

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

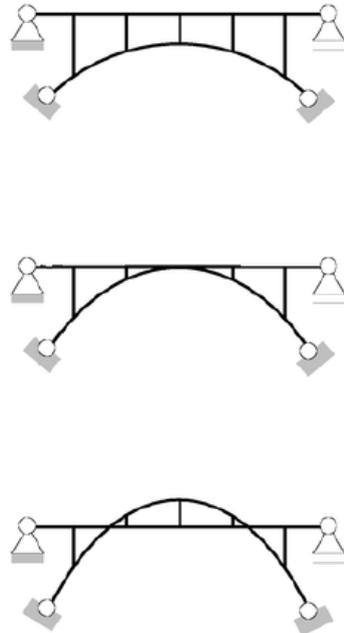
→ Parametric optimization

Classification of Structural Optimization Techniques

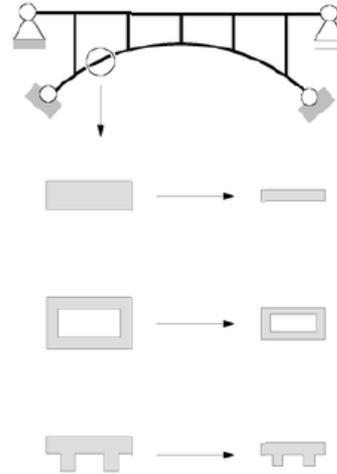
Topology



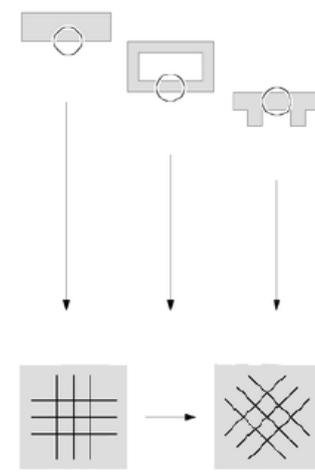
Shape



Sizing



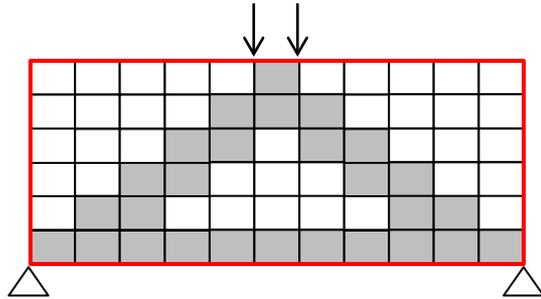
Material



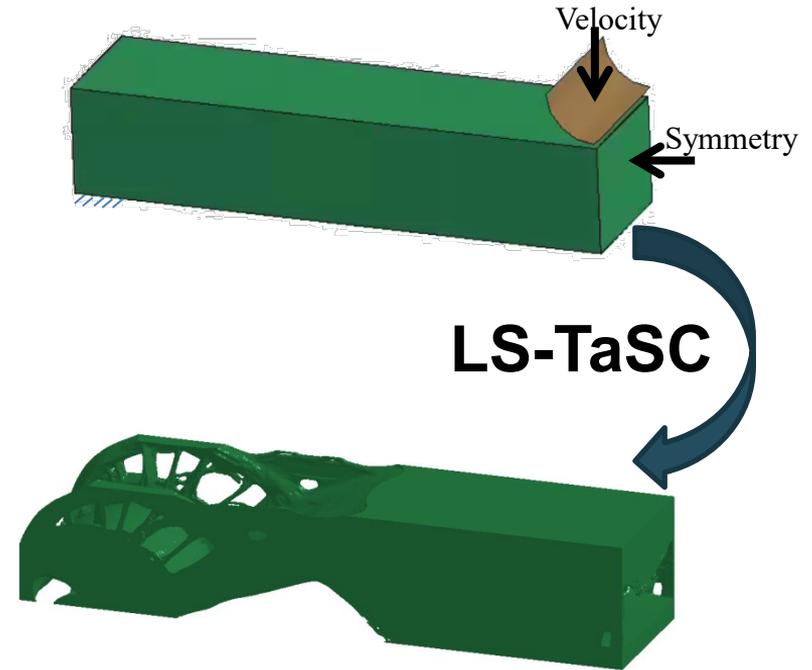
LS-TaSC Overview

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)

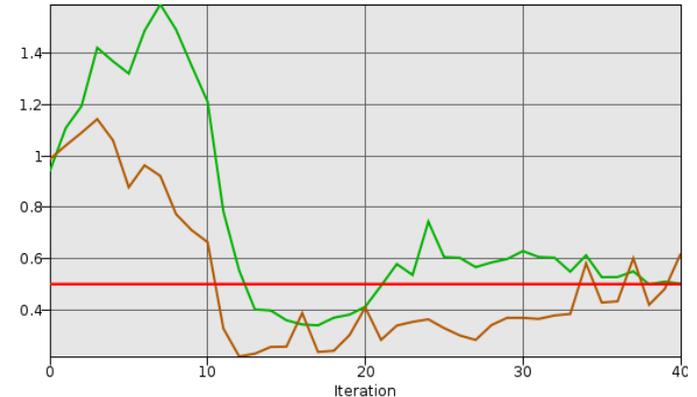
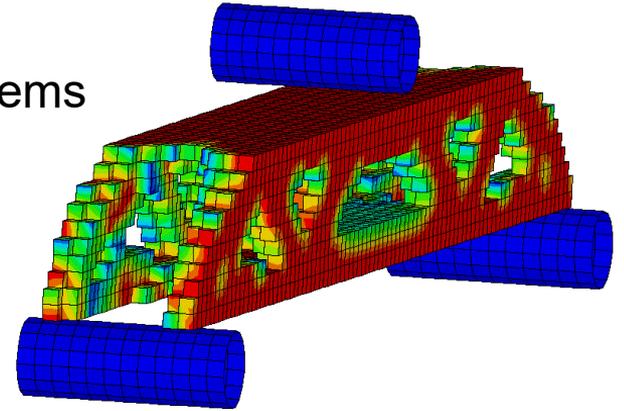
■ Huge LS-DYNA models

- 10 million elements

■ Multiple load cases and disciplines

■ Global constraint handling

- Energy absorption, maximum reaction forces, ...
- Multi-point optimization and metamodels

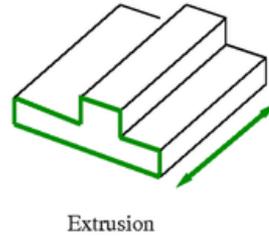


Geometry definitions

- Symmetry



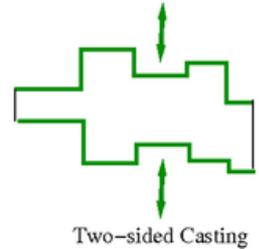
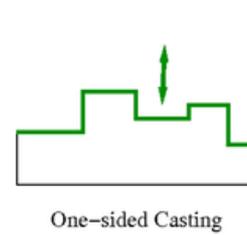
- Extrusion



