Webinar

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

Katharina Witowski, DYNAmore GmbH
Willem Roux, Ansys/LST
Guilian Yi, Ansys/LST
Imtiaz Gandikota, Ansys/LST

17.04.2020

Outline

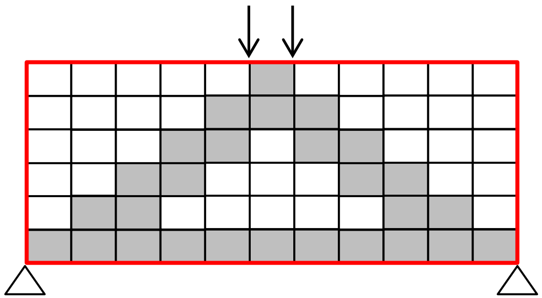
- Overview on LS-TaSC
  - General capabilities
- New Features in Version 4.0

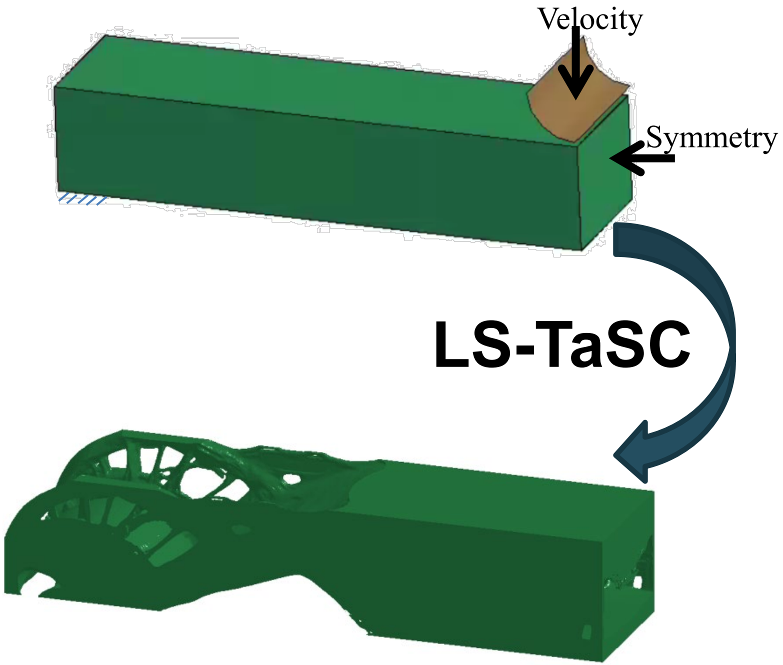
  LS-TaSC 4 focuses on the design of huge models for a combination of **statics, NVH, and impact**
  - Multidisciplinary methodology
    - Projected subgradient method
    - Multidisciplinary optimization
    - Visualization
- New Features in Version 4.1
- Application Examples

Overview on LS-TaSC

Topology Optimization

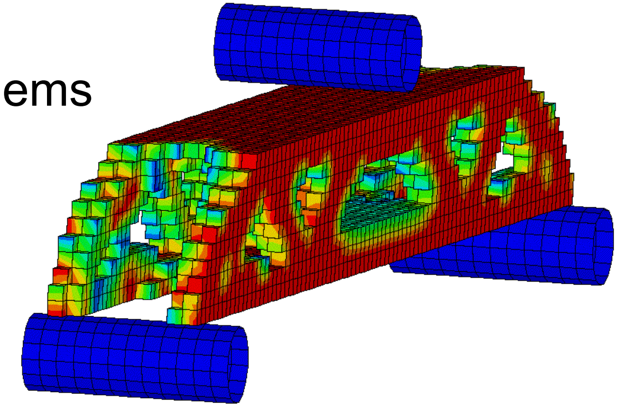
- Redistribution of material within a given domain



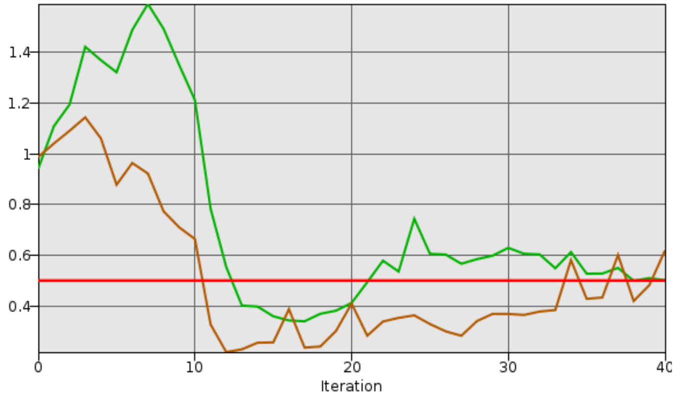


- Design variables
  - Relative density of each element
- Result
  - New material distribution
  - New shape of structure

LS-TaSC - General

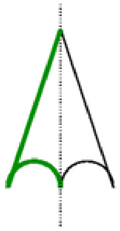


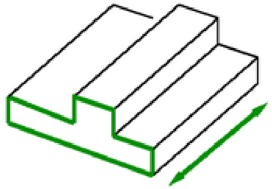
- Topology and shape optimization of non-linear problems
  - Dynamic loads
  - Contact conditions
  - Solids and shells
  - → find a concept design for structures analyzed using LS-DYNA (implicit and explicit)
- Huge LS-DYNA models
  - 10 million elements
- Multiple load cases and disciplines
- Global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

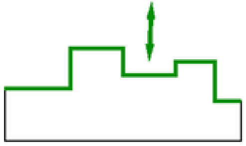


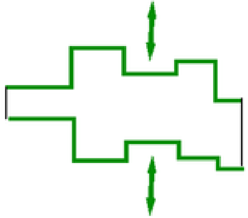
Geometry definitions

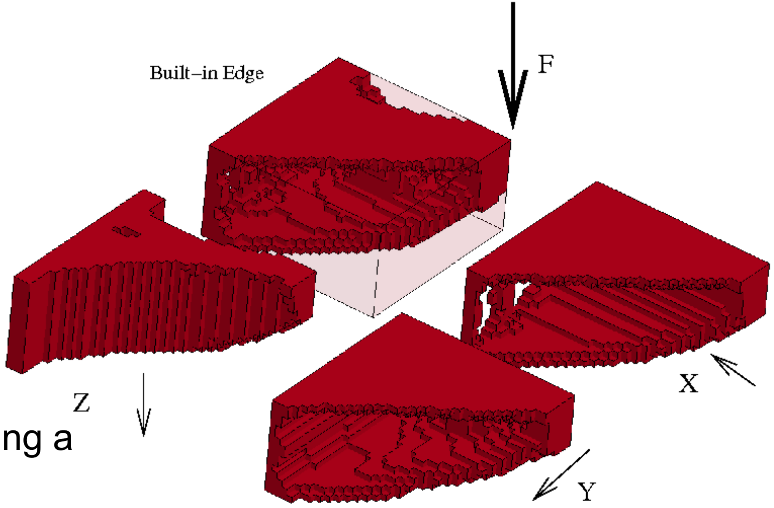
- Symmetry
- Extrusion
- Casting
  - One sided
  - Two sided
- Forging
  - Two sided casting
  - Preserving a minimal thickness







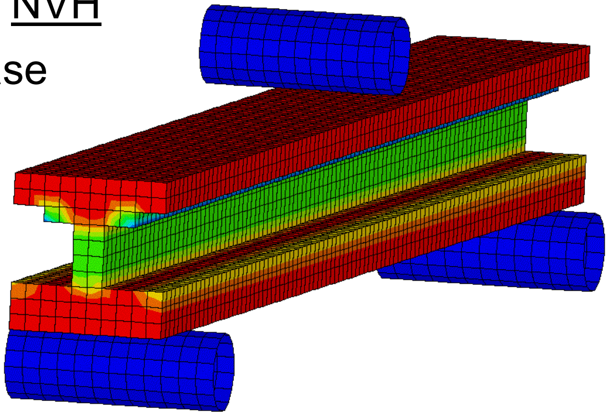




Forging: Two-sided casting preserving a minimum thickness (no holes)

