LS-TaSC™ Product Status

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1 Introduction

The LS-TaSC Version 3.2 topology and shape design tool is presented, as well as the current development that will be available in the next version. The presentation introduces the multipoint numerical derivatives scheme that allows constrained optimization using the mass fractions and load case weights as variables. This allows constrained optimization using any response or mathematical expressions as constraints or objectives. Additionally, topology optimization of NVH load cases is presented. Application examples illustrate these capabilities.

2 Multipoint Method

The multi-point method was already introduced in Version 3.1, but has been significantly upgraded internally in Version 3.2 for both better current use and future expansion.
Multipoint optimization is used to solve constrained optimization problems. Two sets of variables are used in a simultaneous iterative process. The global variables, such as the part mass fraction (Fig. 1) and the load case weights (Fig. 2), are used to satisfy the constraints, while the element density variables are used to simultaneously compute the load paths. The two sets of variables are treated differently in the design algorithm: the local variables are computed using a suitable method such as fully stressed design, while the values of the global variables satisfying the constraints are computed using numerical derivatives and mathematical programming. This methodology has the advantage of allowing more general constraints.

Fig.1: Multi-point method. Final topology depends on part mass fractions, hence part mass fractions can be used as global parameters.

Fig.2: Multi-point method. Final topology depends on load case weights, hence load case weights can be used as global parameters.

2.1 Examples

2.1.1 Two load cases

The two load cases considered in this optimization are depicted in Fig. 3. The objective is to minimize the mass subject to constraints on displacements

- Y1 > -0.002
- Y2 > -0.004.

Therefore asymmetric results are required from a symmetric setup. The global variables are the part mass and the load case weight ratio.
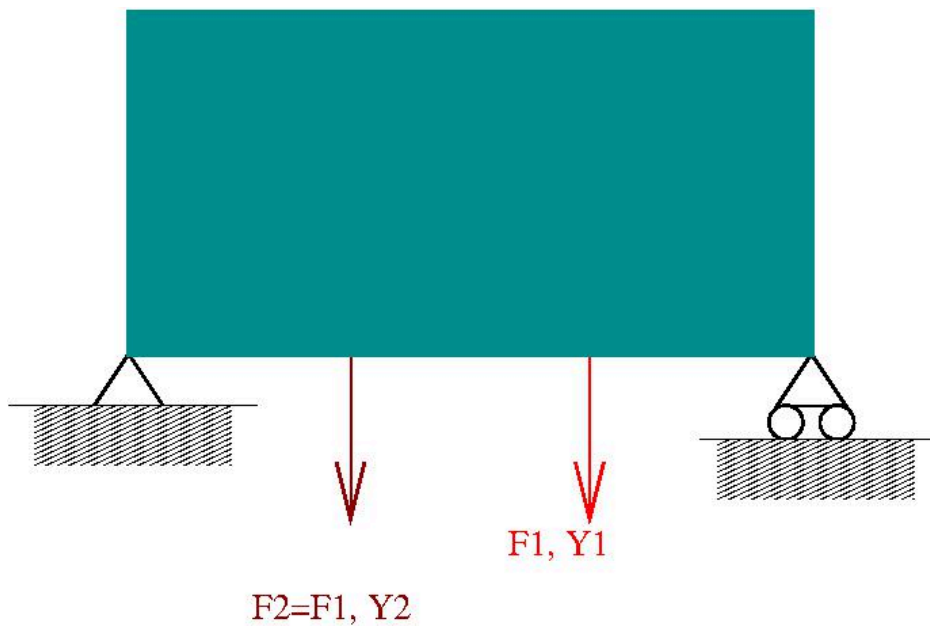The deployment of the global variables and the constraint values are displayed in Fig. 4 and the final topology in Fig. 5.
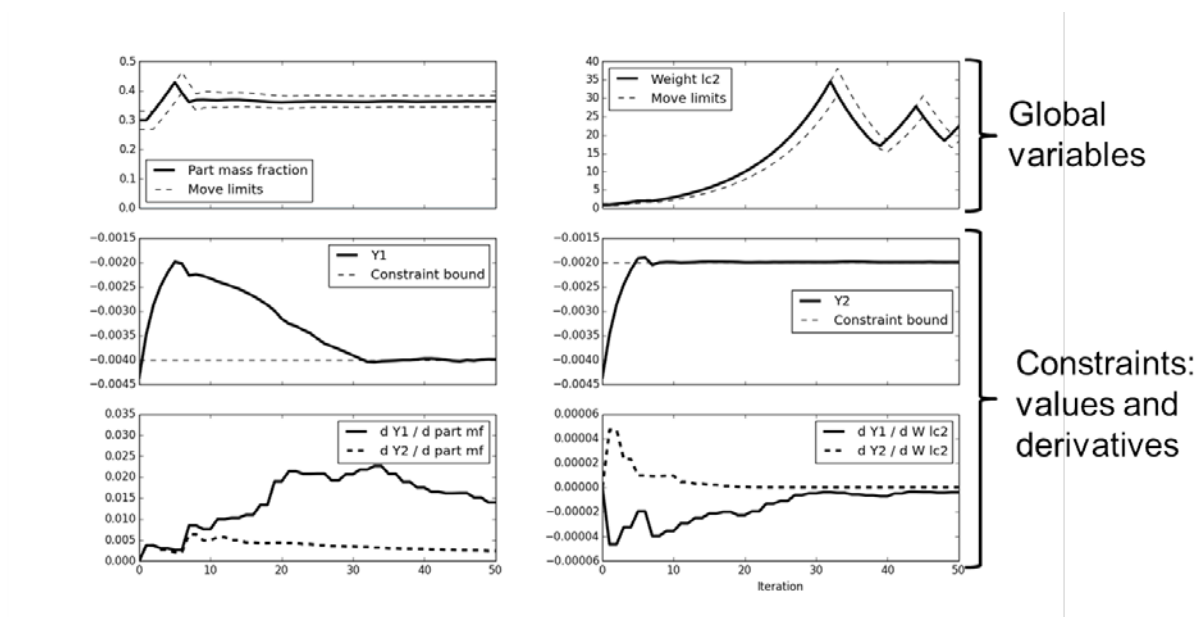

