Optimizing Car Body Models with GENESIS

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Introduction

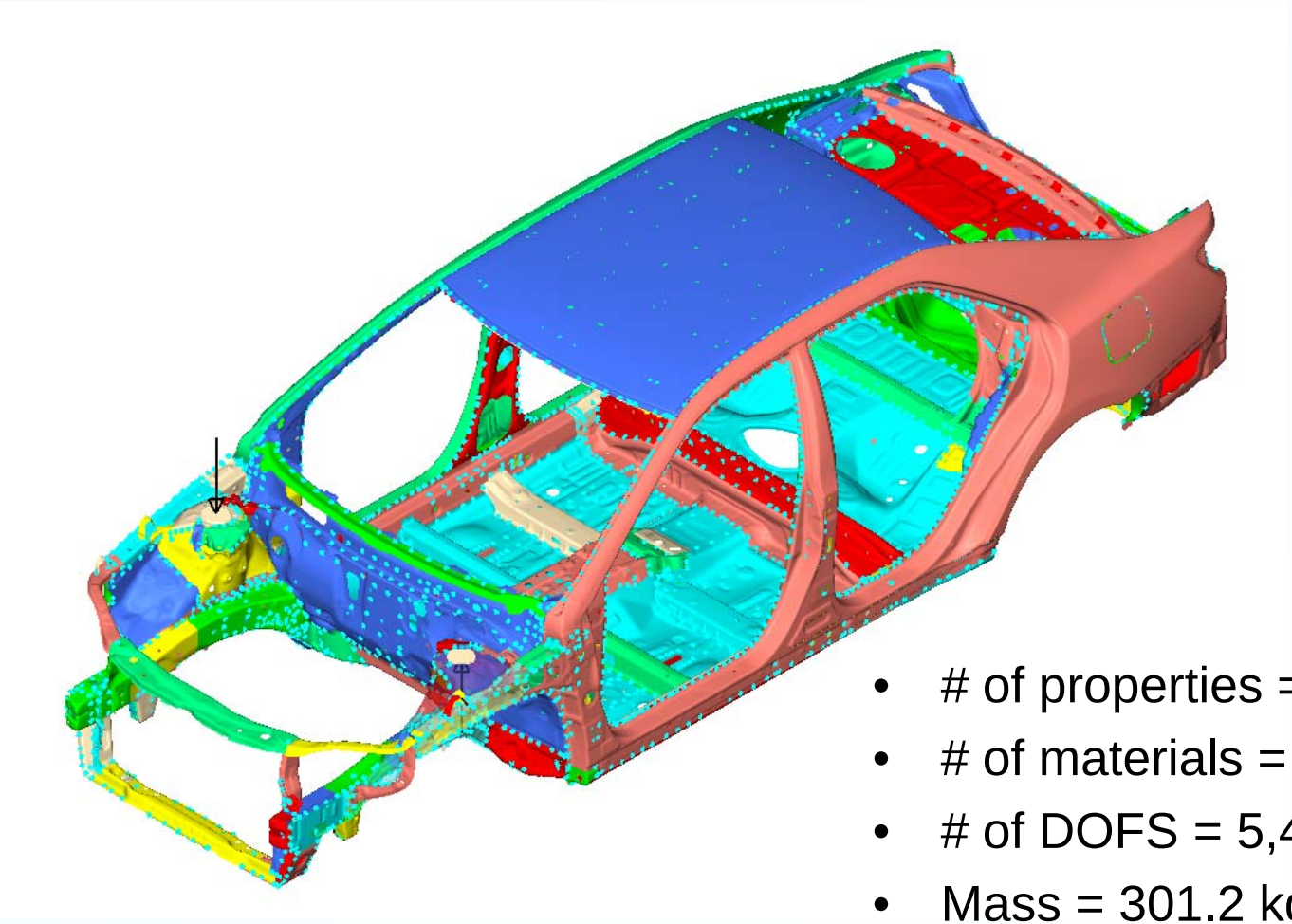
- **Structural Optimization in car body design**

	Preliminary	Stiffness	Strength	Final design	Reinforcement	Bonding
Sizing	yes	yes	yes	yes	yes	occasionally
Shape	yes	yes	yes	yes	-	-
Topology	yes	yes	-	occasionally	yes	yes
Topometry	yes	yes	-	occasionally	yes	yes
Topography	yes	yes	-	occasionally	yes	-
Freeform	yes	yes	-	occasionally	yes	-

Design of Car Bodies

- Apply methods to large scale models
  - Maximize torsional stiffness of BIW
  - Minimize strain energy of BIW

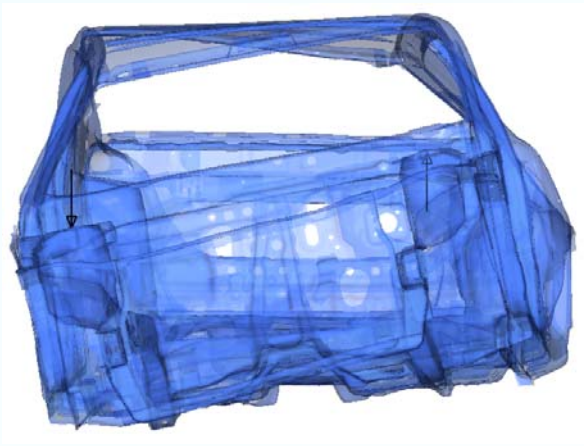
2012 Toyota Camry BIW

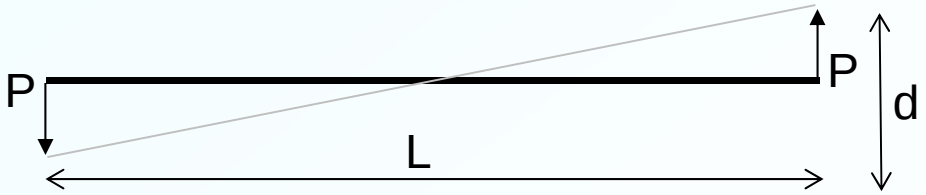


- # of properties = 269
- # of materials = 269
- # of DOFS = 5,478,486
- Mass = 301.2 kg

