Shape Optimization of a Hood

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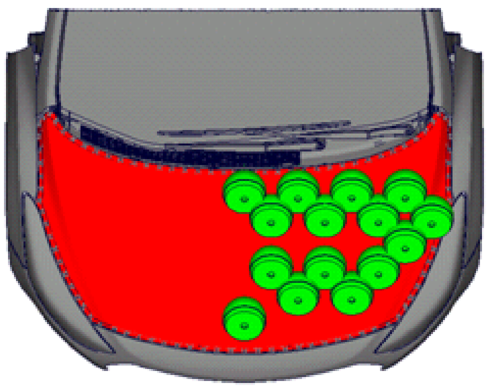
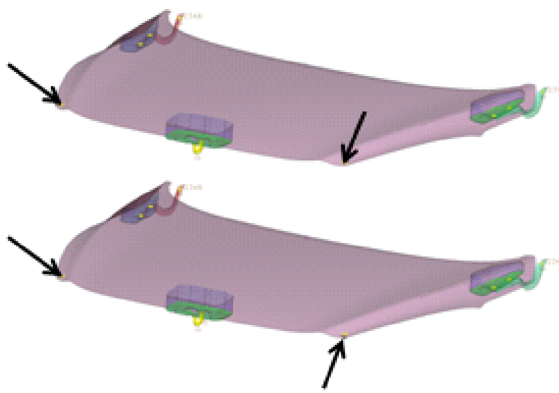
Motivation and overview

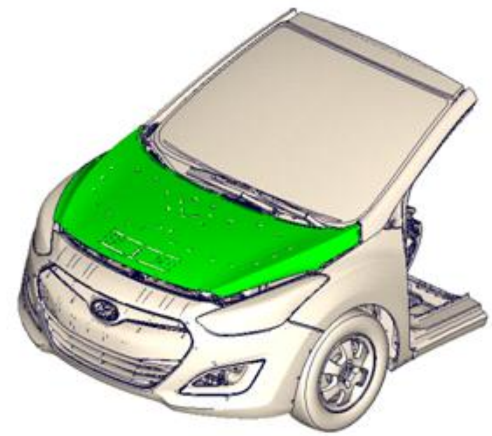
- Geometry of the hood panel is significant regarding the pedestrian safety regulations.
- Main load cases are
  - head impact (pedestrian safety),
  - fatigue and
  - stiffness.



Topometry and Shape Optimization



Topometry and Shape Optimization



Only Shape Optimization

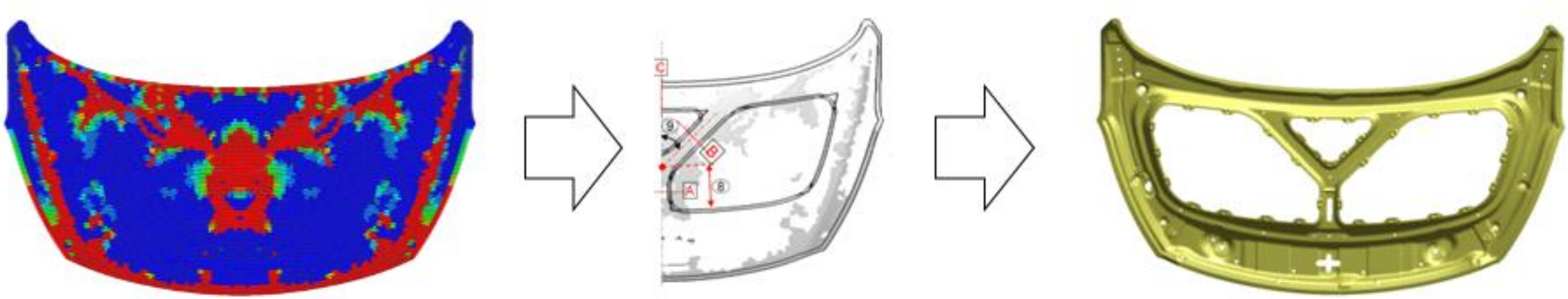
Topometry optimization

with

GENESIS/ESL

Results steel hood

- **Shell thickness distribution and following interpretation of CAD-design of the inner hood.**



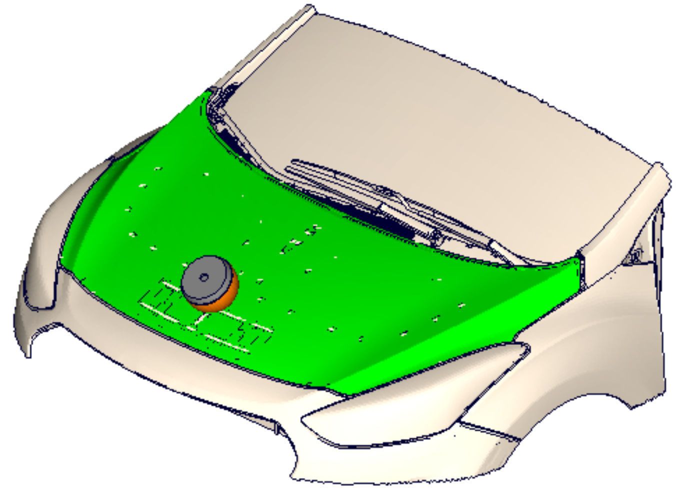
Shape optimization

with

ANSA and LS-OPT

Problem description

- **18 Load cases:**
  - 15 Head impact load cases
  - Stiffness analysis regarding bending and torsion
  - Hood closing analysis
- **Objective: Minimize mass.**
- **Constraints:**
  - Head impact load cases (15 points):
    - HIC total score of improved design ≥ HIC total score of basic design
      → HIC improved design ≤ HIC basic design
  - Displacement of load case bending ≤ C_bending
  - Displacement of load case torsion ≤ C_torsion
  - Hood closing analysis
    - Stress (inner hood/ rail) ≤ C_steel



	HIC < 650	1.00 point
	650 ≤ HIC < 1000	0.75 points
	1000 ≤ HIC < 1350	0.50 points
	1350 ≤ HIC < 1700	0.25 points
	1700 ≤ HIC	0.00 points

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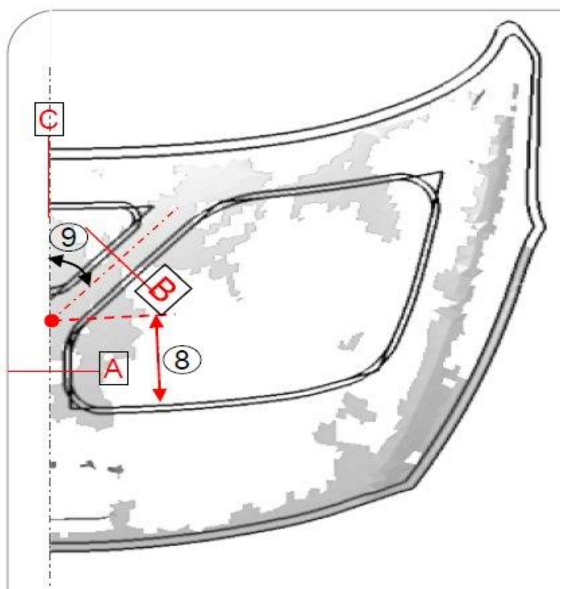
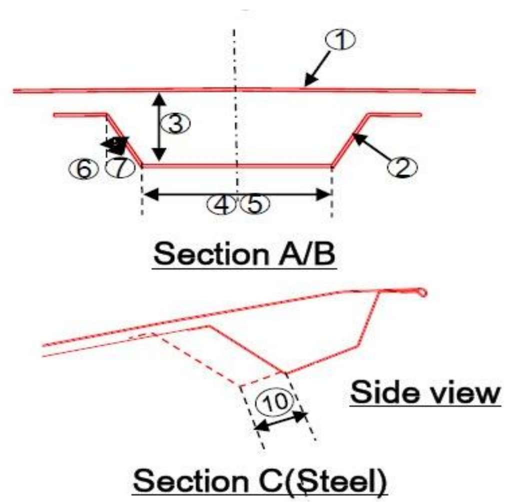
Problem description

- **10 Variables:**
  - Sheet thickness of inner and outer hood → 2 variables
  - Beam depth, width and angle
  - Position of crossing point and angle
  - Rear frame width