Methodologies

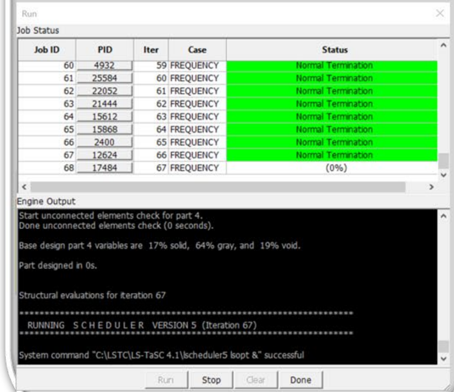
- Topology optimization
  - Optimality Criteria for Dynamic Problems
    - Objective: Homogenization of internal energy density (IED)
  - → uniform loading of material for given mass
  - Projected Subgradient Method
    - Enables multi-disciplinary optimization: Impact, Static, NVH
  - → maximization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



Integration

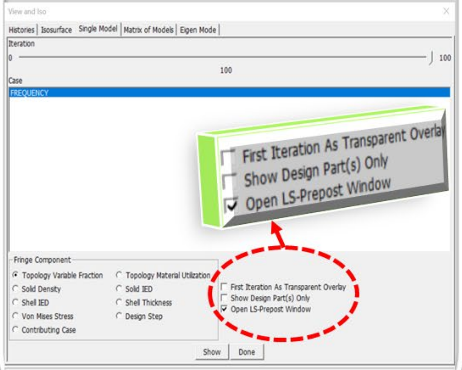
LS-TaSC with LS-DYNA

- no special treatment for nonlinearties



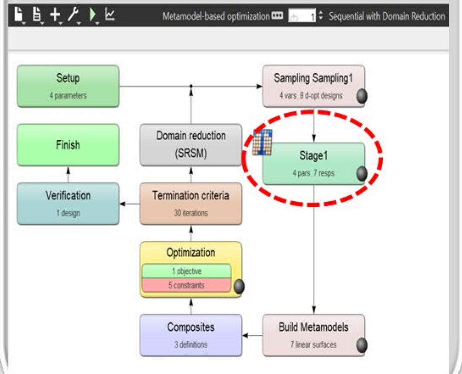
LS-TaSC with LS-PrePost

- results visualization
- model editing



LS-TaSC with LS-Opt

- multilevel and complex design schemes



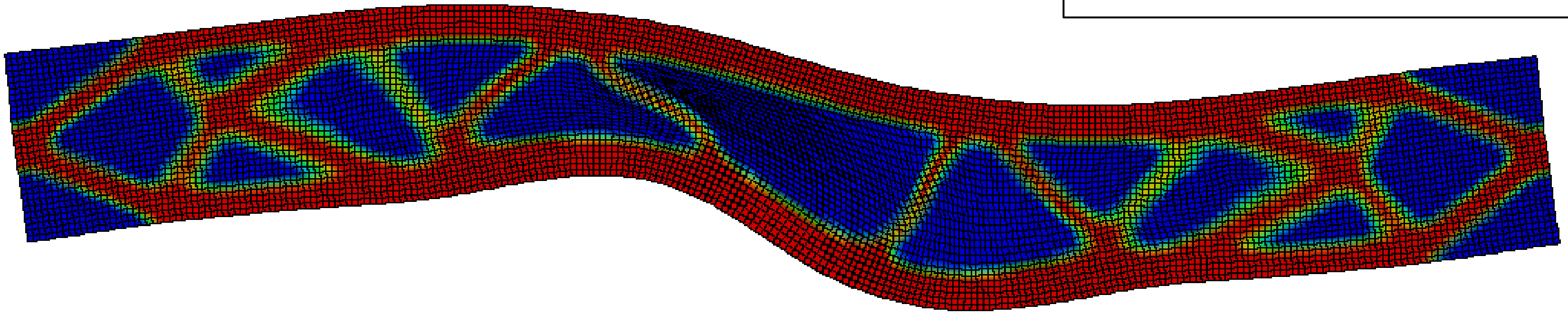
New Features in Version 4.0 and 4.1 -

Designing for the combination of impact, statics, and NVH

Projected Subgradient Method - Motivation

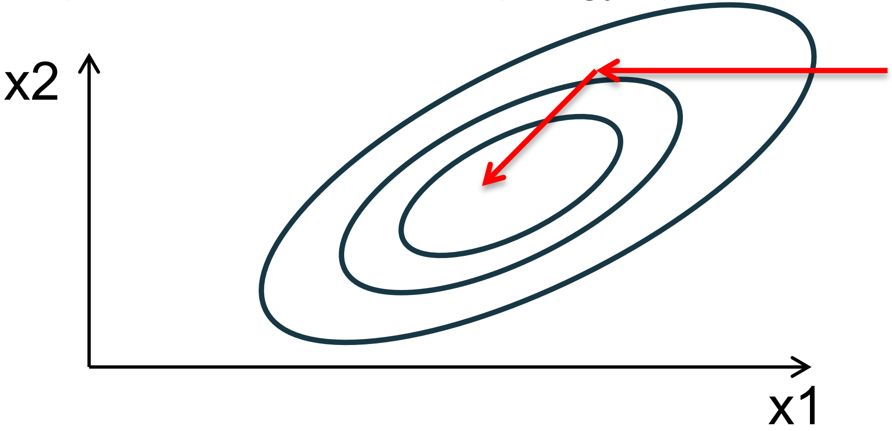
- LS-TaSC 3.2 method: Optimality Criteria for Dynamic Problems
- Objective uniform distribution of Internal Energy Density
  → static and impact load cases
  → not suitable for NVH load cases
  → we need a method that considers frequencies (maximization of fundamental frequency)
  → Projected subgradient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



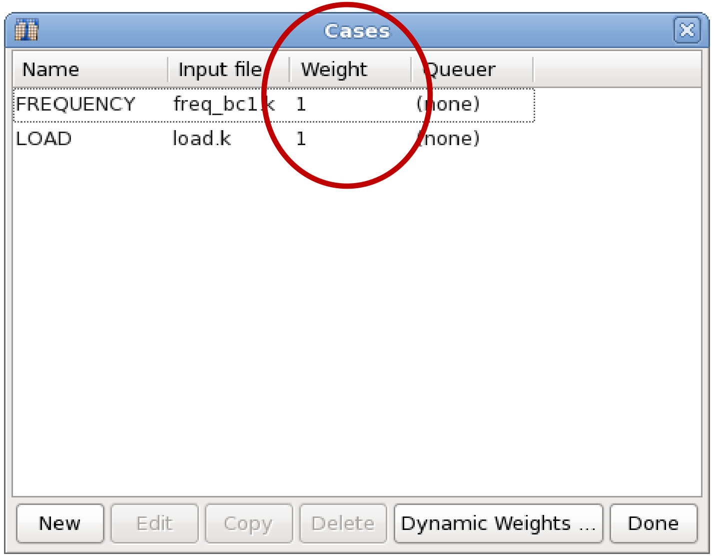
$$x^{k+1} = x^{k} - \alpha_k \, g^{k}$$

- 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

Solidification as Stopping Criteria

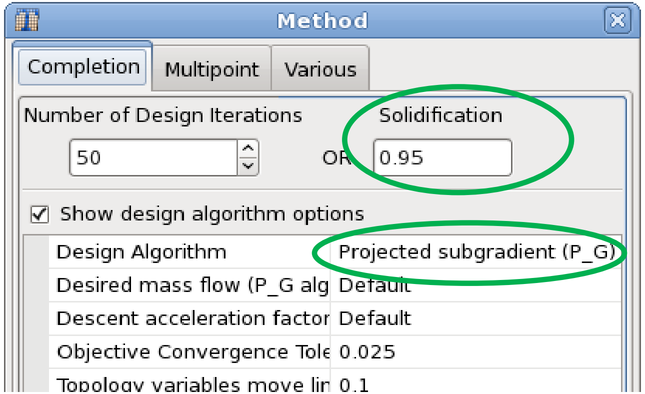
- The Projected Subgradient Method uses a new stopping criterion called **Solidification**, which **measures the discreteness of optimized designs** → fractions of elements fully used or deleted
- Assuming $N = N_{void} + N_{grey} + N_{solid}$, Solidification is defined as