Source: National Crash Analysis Center (http://www.ncac.gwu.edu/)

Maximize Torsional Stiffness of BIW

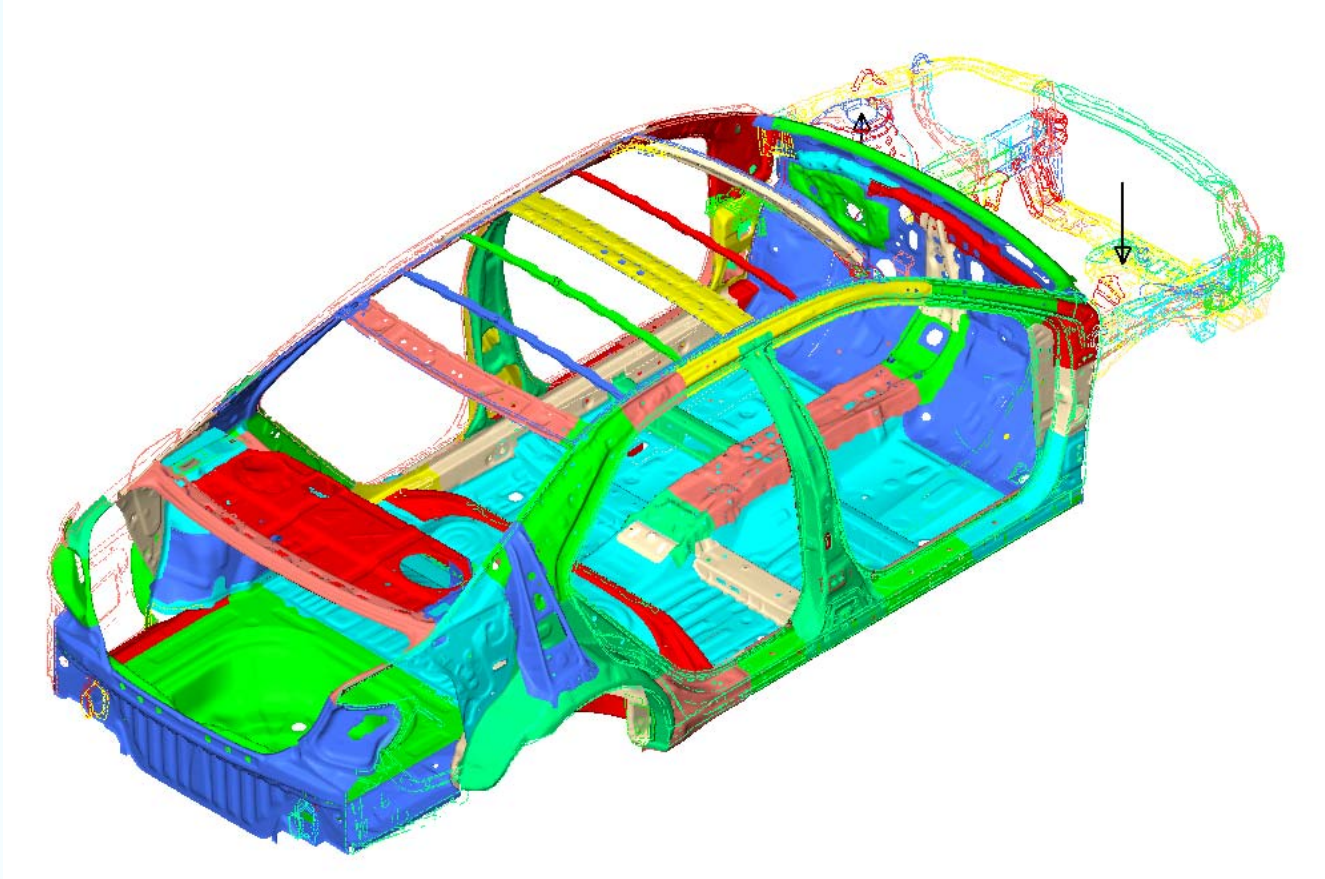




Torsional stiffness = $P*L/\tan^{-1}(d/L)$

Torsional stiffness is maximized by Sizing, Topometry, Topography and Shape optimization

Sizing Optimization



Optimization problem:

Maximize Torsional stiffness

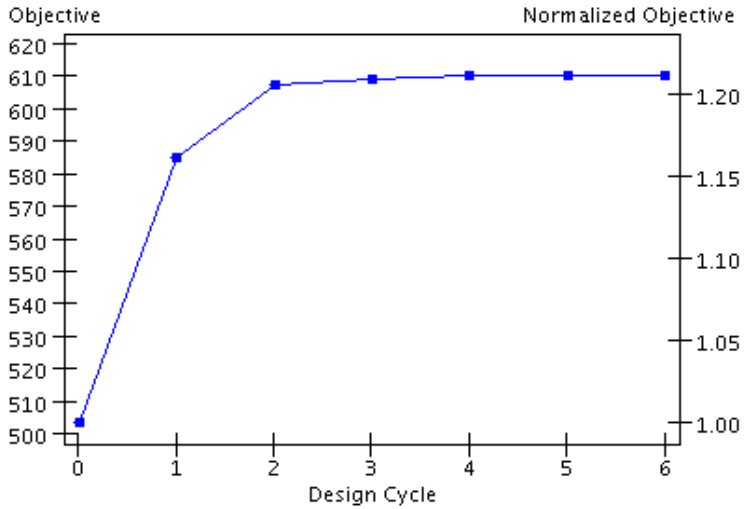
s.t.

