

# Shape Optimization of a Hood

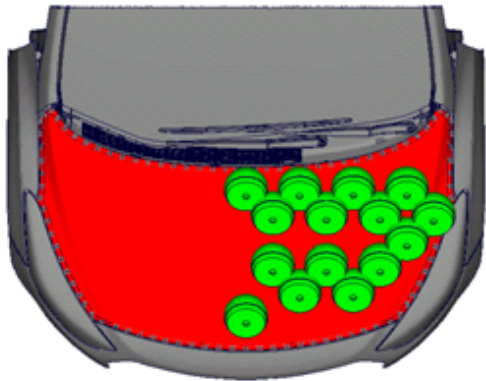


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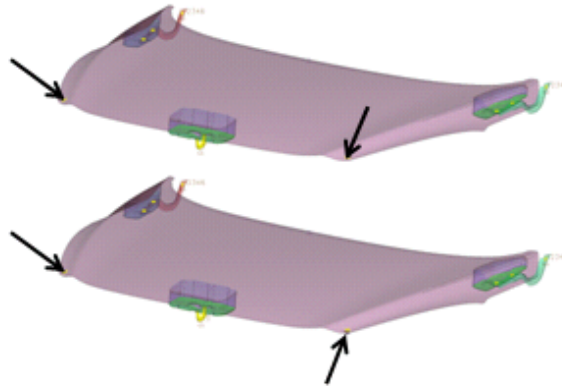
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# Motivation and overview

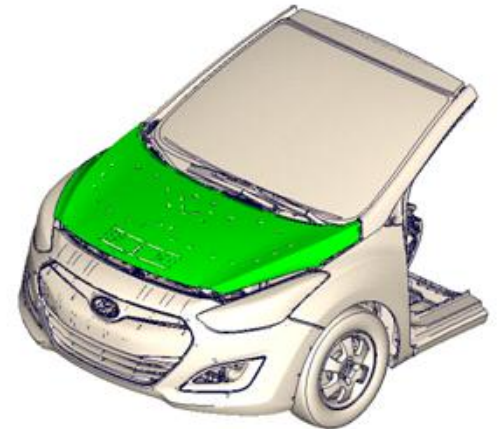
- Geometry of the hood panel is significant regarding the pedestrian safety regulations.
- Main load cases are
  - head impact (pedestrian safety),
  - fatigue and
  - stiffness.



Topometry and Shape Optimization



Topometry and Shape Optimization

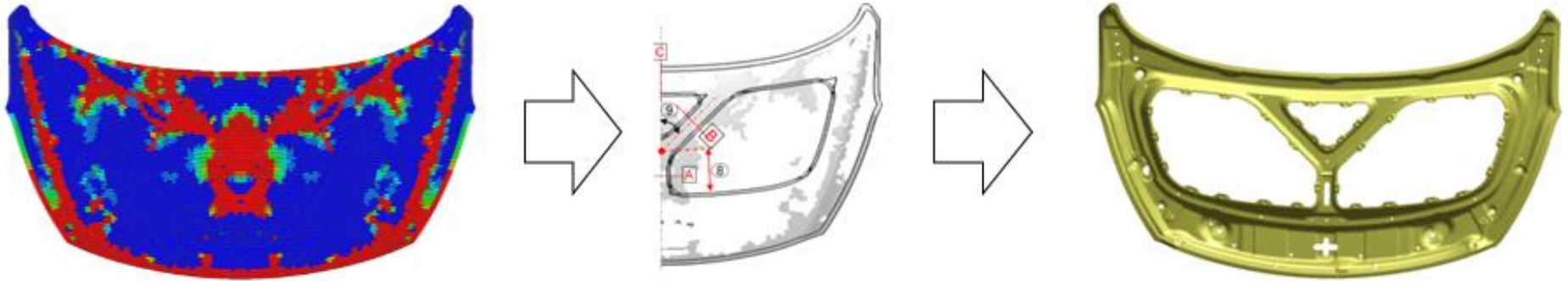


Only Shape Optimization

# Topometry optimization with GENESIS/ESL

# Results steel hood

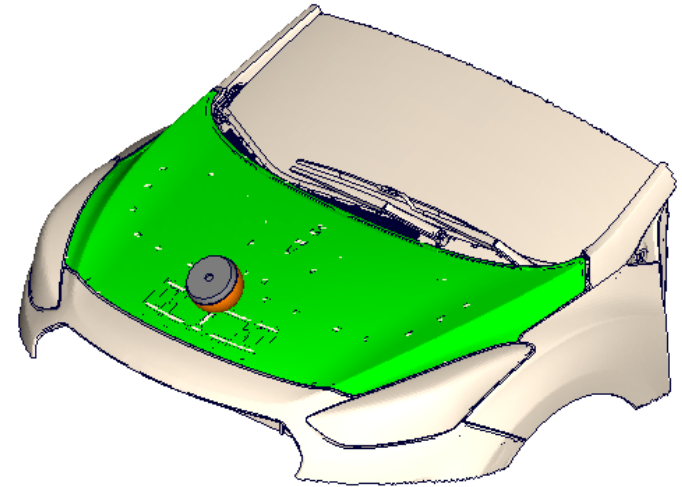
- Shell thickness distribution and following interpretation of CAD-design of the inner hood.



# 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  $\geq$  HIC total score of basic design  
→ HIC improved design  $\leq$  HIC basic design
  - Displacement of load case bending  $\leq C_{\text{bending}}$
  - Displacement of load case torsion  $\leq C_{\text{torsion}}$
  - Hood closing analysis
    - Stress (inner hood/ rail)  $\leq C_{\text{steel}}$



	HIC < 650	1.00 point
	650 $\leq$ HIC < 1000	0.75 points
	1000 $\leq$ HIC < 1350	0.50 points
	1350 $\leq$ HIC < 1700	0.25 points
	1700 $\leq$ HIC	0.00 points

