

Webinar

Overview on LS-TaSC™ and new Features in Version 4.1

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17.04.2020

Outline

- Overview on LS-TaSC

- General capabilities

- New Features in Version 4.0

LS-TaSC 4 focuses on the design of huge models for a combination of **statics, NVH, and impact**

- Multidisciplinary methodology
 - Projected subgradient method
 - Multidisciplinary optimization
 - Visualization

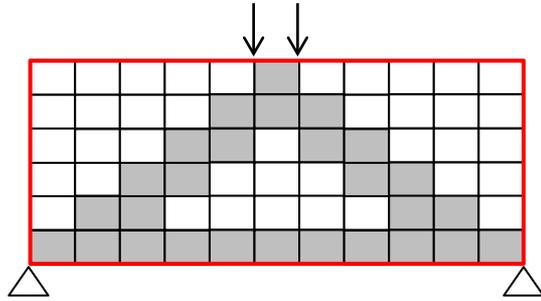
- New Features in Version 4.1

- Application Examples

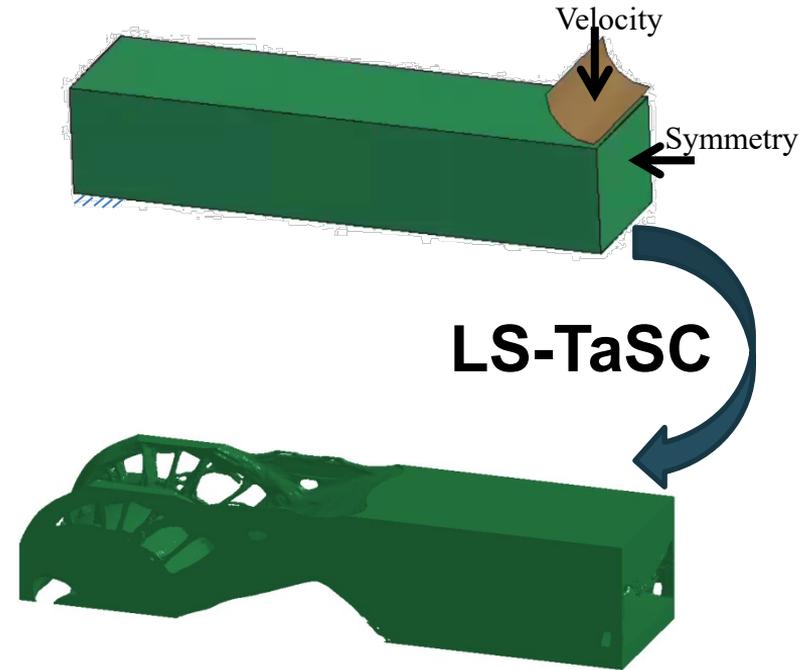
Overview on LS-TaSC

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)

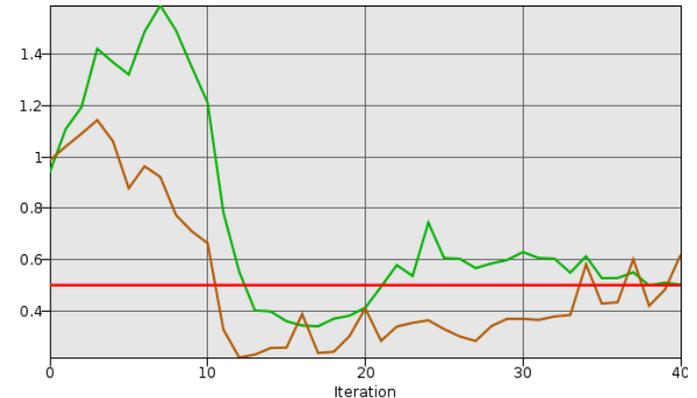
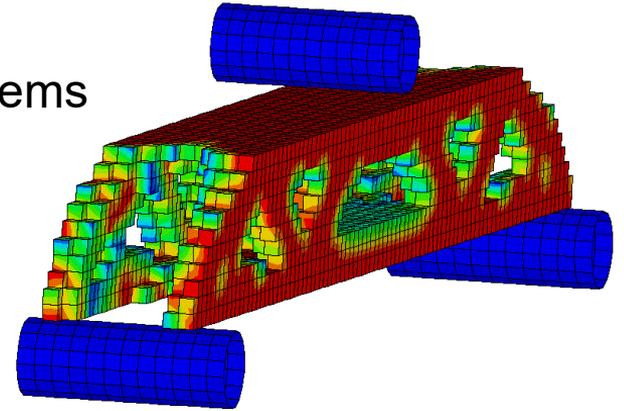
■ Huge LS-DYNA models

- 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

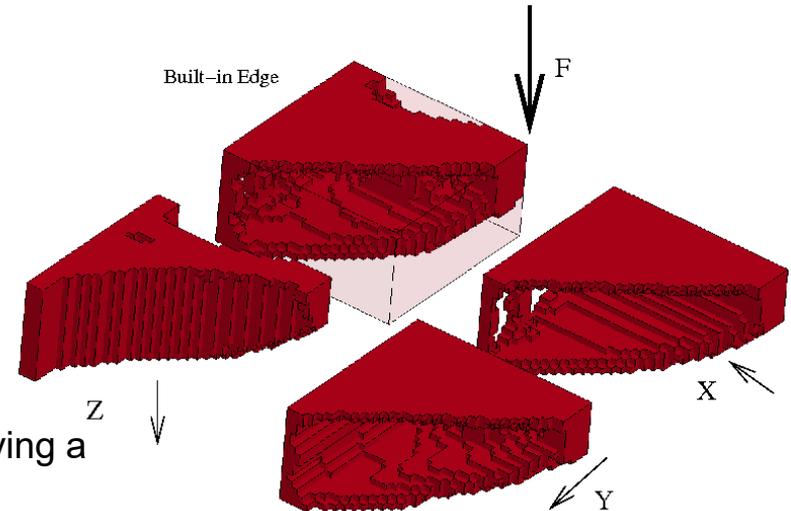
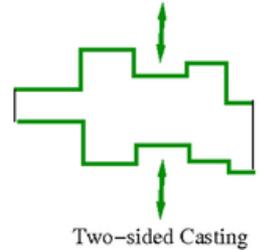
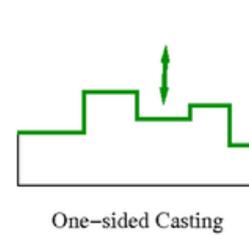
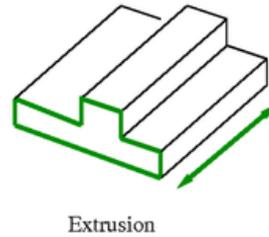
 - One sided

 - Two sided

- Forging

 - Two sided casting

 - Preserving a minimal thickness



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

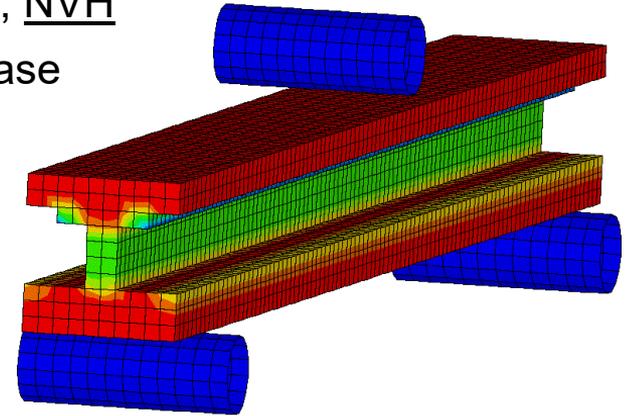
■ Projected Subgradient Method

- 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.

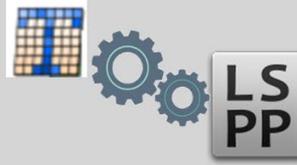
Part designed in 0s.