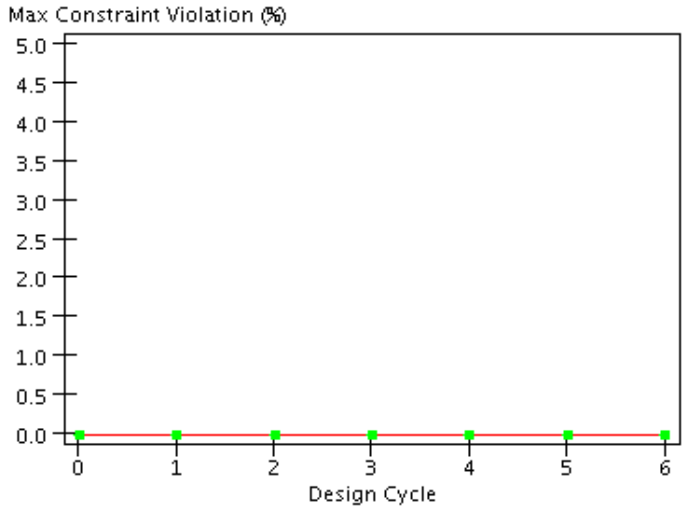
Mass <= Initial mass

Design variables: thickness of 124 PSHELLS

Sizing Optimization

Thickness/Original thickness

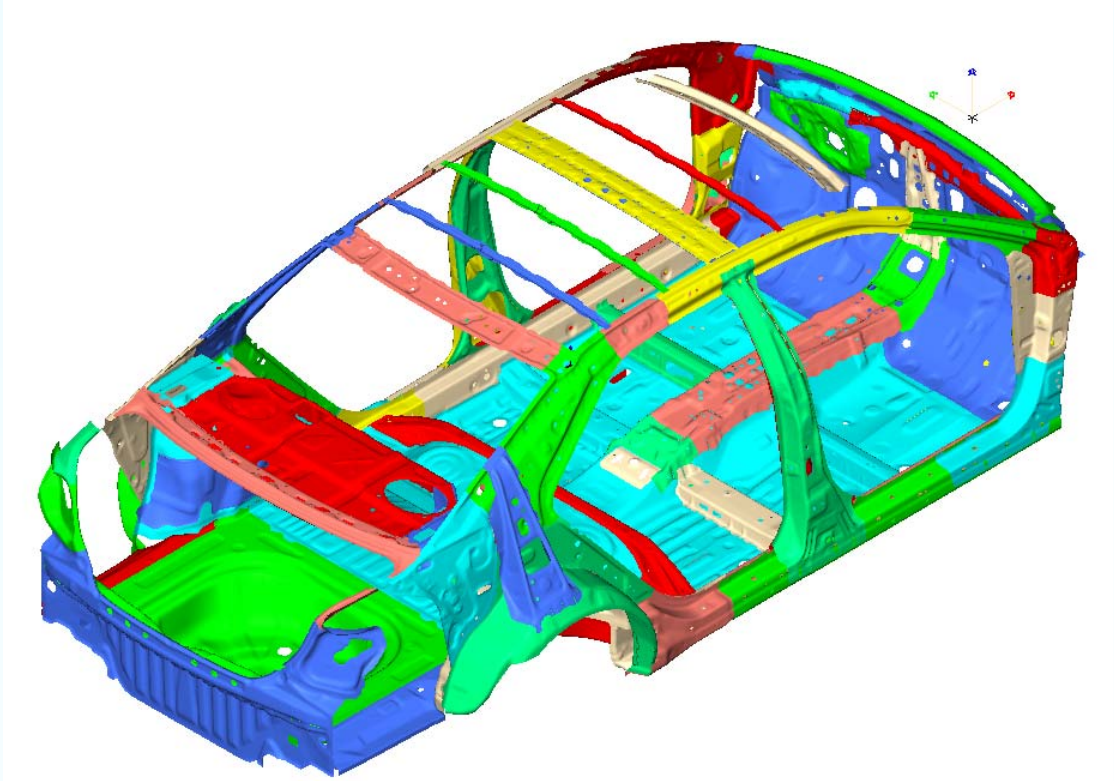




Result:

- 21 % increase in torsional stiffness with no mass change

Topometry Optimization



Optimization problem:

Maximize Torsional stiffness

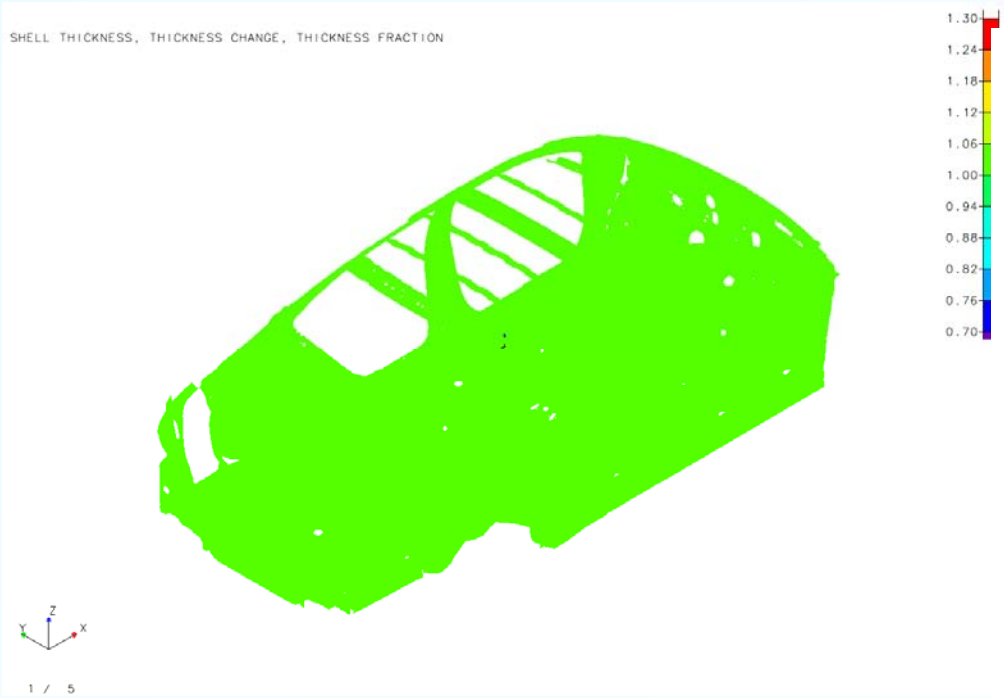
s.t.

Mass <= Initial mass

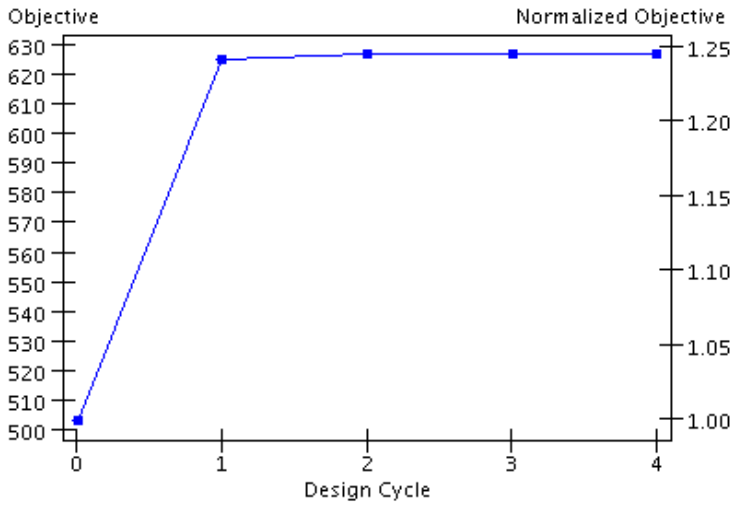
Design variables: thicknesses of shell elements

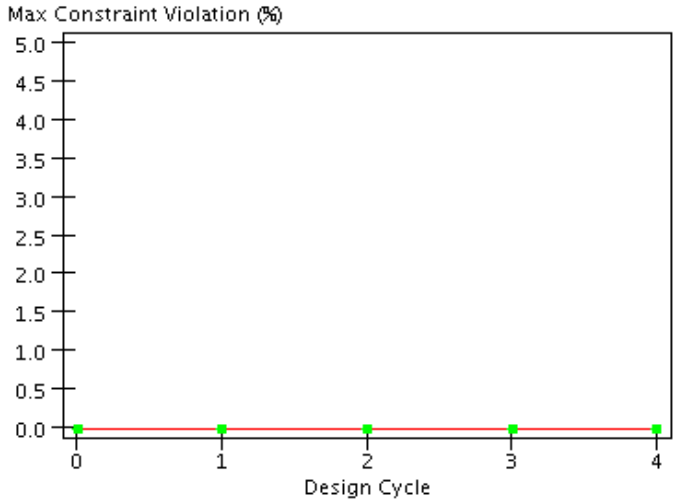
Coarse topometry with mirror symmetry about XZ- plane of local CSYS