→ 8 variables
→ ANSA Morphing Tool

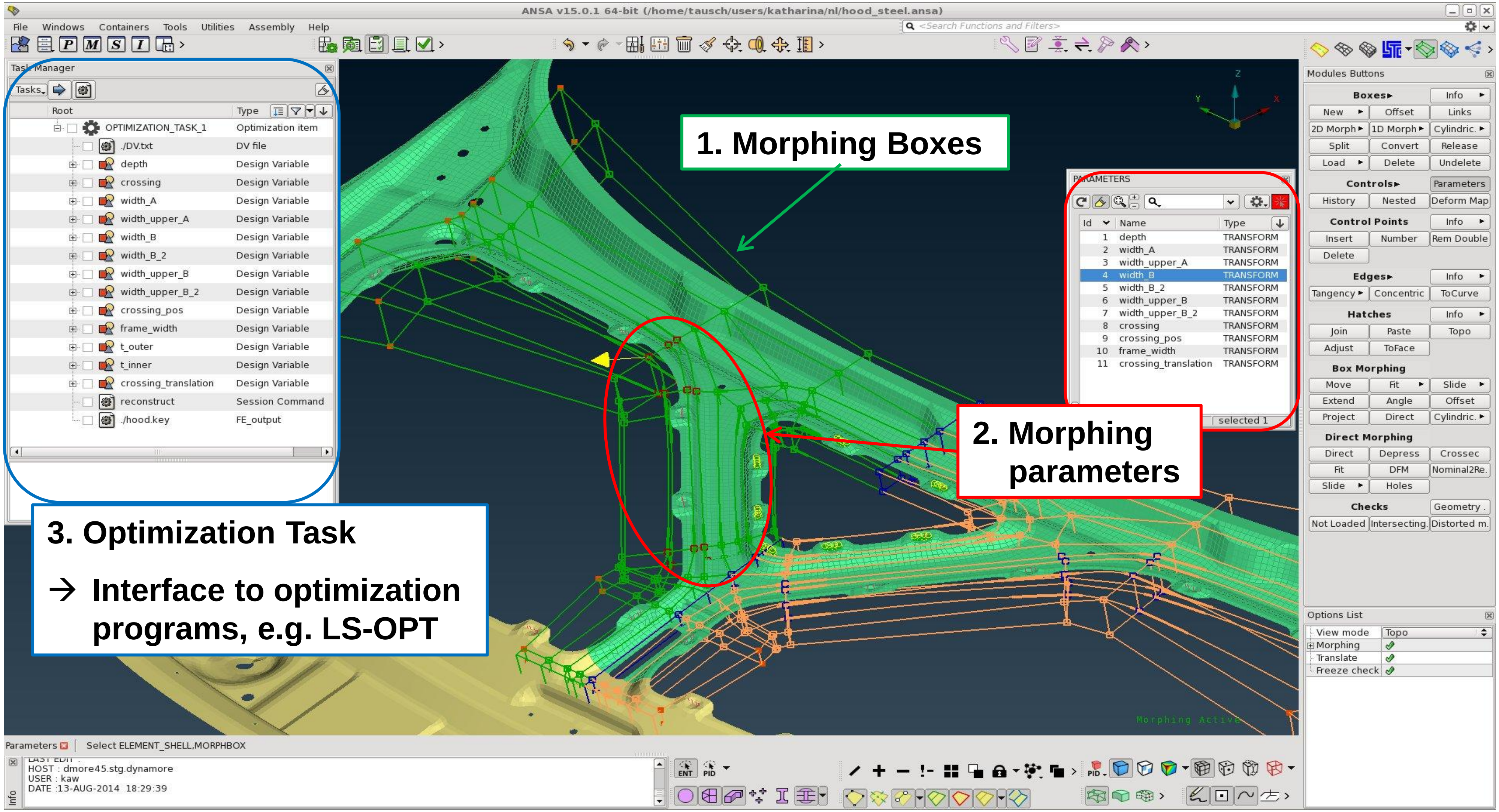


[Steel]



Setup in ANSA

- **Modification of geometry in ANSA using Morph module (steel).**



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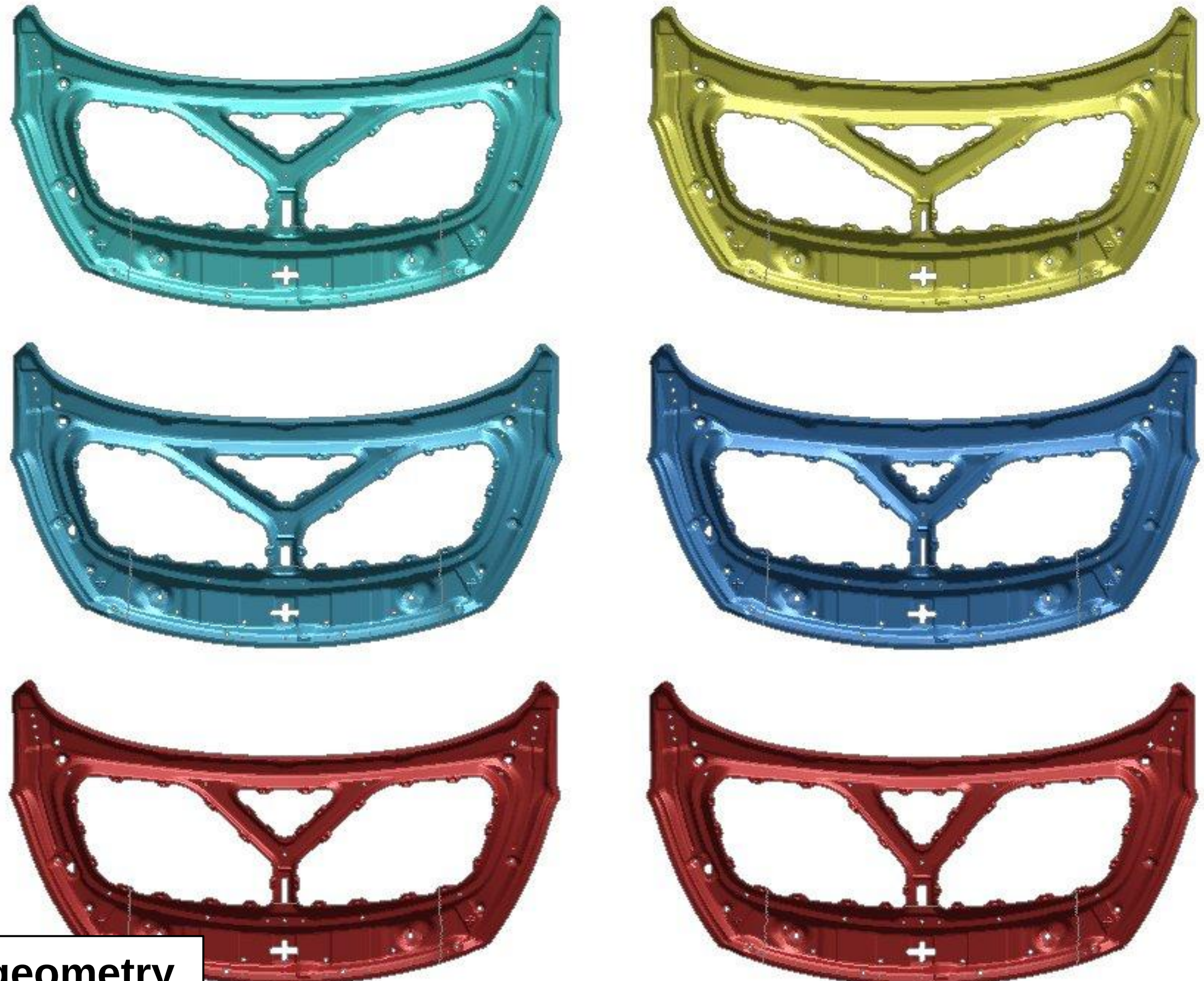
Setup in ANSA