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

where

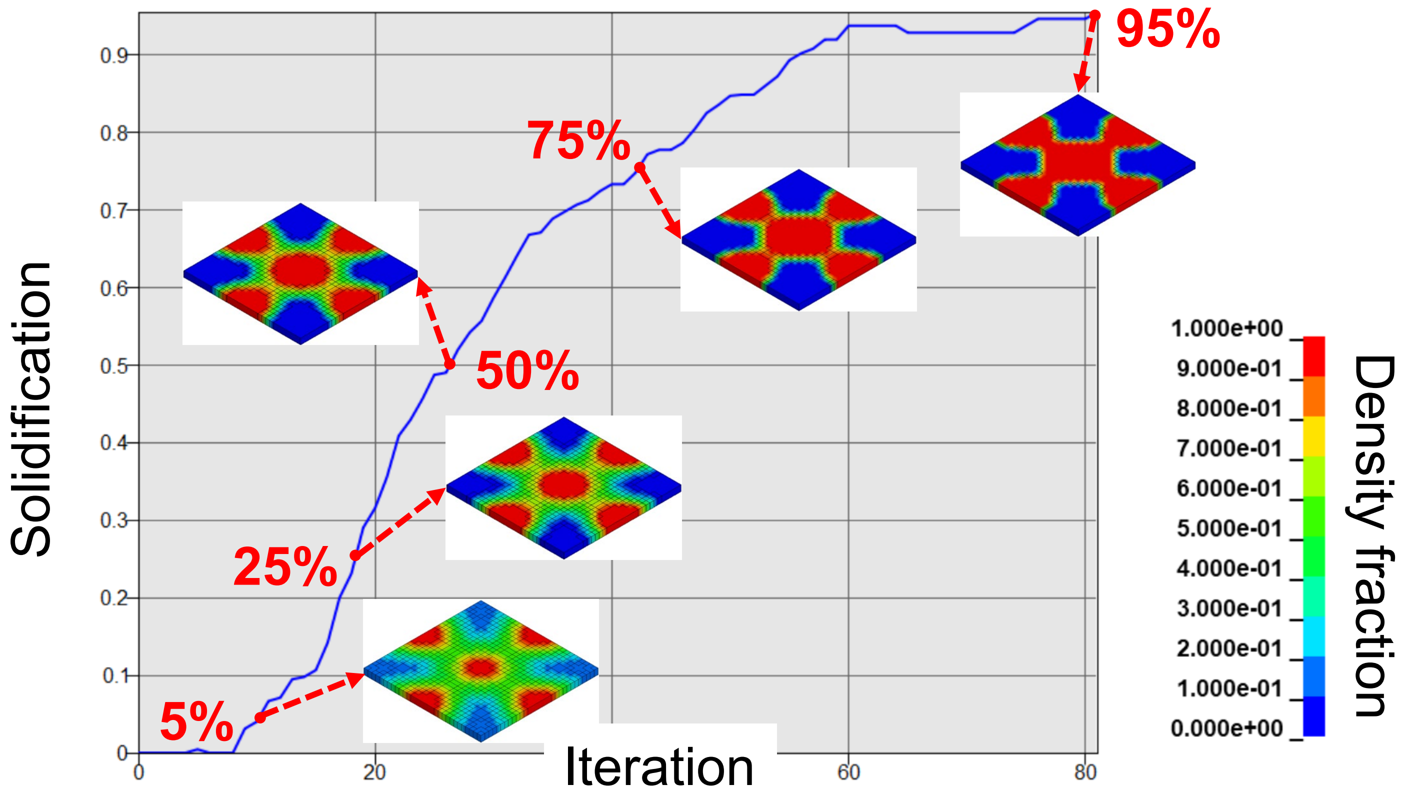
$$M_1 = \frac{N_{void} + N_{solid}}{N}$$

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



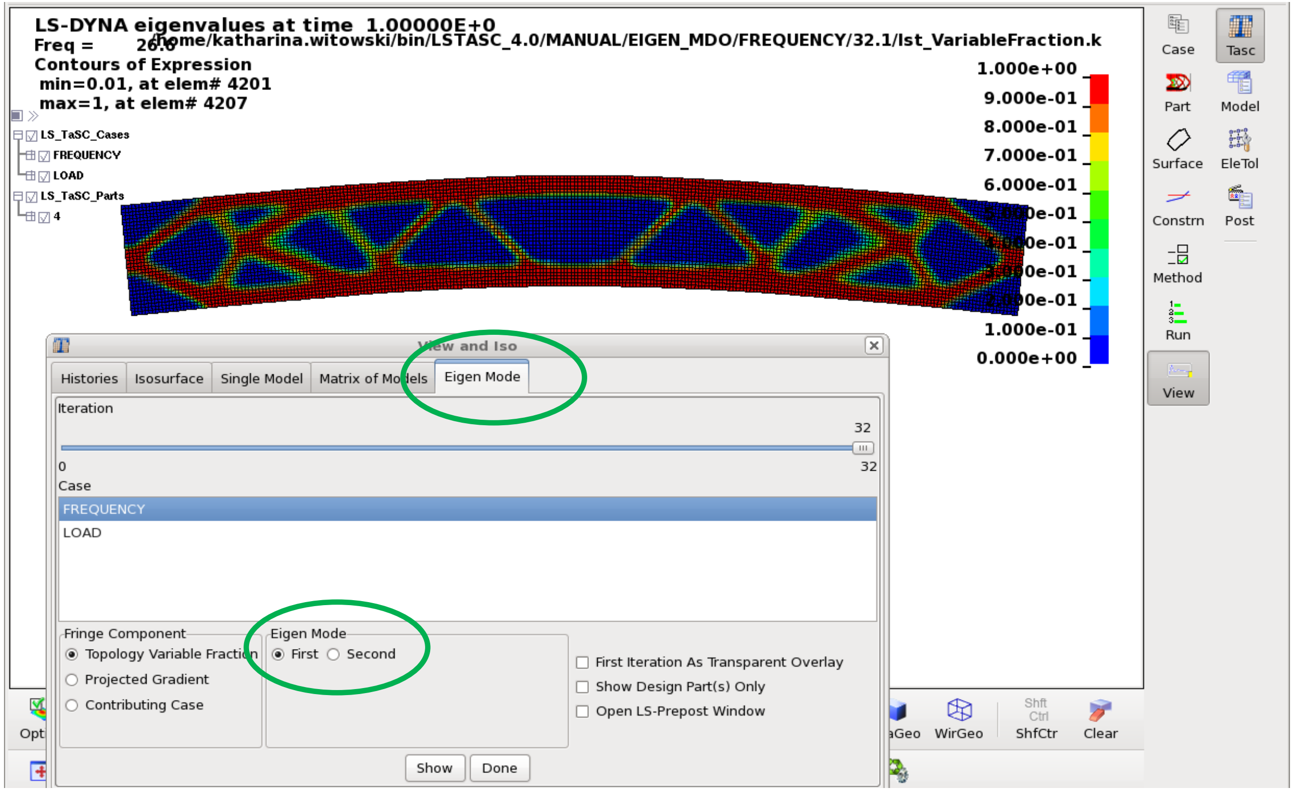
- $M = 1$ → fully converged design
- A Solidification higher than 0.95 gives good designs