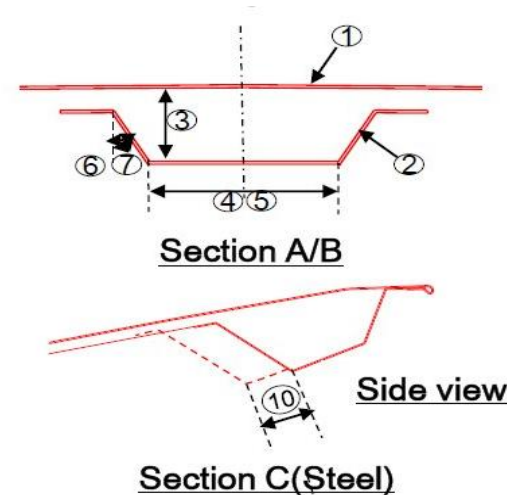
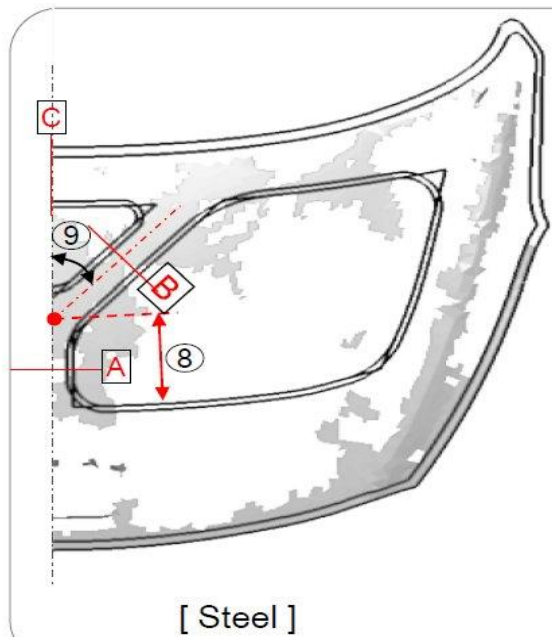
# Problem description

- **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





# Setup in ANSA

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

The screenshot displays the ANSA v15.0.1 64-bit software interface. The main window shows a 3D model of a steel hood with a green mesh overlay. Three callout boxes provide key information:

- 1. Morphing Boxes:** A green box with an arrow pointing to a specific region of the hood's mesh.
- 2. Morphing parameters:** A red box with an arrow pointing to a table of parameters in the 'PARAMETERS' panel.
- 3. Optimization Task:** A blue box with an arrow pointing to the 'Task Manager' panel, which lists various design variables and optimization tasks.

The 'PARAMETERS' panel contains the following table:

Id	Name	Type
1	depth	TRANSFORM
2	width_A	TRANSFORM
3	width_upper_A	TRANSFORM
4	width_B	TRANSFORM
5	width_B_2	TRANSFORM
6	width_upper_B	TRANSFORM
7	width_upper_B_2	TRANSFORM
8	crossing	TRANSFORM
9	crossing_pos	TRANSFORM
10	frame_width	TRANSFORM
11	crossing_translation	TRANSFORM

The 'Task Manager' panel shows a list of tasks and variables:

Task	Type
OPTIMIZATION_TASK_1	Optimization item
/DV.txt	DV file
depth	Design Variable
crossing	Design Variable
width_A	Design Variable
width_upper_A	Design Variable
width_B	Design Variable
width_B_2	Design Variable
width_upper_B	Design Variable
width_upper_B_2	Design Variable
crossing_pos	Design Variable
frame_width	Design Variable
t_outer	Design Variable
t_inner	Design Variable
crossing_translation	Design Variable
reconstruct	Session Command
/hood.key	FE_output

The 'Modules Buttons' panel on the right includes sections for 'Boxes', 'Controls', 'Control Points', 'Edges', 'Hatches', 'Box Morphing', 'Direct Morphing', 'Checks', and 'Options List'. The 'Options List' shows 'Morphing' checked.

# Setup in ANSA

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



Original geometry

# Setup in LS-OPT

- Interface to ANSA

The image shows the LS-OPT 5.0 interface with a workflow diagram on the left and a configuration window on the right. The workflow includes 'Sampling S' (12 vars, 20 d-opt designs), 'morph' (12 pars), and 'Build Metamodels' (0 linear surfaces). The 'morph' stage is highlighted with a yellow oval and an arrow pointing to the 'Stage morph' window.

The 'Stage morph' window has the following configuration:

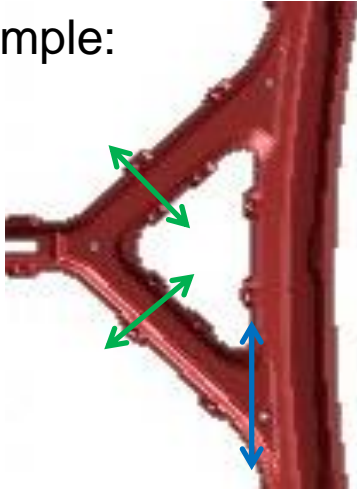
- General**
  - Package Name: ANSA (Red box) **Select ANSA interface**
  - Command: ansa -lm\_retry 60 (Green box) **Command to run ANSA**
  - Do not add input file argument
  - DV File: DV.txt (Green box) **Design Variable file generated by ANSA**
  - copies DV.txt (0 includes) to morph/it.run/ ANSAOpt.inp and substitutes parameters*
  - Extra input files
  - Model Database: \${LSPROJHOME}/hood\_steel.ansa (Blue box) **ANSA database file**
- Execution**
  - Resources
    - Resource: ANSA
    - Units per job: 1
    - Global limit: 1 x
    - [Create new resource](#)
  - Use Queuing
  - Use LSTCVM proxy
  - Environment Variables
  - Run jobs in Directory of Stage

OK

# Sampling Constraints

- Avoid incompatible geometries

- Example:



Beam width = maximal value



Crossing angle = maximal value



But:

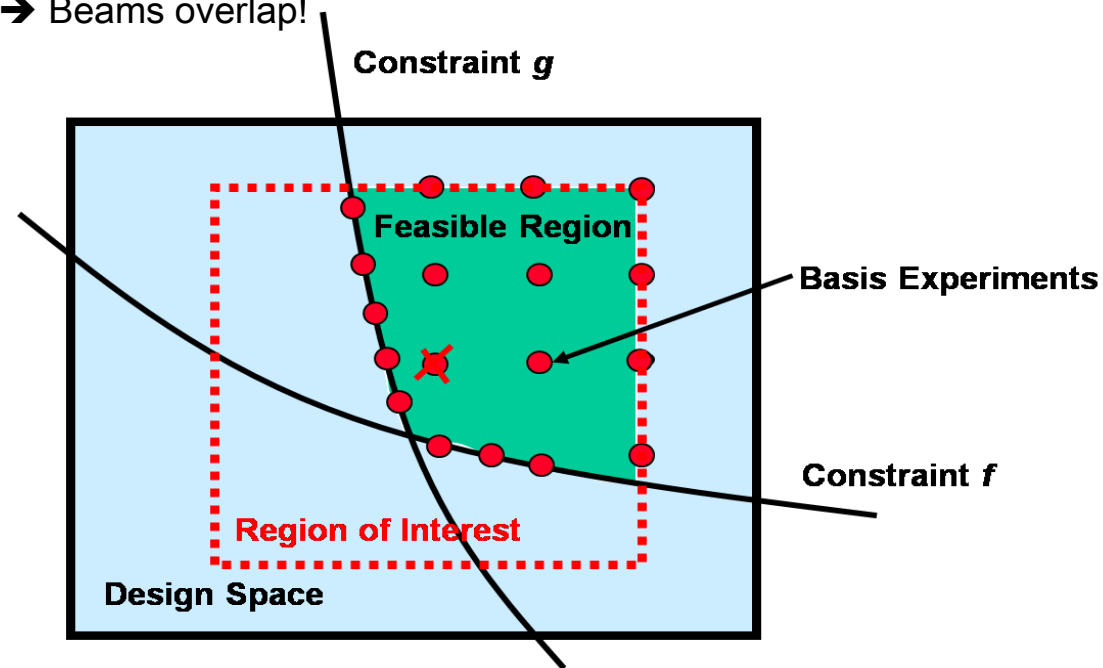
Beam width = maximal value

and

Crossing angle = maximal value

→ Beams overlap!

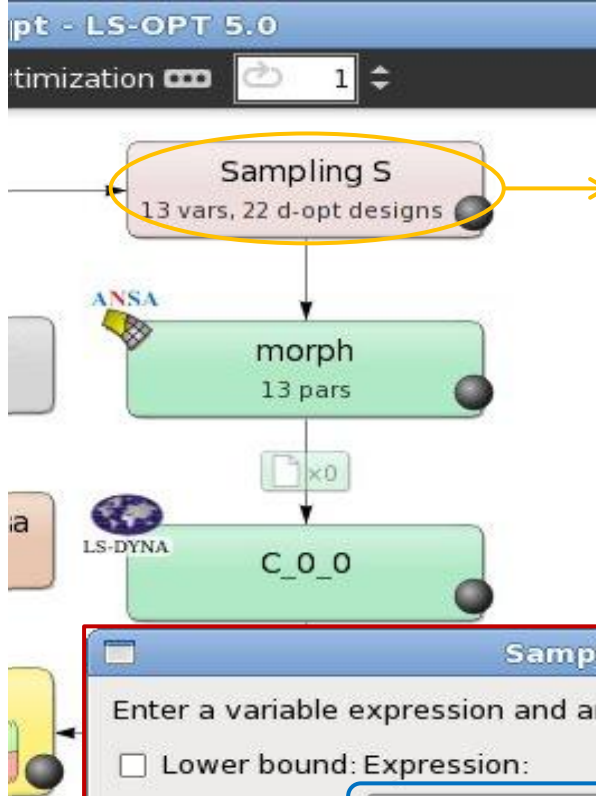
→ Define Sampling constraints to get a reasonable design space





# Setup in LS-OPT

- Sampling Constraints



The 'Sampling S' wizard window is shown with the 'Constraints' tab selected. The 'Sampling Constraints' list contains one entry: 'C\_width\_B\_crossp \*'. A red box highlights the 'Add new' section with the text 'Open wizard to define sampling constraint'. Below it, a red box highlights the 'Create Sampling Constraint' button with the text 'Create Sampling Constraint'.

The 'Sampling constraint wizard' dialog box is shown. It prompts the user to 'Enter a variable expression and any upper/lower bounds:'. The 'Lower bound' checkbox is unchecked, and the 'Upper bound' checkbox is checked. The expression entered is  $60+0.3*\text{crossing\_pos}-\text{width\_B}-(\tan(\text{angle\_B}))*(17+)$  and the upper bound is  $15$ . The name of the constraint is 'C\_width\_B\_crossp'. A green box highlights the 'Create' button with the text 'Create Sampling constraint'.

Enter expression and bounds

Create Sampling constraint

# Setup in LS-OPT

- Constraint functions

Objectives Constraints Algorithms

Constraint scaling

Optimization constraints:

Response	Lower Bound	Strict	Divisor	Upper Bound	Strict	Divisor
× Bending_global_result	Set lower bound	<input checked="" type="checkbox"/>	3 (default)	<input type="text" value="3"/>	<input checked="" type="checkbox"/>	3 (default)
× Torsion_global_result	Set lower bound	<input checked="" type="checkbox"/>	16 (default)	<input type="text" value="16"/>	<input checked="" type="checkbox"/>	16 (default)
× HIC_C_0_0	Set lower bound	<input checked="" type="checkbox"/>	650 (default)	<input type="text" value="650"/>	<input checked="" type="checkbox"/>	650 (default)
× HIC_C_0_5	Set lower bound	<input checked="" type="checkbox"/>	650 (default)	<input type="text" value="650"/>	<input checked="" type="checkbox"/>	650 (default)
× HIC_C_1_2	Set lower bound	<input checked="" type="checkbox"/>	650 (default)	<input type="text" value="650"/>	<input checked="" type="checkbox"/>	650 (default)
× HIC_C_1_4	Set lower bound	<input checked="" type="checkbox"/>	650 (default)	<input type="text" value="650"/>	<input checked="" type="checkbox"/>	650 (default)
× HIC_C_2_1	Set lower bound	<input checked="" type="checkbox"/>	650 (default)	<input type="text" value="650"/>	<input checked="" type="checkbox"/>	650 (default)
× HIC_C_2_5	Set lower bound	<input checked="" type="checkbox"/>	1000 (default)	<input type="text" value="1000"/>	<input checked="" type="checkbox"/>	1000 (default)
× HIC_C_3_2	Set lower bound	<input checked="" type="checkbox"/>	650 (default)	<input type="text" value="650"/>	<input checked="" type="checkbox"/>	650 (default)
× HIC_C_3_4	Set lower bound	<input checked="" type="checkbox"/>	650 (default)	<input type="text" value="650"/>	<input checked="" type="checkbox"/>	650 (default)
× HIC_C_4_1	Set lower bound	<input checked="" type="checkbox"/>	1000 (default)	<input type="text" value="1000"/>	<input checked="" type="checkbox"/>	1000 (default)
× HIC_C_4_5	Set lower bound	<input checked="" type="checkbox"/>	1350 (default)	<input type="text" value="1350"/>	<input checked="" type="checkbox"/>	1350 (default)
× HIC_C_5_2	Set lower bound	<input type="checkbox"/>	650 (default)	<input type="text" value="650"/>	<input type="checkbox"/>	650 (default)

