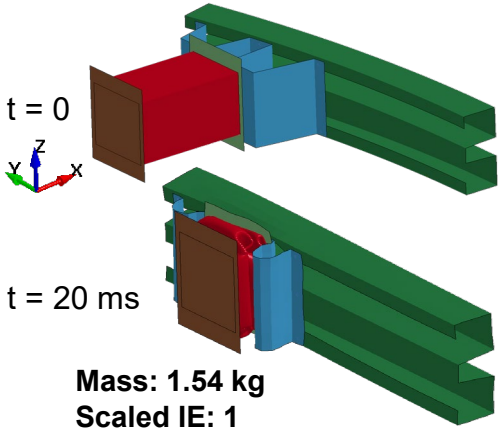
Design Contribution Plot
(Rear beam, torsion, bending)

Model by courtesy of Jaguar Land Rover

Example – Automotive Crash Box

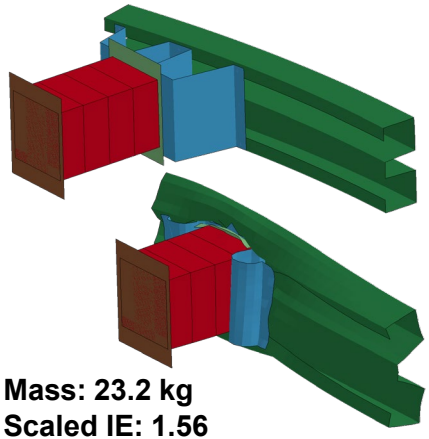
- **Crashworthiness and Lightweight Optimization**
  - Objective: Minimize mass
  - Constraints: Scaled max. Energy Absorption ≥ 1
  - Geometry: solid block split into 4 parts; XY and XZ symmetry

Reference: Shell structure



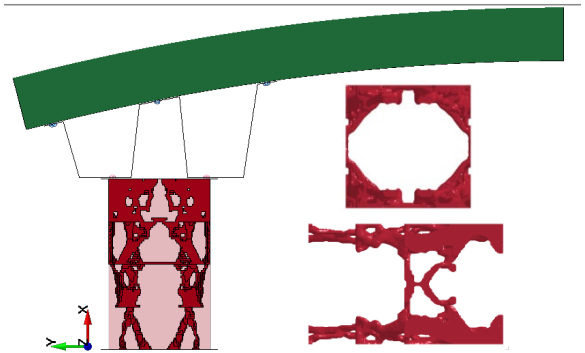
Mass: 1.54 kg
Scaled IE: 1
Scaled Peak Accel: 1

Baseline: Solid block



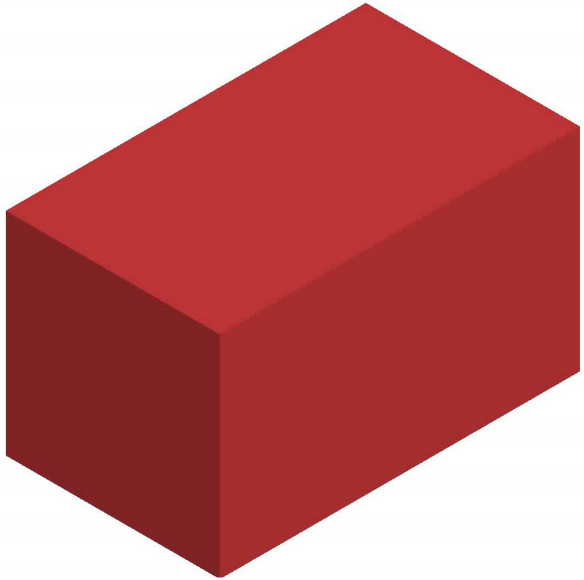
Mass: 23.2 kg
Scaled IE: 1.56
Scaled Peak Accel: 0.51