Fig.3:   *Load cases and constraints*

Fig.4:   *Optimization history of global variables, constraints and derivatives of constraints.*

Fig.5: Final topology

2.1.2 Multi-disciplinary Example

Three load cases are considered in this example, impact, bending and torsion, Fig. 6, and the following constraints are defined for the optimization:

- Impact
    - Energy absorption > 11.2e6
    - Reaction force < 200e6
- Linear bending
    - Displacement < 0.3125
- Linear torsion
    - Displacement < 0.075

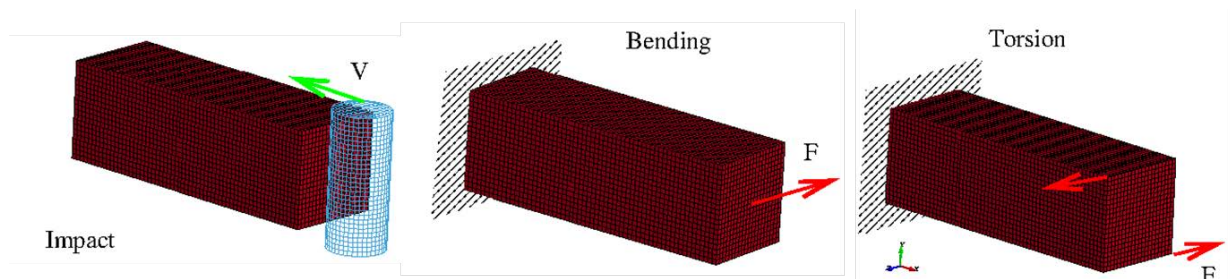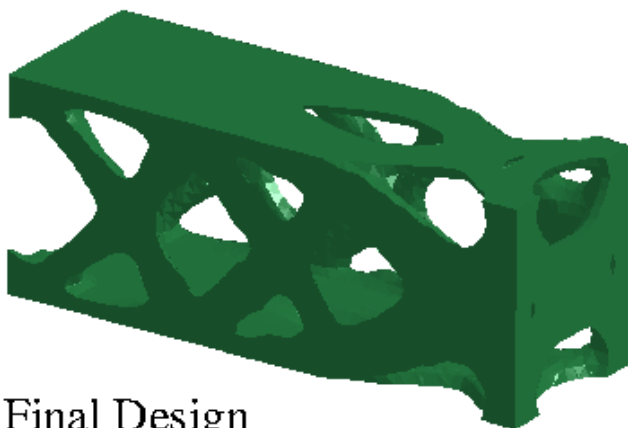The global variables are the part mass fraction and the load case weights.