Topometry Optimization



Thickness/Original thickness

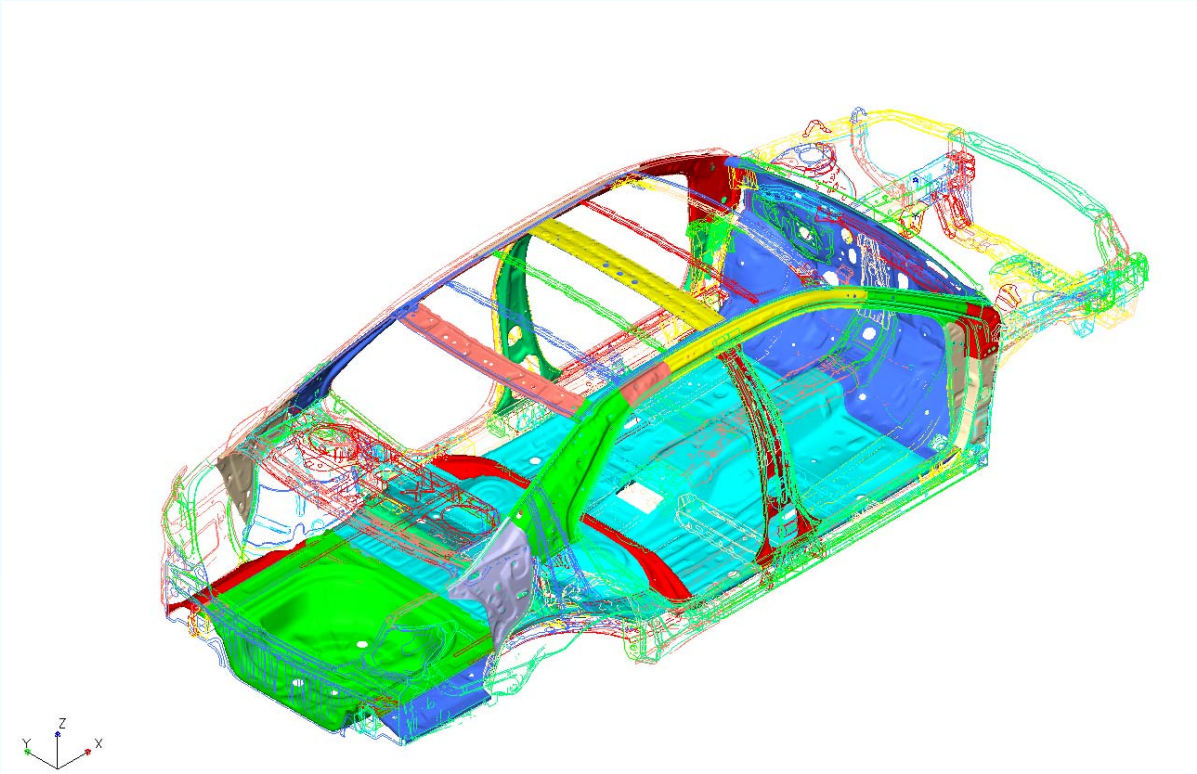




Result:

- 24.5 % increase in torsional stiffness with no mass change

Topography Optimization



Optimization problem:

Maximize Torsional stiffness

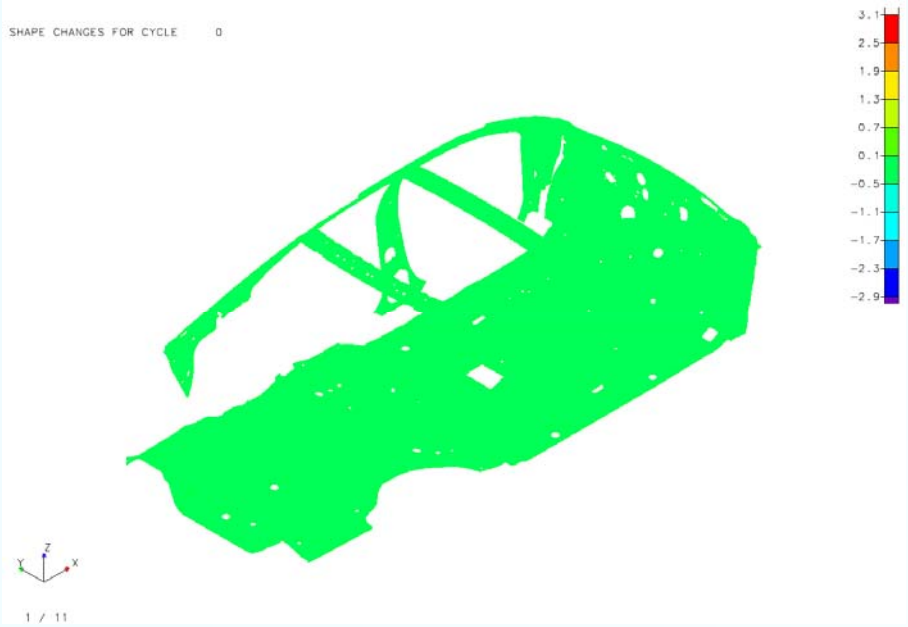
s.t.

Mass <= Initial mass

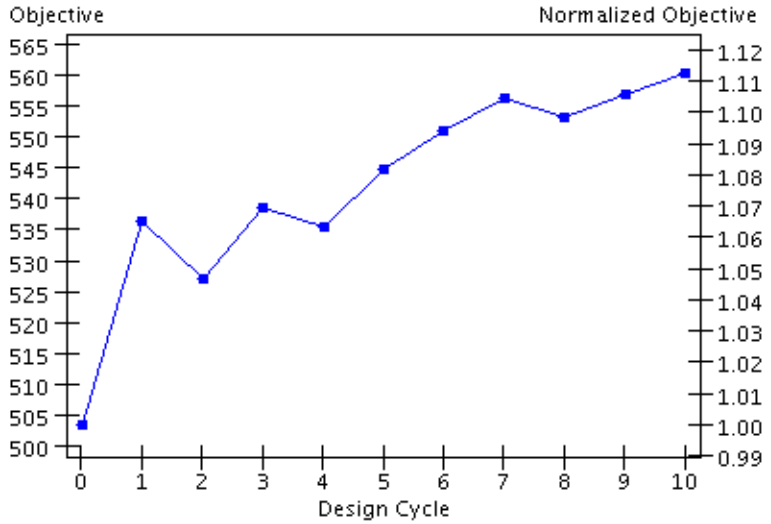
Design variables: Grid locations of shells normal to surface

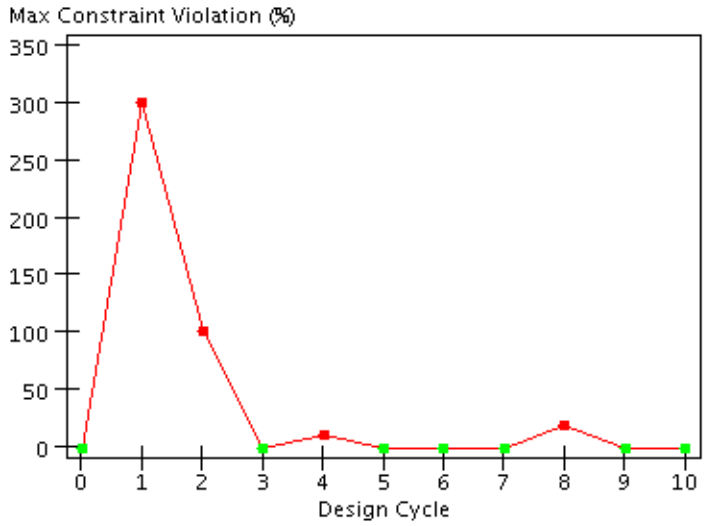
5% of grids moved with mirror symmetry about XZ- plane of local CSYS