- Casting

- One sided

- Two sided

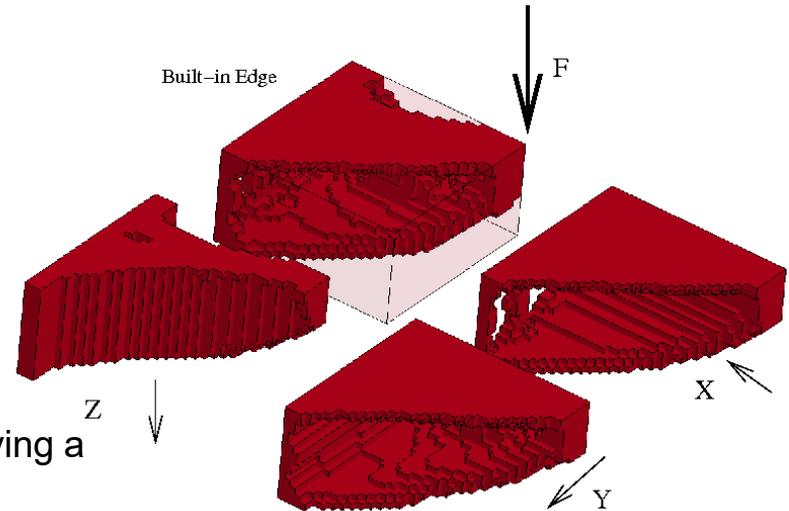


- Forging

- Two sided casting

- Preserving a minimal thickness

- Pattern and cyclic repetition (2022R1)



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

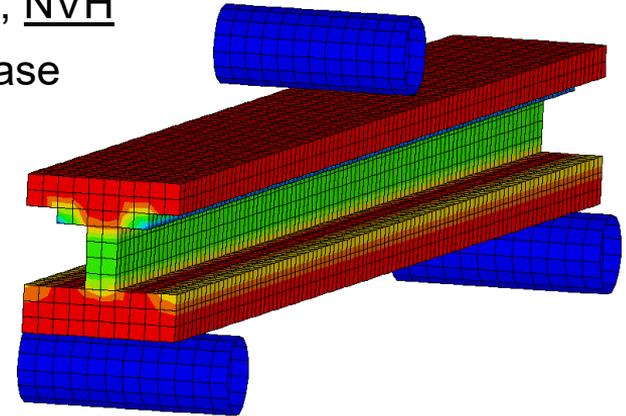
■ Projected Subgradient Method

- 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 nonlinearities



Run

Job Status

Job ID	PID	Iter	Case	Status
60	4932	59	FREQUENCY	Normal Termination
61	25584	60	FREQUENCY	Normal Termination
62	22052	61	FREQUENCY	Normal Termination
63	21444	62	FREQUENCY	Normal Termination
64	15612	63	FREQUENCY	Normal Termination
65	15868	64	FREQUENCY	Normal Termination
66	2400	65	FREQUENCY	Normal Termination
67	12624	66	FREQUENCY	Normal Termination
68	17484	67	FREQUENCY	Normal Termination

Engine Output

Start unconnected elements check for part 4.
Done unconnected elements check (0 seconds).

Base design part 4 variables are 17% solid, 64% gray, and 19% void.

Part designed in 0s.

Structural evaluations for iteration 67

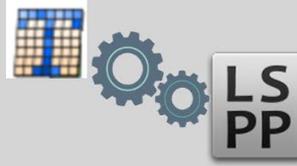
```

.....
RUNNING SCHEDULER VERSION 5 (Iteration 67)
.....
System command "C:\LS-TaSC 4.1\lscheduler\loopt &" successful
    
```

Run Stop Clear Done

LS-TaSC with LS-PrePost

- results visualization
- model editing



View and Edit

Iterations | Isosurface | Single Model | Matrix of Models | Eigen Mode

Iteration: 0 to 100

Case: FREQUENCY

First Iteration As Transparent Overlay
Show Design Part(s) Only
Open LS-Prepost Window

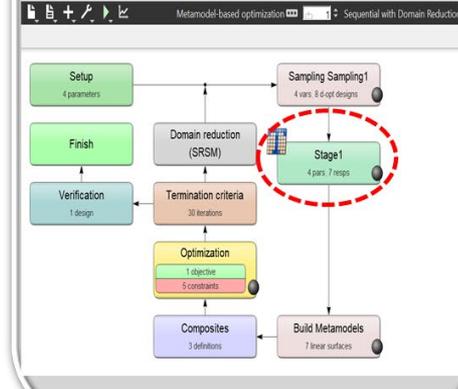
Fringe Component:

- Topology Variable Fraction
- Solid Density
- Shell ID
- Von Mises Stress
- Contributing Case
- Topology Material Utilization
- Solid ID
- Shell Thickness
- Design Step
- First Iteration As Transparent Overlay
- Show Design Part(s) Only
- Open LS-Prepost Window

Show Done

LS-TaSC with LS-Opt

- multilevel and complex design schemes

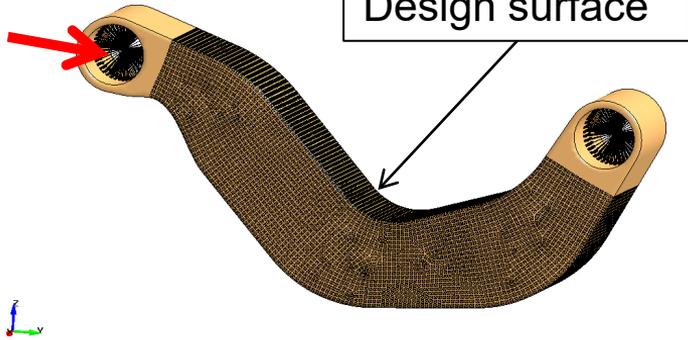


Application Examples

Example – Free Surface Design

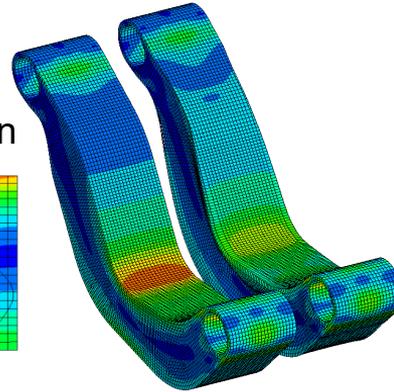
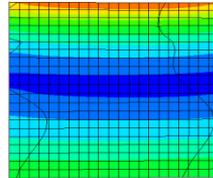
- Objective: uniform surface stress
→ reduction of stress concentration

$F = 20kN$

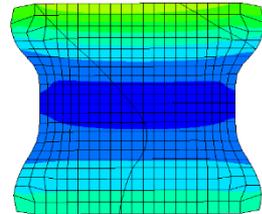


LS-DYNA keyword deck by LS-PrePost
Time = 1
Contours of Effective Stress (v-m)
min=1.11607, at elem# 49179
max=100.237, at elem# 855