Solidification as Stopping Criteria



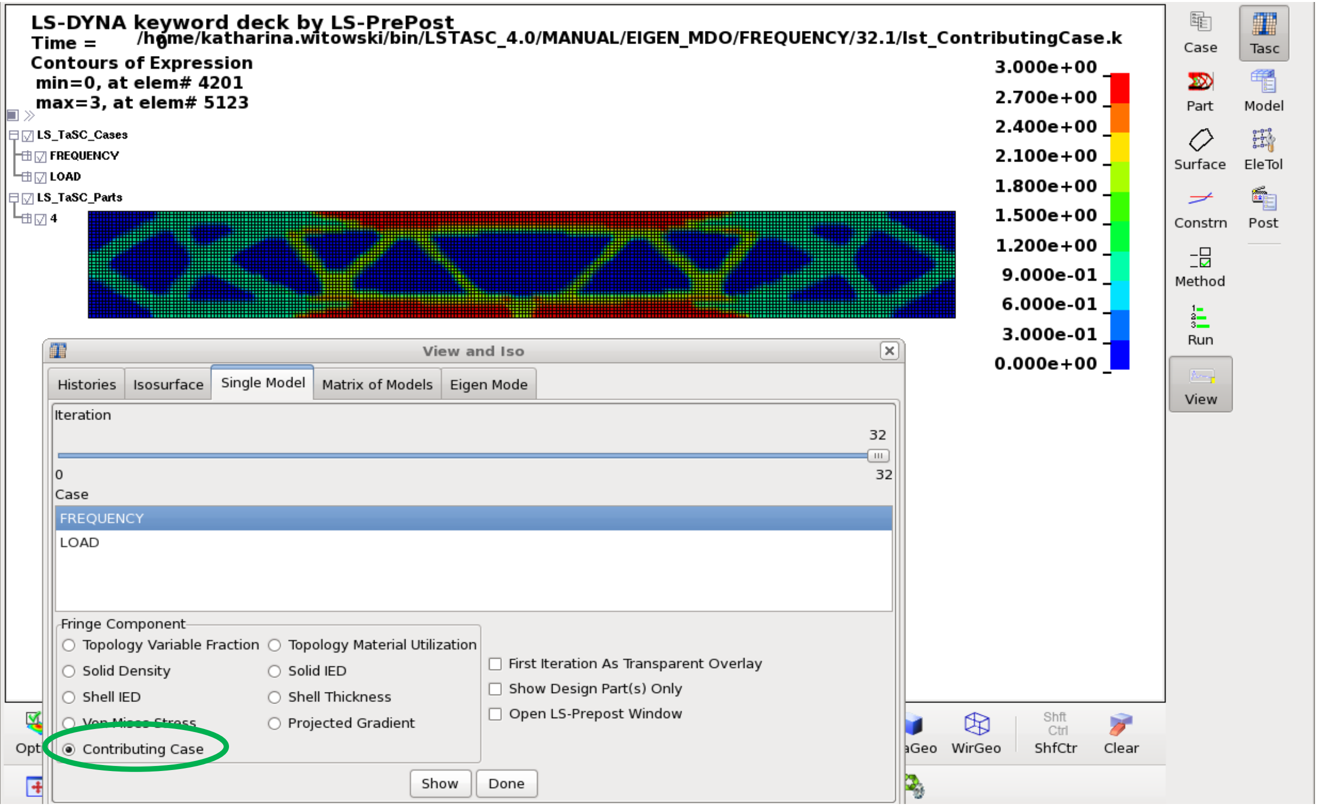
New Visualization Features

- NVH load cases: Eigen Modes



New Visualization Features

- MDO: Contributing Case
  - 0 = none
  - 1 = LC 1
  - 2 = LC 2
  - 3 = LC 1+2
  - …



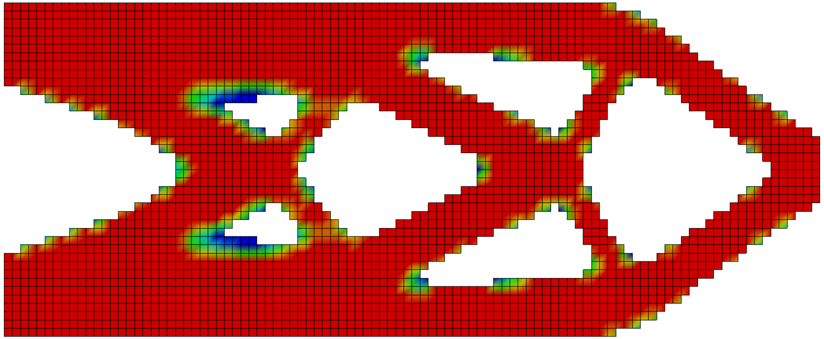
Examples

The benchmark problems demonstrate the new multidisciplinary solver:

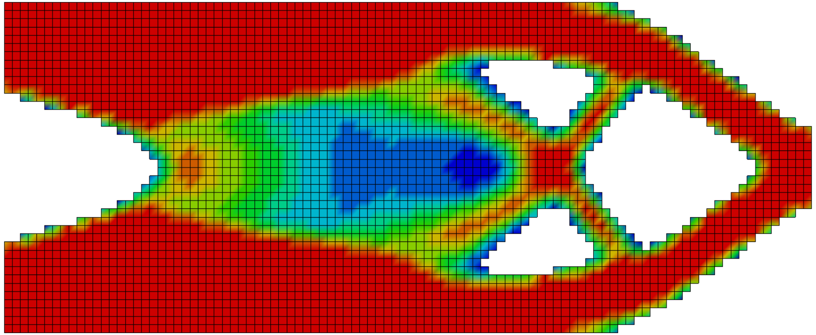
- Huge models
- NVH benchmark problems
- Multi-disciplinary design optimization considering NVH and static
- Impact, static, and NVH

Performance relative to previous method

- Mathematical programming techniques allow many power-ups



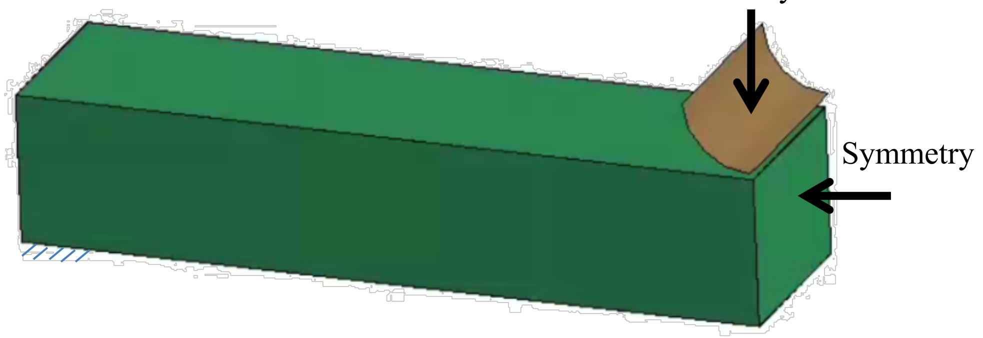
Projected subgradient (new):
- 30 FEA calls
- 0.1 step size

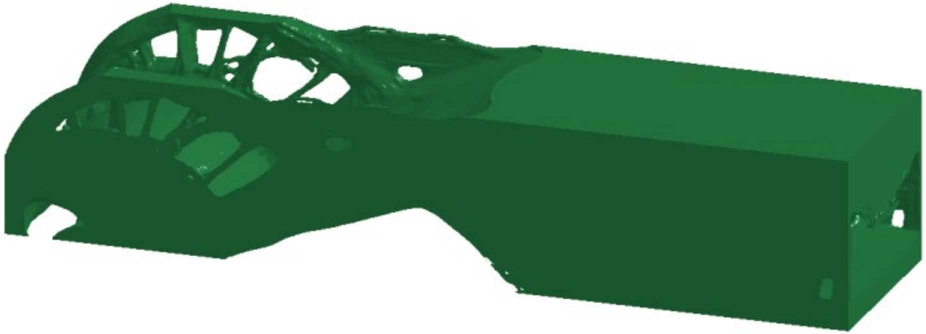


Optimality Criteria (old):
- 30 FEA calls
- 0.1 step size
- Needs about 50 iterations to match the new algorithm