Topography Optimization



Shape change normal to surface

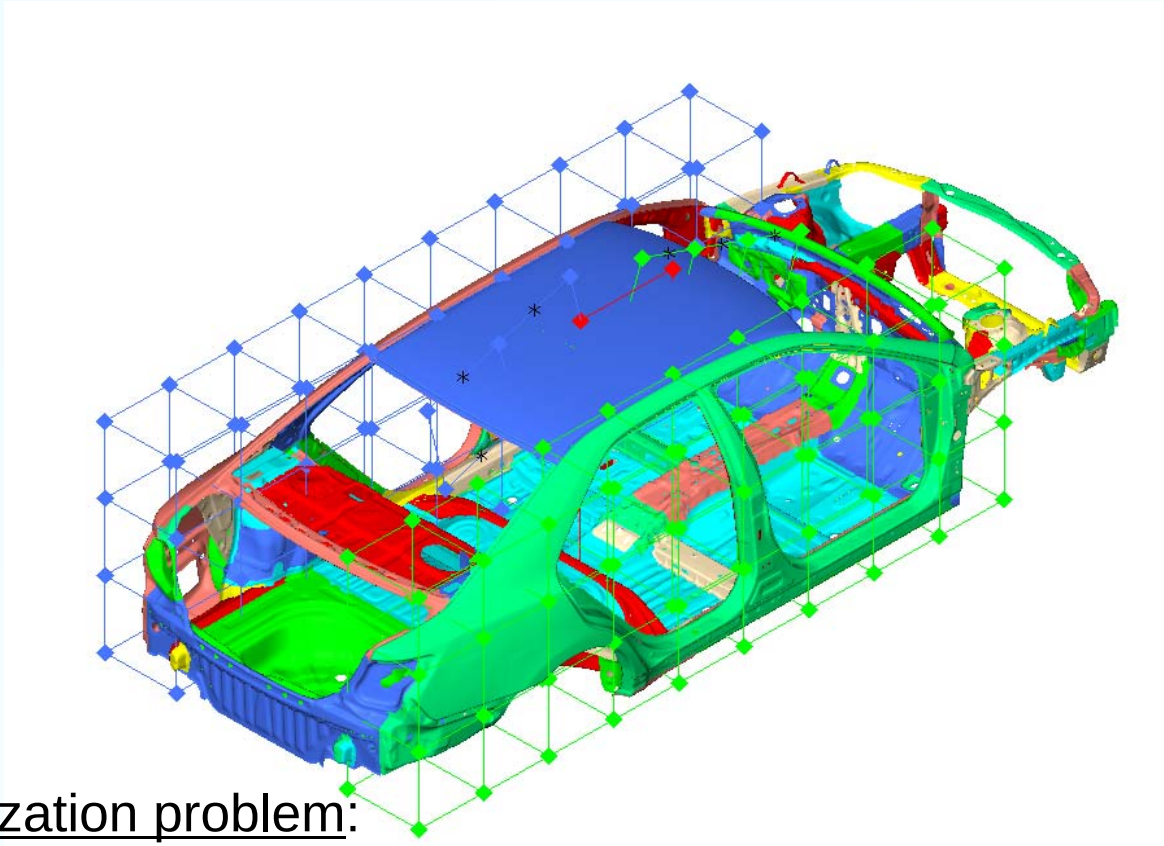




Result:

- 11.3 % increase in torsional stiffness with no mass change

Shape Optimization



Optimization problem:

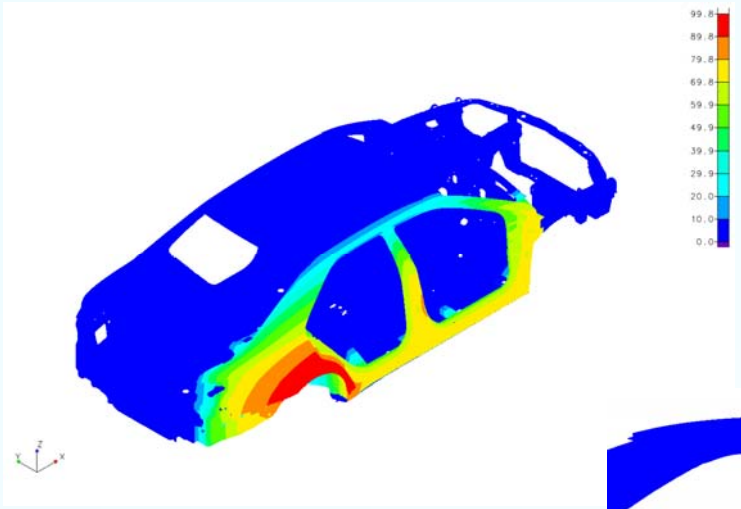
Maximize Torsional stiffness

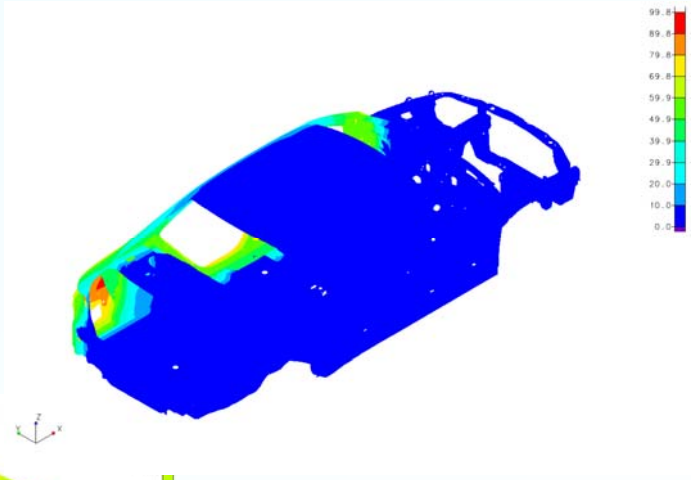
s.t.