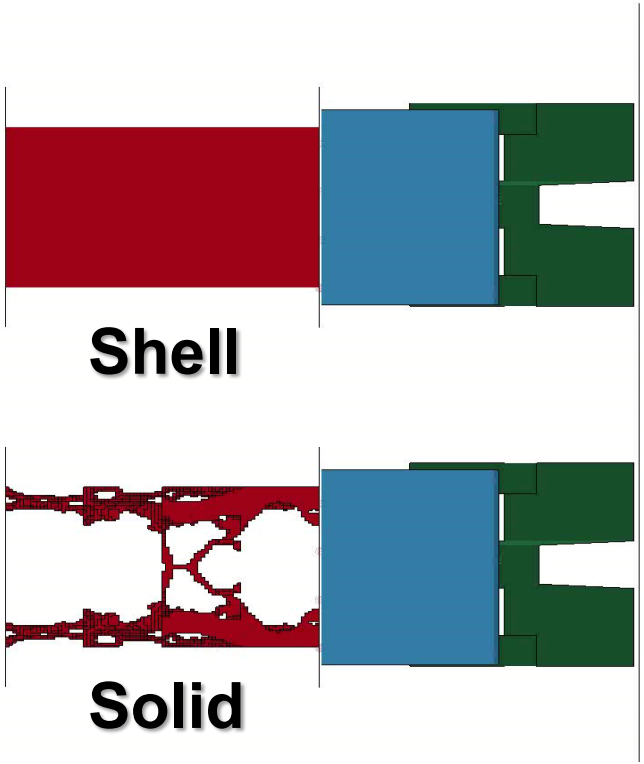
Optimal Solid structure



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

Example – Automotive Crash Box

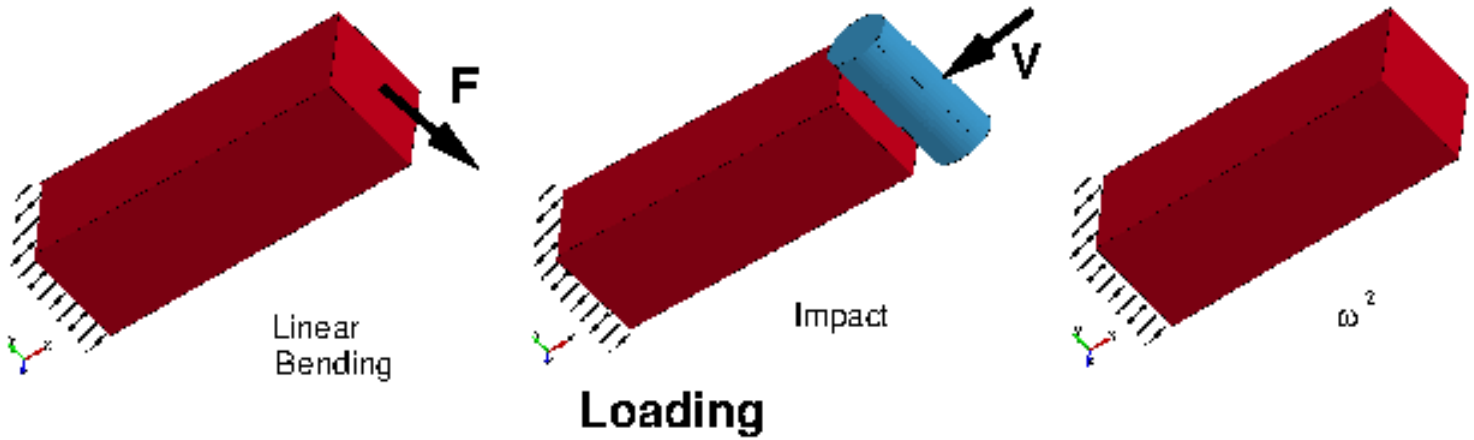




Gandikota I, Yi G, and Roux W,
Crashworthiness and lightweight optimization
of an automotive crash box using LS-TaSC.
FEA Information Engineering Solutions, October 2019

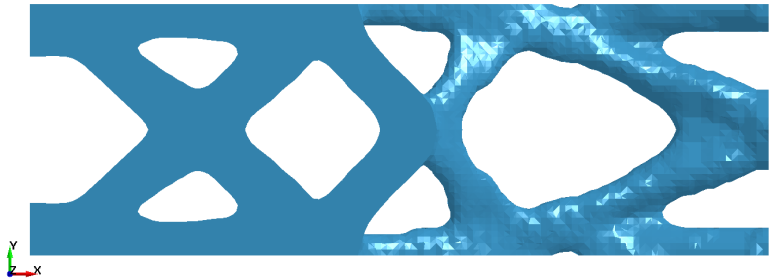
Impact, statics, and NVH

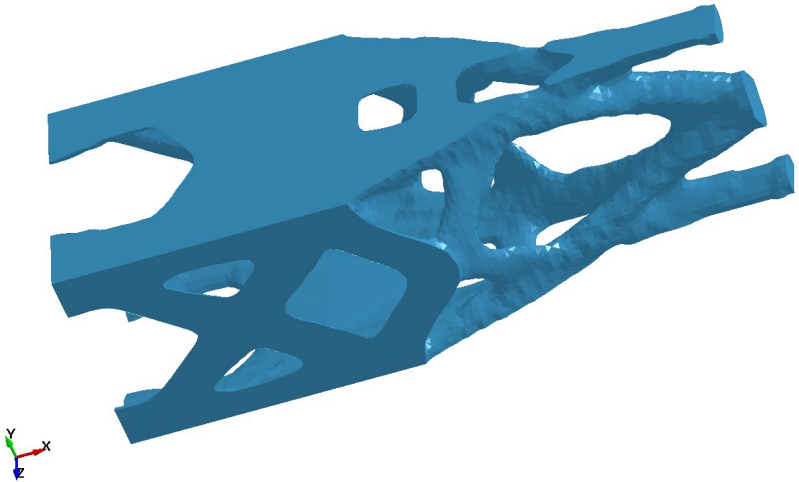
- Multi-disciplinary optimization, 3 load cases
  - Equal weights
- Mass fraction: 0.1