Add new

**Responses**

- mass
- Composites**
- Points\_C\_0\_0
- Points\_C\_0\_5
- Points\_C\_1\_2
- Points\_C\_1\_4
- Points\_C\_2\_1
- Points\_C\_2\_5
- Points\_C\_3\_2
- Points\_C\_3\_4
- Points\_C\_4\_1
- Points\_C\_4\_5
- Points\_C\_5\_2
- Points\_C\_5\_4
- Points\_C\_6\_3
- Points\_C\_6\_5
- Points\_C\_7\_4

Select upper/lower bounds

Select functions to be satisfied out of previously defined responses

Optimization: 0 objectives, 0 constraints

# Constraints

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

***Phase I :***

Min.  $e$  (max. violation)

subject to

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

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

$$e \geq 0$$

***Phase II (if  $e = 0$ , otherwise stop) :***

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

subject to

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

Most feasible design

$e =$  Slack variable Note:  $e$  is automatic, internal

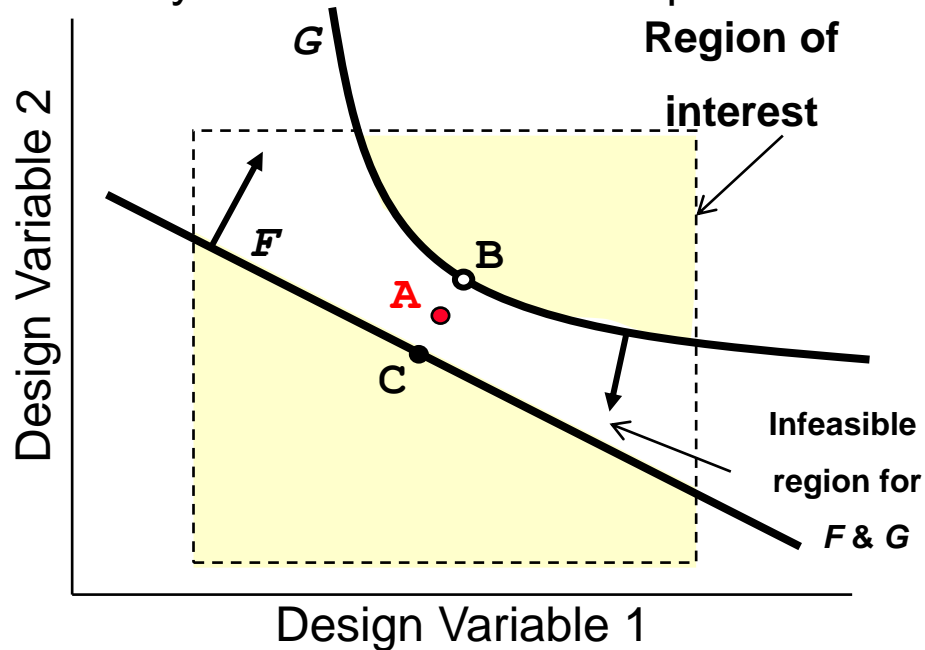
**SLACK:** Constraint will be compromised, if necessary.  
( $e > 0$  if feasibility is not possible)

**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 constraints 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

- 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.

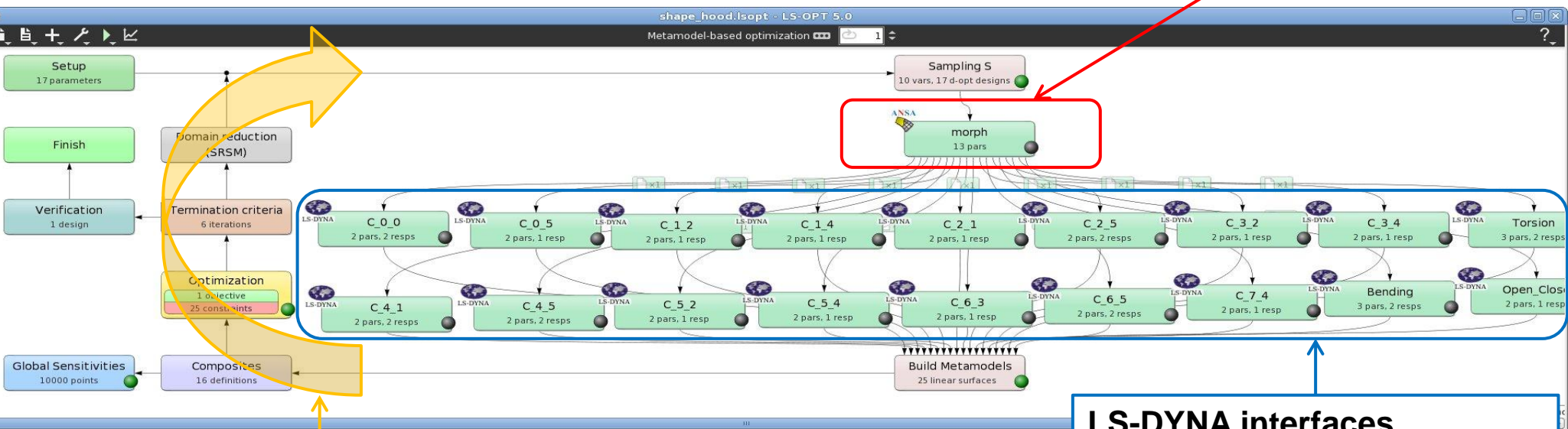
	$HIC < 650$	1.00 point
	$650 \leq HIC < 1000$	0.75 points
	$1000 \leq HIC < 1350$	0.50 points
	$1350 \leq HIC < 1700$	0.25 points
	$1700 \leq HIC$	0.00 points



# Setup in LS-OPT

- LS-OPT main GUI window – final setup.