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

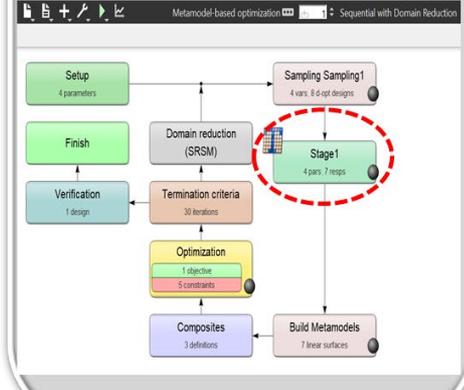
Fringe Component:

- 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



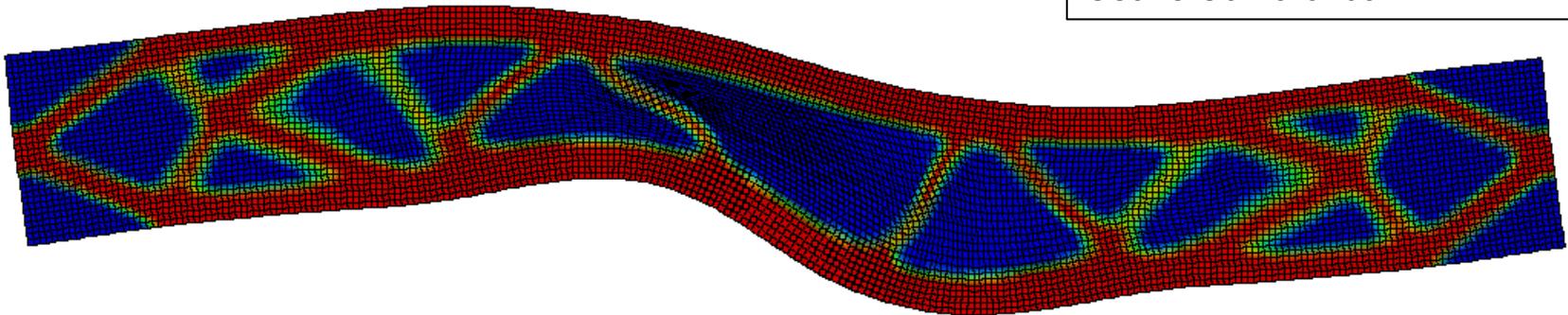


**New Features in Version 4.0 and 4.1 -
Designing for the combination of
impact, statics, and NVH**

Projected Subgradient Method - Motivation

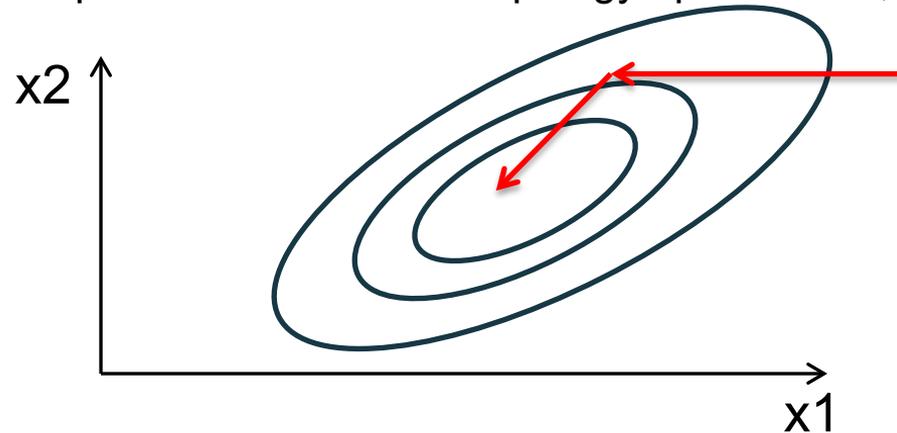
- LS-TaSC 3.2 method: Optimality Criteria for Dynamic Problems
- Objective uniform distribution of Internal Energy Density
 - static and impact load cases
 - not suitable for NVH load cases
 - we need a method that considers frequencies (maximization of fundamental frequency)
 - Projected subgradient method

Implementation of the Projected Subgradient Method in LS-TaSC™
Roux, W., Yi, G., Gandikota, I.
15th International LS-DYNA
User's Conference



Projected Subgradient Method

- The projected subgradient method is related to the steepest descent method
 - This family of methods related to steepest descent is popular again in general, because of the *huge data sets*. Our implementation of the projected subgradient is unique to both to us and topology optimization, again because of *the huge data sets*.



$$x^{k+1} = x^k - \alpha_k g^k$$

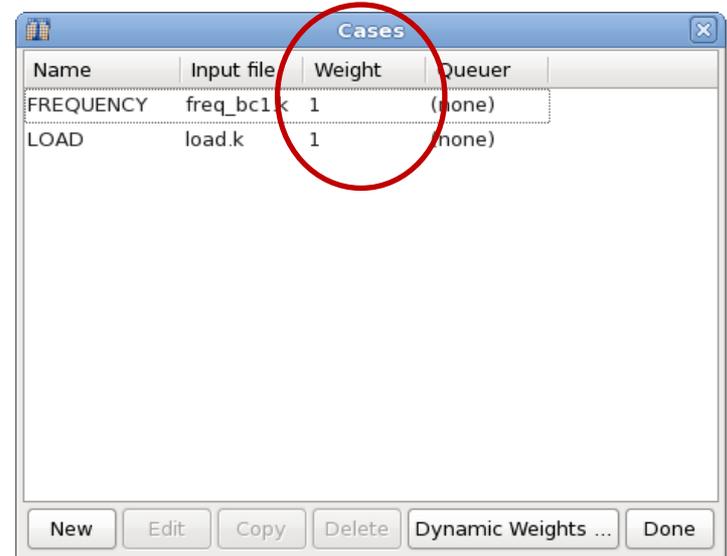
- Topology optimization requires that the mass stay constant over the iterations. The design vector is therefore mapped onto the plane of constant mass.

Multidisciplinary Optimization

- The descent vector is sourced from the various discipline descent vectors
- Combine normalized vectors using weighting:

$$s = \sum_{lc=1}^m w_{lc} \frac{s_{lc}}{\|s_{lc}\|}$$

- The weights are provided by the engineer, or computed from information provided by the engineer
 - Solution depends on weights



Name	Input file	Weight	Queuer
FREQUENCY	freq_bc1.k	1	(none)
LOAD	load.k	1	(none)

Solidification as Stopping Criteria

- The Projected Subgradient Method uses a new stopping criterion called **Solidification**, which **measures the discreteness of optimized designs**
→ fractions of elements fully used or deleted
- Assuming $N = N_{void} + N_{grey} + N_{solid}$, Solidification is defined as