Fig.6: Load cases impact, bending and torsion.

The deployment of the global variables and the constraint values are displayed in Fig. 8 and the final topology in Fig. 7.
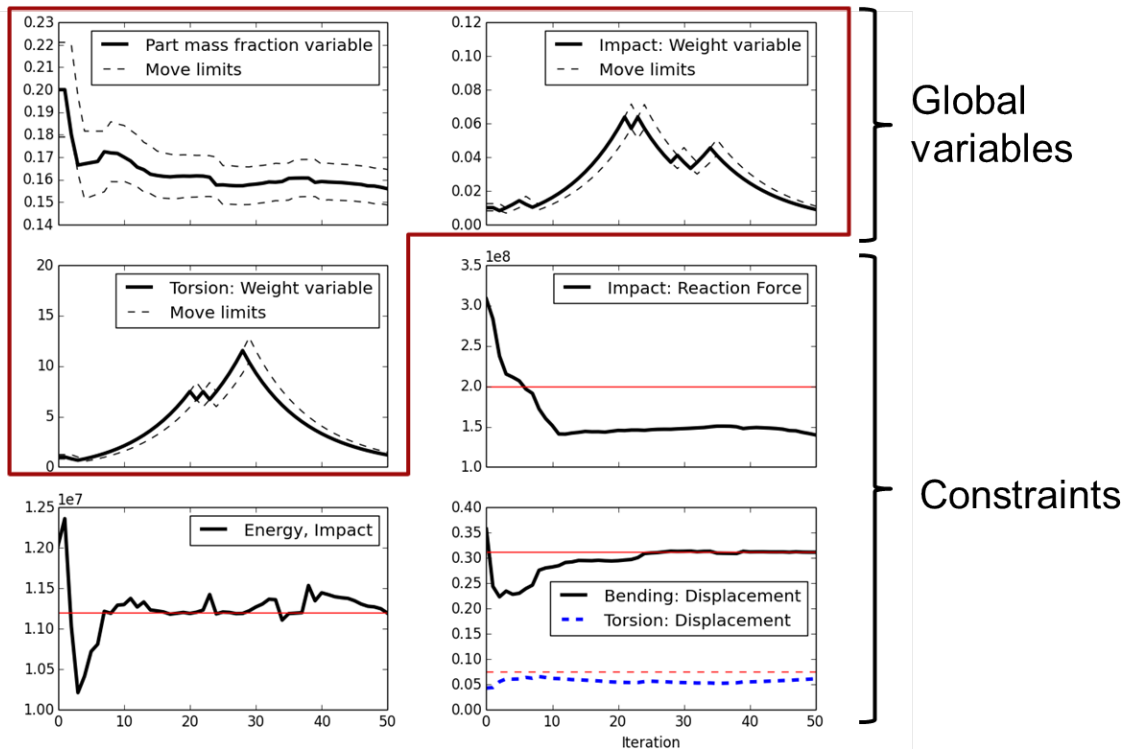

Fig.7: Final topology

Fig.8:   Optimization history of global variables and constraints

2.1.3 Multiple Parts Example

The load case considered in this example is displayed in Fig. 9. The objective is to minimize the mass subject to the following constraints:

- Intrusion: XDISP_N987 - XDISP_N1523 > 0.003
- Energy ratio: ENER_P3 / ENER_P5 > 1.5
- Energy absorption: ENER_P3 + ENER_P5 > 800.0