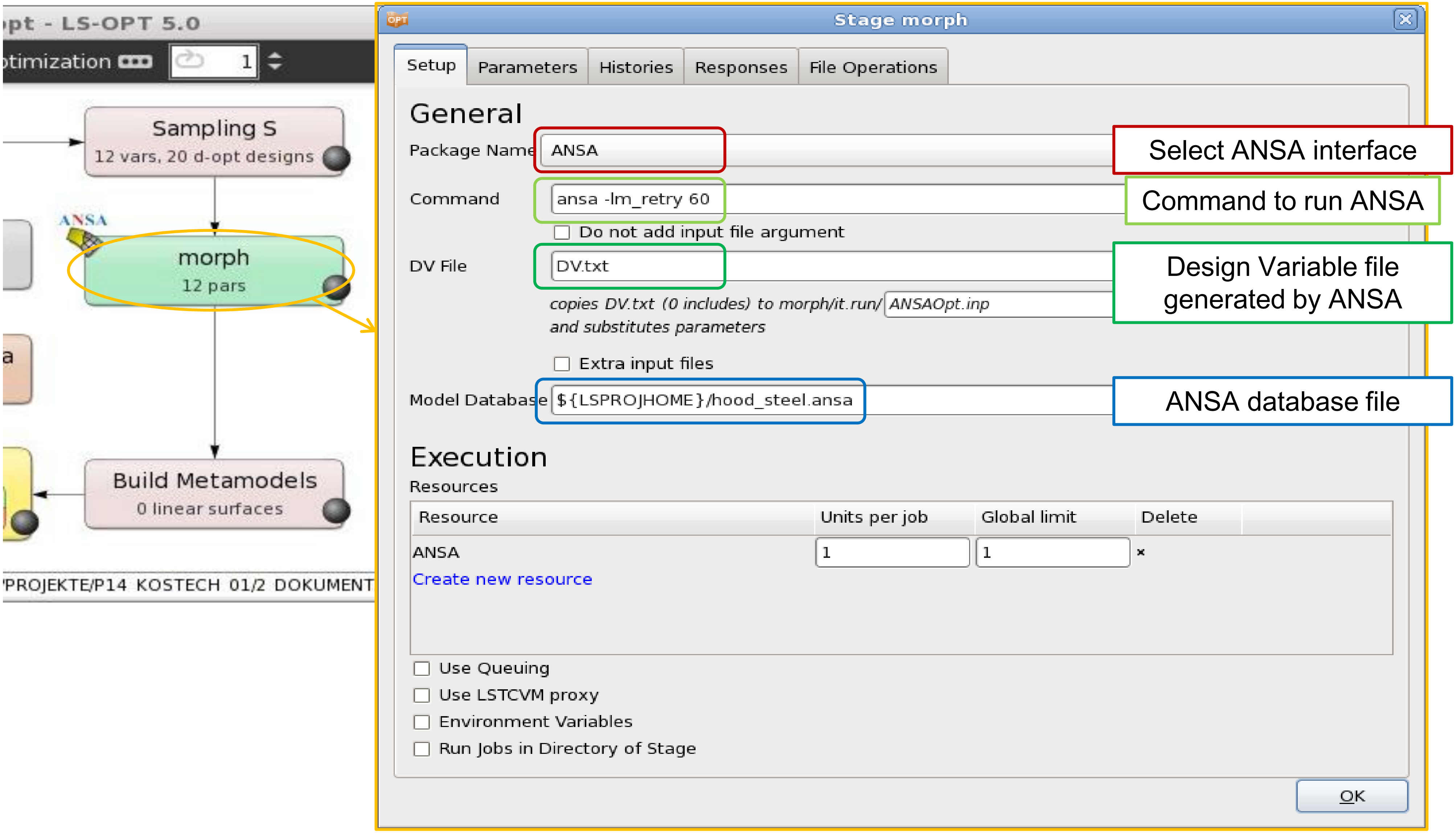
- **Modification of geometry in ANSA using Morph module (steel)**
  - selection of geometries.



Original geometry

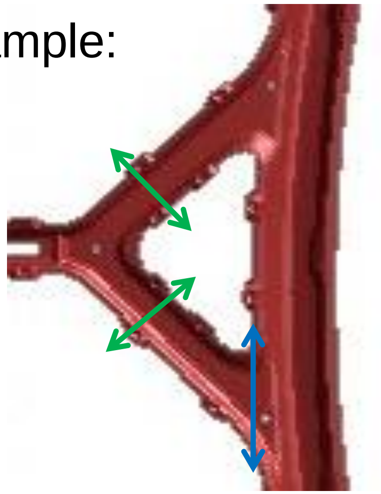
Setup in LS-OPT

- **Interface to ANSA**



Sampling Constraints

- **Avoid incompatible geometries**
- Example:



Beam width = maximal value ✓

Crossing angle = maximal value ✓

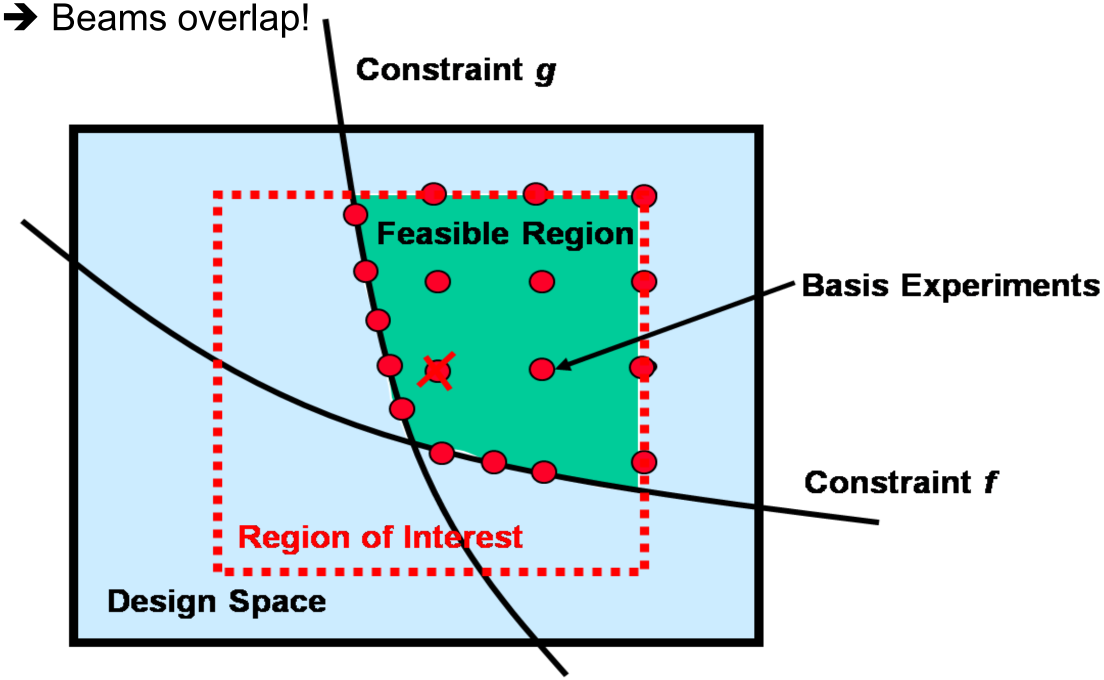
But:

Beam width = maximal value

and

Crossing angle = maximal value

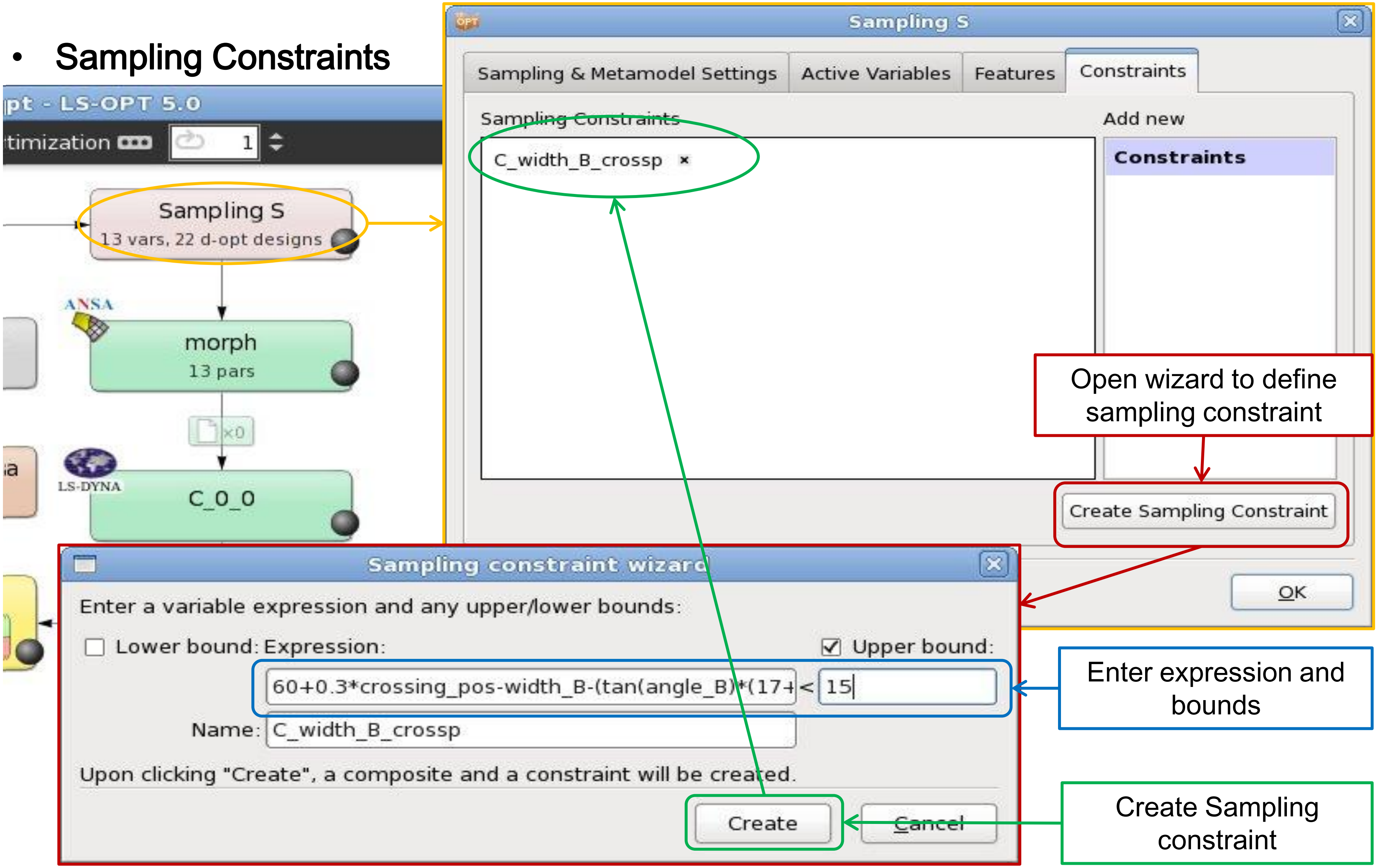
→ Beams overlap!



→ Define Sampling constraints to get a reasonable design space

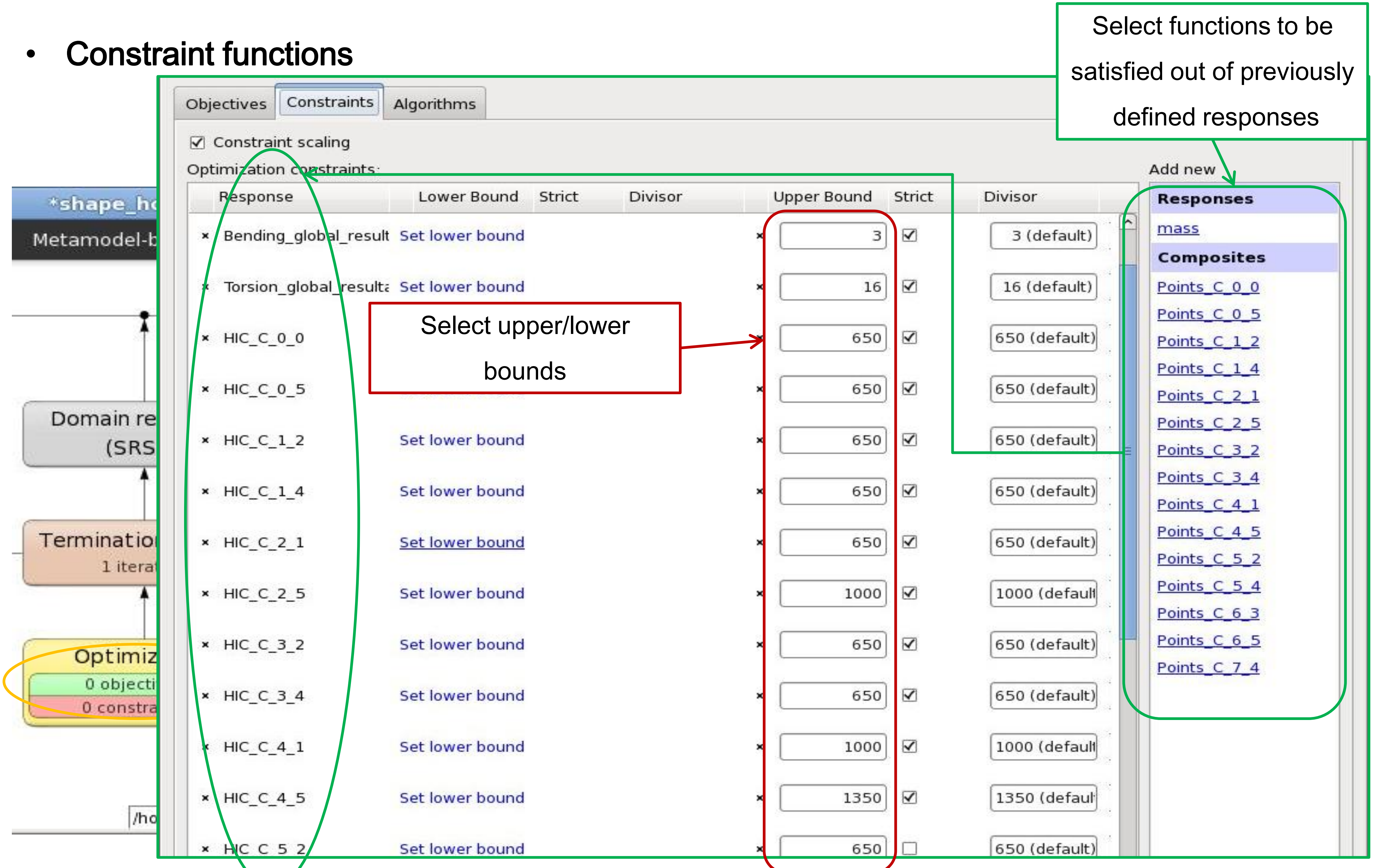
Setup in LS-OPT

- **Sampling Constraints**



Setup in LS-OPT

- **Constraint functions**



Constraints

- **Feasibility of constraints – standard internal formulation in LS-OPT**

$$\textbf{\textit{Phase I:}}$$

$$\text{Min. } e \qquad (\text{max. violation})$$

subject to

$$g_j(\mathbf{x}) \le e \quad ; \quad j = 1,\dots,p$$

$$g_j(\mathbf{x}) \le 0 \quad ; \quad j = p+1,\dots,m$$

$$e \ge 0$$

$$\textbf{\textit{Phase II (if } e = 0, \textit{otherwise stop):}}$$

$$\text{Min. } f(\mathbf{x})$$

subject to

$$g_j(\mathbf{x}) \le 0 \quad ; \quad j = 1,\dots,m$$

Most feasible design

e = Slack variable

Note: e is automatic, internal

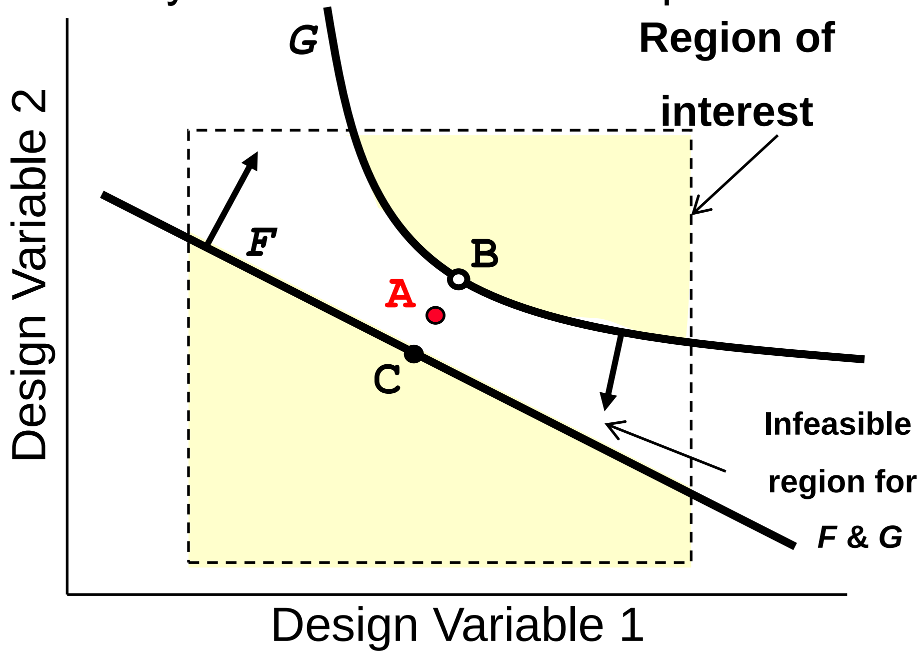
SLACK: Constraint will be compromised, if necessary. (*e* > 0 if feasibility is not possible)

STRICT: Constraint is strictly enforced, unless impossible.