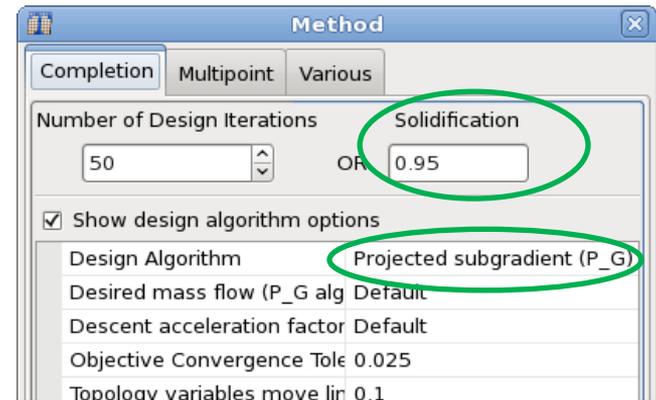
$$M = \min(M_1, M_2)$$

where

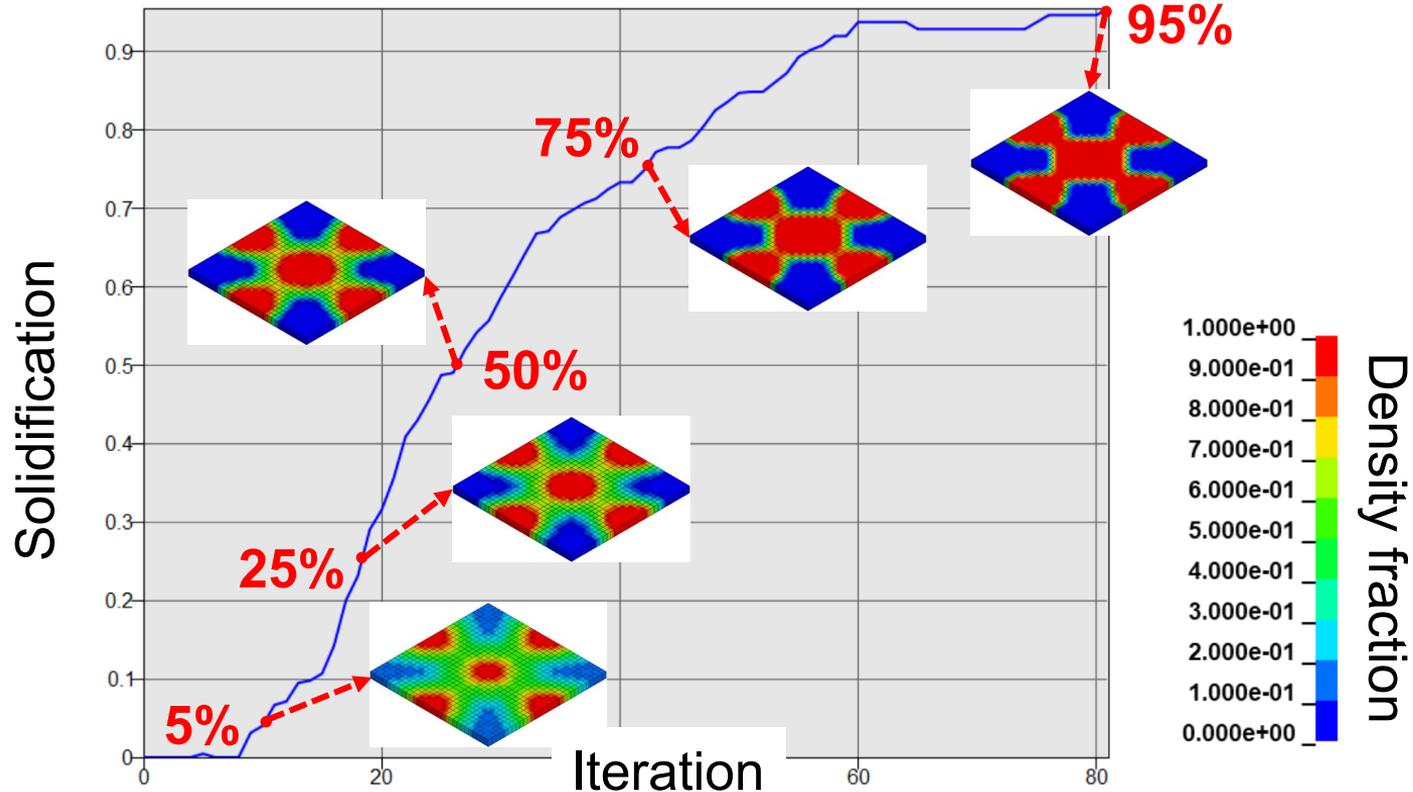
$$M_1 = \frac{N_{void} + N_{solid}}{N}$$

$$M_2 = 1 - \frac{\sum_{i=1}^N 4x_i(1 - x_i)}{N}$$

- $M = 1$ → fully converged design
- A Solidification higher than 0.95 gives good designs

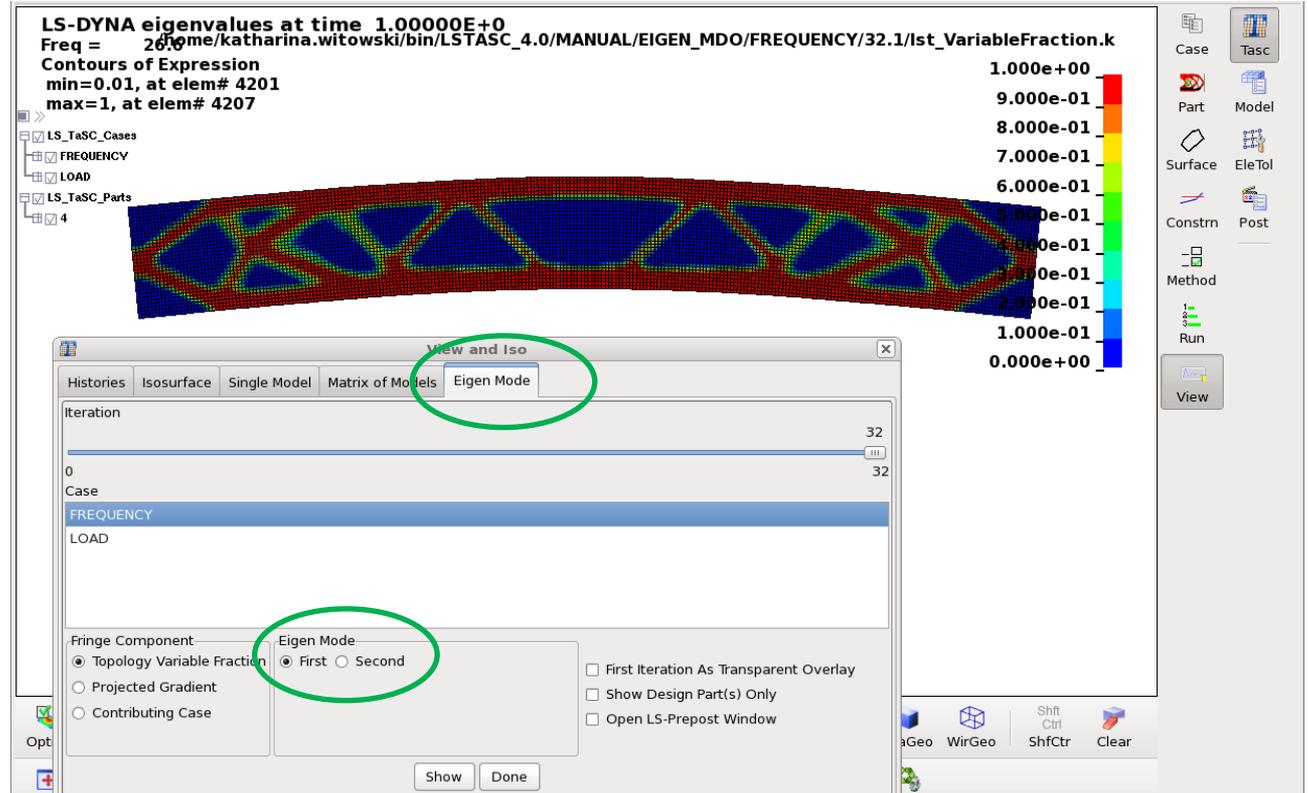


Solidification as Stopping Criteria



New Visualization Features

- NVH load cases:
Eigen Modes



New Visualization Features

■ MDO: Contributing Case

- 0 = none
- 1 = LC 1
- 2 = LC 2
- 3 = LC 1+2
- ...

The screenshot displays the LS-PrePost interface. At the top, the title bar reads "LS-DYNA keyword deck by LS-PrePost" and the file path is "/home/katharina.witowski/bin/LSTASC_4.0/MANUAL/EIGEN_MDO/FREQUENCY/32.1/1st_ContributingCase.k". The main window shows a contour plot of a mechanical part with a color scale on the right ranging from 0.000e+00 (blue) to 3.000e+00 (red). The plot shows high values (red/yellow) in the central regions and lower values (blue/green) at the ends. A tree view on the left shows the model structure: LS-TaSC_Cases, FREQUENCY, LOAD, LS-TaSC_Parts, and 4. Below the plot, the "View and Iso" dialog box is open, showing the "Single Model" tab. The "Iteration" list shows iteration 32 selected. The "Case" list shows "FREQUENCY" and "LOAD". The "Fringe Component" section has "Contributing Case" selected and circled in green. Other options include "Topology Variable Fraction", "Solid Density", "Shell IED", "Von-Mises Stress", "Topology Material Utilization", "Solid IED", "Projected Gradient", "First Iteration As Transparent Overlay", "Show Design Part(s) Only", and "Open LS-Prepost Window". The "Show" and "Done" buttons are at the bottom of the dialog.