Impact, statics, and NVH

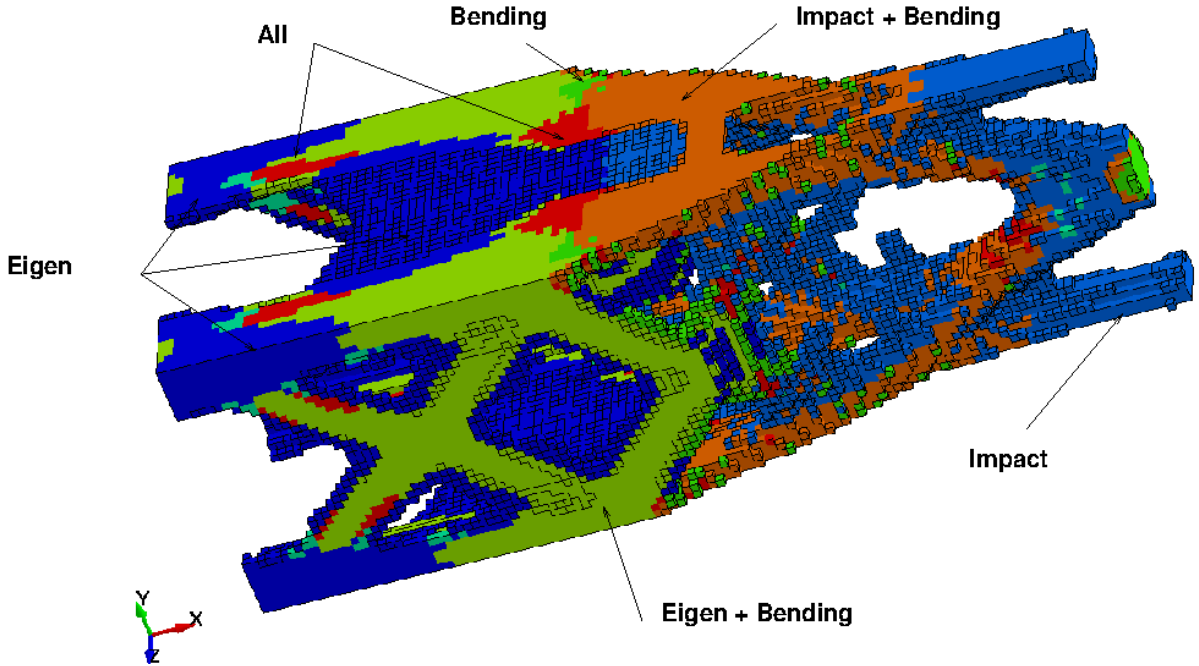
- Results (80 Iterations)
  - Optimal geometry





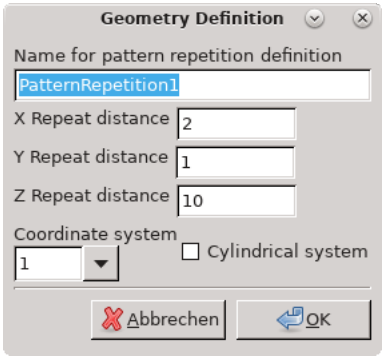
Impact, statics, and NVH

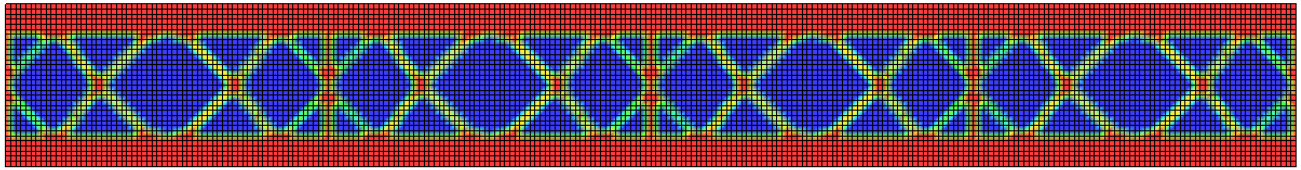
- Results
  - shows which load case contributes the material used in the part



New Features in 2022R1

- The d3plot interface was updated
- Surface designs can be exported to STL
  - Already available for isosurfaces of topology design of solid elements
- *ELEMENT_SOLID_ORTHO is supported
- Pattern and cyclic repetitions geometry definitions were added