The deployment of the global variables and the constraint values are displayed in Fig. 10 and the final topology in Fig. 11.
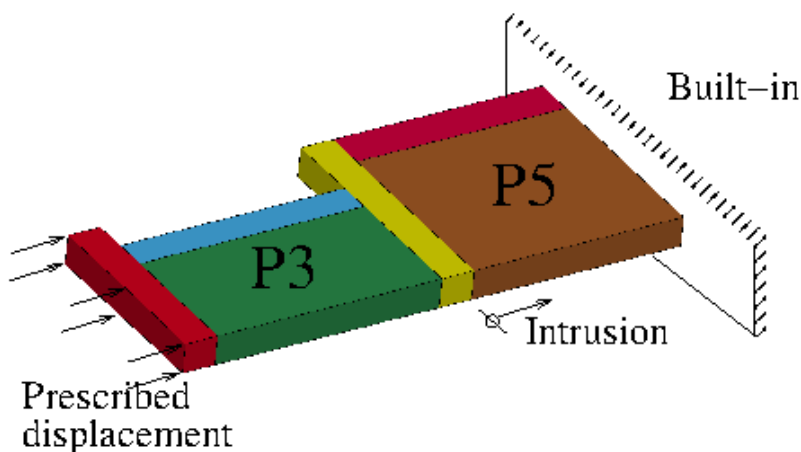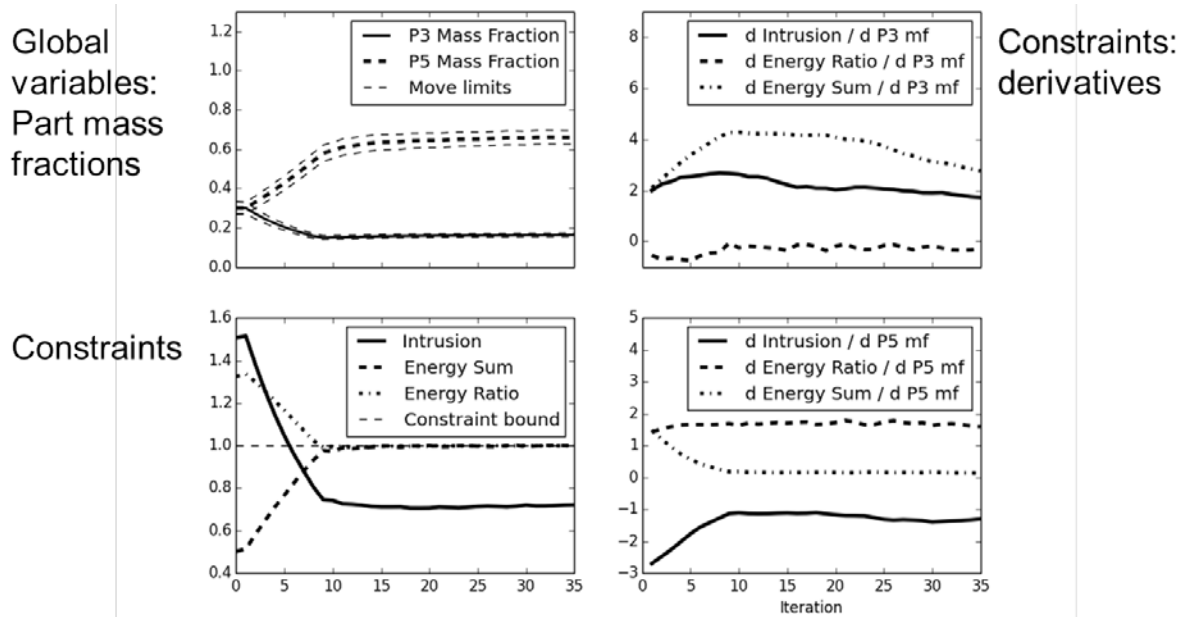

Fig.9:   Load case

Fig.10: Optimization history of global variable, constraints and derivatives of constraints.
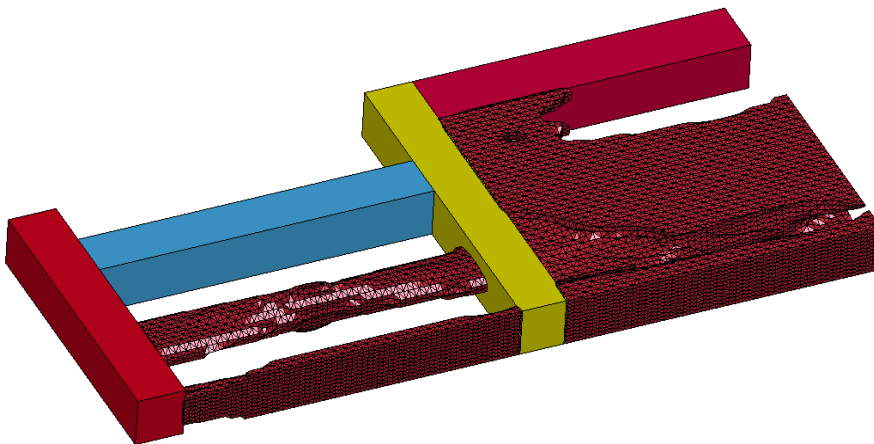