Huge model performance

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





Isosurface plot
of optimal design

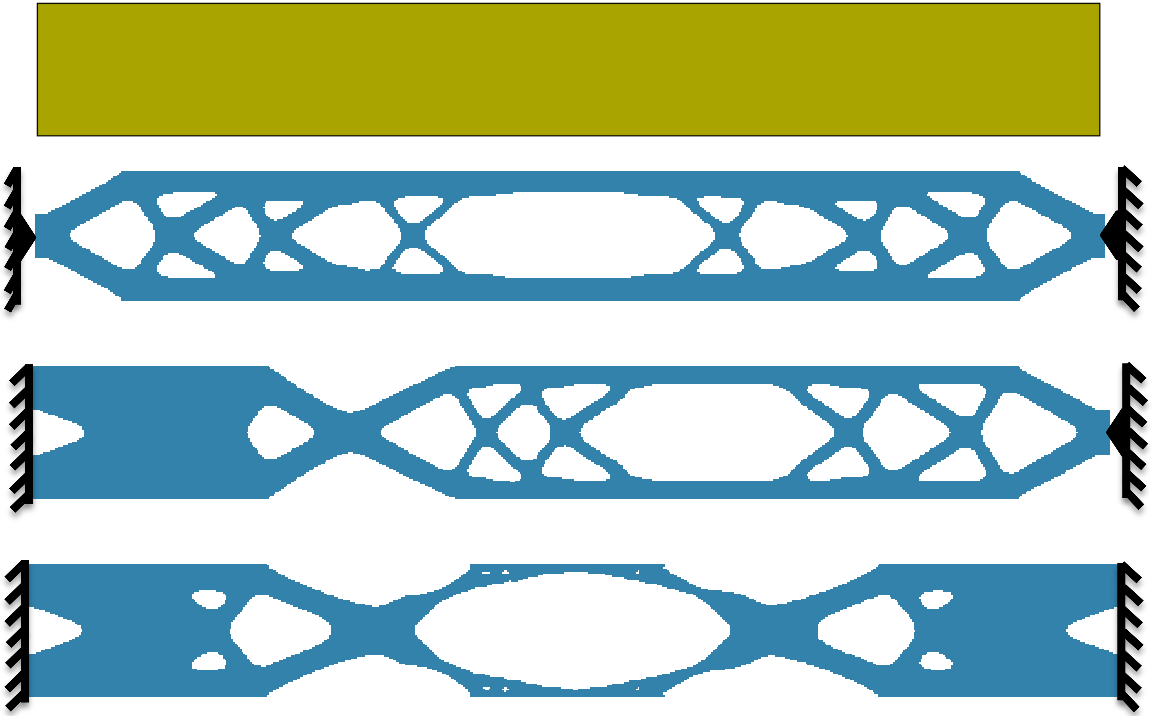
Huge model performance

- 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

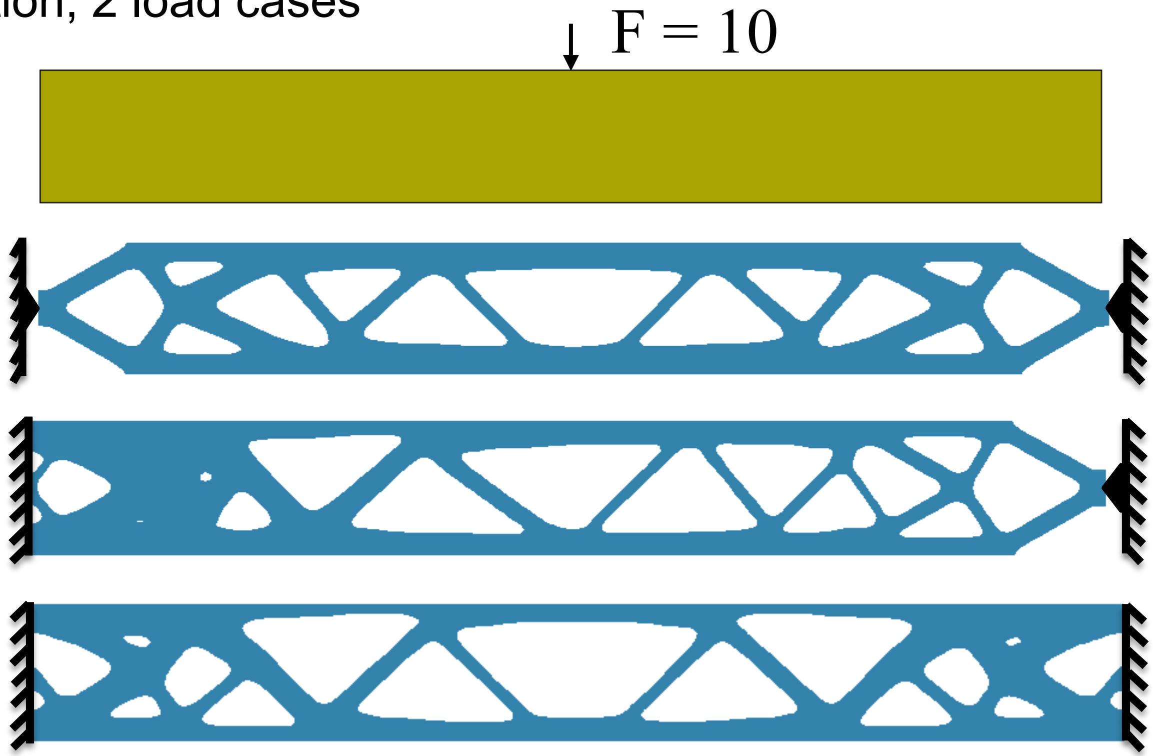
- Maximization of Fundamental Frequency
- Mass fraction: 0.5
- 3 different boundary conditions



Symmetric boundary conditions
→ Symmetric results

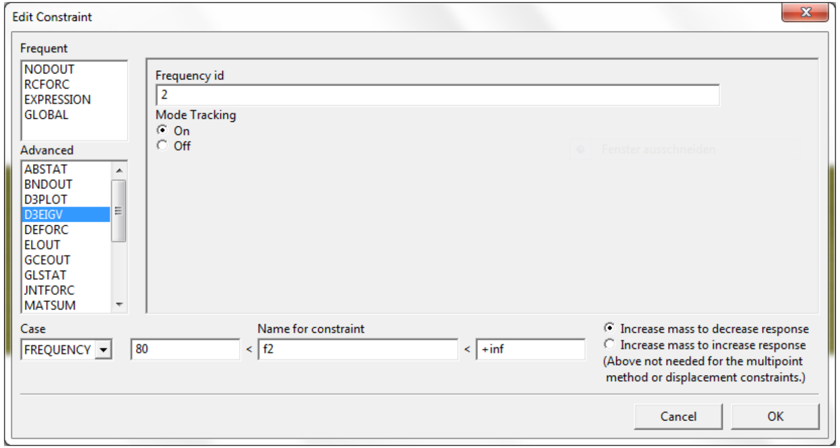
NVH Benchmarks

- 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.