LS-OPT Overview

About LS-OPT

- LS-OPT is a stand alone optimization software

  → can be linked to any (simulation) code –

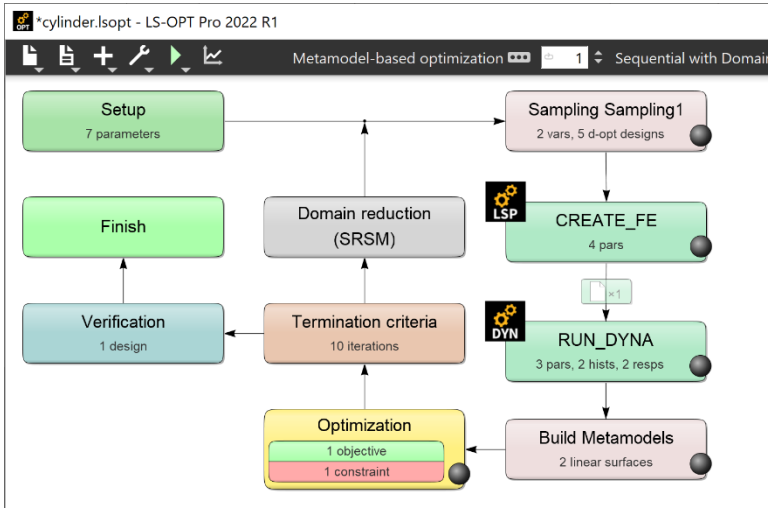
  - Interface to LS-DYNA, Excel, Matlab
  - Interface to LS-PrePost, PRIMER, ANSA, Hypermorph, …

    → shape optimization
  - Interface to META Post

    → result extraction
  - Interface to LS-OPT, LS-TaSC

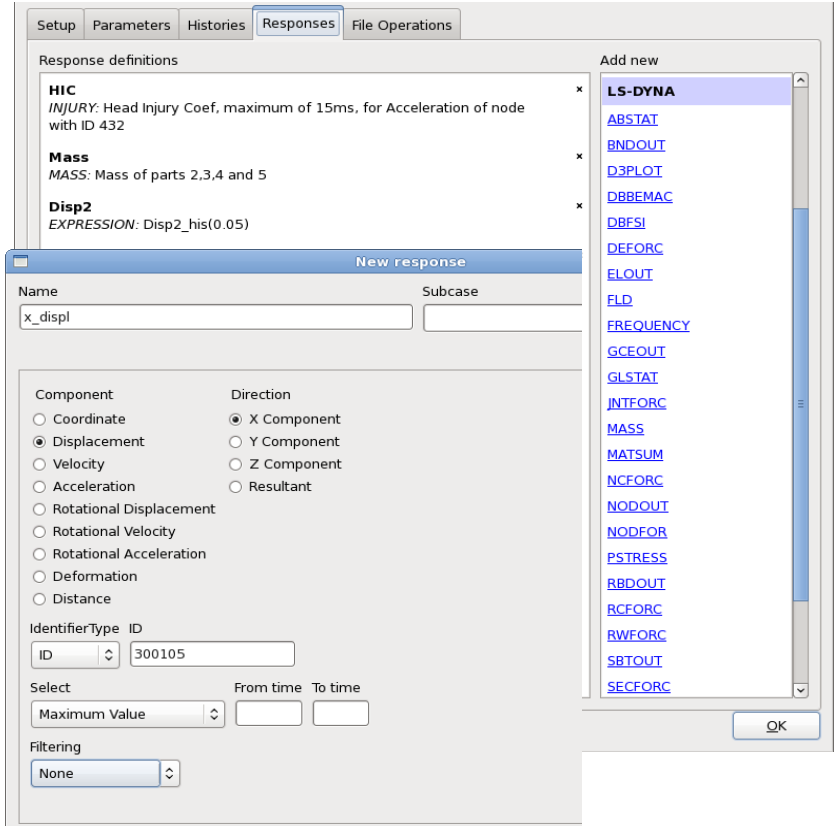
    → nested optimization
  - User-defined interface
  - Interface to Queuing Systems
    - PBS, LSF, SLURM, AQS, User-defined, …