The objective function is ignored if the problem is infeasible

Constraints

- Feasibility of constraints – Example



A: Most feasible design if both constrai nts contain the slack variable, e

B: Most feasible design if constraint G is strict, i.e. it contains no slack variable

C: Most feasible design if constraint F is strict, i.e. it contains no slack variable

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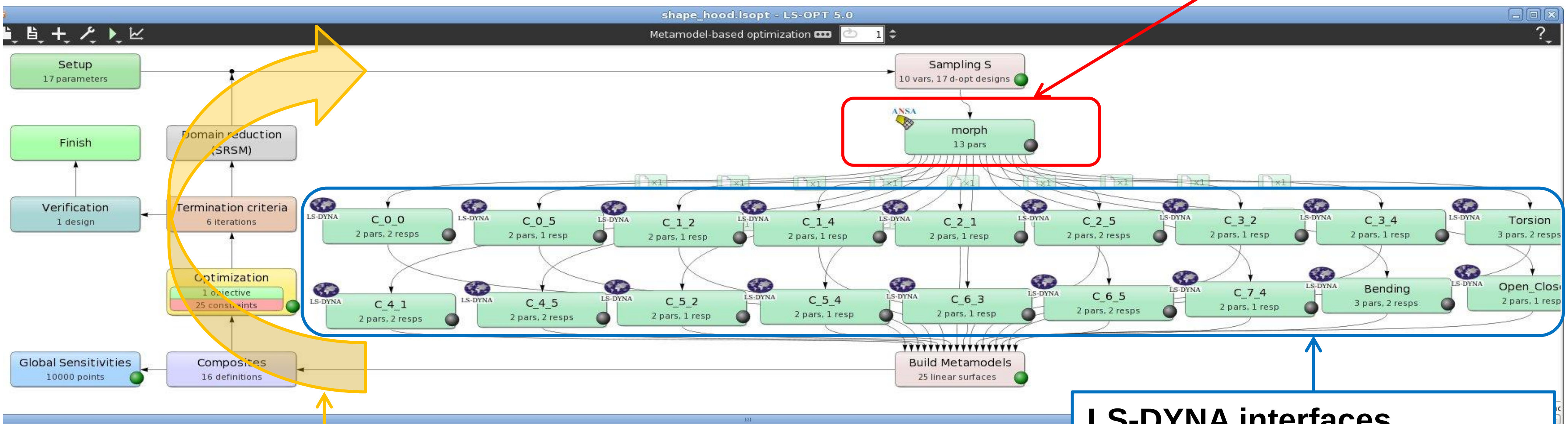
- E.g. G: HIC_1< 650, F: HIC_2< 650
- Possible result if both constraints slack: HIC_1= 705, HIC_2 = 697
- Possible results if F strict: HIC_1 = 753, HIC_2 = 645
  → better for this application!

➔ Define strict constraints for some HIC values that are already close to bound, values for bounds selected depending on initial values.