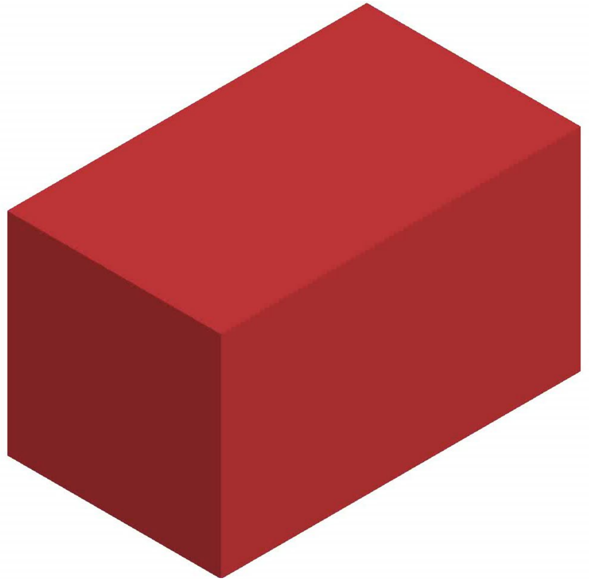
New Features in Version 4.1

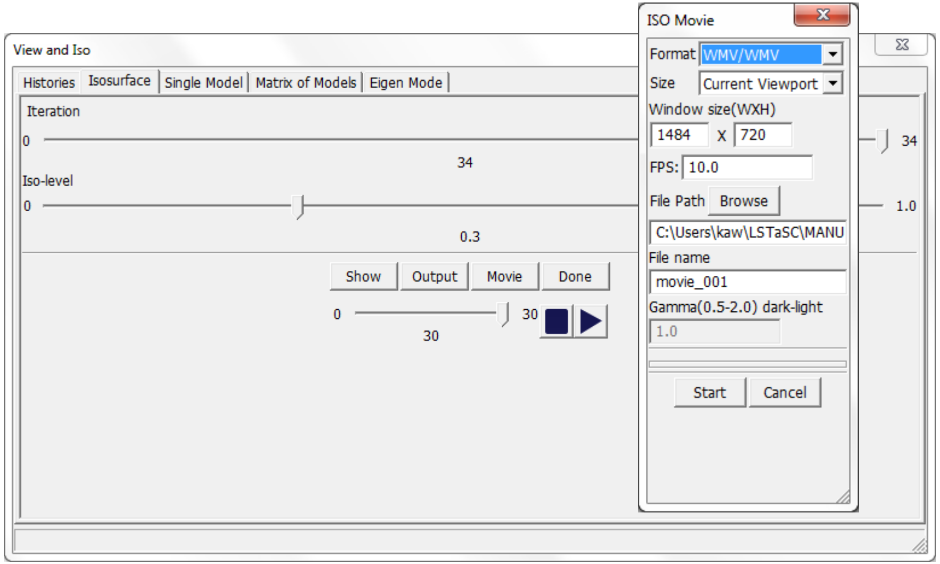
- Multi-disciplinary design optimization
  - Projected Subgradient Method
  - Multipoint scheme
  - Spatial kernel
  - → Constrained multidisciplinary topology optimization
  - → Crash, NVH, static load cases
  - → High performance of computing huge models with more than 10 million elements

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

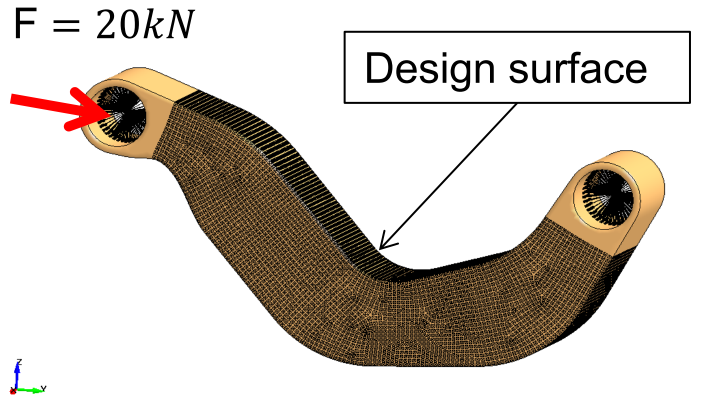


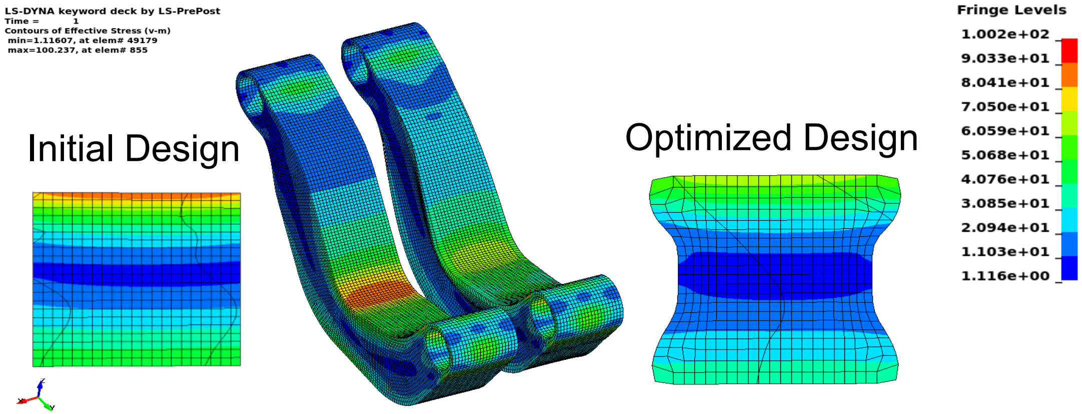


Application Examples

Example – Free Surface Design

- Objective: uniform surface stress
  → reduction of stress concentration

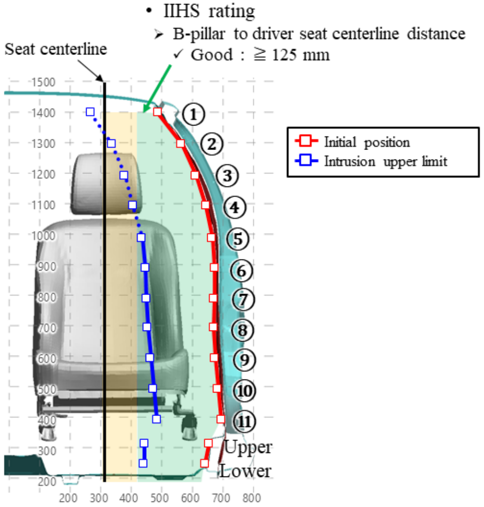




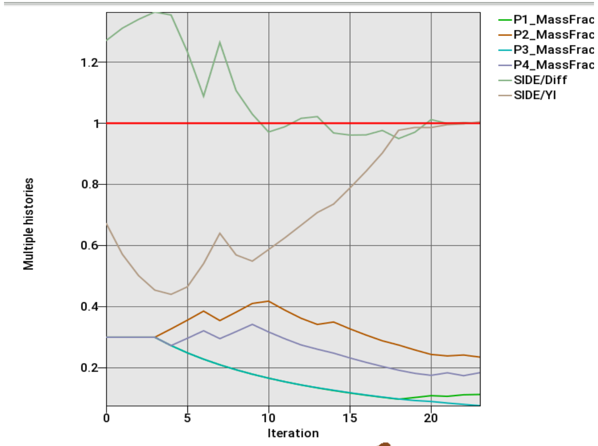
→ 20% stress reduction

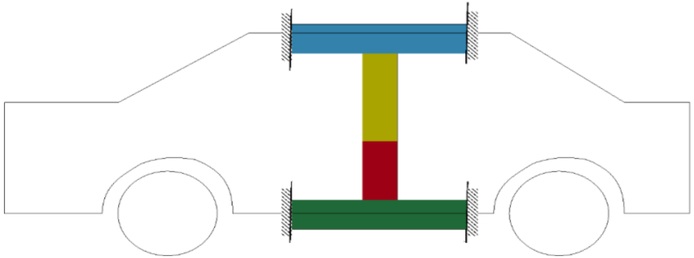
Example – Side Impact

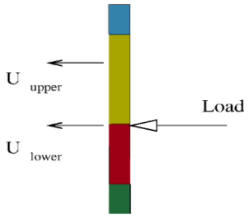
- Simplified B-pillar
  - Objective
    - Stiffest structure
    - satisfy constraints
    - and minimize mass
  - Constraints
    - $-10\,u_{lower} < 1,$
    - $2u_{upper}/u_{lower} < 1$