  → LS-OPT as process manager



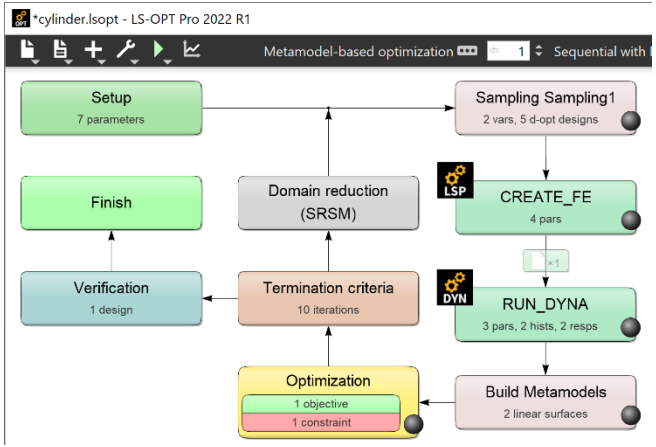
About LS-OPT

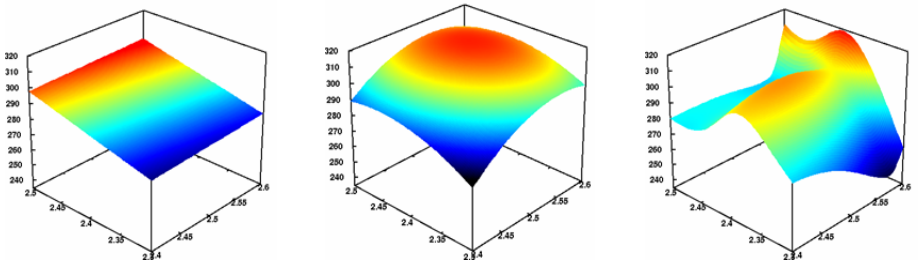
- LS-DYNA integration
  - Importation of design parameters from LS-DYNA keyword files (*PARAMETER)
  - Support of include files (*INCLUDE)
  - Result extraction of most LS-DYNA response types
  - Checking of LS-DYNA keyword files (*DATABASE_)
  - Monitoring of LS-DYNA progress



Methodologies

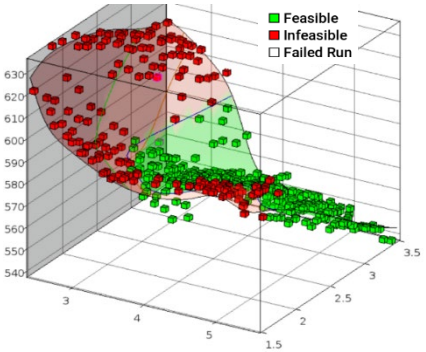
- (Sequential) Response Surface Method ((S)RSM)
  - → Metamodels
    - Polynomials
    - Radial Basis Functions (RBF)
    - Feedforward Neural Networks (FFNN)
- Genetic Algorithm (MOGA->NSGA-II)
  - → Multi-objective Optimization
    - Direct and metamodel-based
- Monte Carlo Analysis
  - → Robustness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



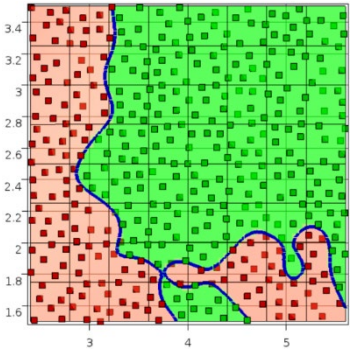


Methodologies

- Classifiers (Support Vector Classification)



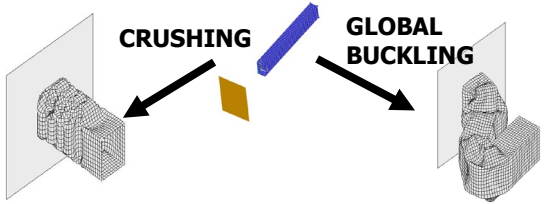
Metamodel
Approximation of response



Classifier
Approximation of constraint boundary

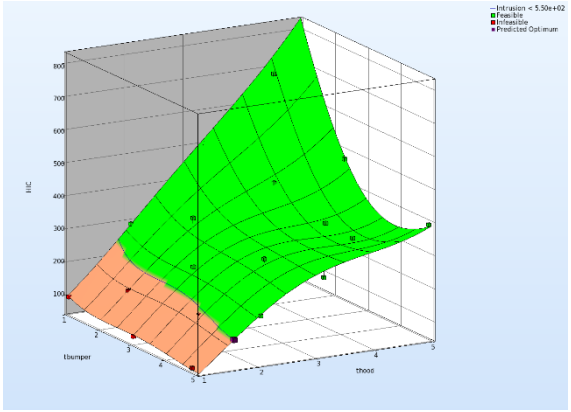
- Design point (variable values)
- Feasibility of each design

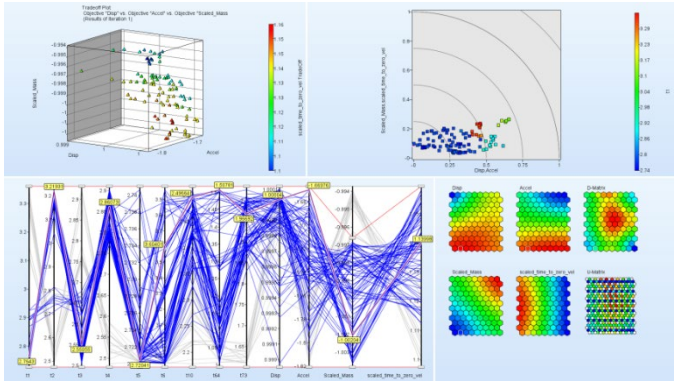
- Discontinuous responses
- Binary responses
- → Constraints for optimization or reliability analysis