**ANSA interface**



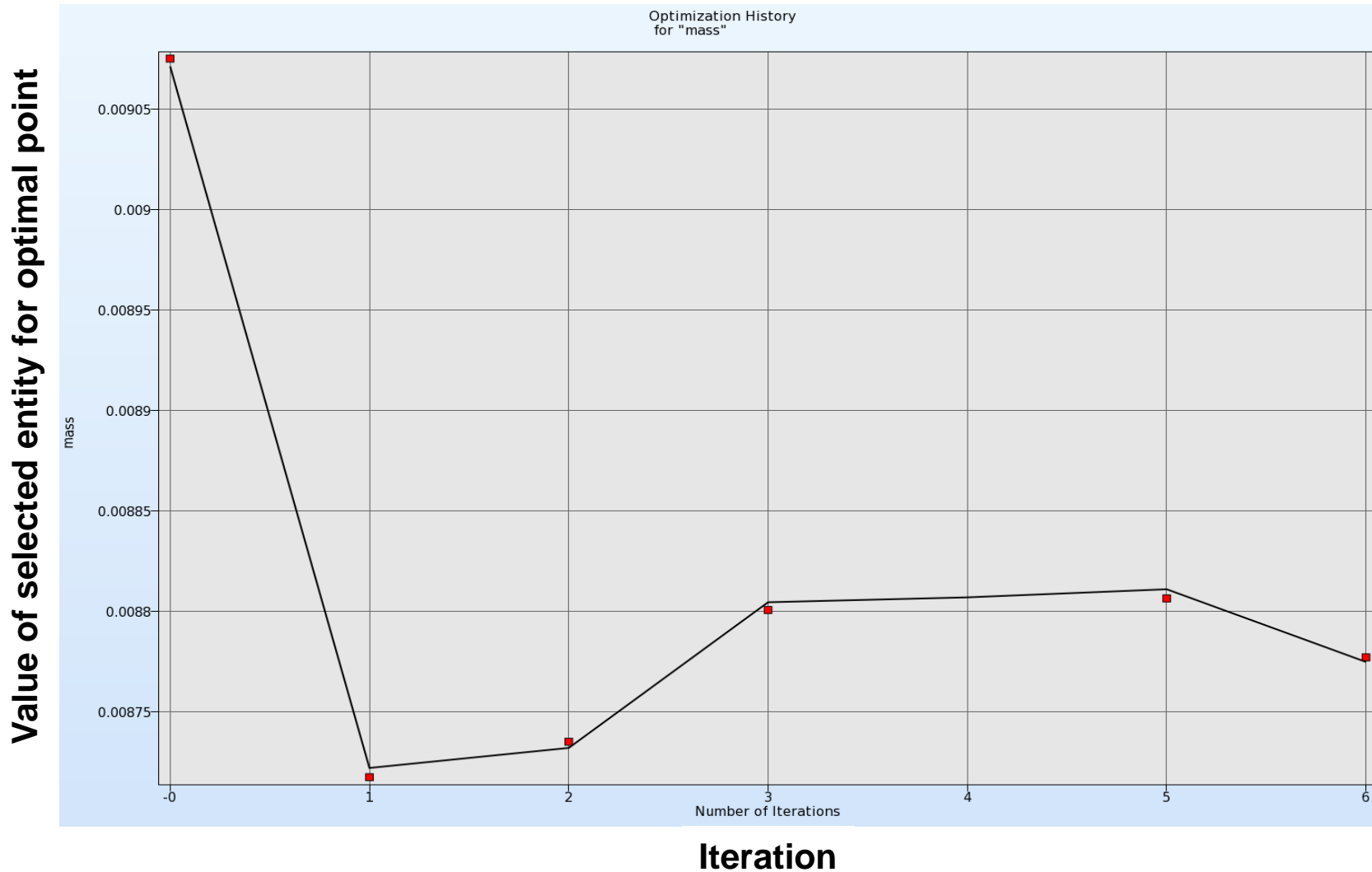
**Optimization loop  
- 6 iterations**

**LS-DYNA interfaces**

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

# Results - Steel

- Optimization History – Objective mass.

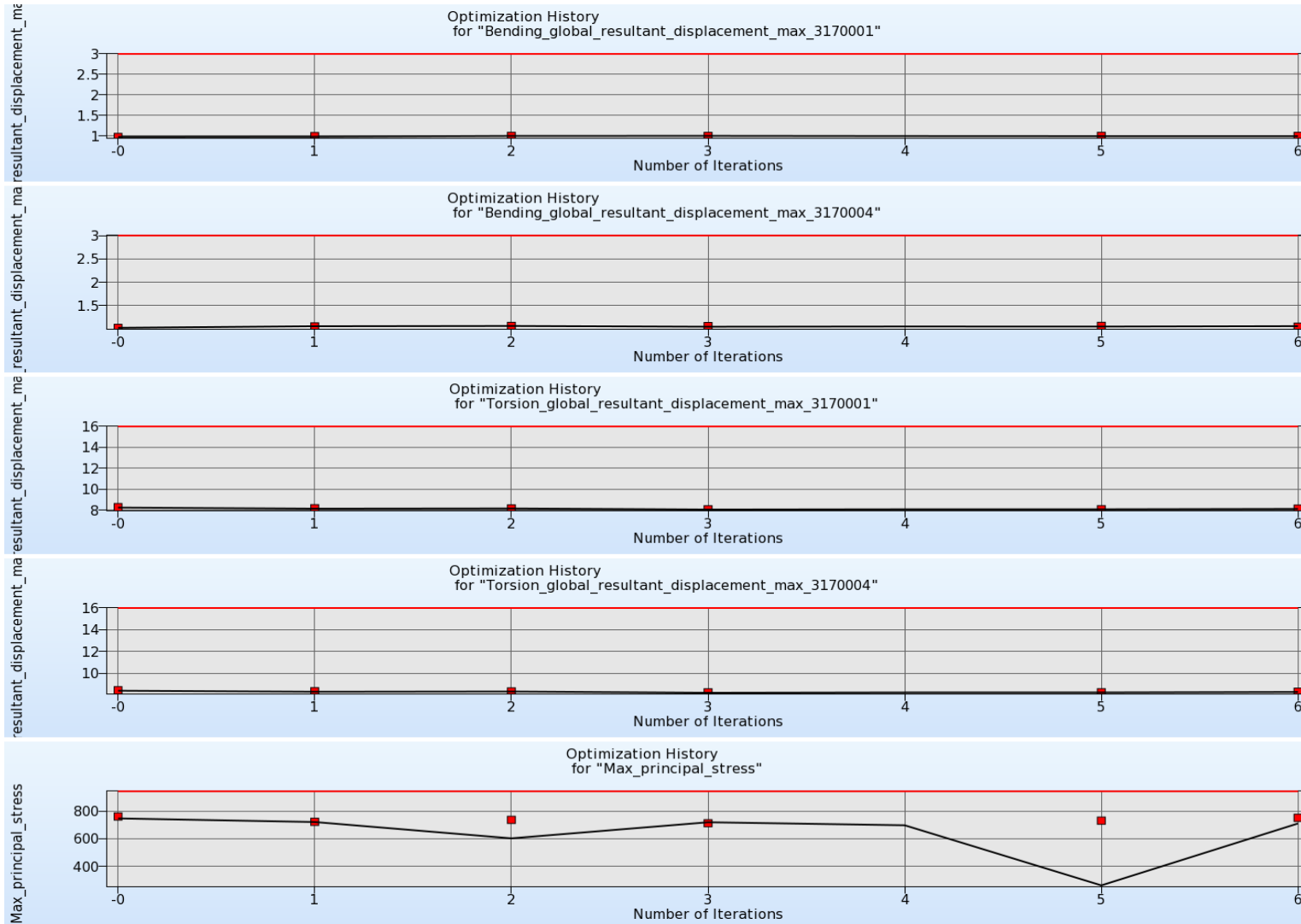


Improvement



# Results - Steel

- Optimization History – Constraints Torsion, Bending, Closing.