Problem statement by courtesy of JSOL

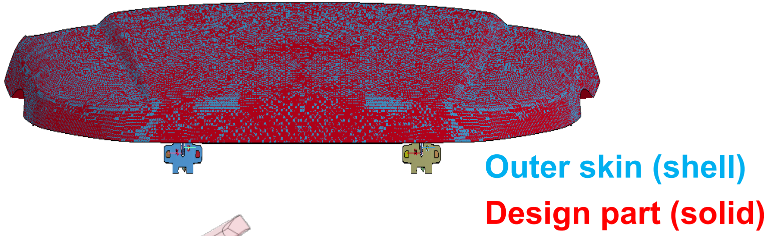


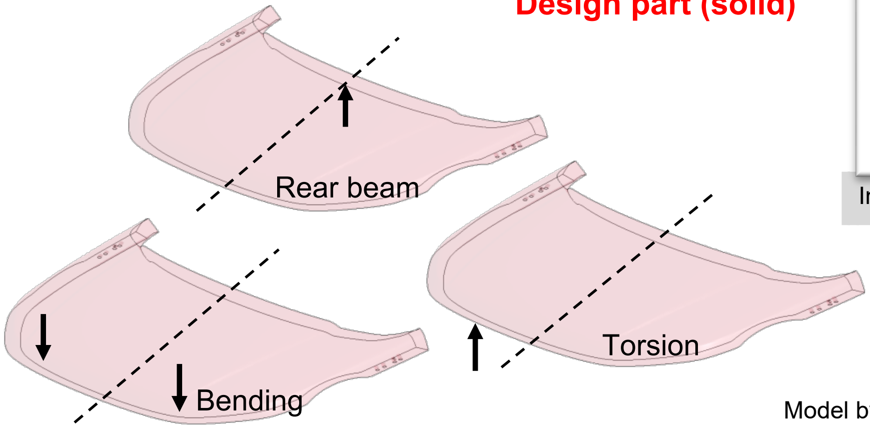




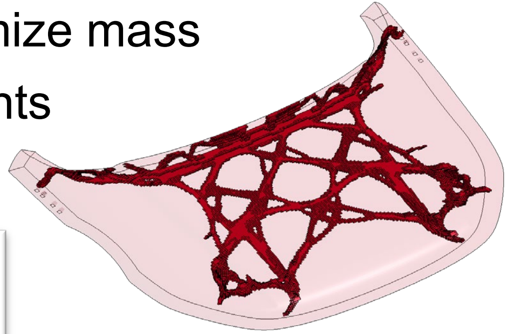
Example – Hood Design

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

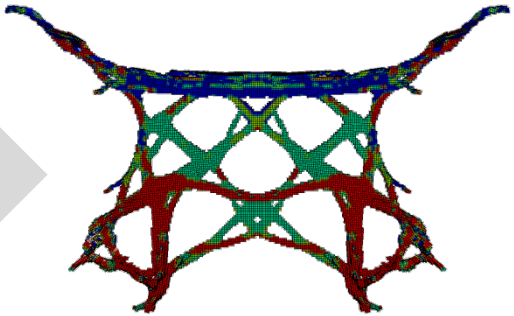




Initial Design has very low mass fraction of 0.01.



Optimum



Design Contribution Plot
(Rear beam, torsion, bending)

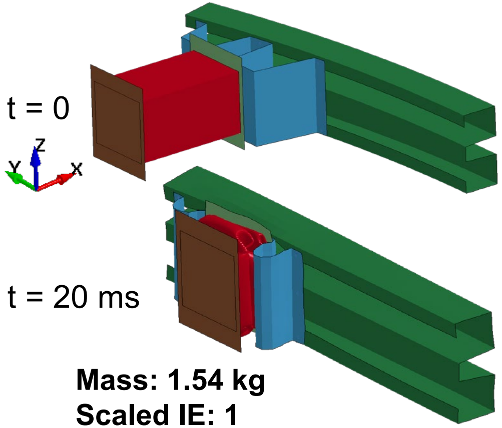
Model by courtesy of Jaguar Land Rover

Example – Automotive Crash Box

Crashworthiness and Lightweight Optimization

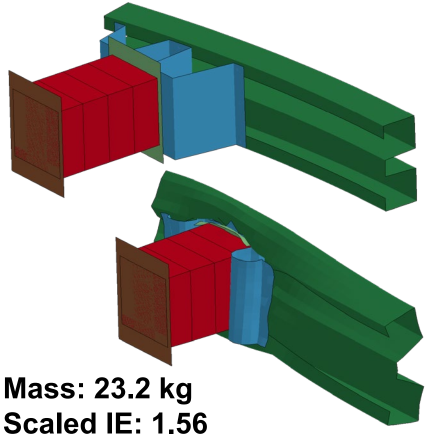
- Objective: Minimize mass
- Constraints: Scaled max. Energy Absorption ≥ 1
- Geometry: solid block split into 4 parts; XY and XZ symmetry

Reference: Shell structure



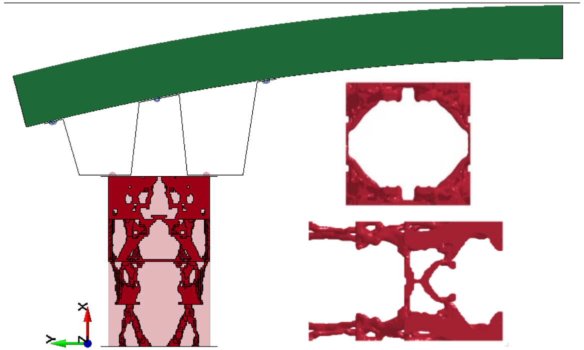
Mass: 1.54 kg
Scaled IE: 1
Scaled Peak Accel: 1

Baseline: Solid block



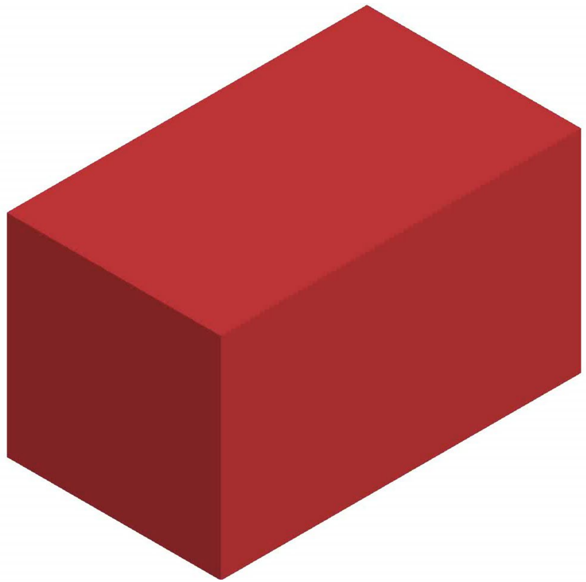
Mass: 23.2 kg
Scaled IE: 1.56
Scaled Peak Accel: 0.51