Fig.11: Final topology

2.1.4 Highly nonlinear Example

The two load cases considered in this example are displayed in Fig. 12. The objective is to minimize the difference in the reaction forces between the load cases. The global variable is the load case weight of the second load case, whereas the mass fraction is constant.
The Response Surface Method as well as Direct Search were used to solve the global optimization.

Intermediate results are displayed in Fig. 13. Between iteration 20 and 21, the buckling mode changes for the offset impact load case. Buckling modes may also change within the multipoint loop. The topology changes due to the contact closures.

The final topologies are displayed in Fig. 14 (undeformed) and Fig. 15 (deformed). Note the effect of the internal contact closure. The design algorithm must handle the load paths changes.
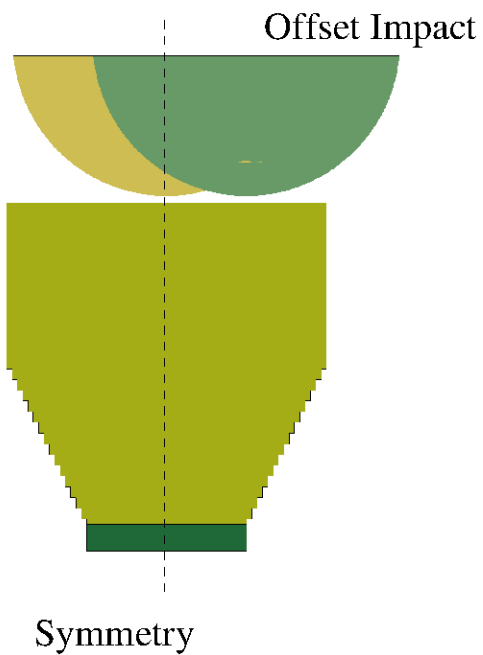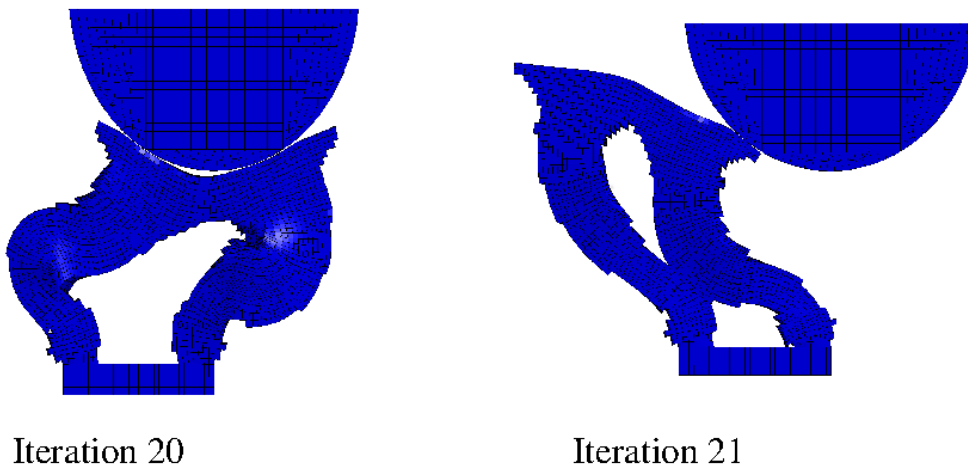
Center Impact