Initial Design



Optimized Design



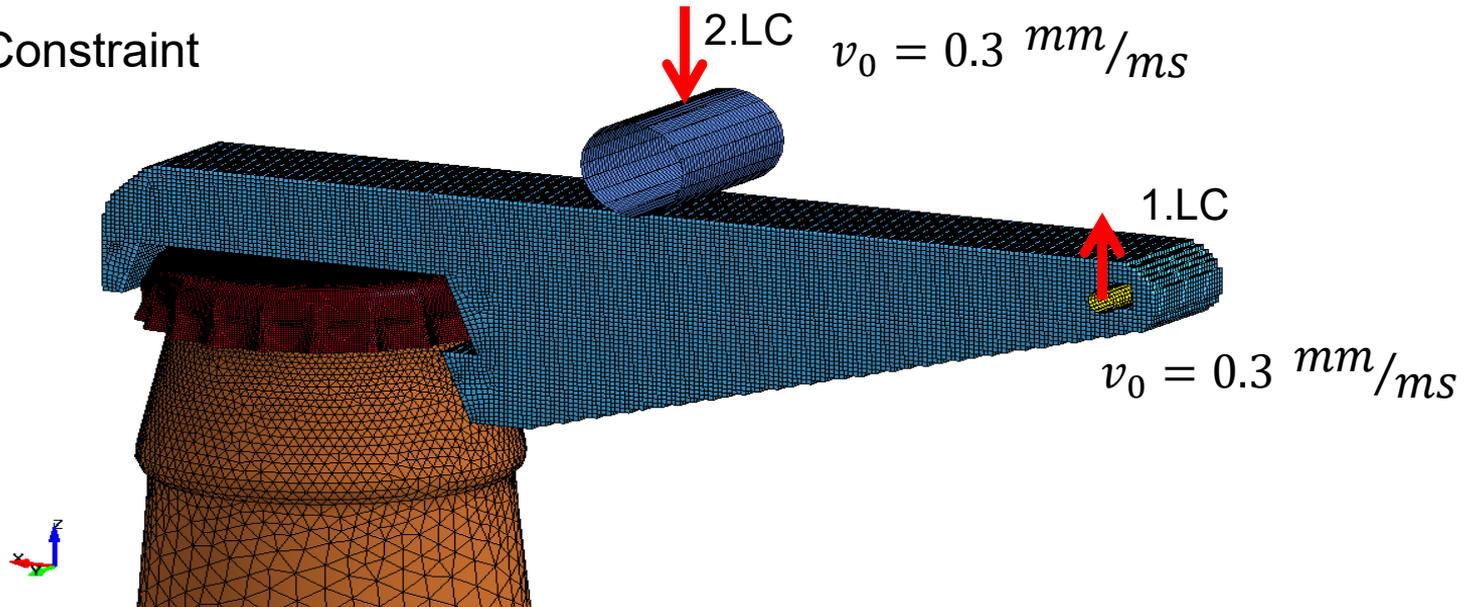
Fringe Levels



→ 20% stress reduction

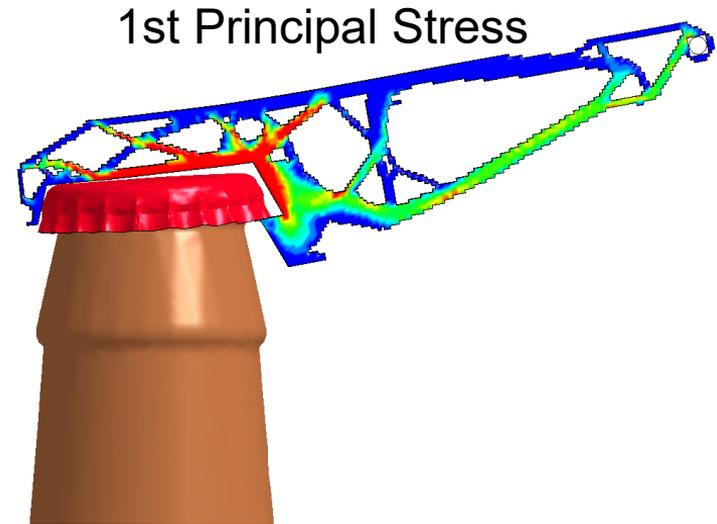
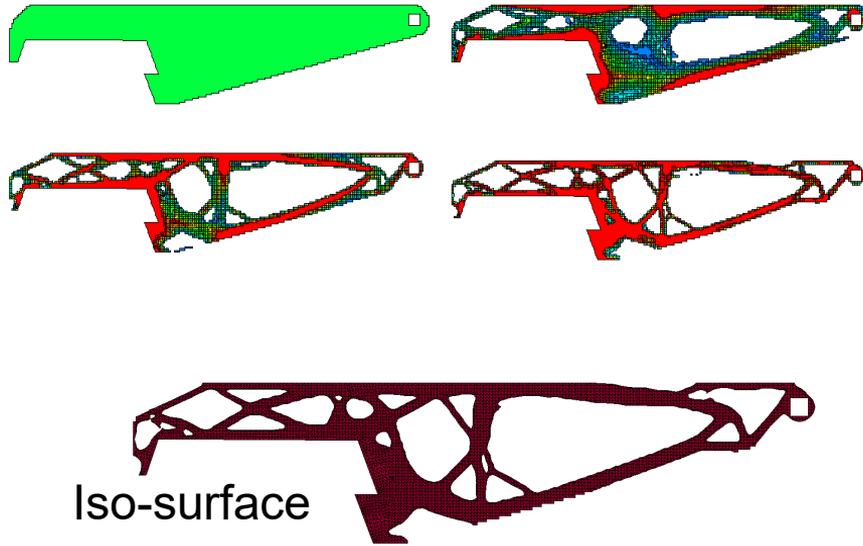
Example – Bottle Opener

- 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)



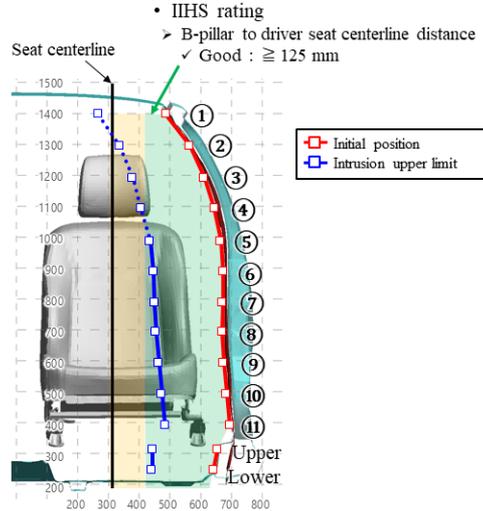
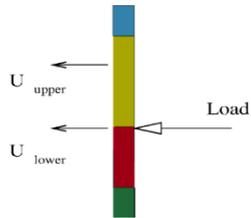
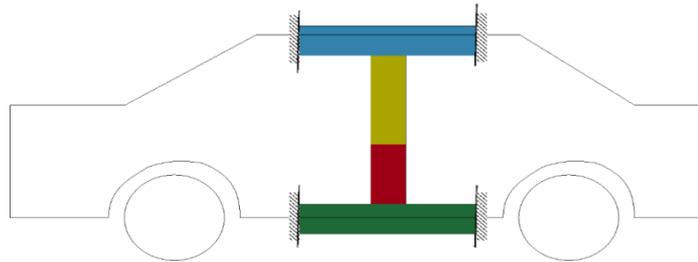
Example – Side Impact

■ Simplified B-pillar

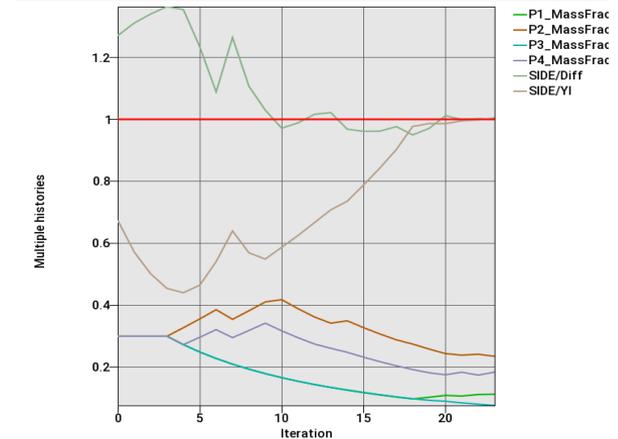
- Objective
 - Stiffest structure
 - satisfy constraints
 - and minimize mass