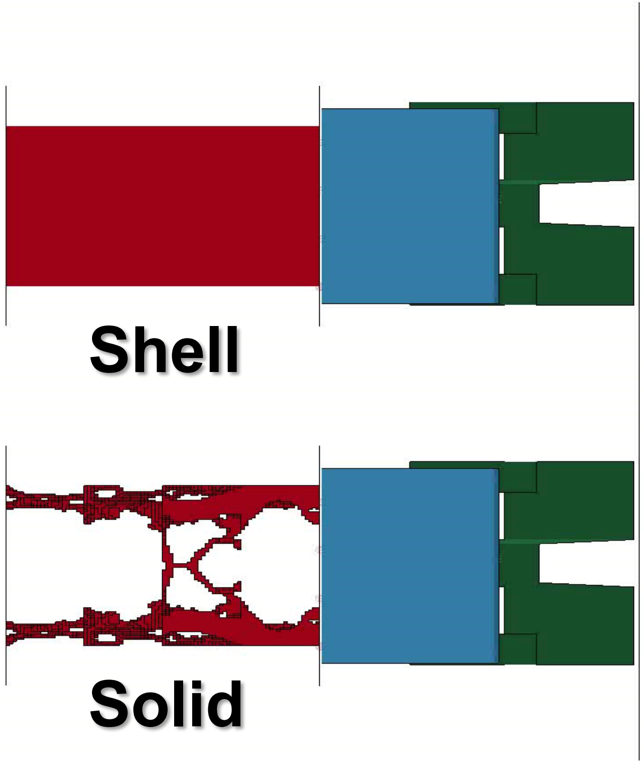
Optimal Solid structure



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

Example – Automotive Crash Box

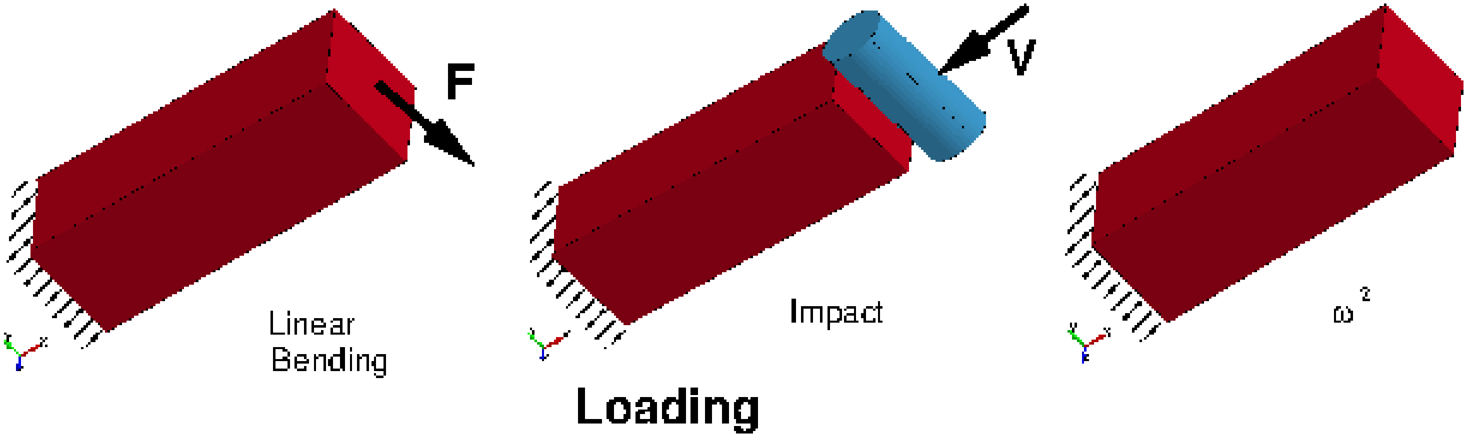




Gandikota I, Yi G, and Roux W,
Crashworthiness and lightweight optimization
of an automotive crash box using LS-TaSC.
FEA Information Engineering Solutions, October 2019

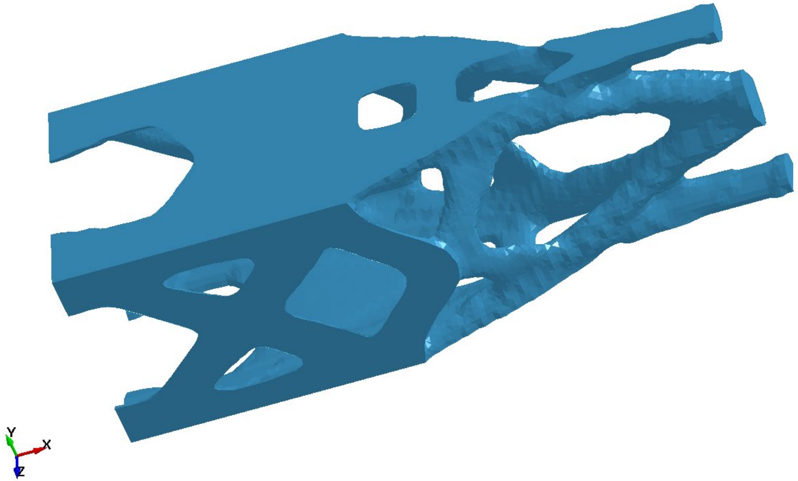
Impact, statics, and NVH

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



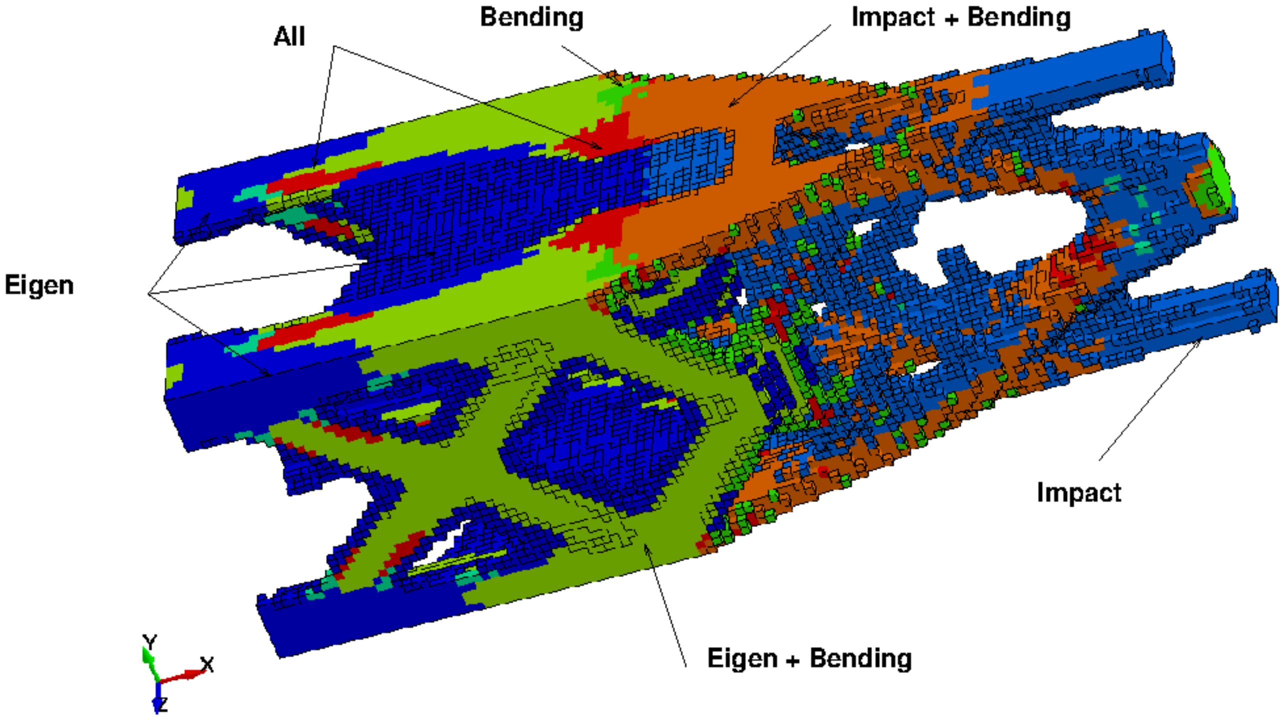
Impact, statics, and NVH

- Results (80 Iterations)
  - Optimal geometry



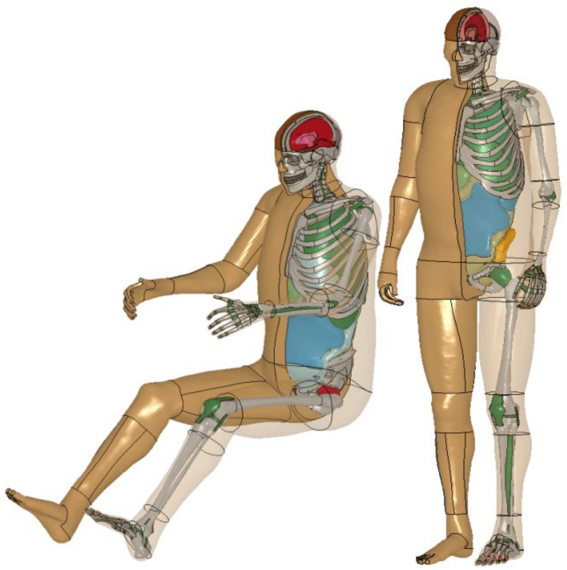
Impact, statics, and NVH

- 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
  - European Master Distributor
    www.dynamore.de
- LS-PrePost
  - Support / Tutorials / Download
    www.lstc.com/lspp
- LS-OPT/LS-TaSC
  - Support / Tutorials / Examples
    www.lsoptsupport.com



[THUMS® www.dynamore.de]

Thank you for your attention!

Your LS-DYNA distributor and more