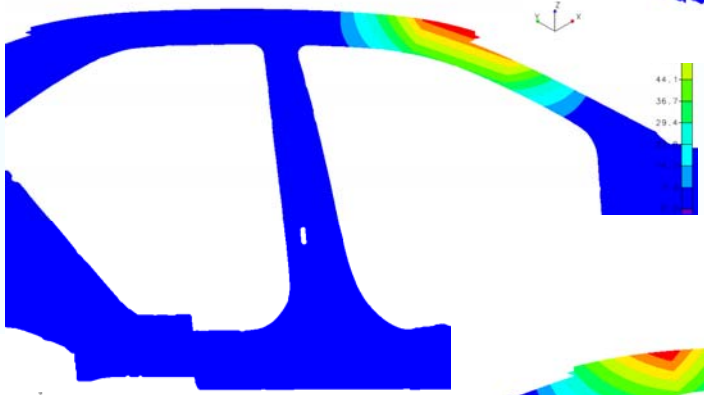
Mass <= Initial mass

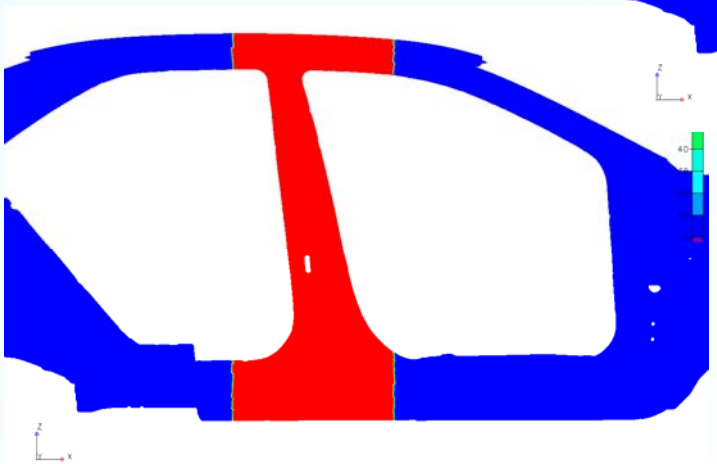
Design variables: Magnitude of perturbations on shape domains