■ Constraints

- $-10 u_{lower} < 1$,
- $2u_{upper}/u_{lower} < 1$

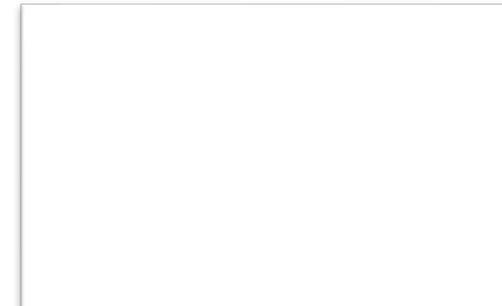
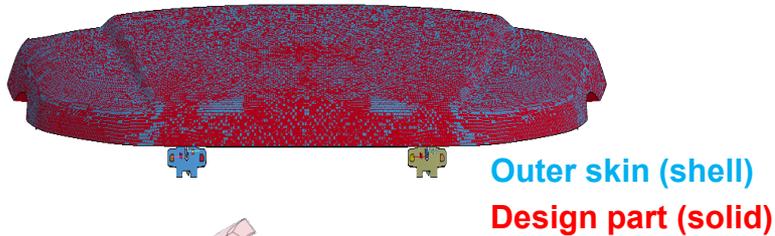


Problem statement by courtesy of JSOL

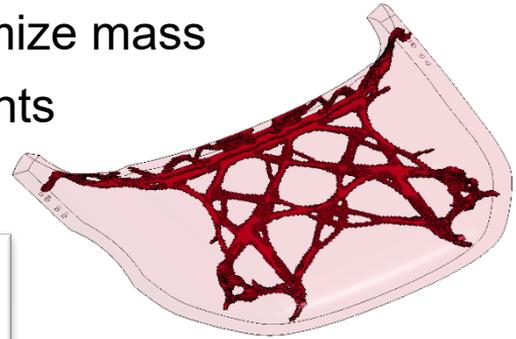


Example – Hood Design

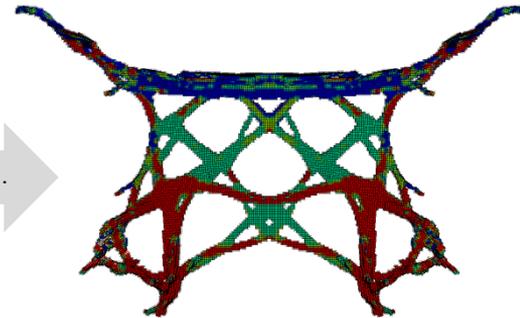
- Objective: Stiffest structure, satisfy constraints and minimize mass
- Constraints: rear beam, bending and torsion displacements



Initial Design has very low mass fraction of 0.01.



Optimum



Design Contribution Plot
(Rear beam, torsion, bending)

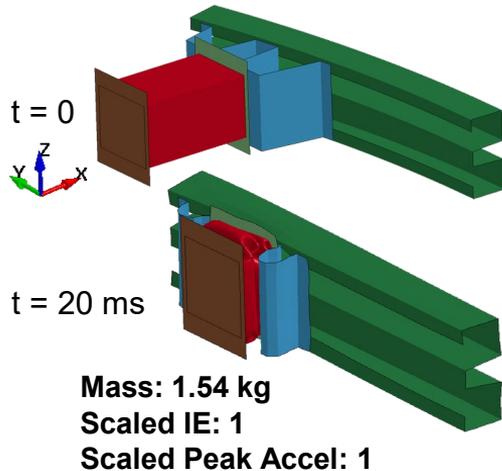
Model by courtesy of Jaguar Land Rover

Example – Automotive Crash Box

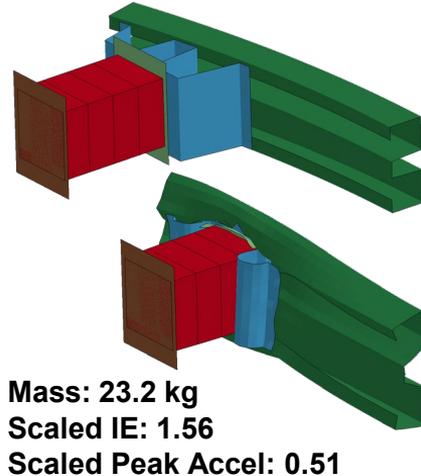
■ Crashworthiness and Lightweight Optimization