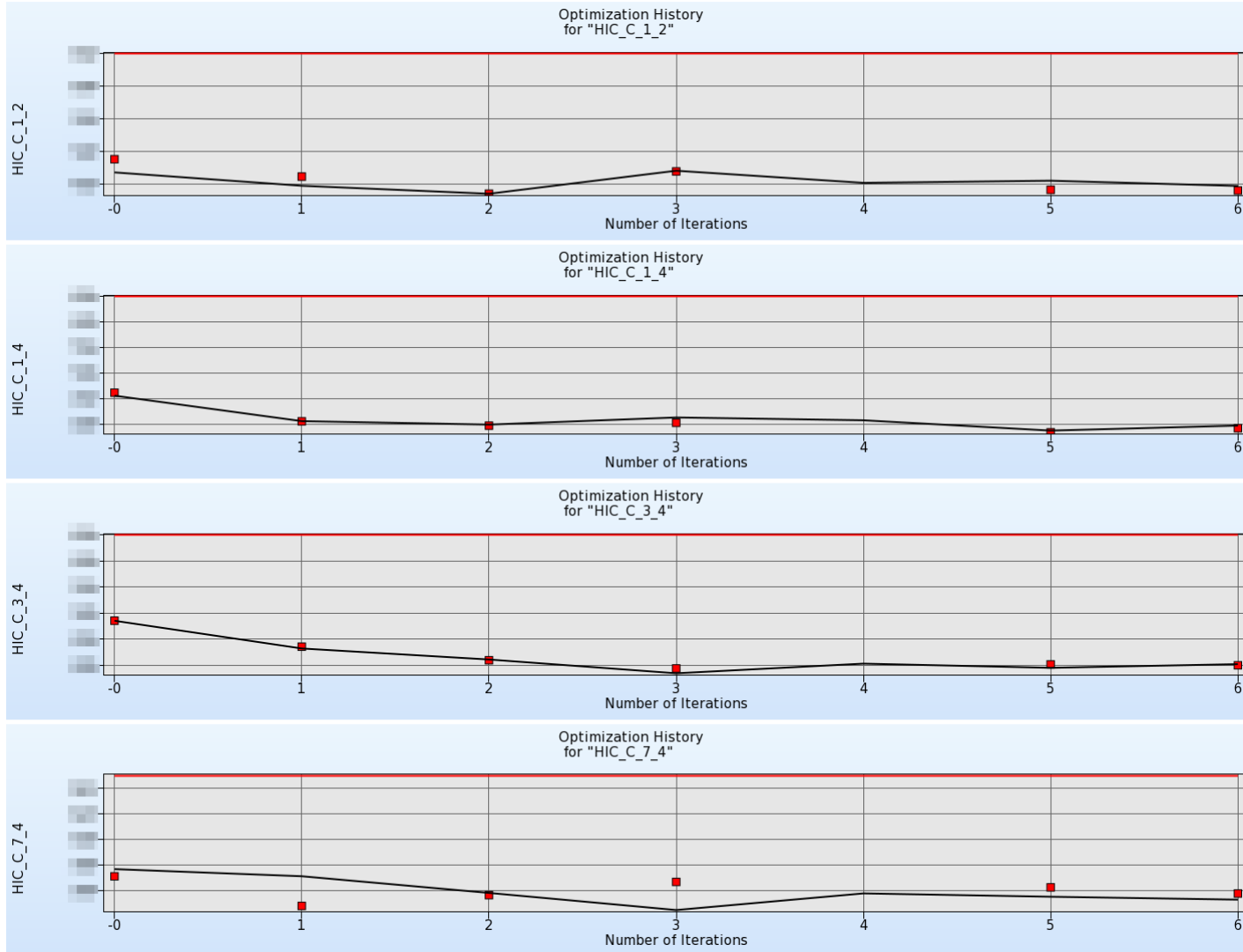


Always feasible



# Results - Steel

- Optimization History – Head impact C\_1\_2, C\_1\_4, C\_3\_4, C\_7\_4.