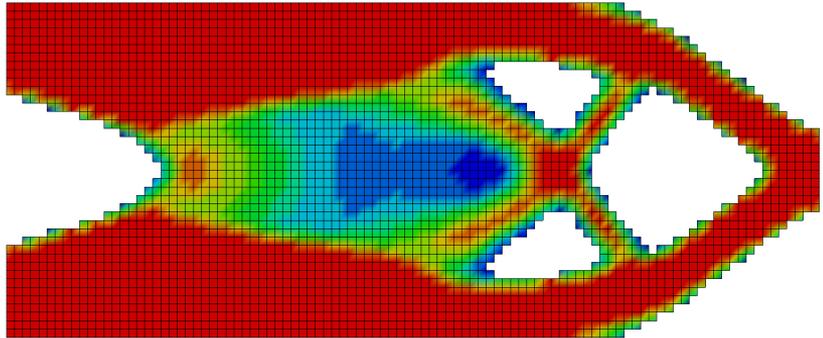
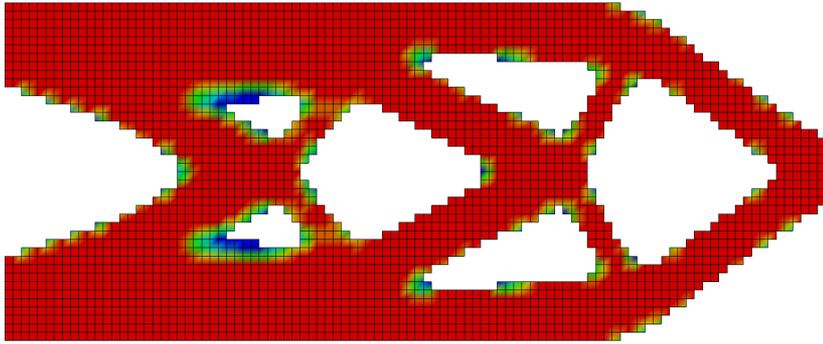
Examples

The benchmark problems demonstrate the new multidisciplinary solver:

- Huge models
- NVH benchmark problems
- Multi-disciplinary design optimization considering NVH and static
- Impact, static, and NVH

Performance relative to previous method

- Mathematical programming techniques allow many power-ups



Projected subgradient (new):

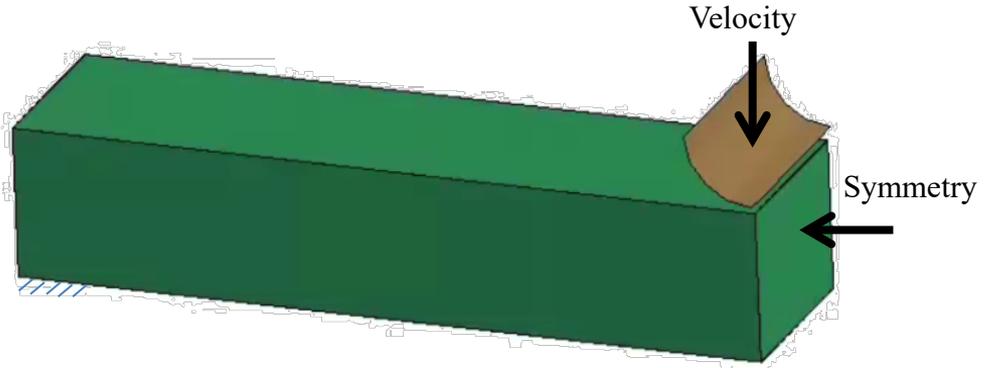
- 30 FEA calls
- 0.1 step size

Optimality Criteria (old):

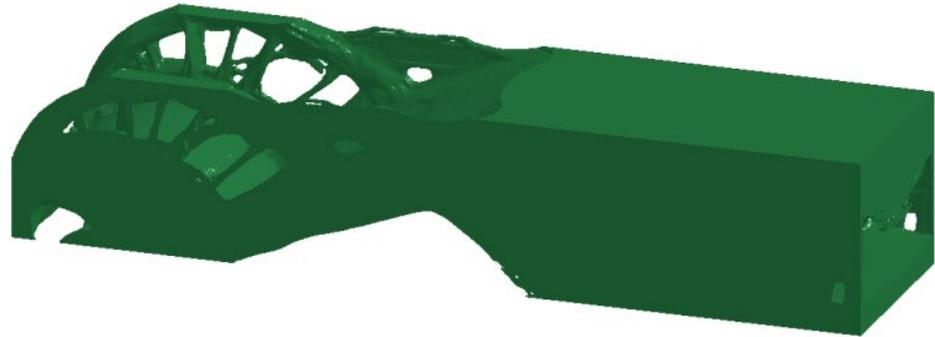
- 30 FEA calls
- 0.1 step size
- Needs about 50 iterations to match the new algorithm

Huge model performance

- Impact load case
 - 13.1 million elements
- Mass fraction: 0.25
- Projected subgradient method
 - 30 Iterations



Isosurface plot of optimal design



Huge model performance

- Computational cost for huge problem

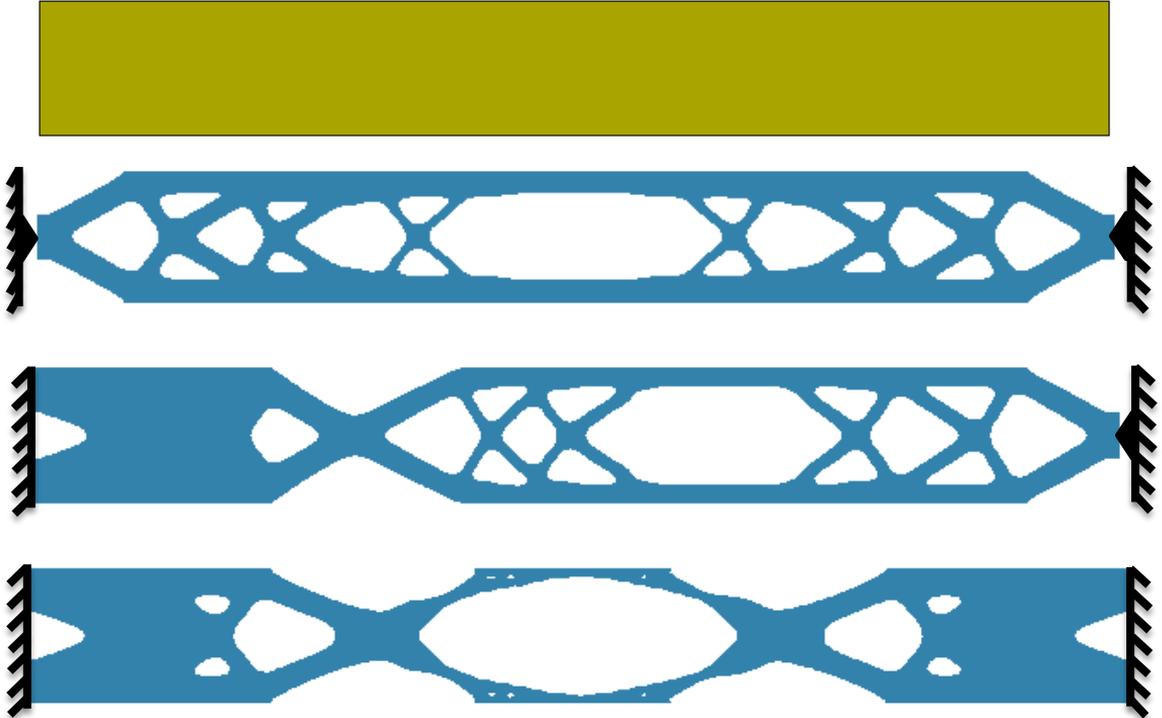
HUGE MODEL PERFORMANCE

Model size	13.1 million elements
Physics	Explicit impact analysis
LS-DYNA analysis time for one iteration	600 CPU hours (5 hours using 120 CPUs on a remote cluster)
Part design time – first iteration	25 CPU minutes (1 CPU)
Part design time – all other iterations	2 CPU minutes (1 CPU)
Peak memory use by LS-TaSC	15 GB