Setup in LS-OPT

- **LS-OPT main GUI window – final setup.**

ANSA interface



LS-DYNA interfaces

- **15 head impact load cases**
- **Bending**
- **Torsion**
- **Hood closing**

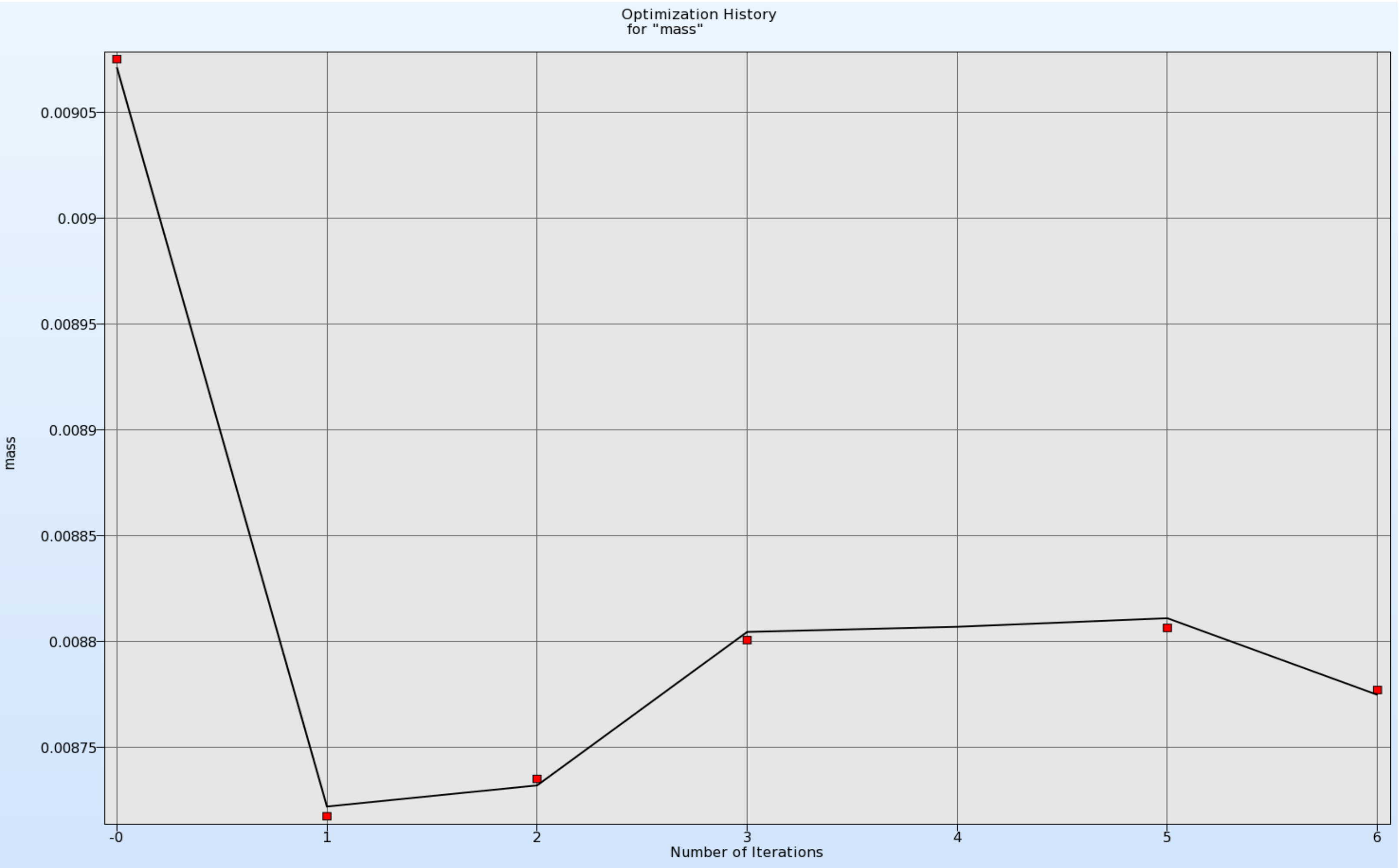
Optimization loop

- 6 iterations

Results - Steel

- **Optimization History – Objective mass.**

Improvement

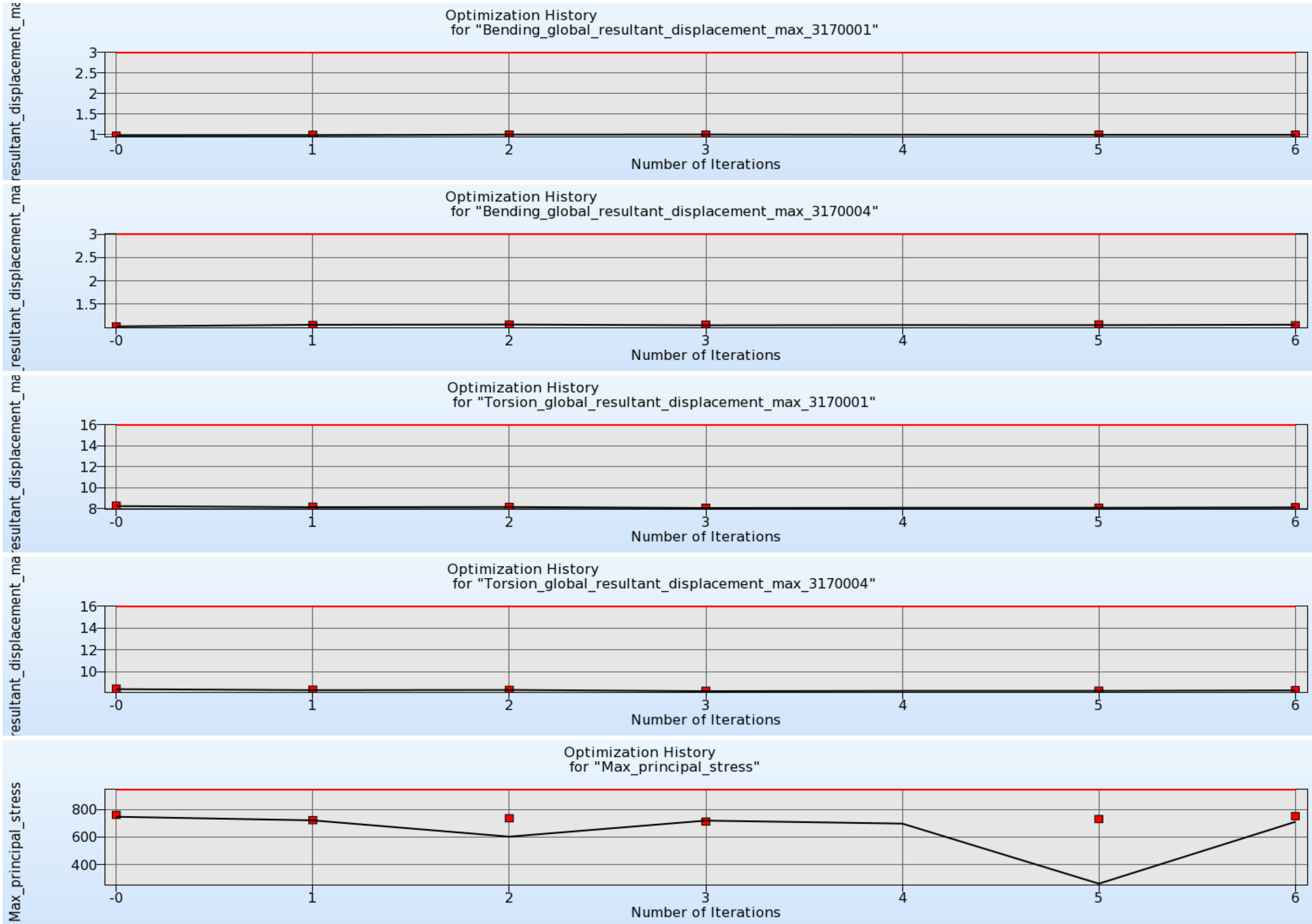


Value of selected entity for optimal point

Iteration

Results - Steel

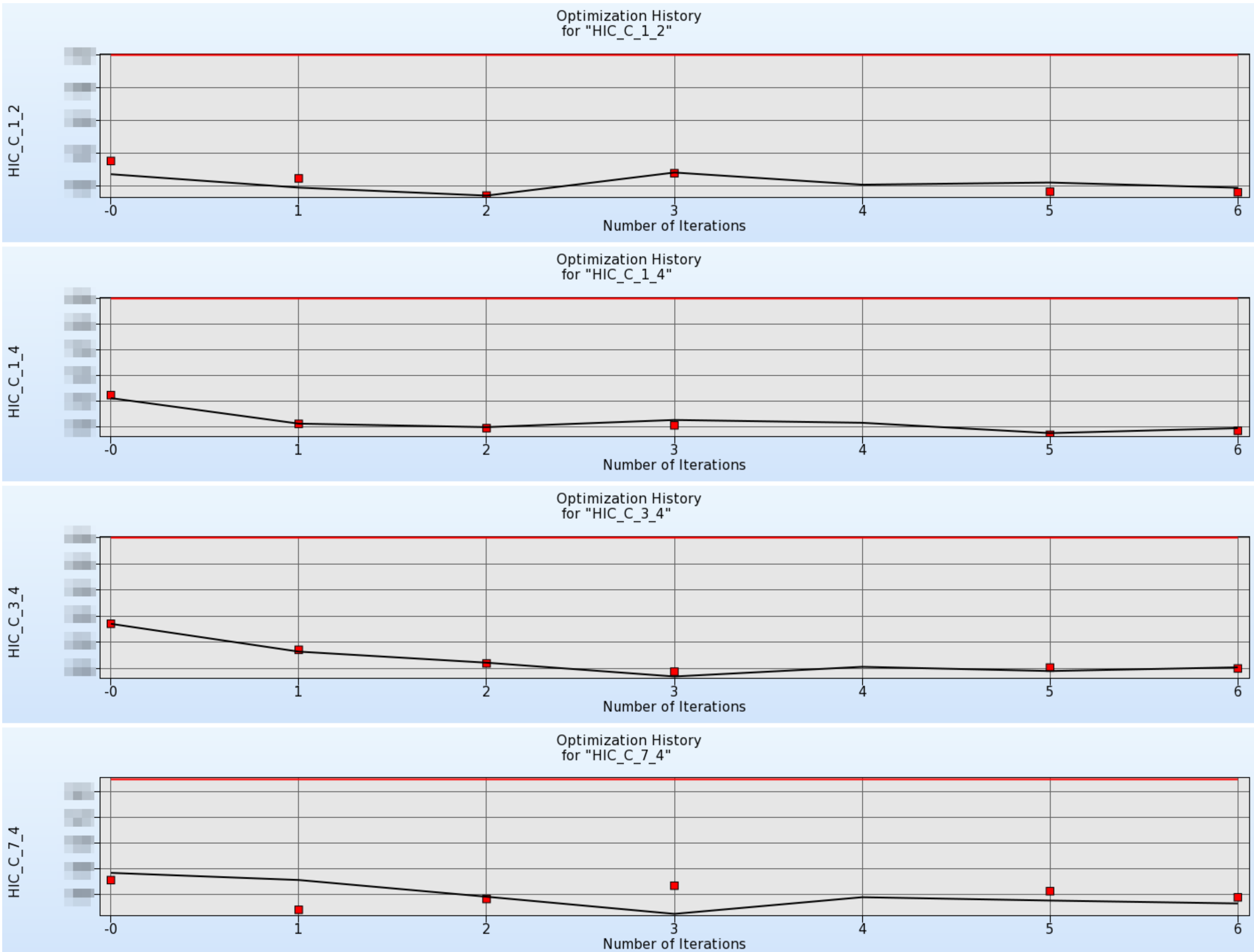
- **Optimization History – Constraints Torsion, Bending, Closing.**