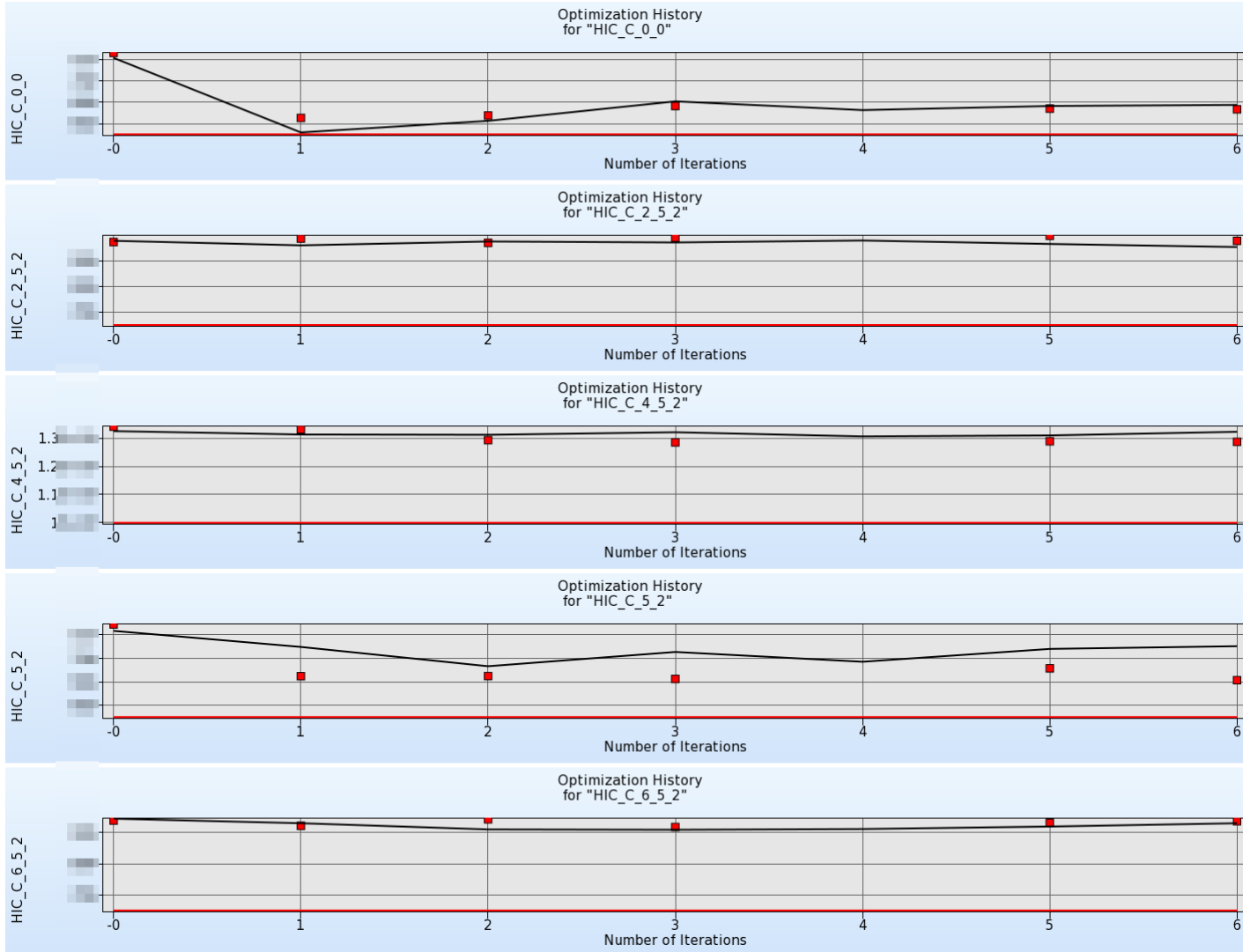


Always feasible



# Results - Steel

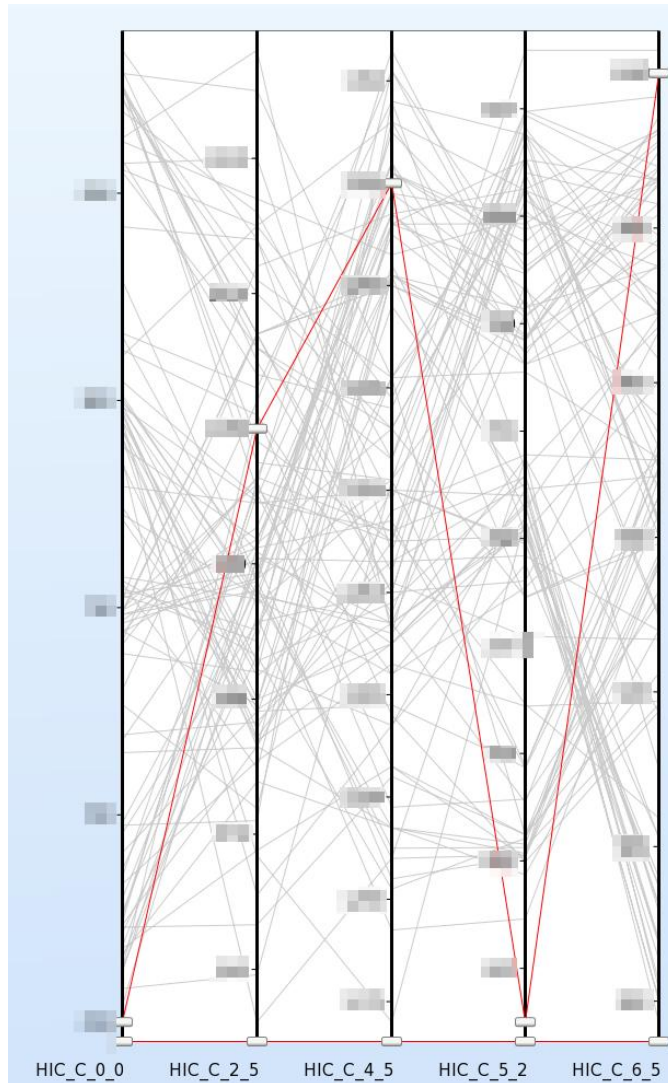
- Optimization History – Head impact C\_0\_0, C\_2\_5, C\_4\_5, C\_5\_2, C\_6\_5.



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.