Offset Impact

Symmetry

Fig.12: Load cases center impact and offset impact

Iteration 20

Iteration 21

Offset impact load case

Fig.13: Deformed result of iteration 20 and iteration 21; buckling mode changes between those iterations.
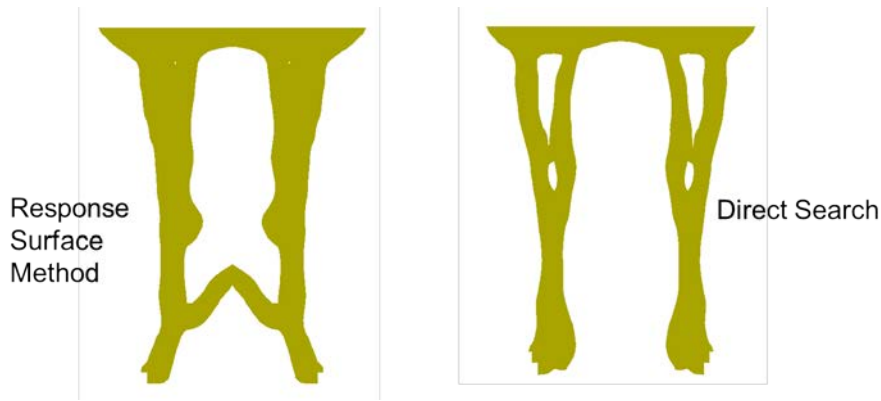
Fig.14: Final topology for different approaches to solve the global optimization problem; Response Surface Method (left) and Direct Search (right).
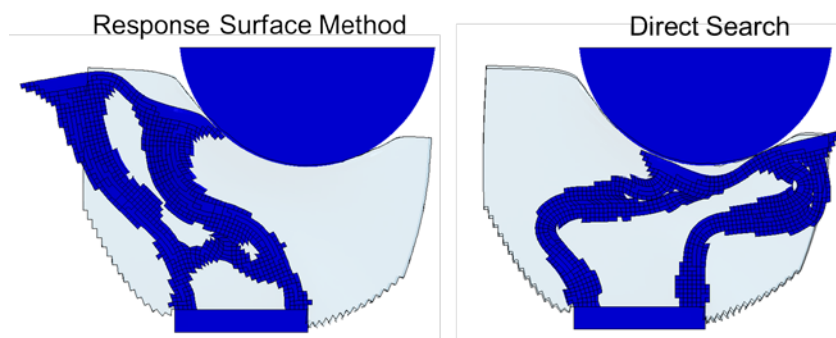

Fig.15: Final topology (deformed) for different approaches to solve the global optimization problem; Response Surface Method (left) and Direct Search (right).

2.2 Bonnet Case Study (Courtesy of JLR)

The Finite Element model used in this example consists of solid elements with a layer of shell elements on top. The design part is the solid part. Three nonlinear load cases are considered, latch bend, rear beam and torsion. The target mass fraction is 1%, subject to following constraints:

- Latch bend: z disp > -1.7
- Rear beam: resultant disp < 6.7
- Torsion: resultant disp < 17.6

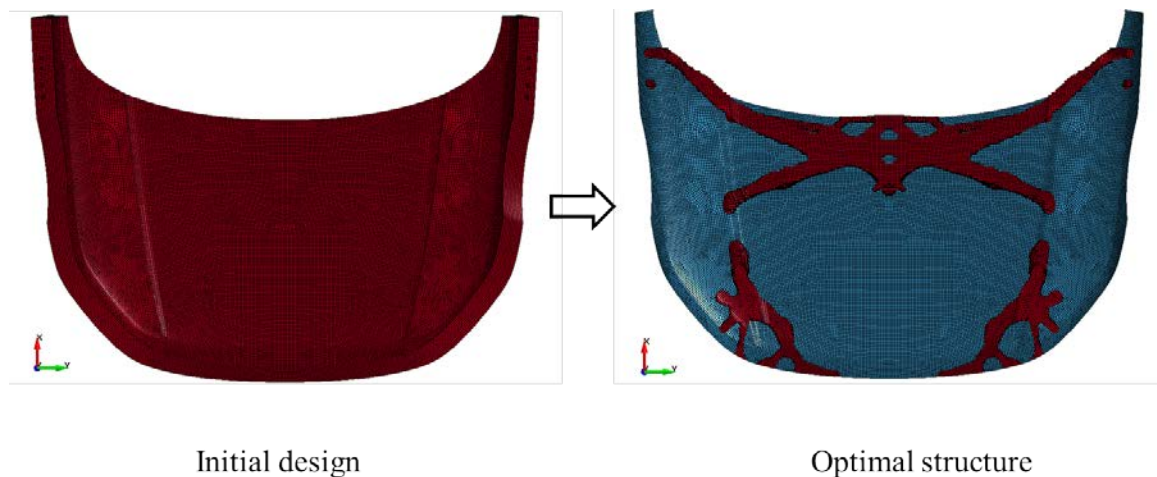The global parameters are the load case weights and the mass fraction.