NVH Benchmarks

- Maximization of Fundamental Frequency
- Mass fraction: 0.5
- 3 different boundary conditions

Symmetric boundary conditions
→ Symmetric results



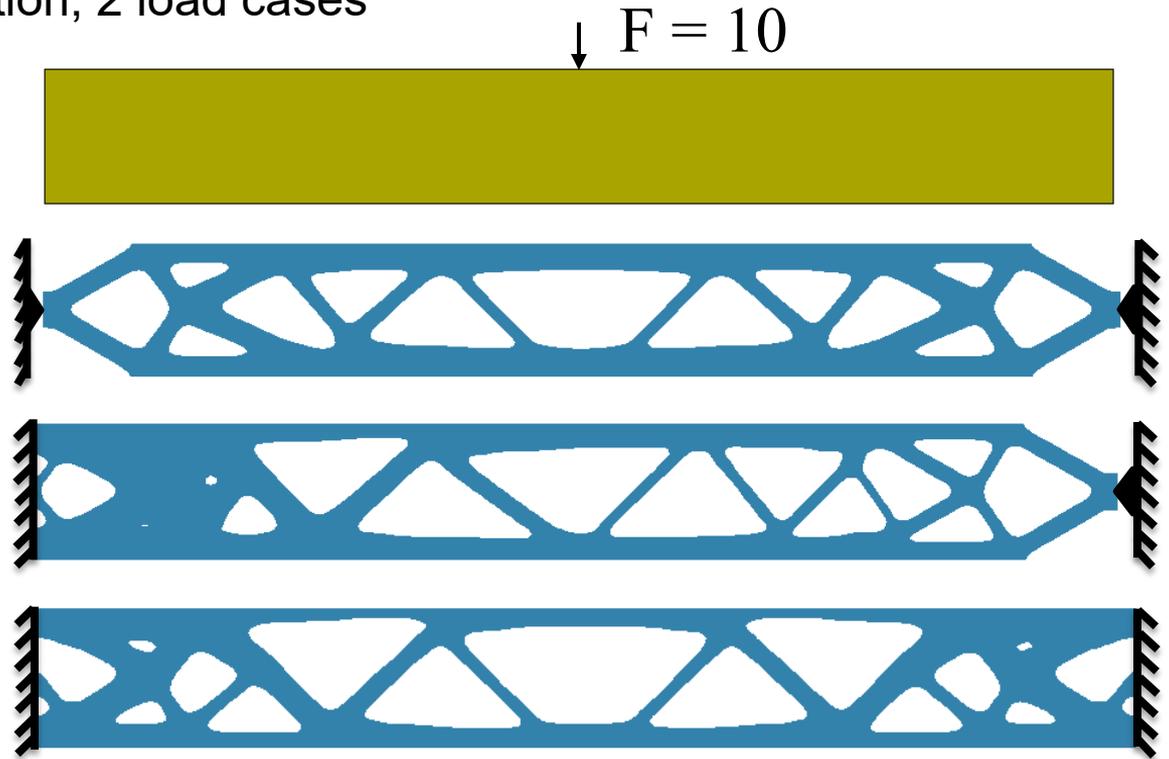
NVH Benchmarks

- Multi-disciplinary optimization, 2 load cases

- fundamental frequency
- linear static load

- Mass fraction: 0.5

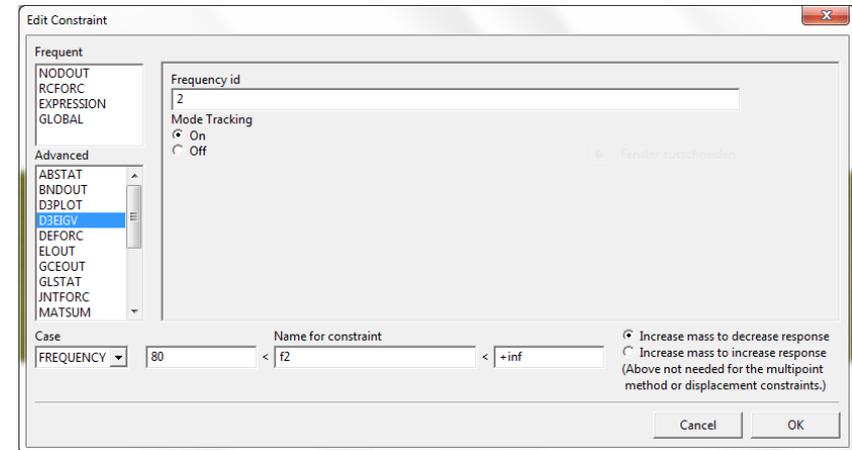
- 3 different boundary conditions



New Features in Version 4.1

■ Extended Frequency capabilities

- Constraint bounds can be placed on a frequency. This is possible only for a single eigenvalue load case – full MDO will follow in a later release.
- Mode tracking for frequency constraints.
- Linear pentahedral and tetrahedral elements are supported for frequency design.
- *CONSTRAINED_NODAL_RIGID_BODY keyword is supported for frequency design.



New Features in Version 4.1

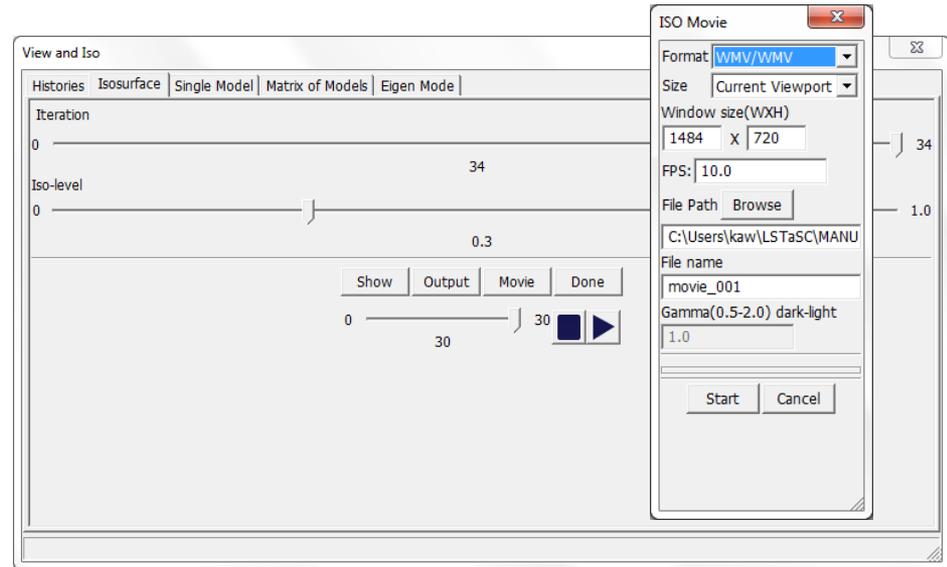
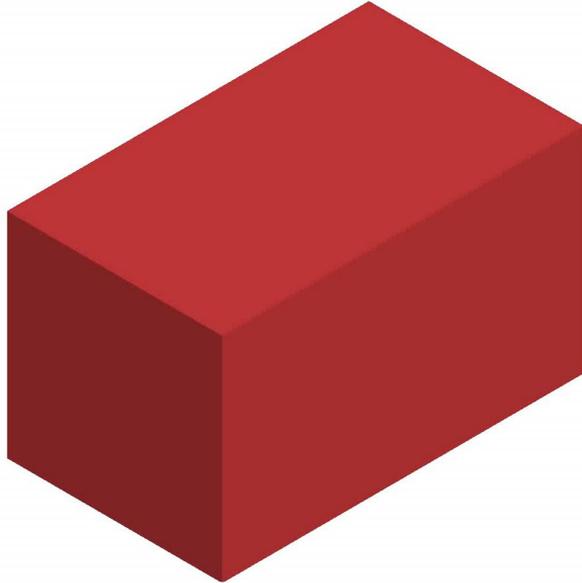
■ Multi-disciplinary design optimization