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

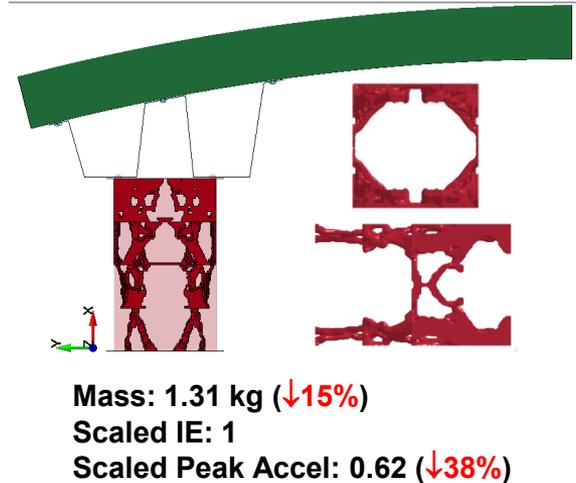
Reference: Shell structure



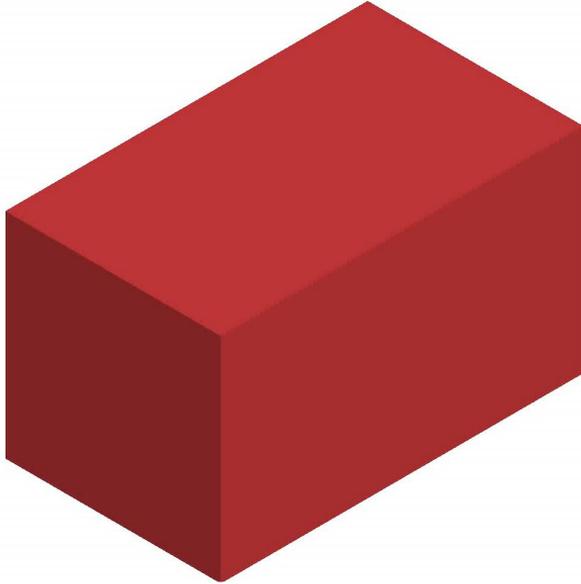
Baseline: Solid block



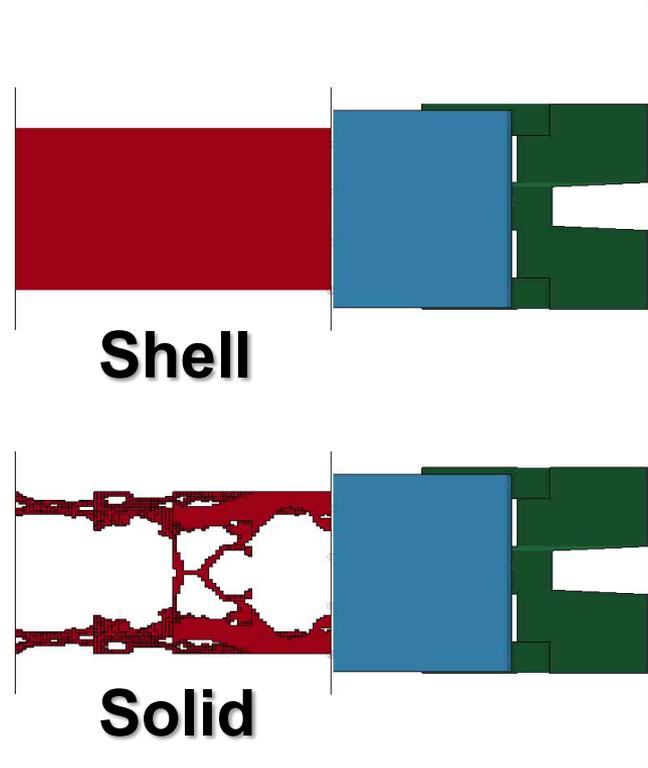
Optimal Solid structure



Example – Automotive Crash Box

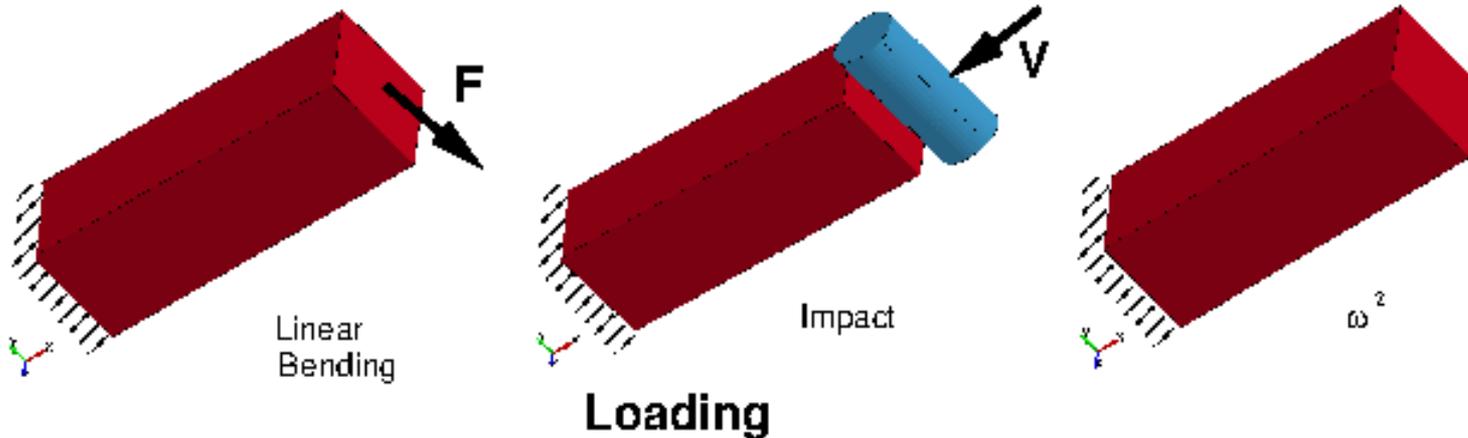


Gandikota I, Yi G, and Roux W,
Crashworthiness and lightweight optimization
of an automotive crash box using LS-TaSC.
FEA Information Engineering Solutions, October 2019



Impact, statics, and NVH

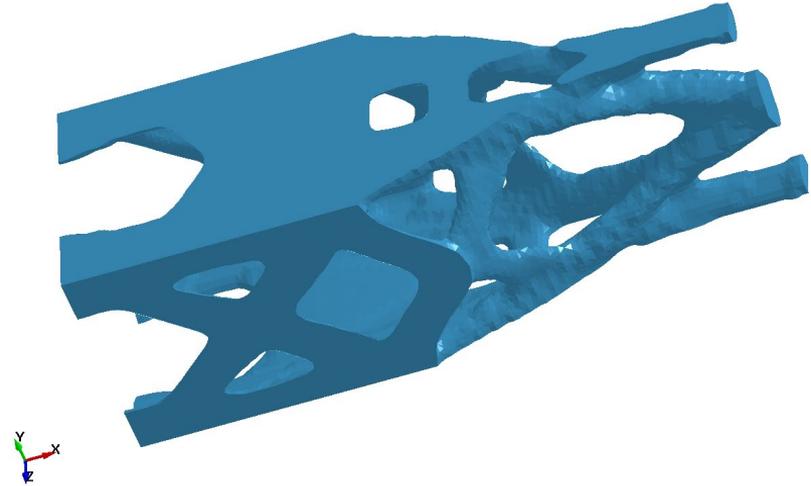
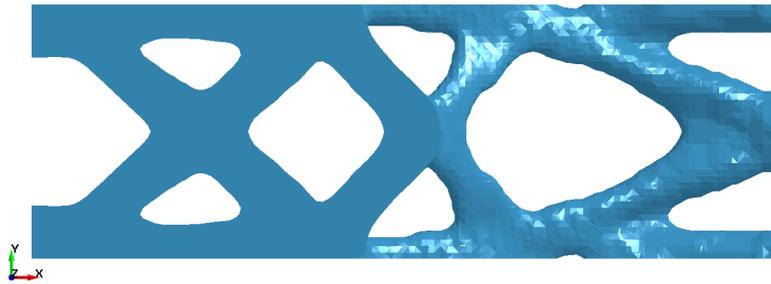
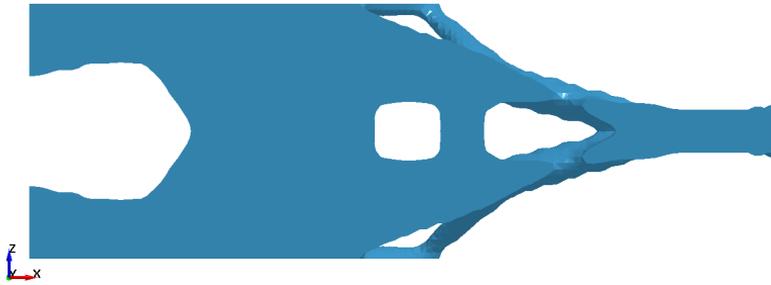
- Multi-disciplinary optimization, 3 load cases
 - Equal weights
- Mass fraction: 0.1



Impact, statics, and NVH

■ Results (80 Iterations)