Initial design → Optimal structure

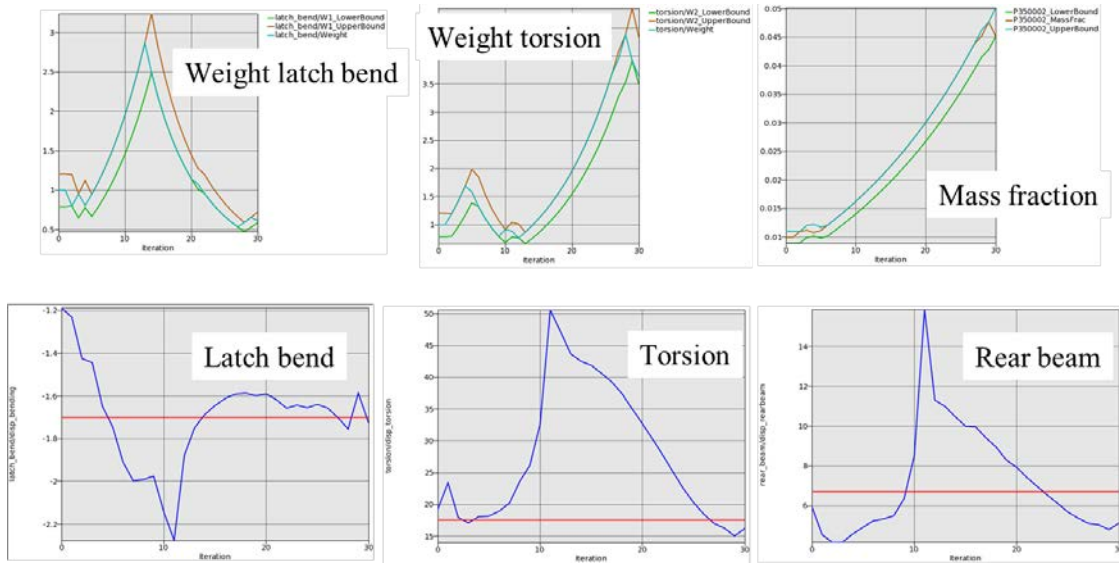*Fig.16: Initial design (left) and final topology (right)*

Fig.17: Optimization history of global variables and constraints.

3 Current Development – Topology optimization for NVH load cases

Topology optimization for eigenfrequency analysis will be available in the next version of LS-TaSC. The objective is the design for the maximum fundamental frequency of the structure. Multi-disciplinary optimization will be available as well, the NVH load case can e.g. be combined with linear statics or impact load cases.

3.1 Examples

3.1.1 Mixed NVH and Linear Statics

In this example, the structure is designed for both the highest eigenfrequency and a linear static load case, Fig. 18. The results shown in Fig. 18 are for different weighting of the load cases.
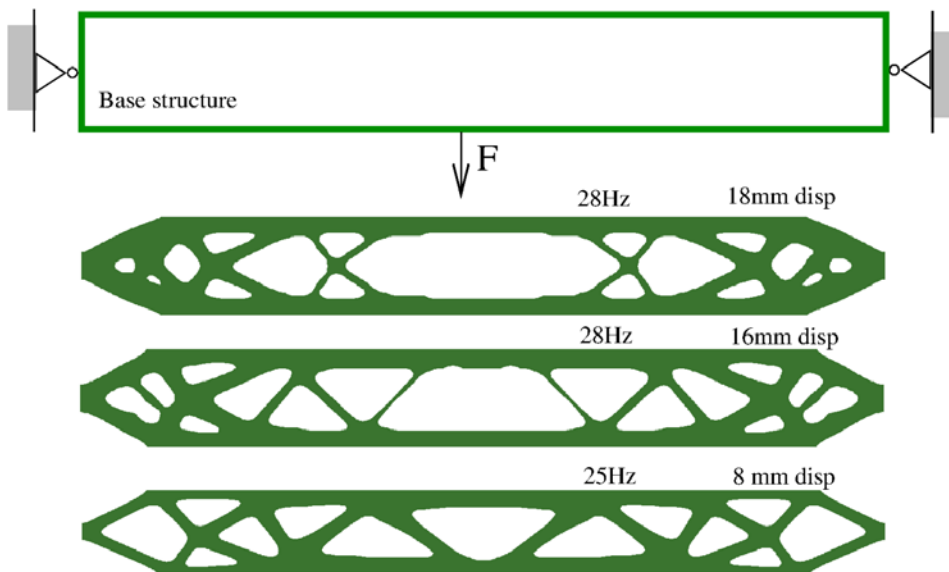