Applications of LS-OPT

- 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

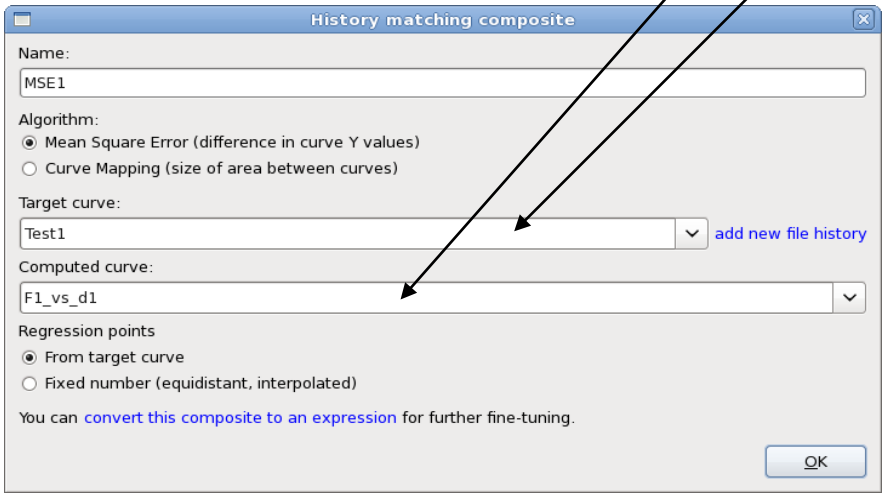




Applications of LS-OPT

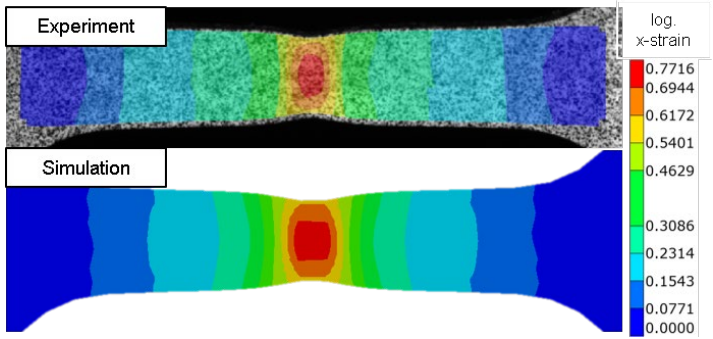
- Optimization
  - Parameter/System Identification Module: Calibration of test and simulation curves or scalar values