Always feasible

Results - Steel

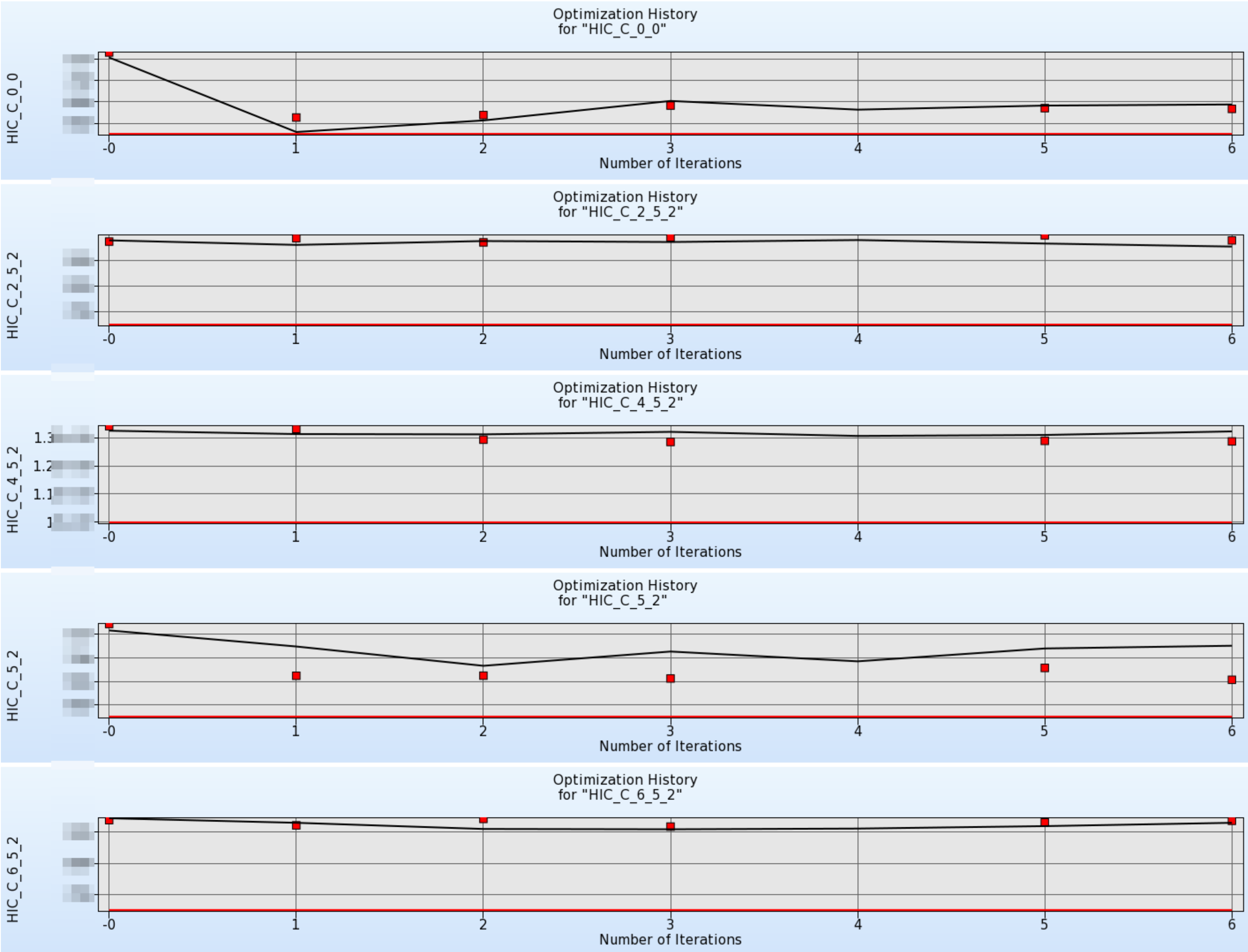
- **Optimization History – Head impact C_1_2, C_1_4, C_3_4, C_7_4.**



Always feasible

Results - Steel

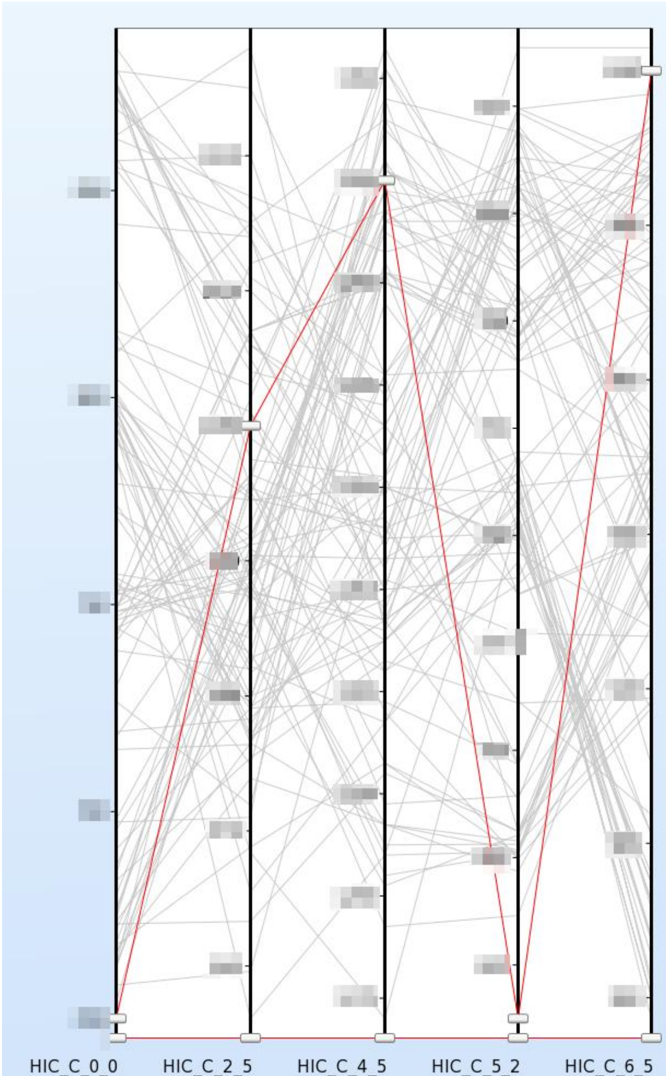
- **Optimization History – Head impact C_0_0, C_2_5, C_4_5, C_5_2, C_6_5.**



Always same interval

Results - Steel

- **Parallel coordinate plot – Head impact C_0_0, C_2_5, C_4_5, C_5_2, C_6_5.**



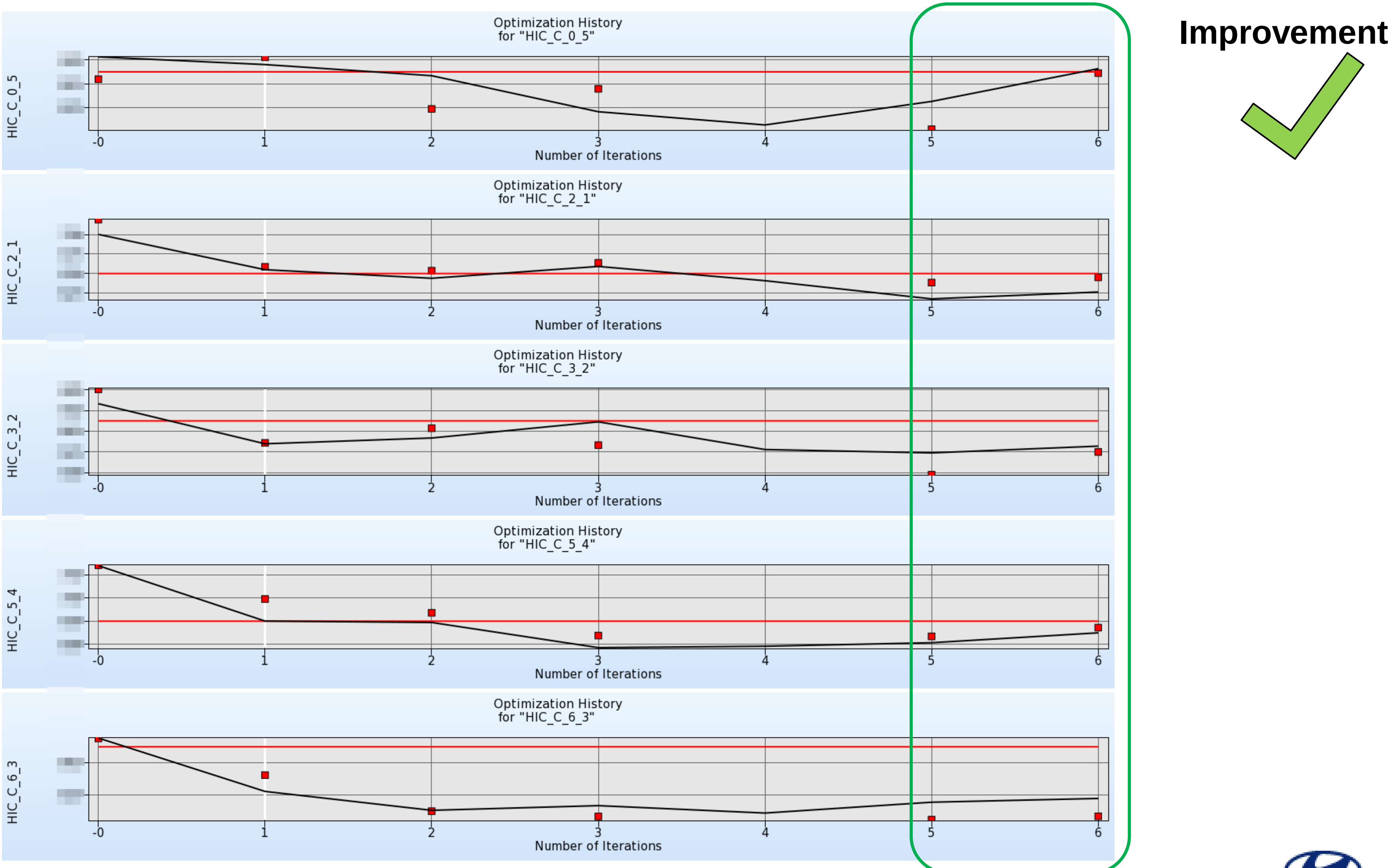
All simulation results:

Some points are even worse, but no better points

→ Probably not possible to improve those values

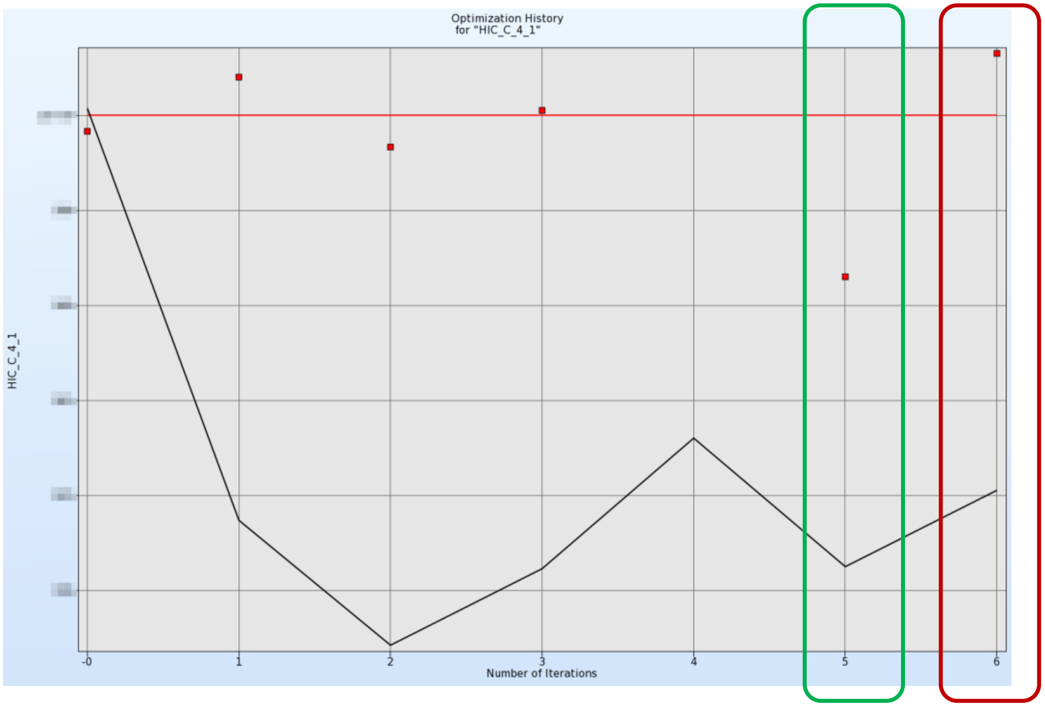
Results - Steel

- **Optimization History - Head impact C_0_5, C_2_1, C_3_2, C_5_4, C_6_3.**



Results - Steel

- **Optimization History – Head impact C_4_1.**



- **Final computed optimal value is infeasible (Optimization is performed on the metamodel, accuracy!).**
- **But optimal value of 5th iteration is feasible.**
- **Optimum of 5th iteration of C_0_5, C_2_1, C_3_2, C_5_4, C_6_3 was also already improved.**

→ Optimum of 5th iteration is final optimal solution.

Results - Steel

- **Optimal Geometry.**

Initial geometry

Interpreted topometry optimization result

Optimal geometry

depth	width A	angle A	width B	angle B	crossing point	crossing angle	rear frame width	Outer hood gauge	Inner hood gauge
-0.55	+5.4	34°	+1.60	36°	+20.0	40°	+30	0.6	0.6

Results - Steel

- **Optimal Result.**

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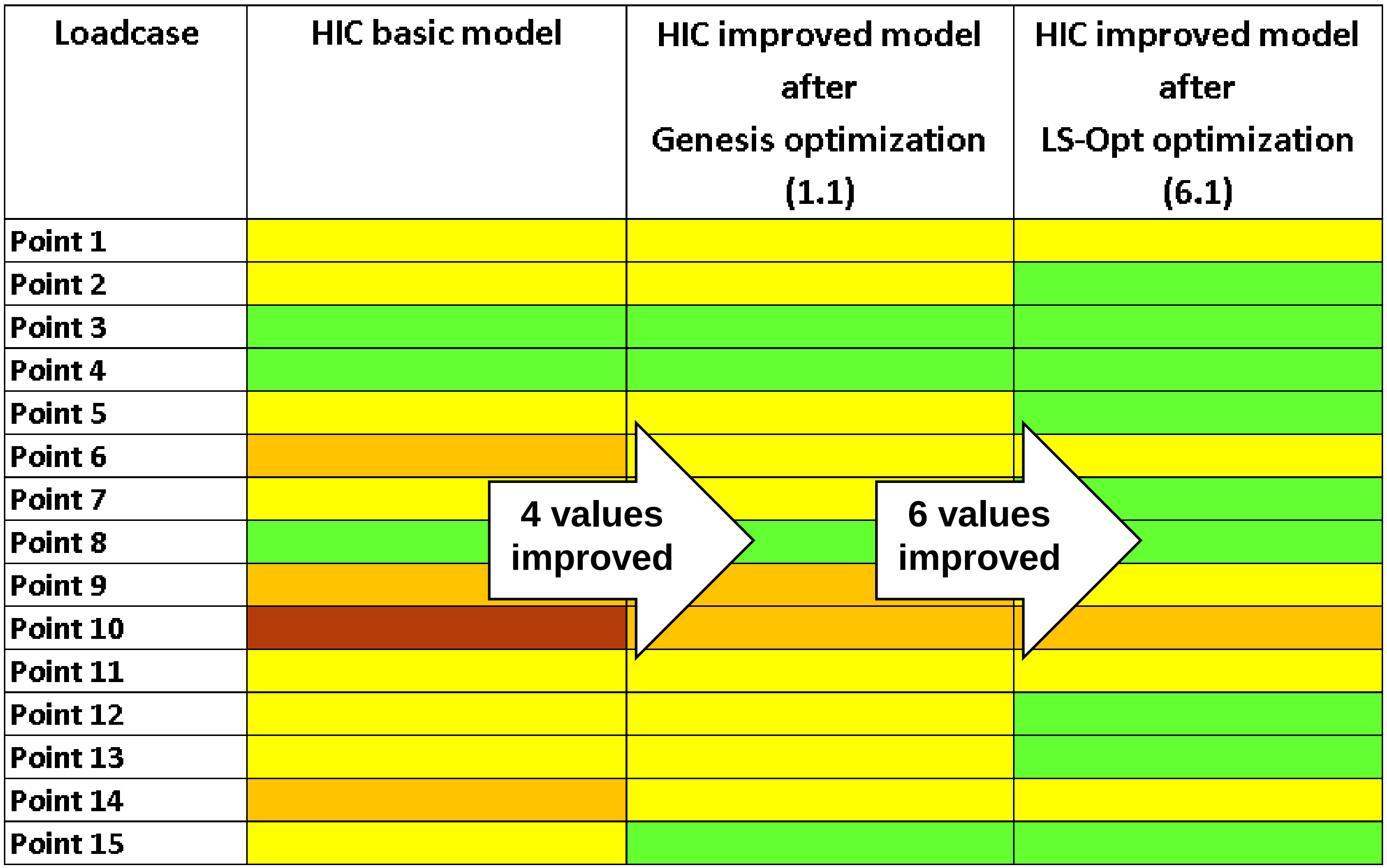
Steel



Summary

- As a first step topometry optimization with ESL was performed in order to get a rough idea of the shape of an improved inner panel structure .
- The interpretation of the result of the topometry optimization was a design with improved HIC values for four load cases for the steel hood
- In a next step nonlinear parameter optimization with LS-OPT and ANSA was performed on the basis of the preliminary CAD design to refine functional requirements.
- The mass as well as six HIC values could be further improved.
- In total, 10 HIC values could be improved for the steel hood.

Thank you for your attention!