Fig.18: Mixed NVH and linear statics

3.1.2 Mixed NVH and Impact

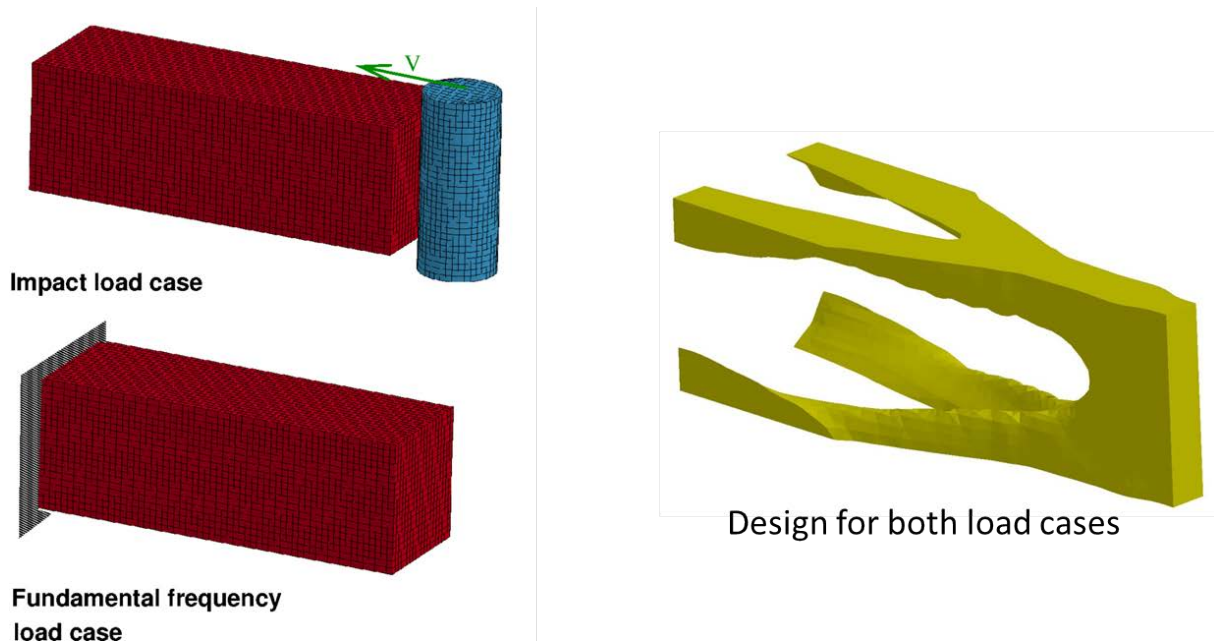In this example, the structure is designed for both an impact and a fundamental frequency load case, Fig. 19.

Fig.19: Mixed NVH and impact topology optimization; load cases (left) and final topology (right)

4 Summary

This paper shows the use of the major new features in LS-TaSC. In Version 3.2 the constrained optimization capability has been significantly upgraded, with the multipoint method allowing more general constraints. Other examples illustrate the current results of the new design for the fundamental eigenfrequency capability — LS-TaSC can now design a part considering both an impact and a fundamental frequency case.

5 Literature

[1]   "LS-TaSC™ Tool Topology and Shape Computations User's Manual", Version 3.2, Livermore Software Technology Corporation, Livermore 2016
[2]   Roux, W.: "The LS-TaSC^{TM} Multipoint Method for Constrained Topology Optimization", 14th International LS-DYNA Users Conference, Detroit 2016