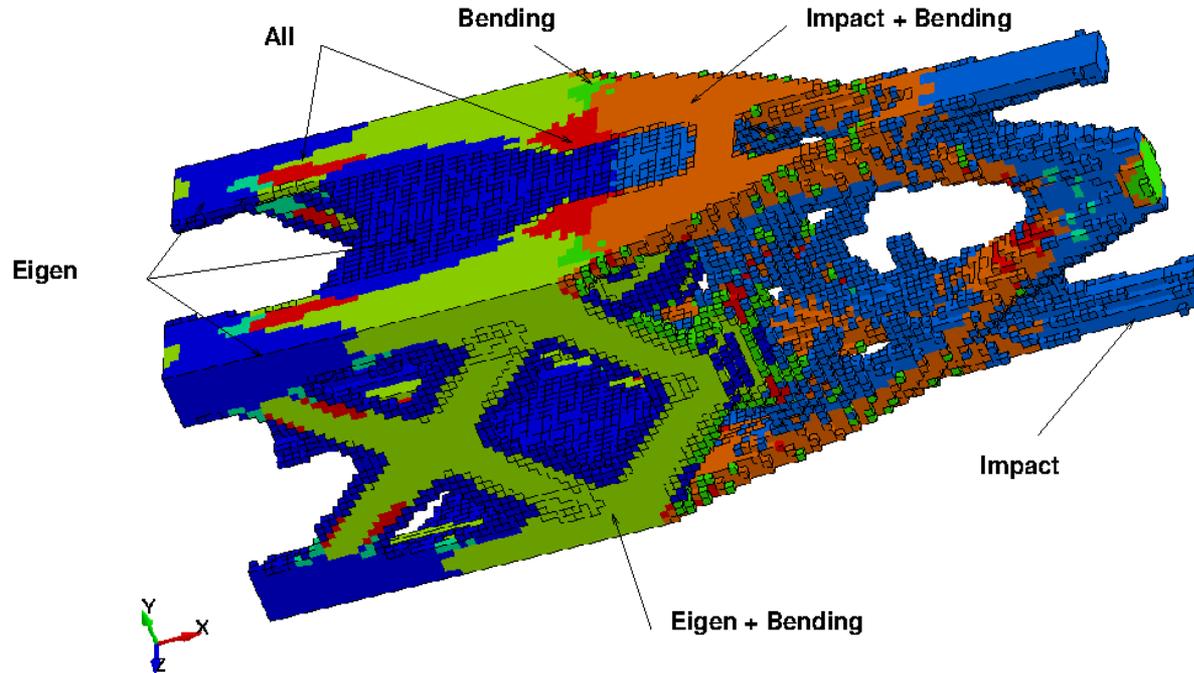
■ Optimal geometry



Impact, statics, and NVH

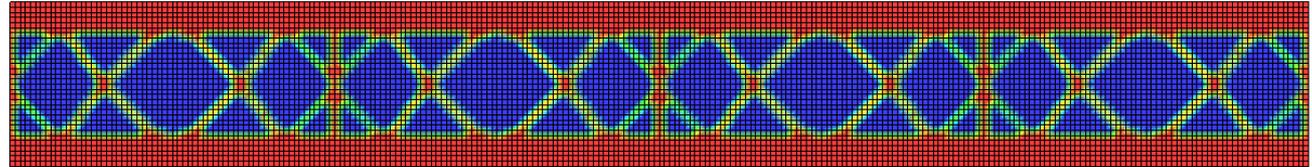
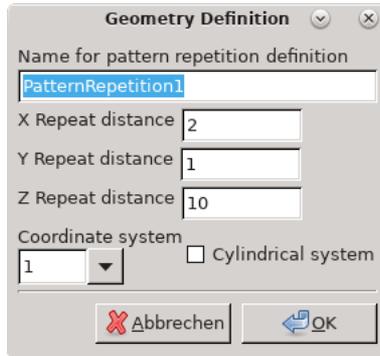
■ Results

- 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

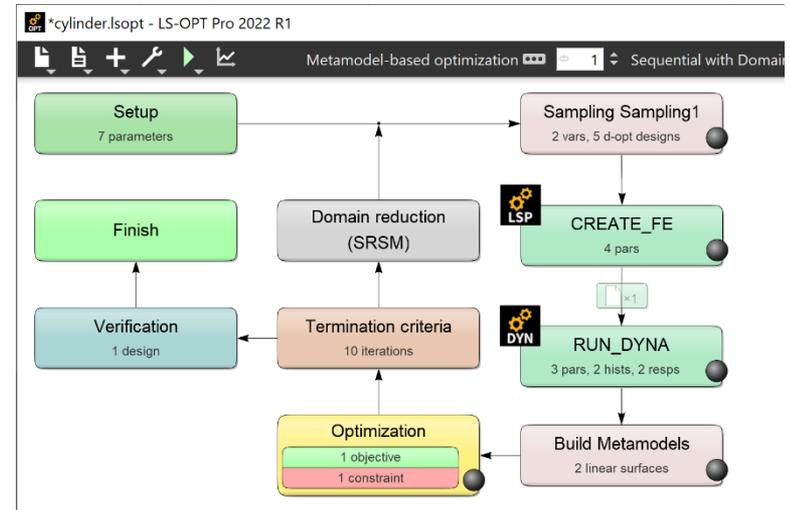
→ **nested optimization**

■ User-defined interface

■ Interface to Queuing Systems

■ PBS, LSF, SLURM, AQS, User-defined, ...

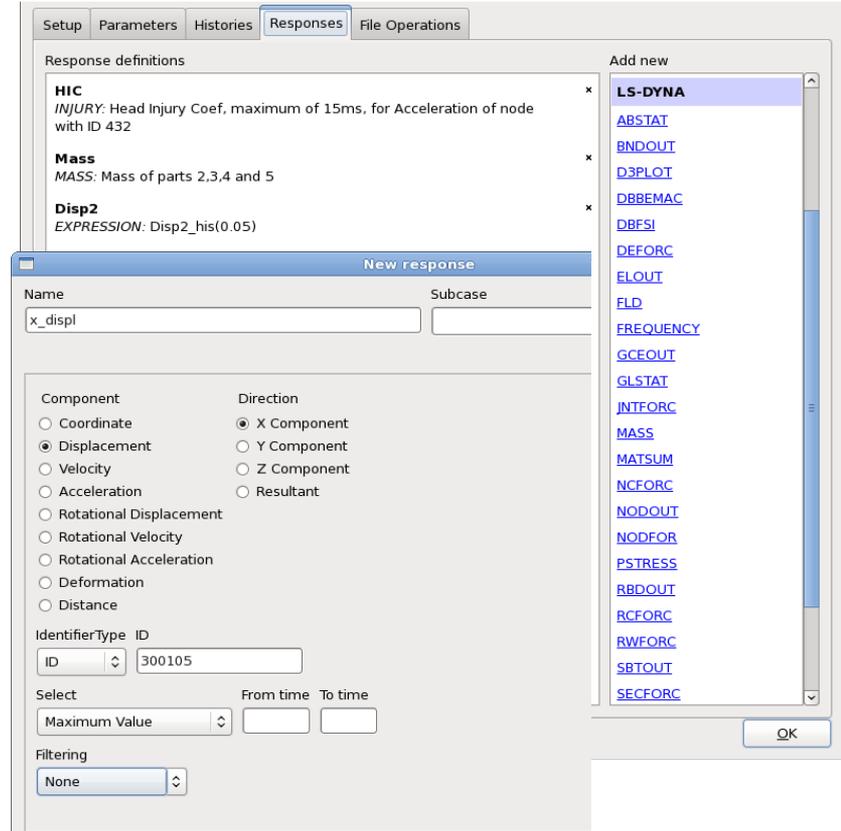
→ **LS-OPT as process manager**



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)

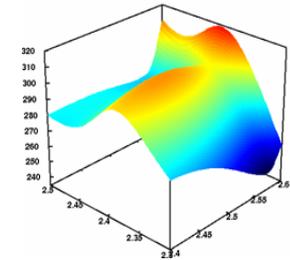
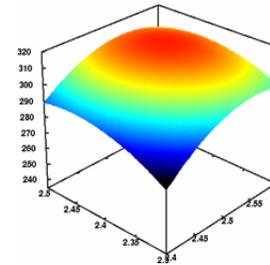
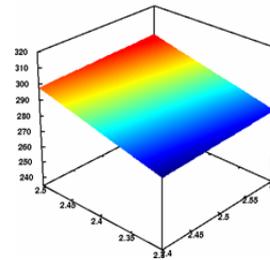
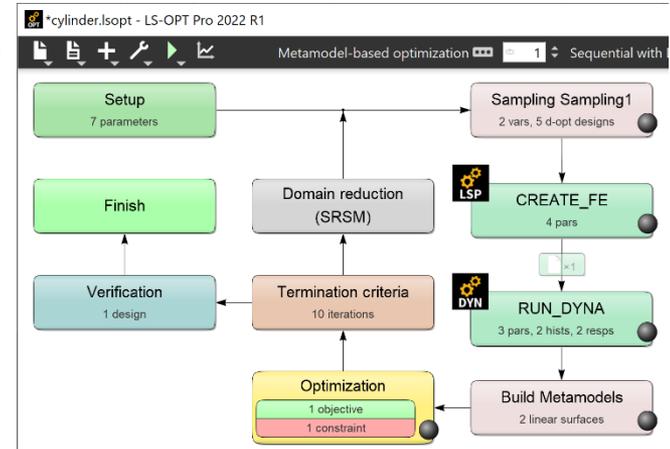
→ Multi-objective Optimization