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

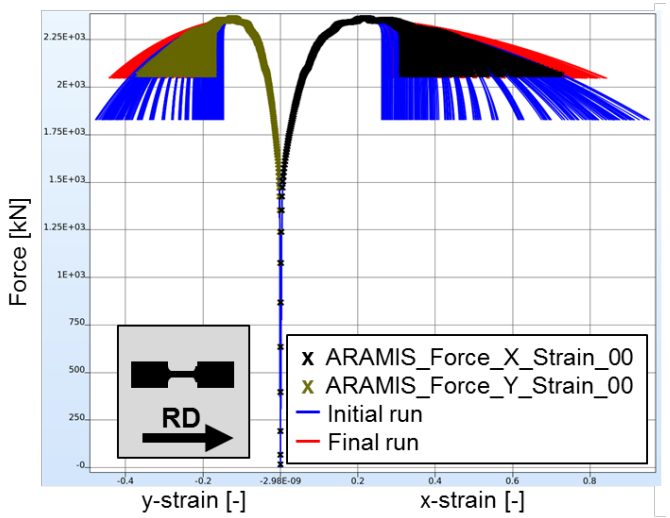


Applications of LS-OPT

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

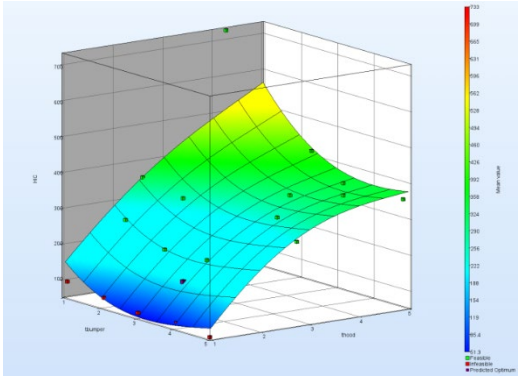


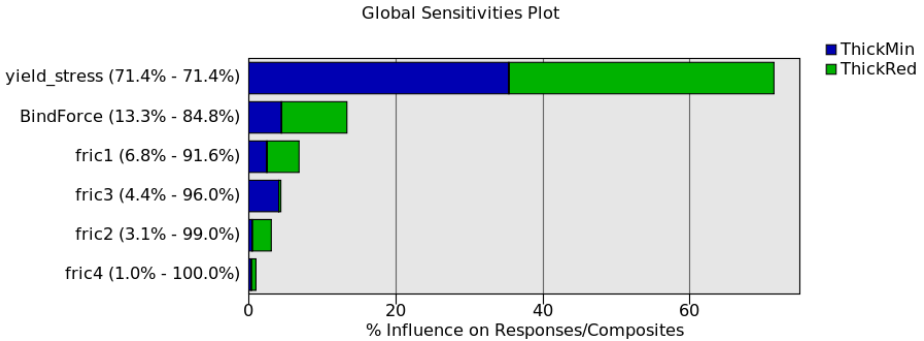
Deformation field of tensile test



Applications of LS-OPT

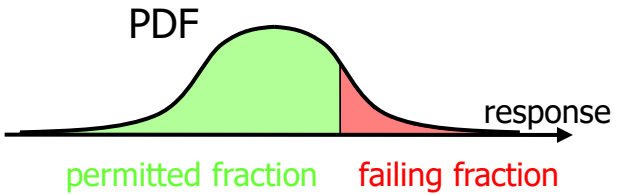
- Sensitivity Analysis
  - Design Exploration
  - DOE Studies for Variable Screening (ANOVA, Sobol)
    - *Contribution of variables to system performance*
    - *Identification of significant and insignificant variables*
    - *Ranking of importance*
  - Principal Component Analysis (PCA)

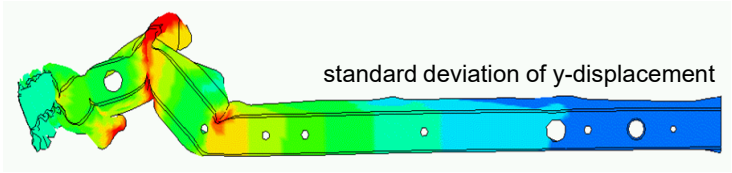


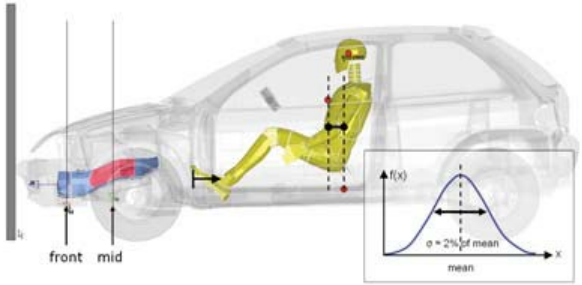


Applications of LS-OPT

- 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

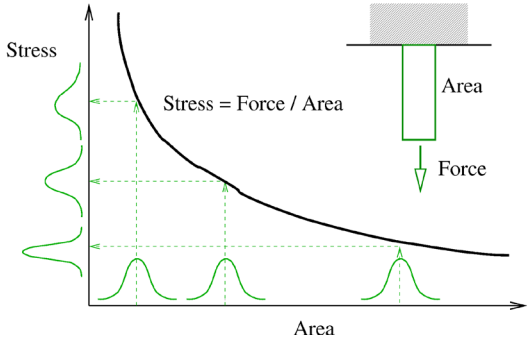


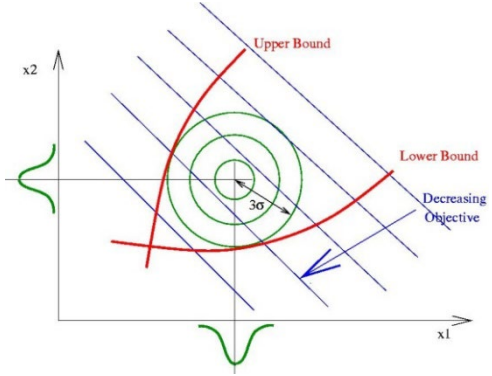




Applications of LS-OPT

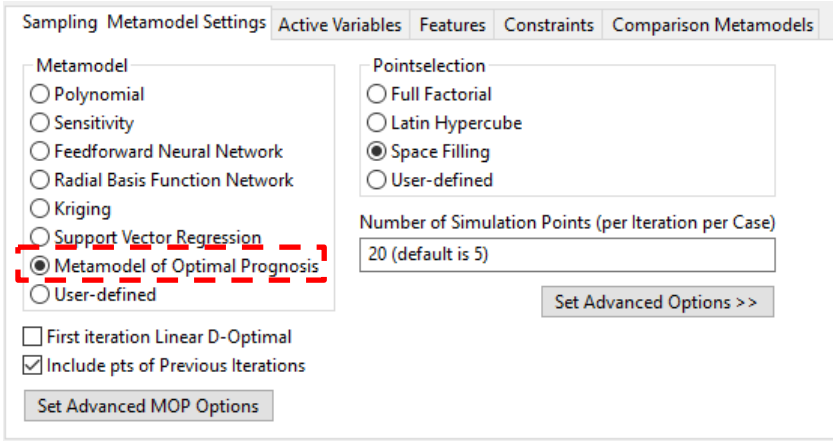
- Optimization incorporating uncertainties
  - Robust Parameter Design (RDO)
    - Improve/Maximize the robustness of the optimum
  - Reliability Based Design Optimization (RBDO)
    - Improve failure probability of optimum