- Projected Subgradient Method
- Multipoint scheme
- Spatial kernel
- Constrained multidisciplinary topology optimization
- Crash, NVH, static load cases
- High performance of computing huge models with more than 10 million elements

A spatial kernel approach for topology Optimization, Roux, W., Yi, G., Gandikota, I. Computer Methods in Applied Mechanics and Engineering 361, 2020

New Features in Version 4.1

- Animations of the design iterations

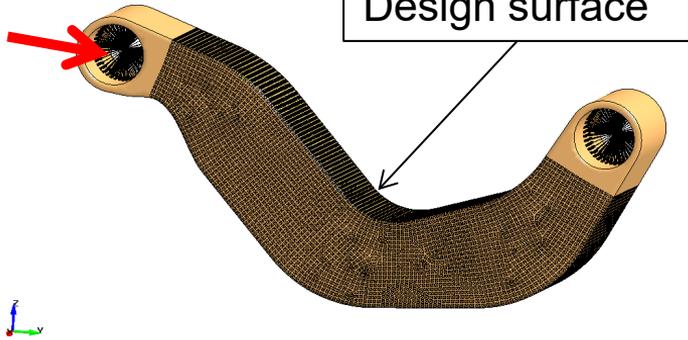


Application Examples

Example – Free Surface Design

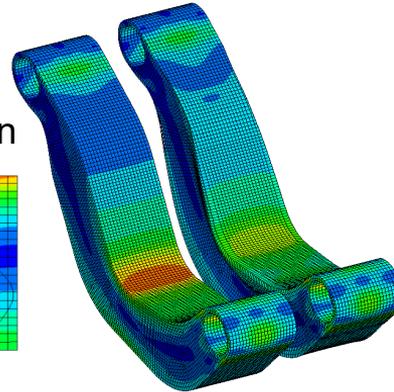
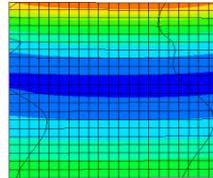
- Objective: uniform surface stress
→ reduction of stress concentration

$F = 20kN$

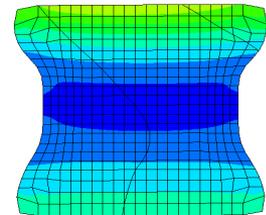


LS-DYNA keyword deck by LS-PrePost
Time = 1
Contours of Effective Stress (v-m)
min=1.11607, at elem# 49179
max=100.237, at elem# 855

Initial Design



Optimized Design



Fringe Levels



→ 20% stress reduction

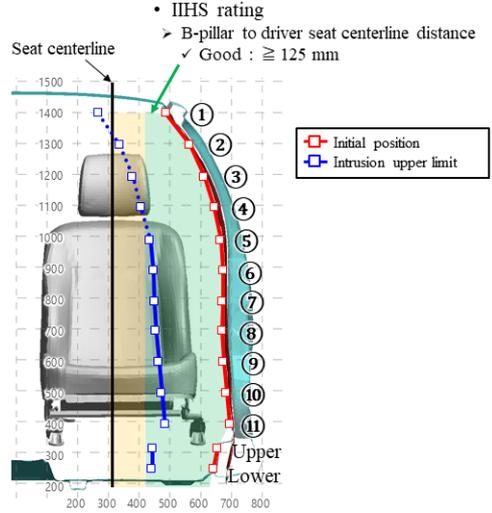
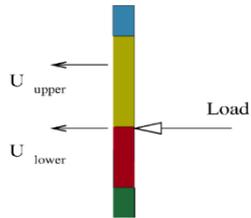
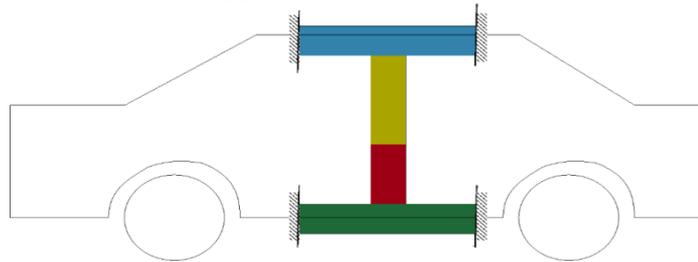
Example – Side Impact

Simplified B-pillar

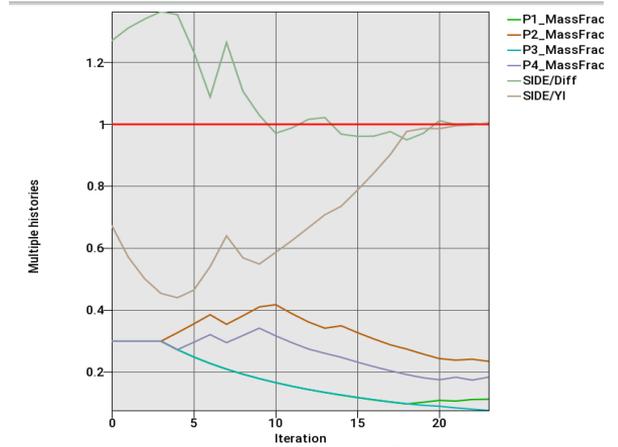
- Objective
 - Stiffest structure
 - satisfy constraints
 - and minimize mass

Constraints

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

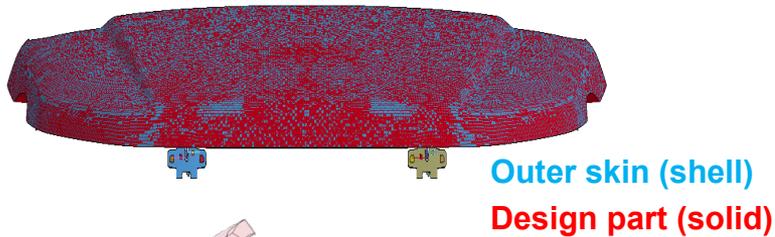


Problem statement by courtesy of JSOL

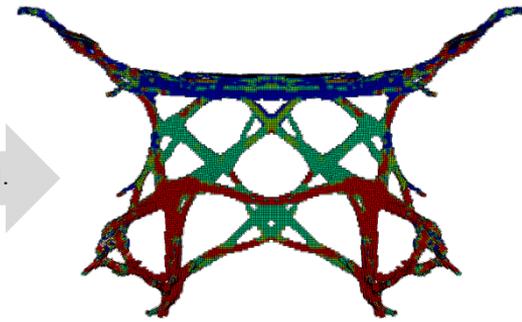
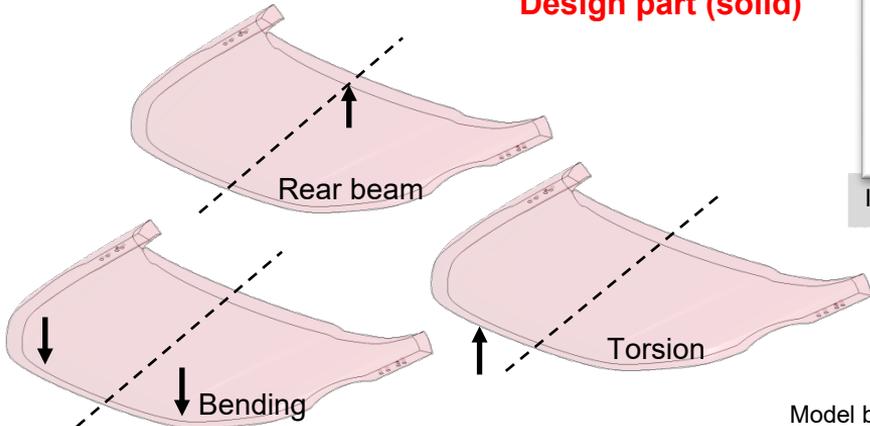
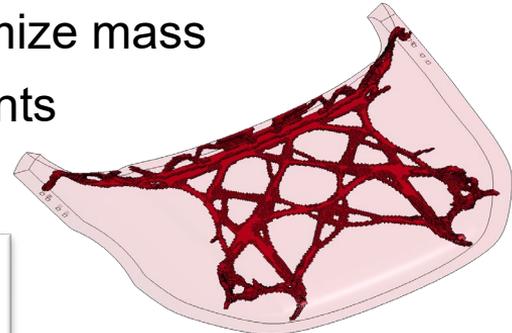


Example – Hood Design

- 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.