- Direct and metamodel-based

■ Monte Carlo Analysis

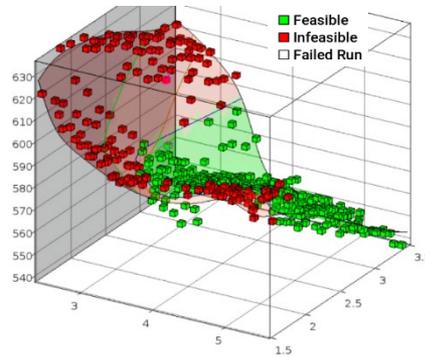
→ Robustness Analysis

- Direct and metamodel-based

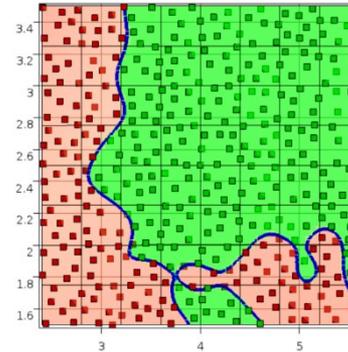


Methodologies

■ Classifiers (Support Vector Classification)



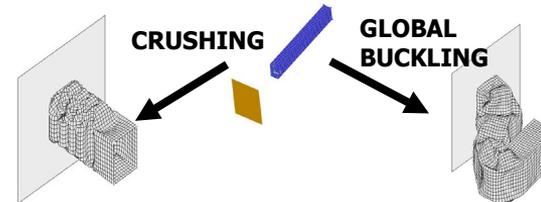
Metamodel
Approximation of response



Classifier
Approximation of constraint boundary

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

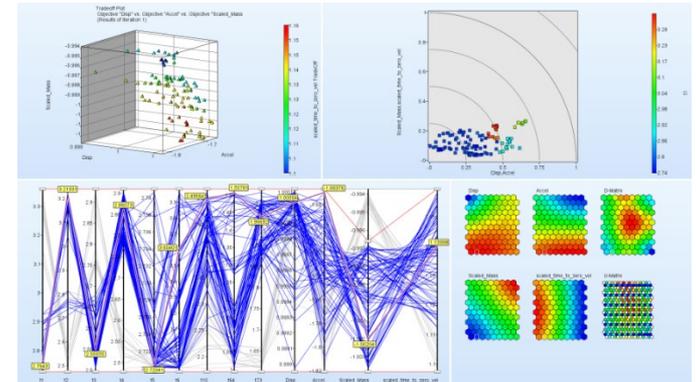
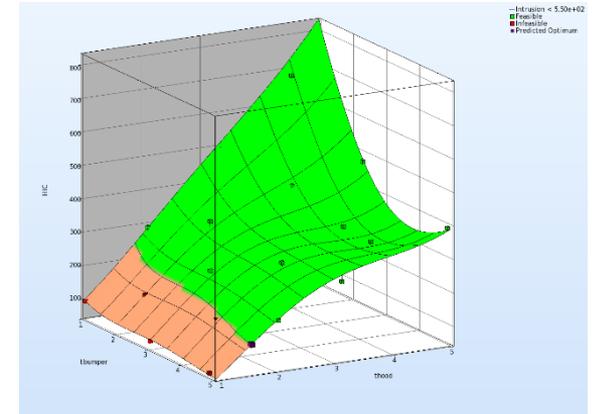
- Discontinuous responses
- Binary responses
- Constraints for optimization or reliability analysis



Applications of LS-OPT

■ Optimization

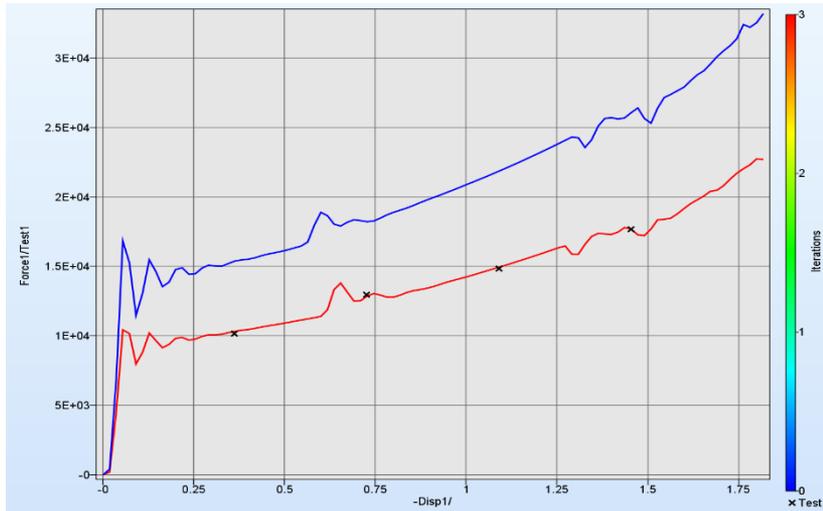
- Size-/Shape optimization
- Mixed continuous/discrete variables
 - Specify sets of discrete variables (e.g. sheet thicknesses)
- Parameter/System Identification
- Multiple load cases
 - Multi-disciplinary Optimization (MDO)
- Multi-objective optimization (Pareto Frontier)
- Multi-level optimization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



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

History matching composite

Name: MSE1

Algorithm:
 Mean Square Error (difference in curve Y values)
 Curve Mapping (size of area between curves)

Target curve: Test1 [add new file history](#)

Computed curve: F1_vs_d1

Regression points
 From target curve
 Fixed number (equidistant, interpolated)

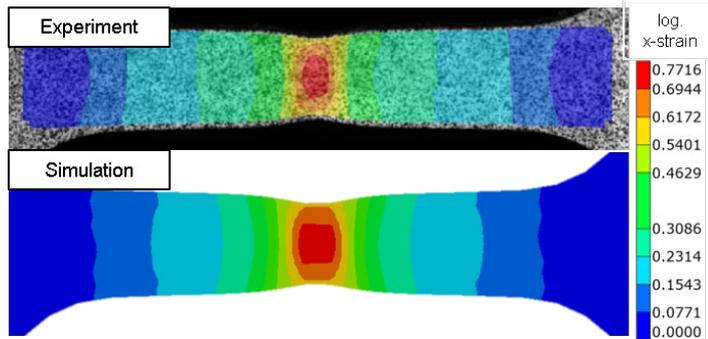
You can [convert this composite to an expression](#) for further fine-tuning.