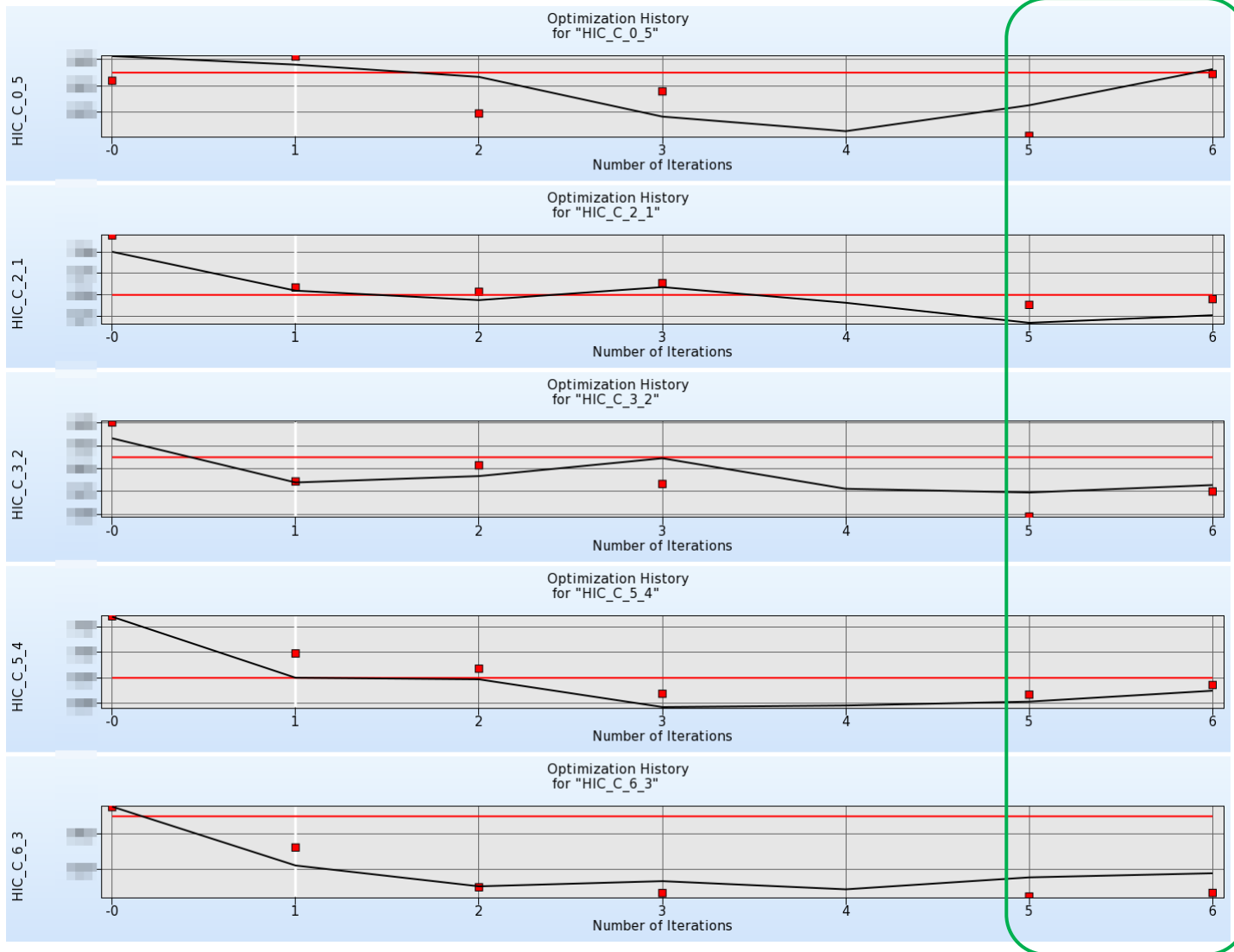
**All simulation results:**

**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.

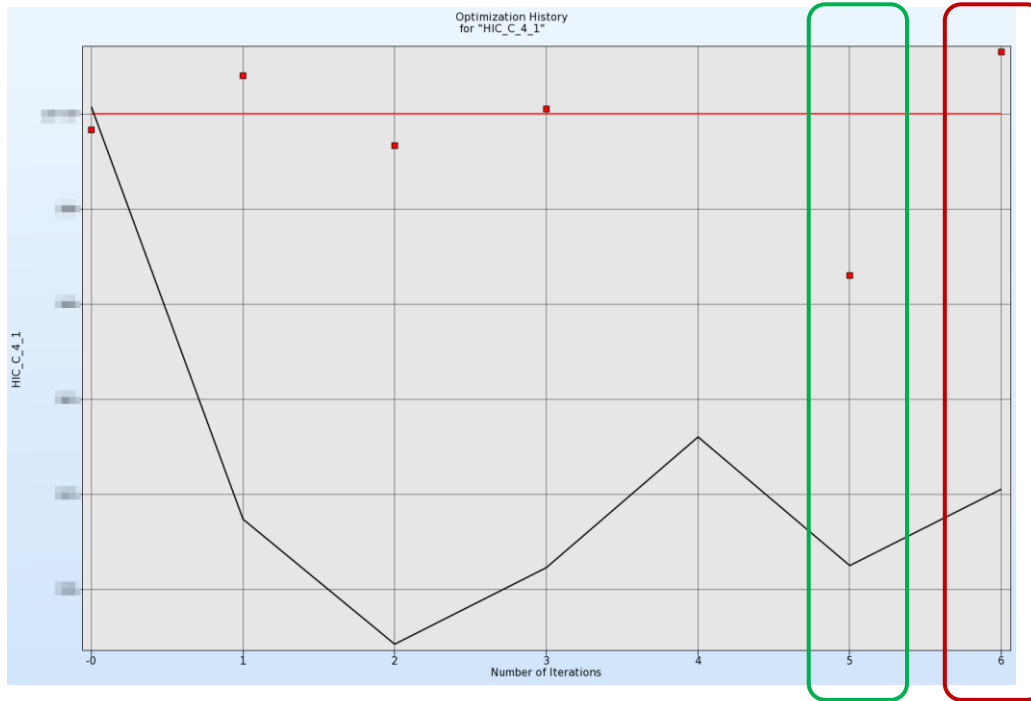


Improvement



# 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 5<sup>th</sup> iteration is feasible.
- Optimum of 5<sup>th</sup> iteration of C\_0\_5, C\_2\_1, C\_3\_2, C\_5\_4, C\_6\_3 was also already improved.

→ Optimum of 5<sup>th</sup> iteration is final optimal solution.



# Results - Steel

- **Optimal Geometry.**



Steel

**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.

	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

## Steel

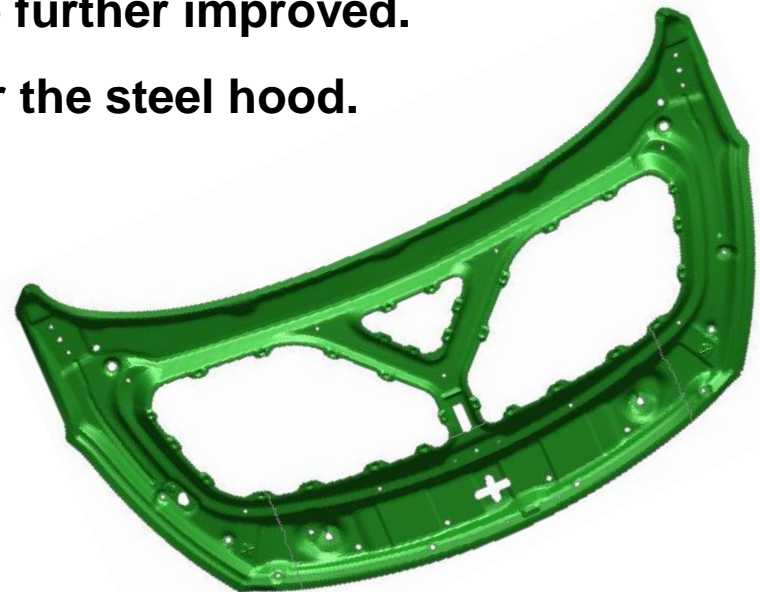
Loadcase	HIC basic model	HIC improved model after Genesis optimization (1.1)	HIC improved model after LS-Opt optimization (6.1)
Point 1			
Point 2			
Point 3			
Point 4			
Point 5			
Point 6			
Point 7			
Point 8			
Point 9			
Point 10			
Point 11			
Point 12			
Point 13			
Point 14			
Point 15			

4 values improved

6 values improved

# 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!**