New Features in 2022R1

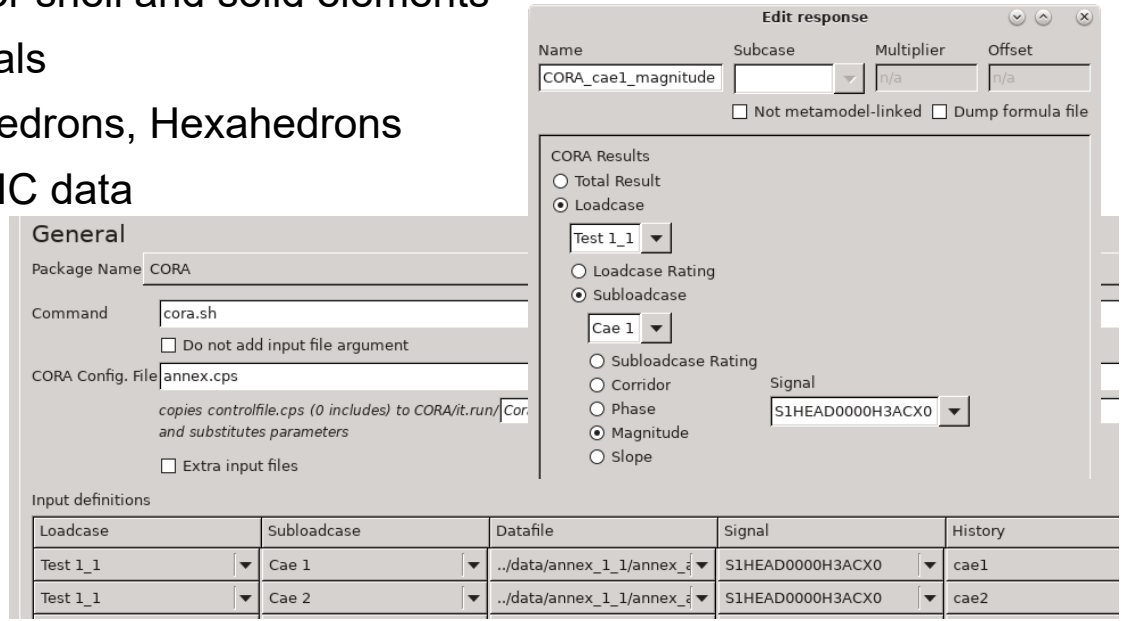
- LS-OPT Pro
  - Version naming will change to **YYYY R1 or R2**
  - The first version of LS-OPT Pro is 2022 R1
    - Released Jan, 2022
  - LS-OPT Pro part of 3-Tiered licensing system
    - **LS-OPT Pro (Licensed)**
    - optiSLang Premium
    - optiSLang Enterprise
- Metamodel of Optimal Prognosis (MOP)
  - integrated from optiSLang
  - best metamodel is selected automatically
    - Linear, Quadratic, Kriging



New Features in 2022R1

- The d3plot interface was updated
- 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



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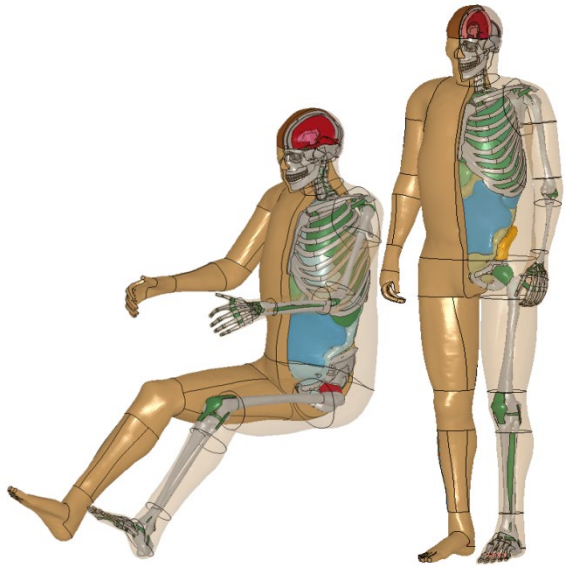

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Your questions, please