OK

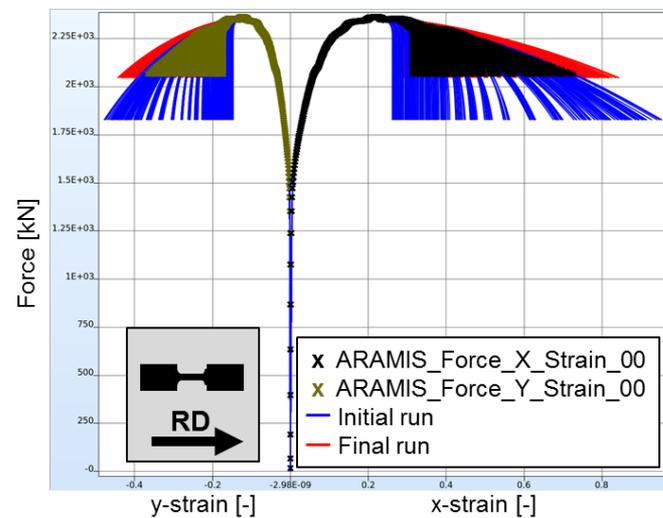
Applications of LS-OPT

■ Optimization

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



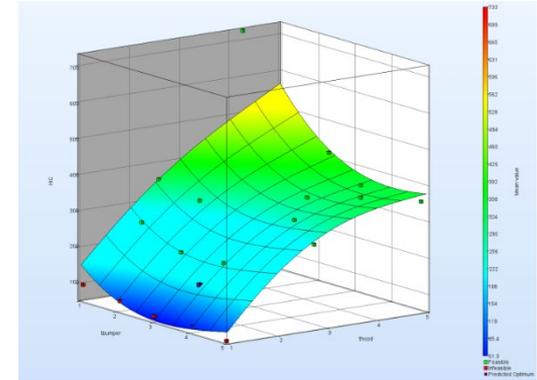
Deformation field of tensile test



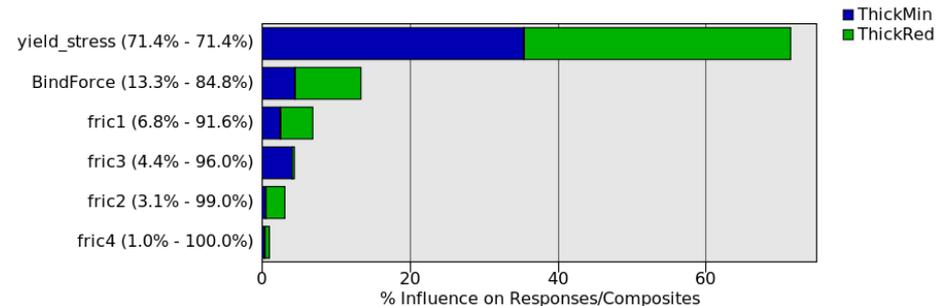
Applications of LS-OPT

■ 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)



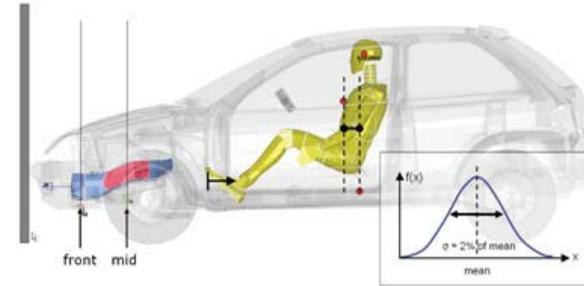
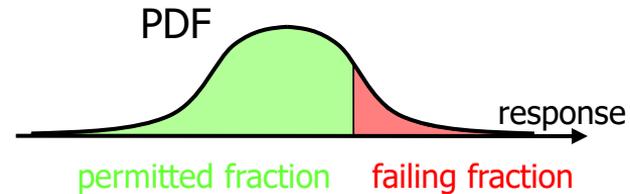
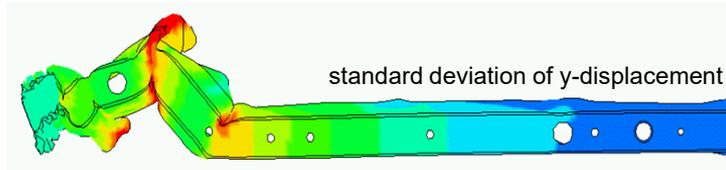
Global Sensitivities Plot



Applications of LS-OPT

■ Stochastic/Probabilistic Analysis: Consideration of uncertainties

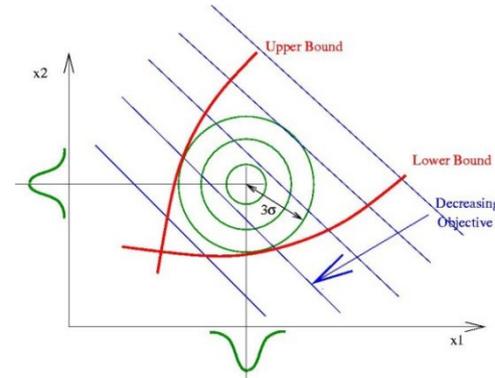
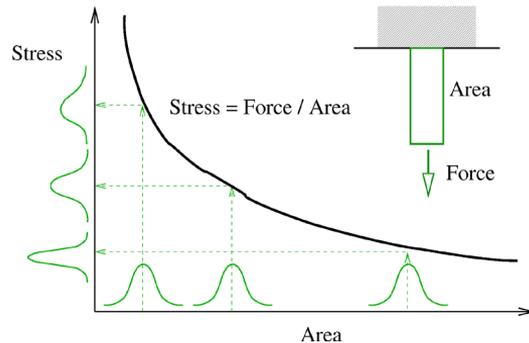
- Test of Model Robustness
 - Statistics (mean, standard deviation)
 - Correlation Analysis
- Reliability (Probability of Failure)
- Outlier Detection
- Fringe statistical results on FE model



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

Sampling Metamodel Settings Active Variables Features Constraints Comparison Metamodels

Metamodel

- Polynomial
- Sensitivity
- Feedforward Neural Network
- Radial Basis Function Network
- Kriging
- Support Vector Regression
- Metamodel of Optimal Prognosis
- User-defined

Pointselection

- Full Factorial
- Latin Hypercube
- Space Filling
- User-defined

Number of Simulation Points (per Iteration per Case)

20 (default is 5)

Set Advanced Options >>

Set Advanced MOP Options

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

The screenshot displays the CORAplus interface. On the right, the 'Edit response' dialog box is open, showing the following settings:

- Name: CORA_cae1_magnitude
- Subcase: (dropdown)
- Multiplier: n/a
- Offset: n/a
- Not metamodel-linked
- Dump formula file

Under 'CORA Results', the 'Loadcase' radio button is selected, with 'Test 1_1' in the dropdown. The 'Subloadcase' radio button is also selected, with 'Cae 1' in the dropdown. The 'Signal' dropdown is set to 'S1HEAD0000H3ACX0'. Other options like 'Total Result', 'Loadcase Rating', 'Subloadcase Rating', 'Corridor', 'Phase', 'Magnitude', and 'Slope' are unselected.

On the left, the 'General' settings panel is visible:

- Package Name: CORA
- Command: cora.sh
- Do not add input file argument
- CORA Config. File: annex.cps
- copies controlfile.cps (0 includes) to CORA/it.run/Cor and substitutes parameters*
- Extra input files

Below the settings is an 'Input definitions' table:

Loadcase	Subloadcase	Datafile	Signal	History
Test 1_1	Cae 1	../data/annex_1_1/annex_1_1	S1HEAD0000H3ACX0	cae1
Test 1_1	Cae 2	../data/annex_1_1/annex_1_1	S1HEAD0000H3ACX0	cae2

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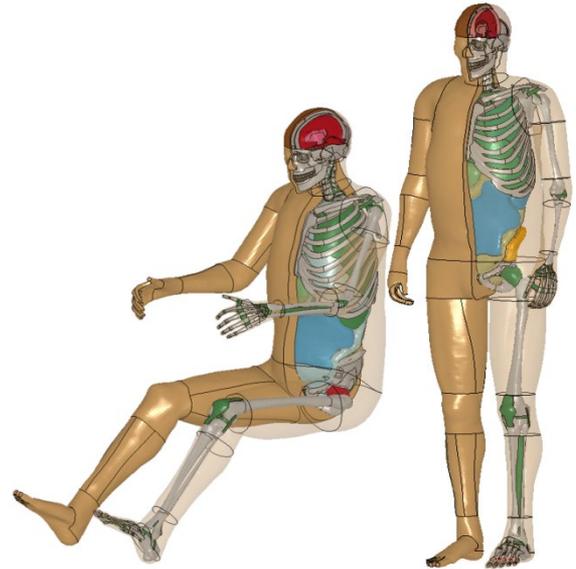
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Your questions, please