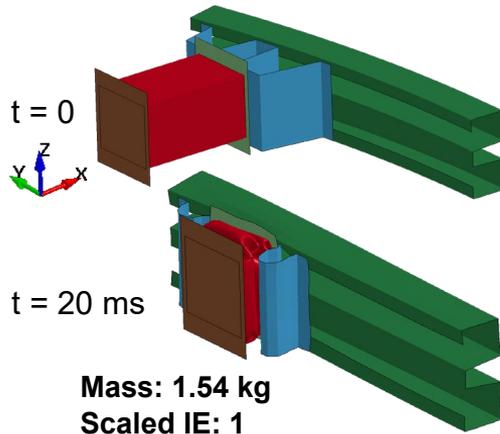
Model by courtesy of Jaguar Land Rover

Example – Automotive Crash Box

■ Crashworthiness and Lightweight Optimization

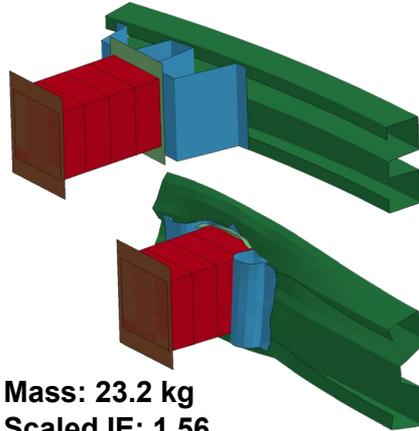
- Objective: Minimize mass
- Constraints: Scaled max. Energy Absorption ≥ 1
- Geometry: solid block split into 4 parts; XY and XZ symmetry

Reference: Shell structure



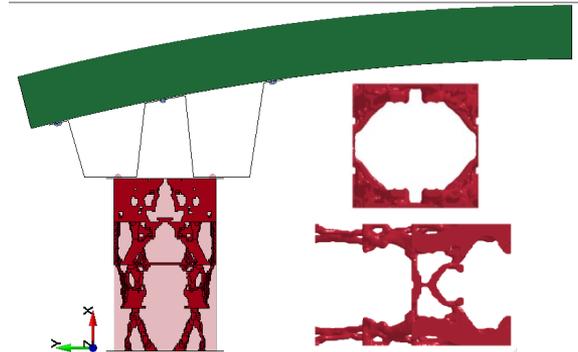
Mass: 1.54 kg
Scaled IE: 1
Scaled Peak Accel: 1

Baseline: Solid block



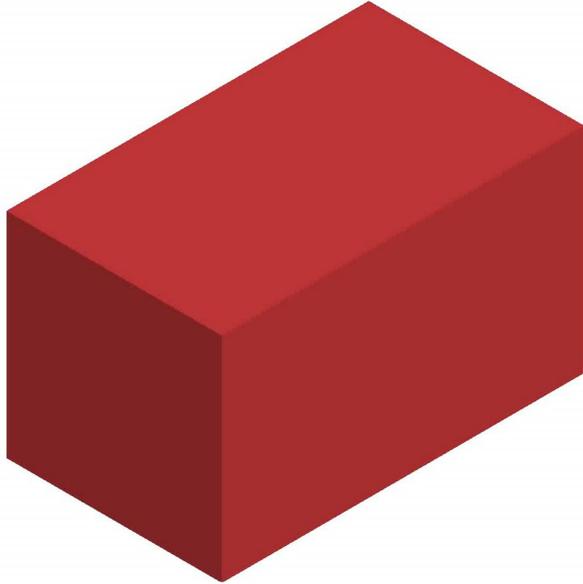
Mass: 23.2 kg
Scaled IE: 1.56
Scaled Peak Accel: 0.51

Optimal Solid structure

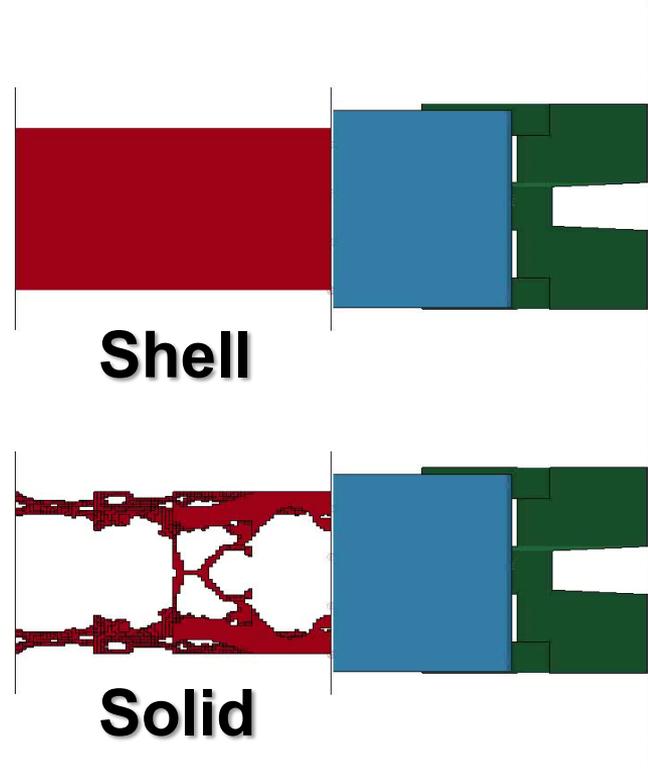


Mass: 1.31 kg (↓15%)
Scaled IE: 1
Scaled Peak Accel: 0.62 (↓38%)

Example – Automotive Crash Box

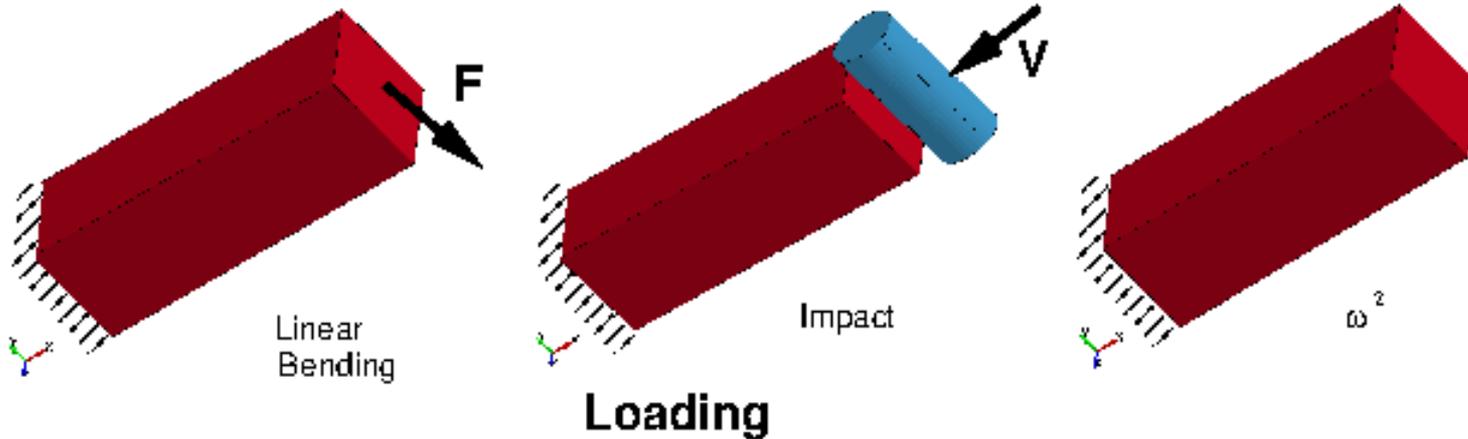


Gandikota I, Yi G, and Roux W,
Crashworthiness and lightweight optimization
of an automotive crash box using LS-TaSC.
FEA Information Engineering Solutions, October 2019



Impact, statics, and NVH

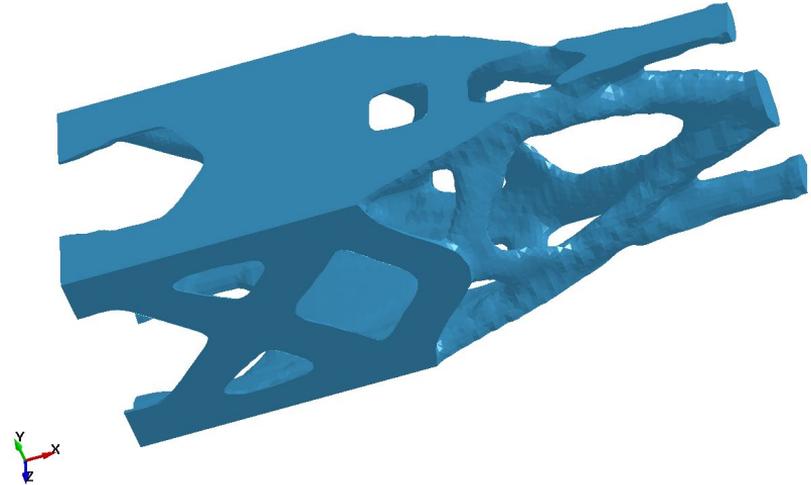
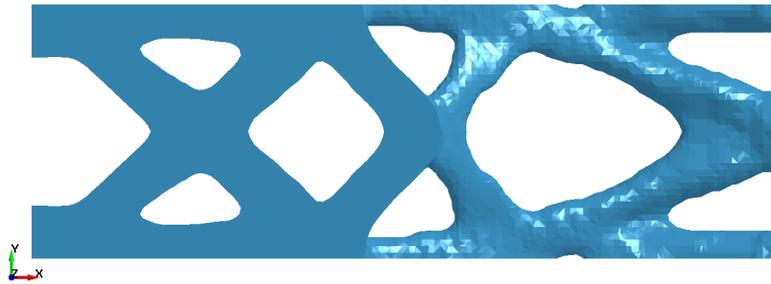
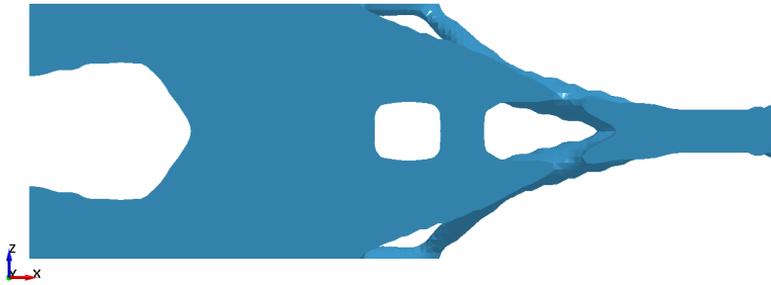
- Multi-disciplinary optimization, 3 load cases
 - Equal weights
- Mass fraction: 0.1



Impact, statics, and NVH

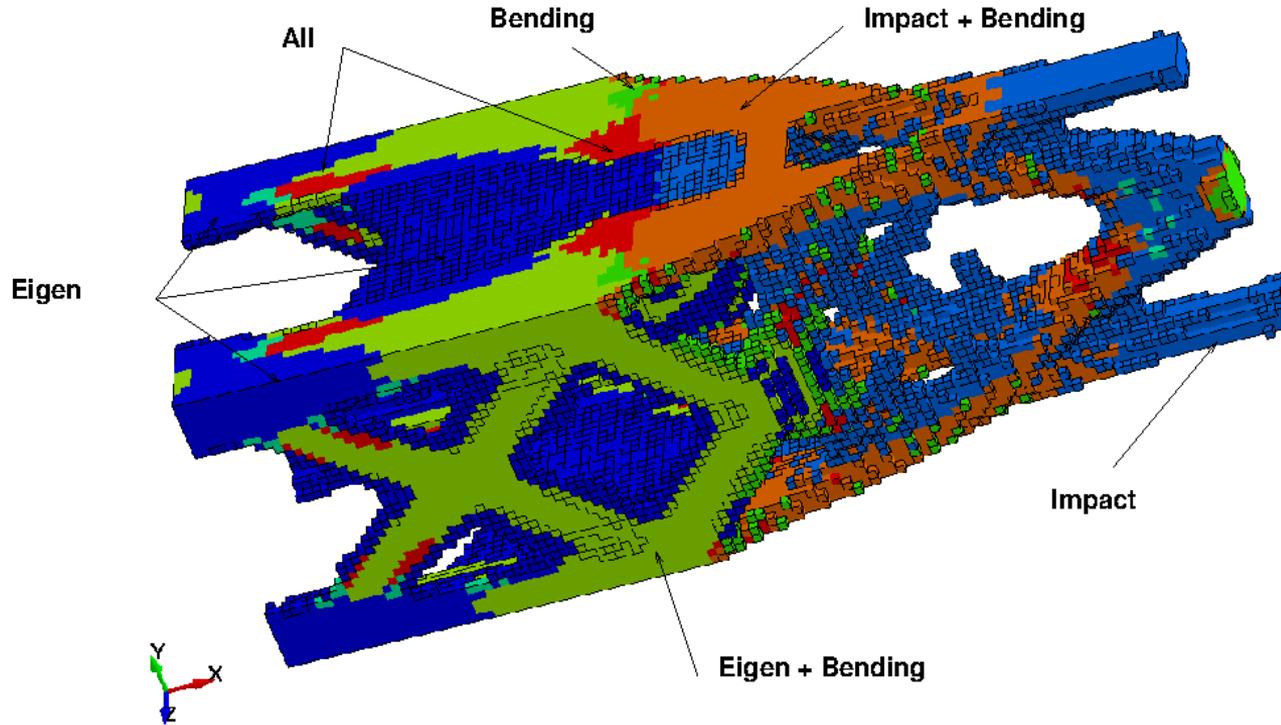
■ Results (80 Iterations)

■ Optimal geometry



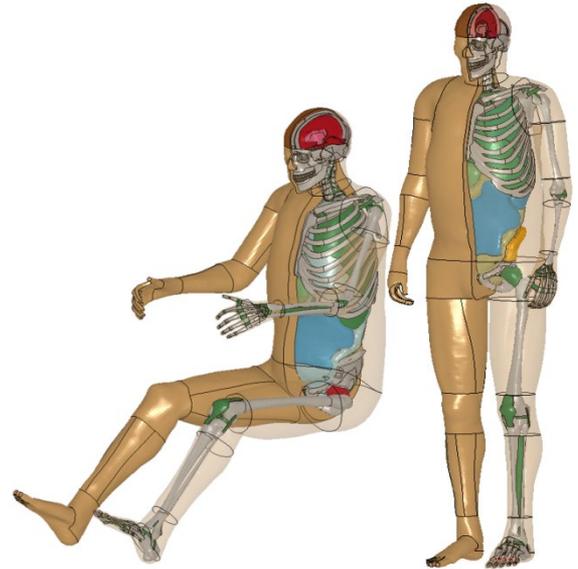
Impact, statics, and NVH

- New plot type shows which load case contributes the material used in the part.



More Information on the LSTC Product Suite

- Livermore Software Technology Corp. (LSTC)
www.lstc.com
- LS-DYNA
 - Support / Tutorials / Examples / FAQ
www.dynasupport.com
 - More Examples
www.dynaexamples.com
 - Conference Papers
www.dynalook.com
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