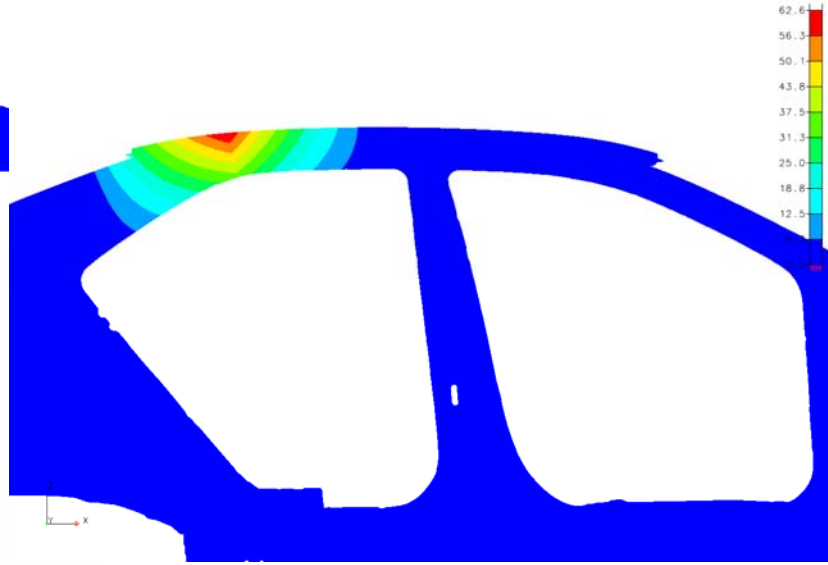
Shape Domains



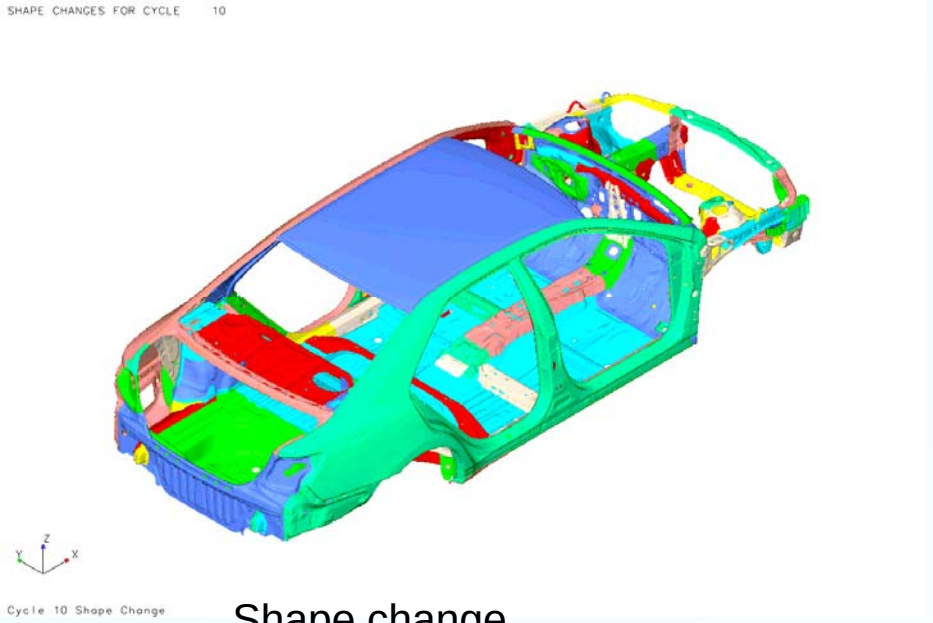




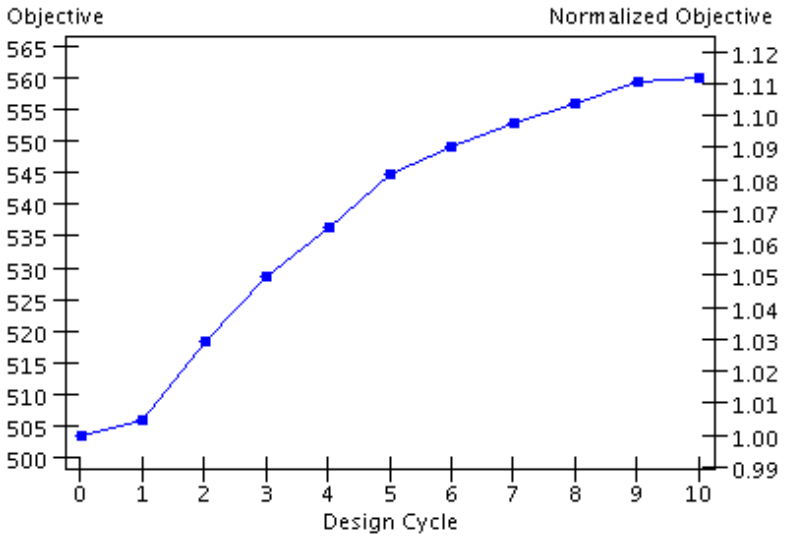


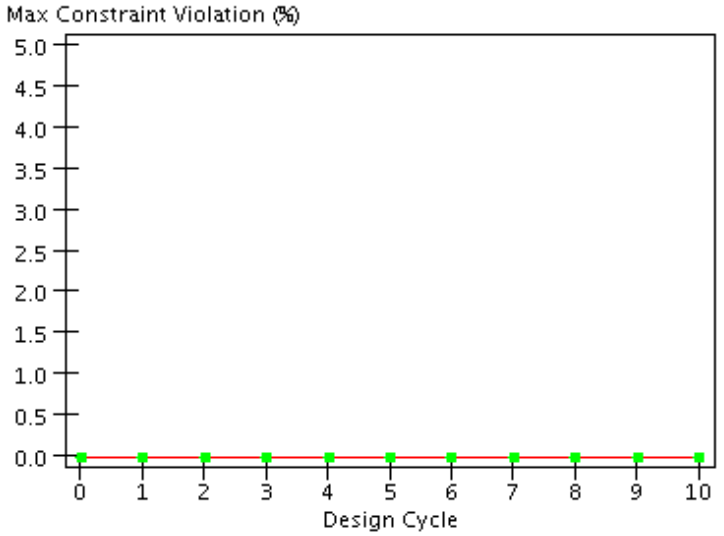


Shape Optimization



Shape change

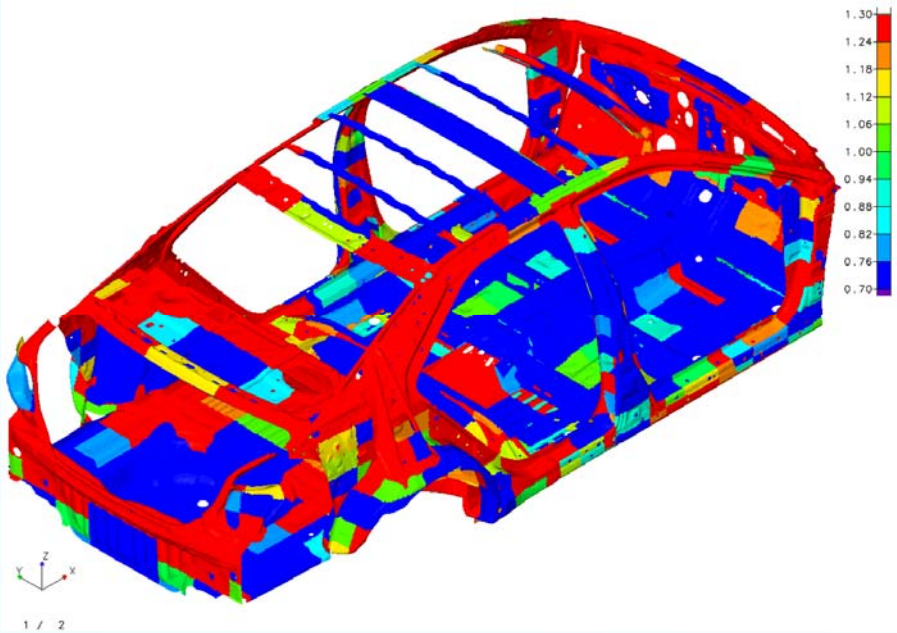


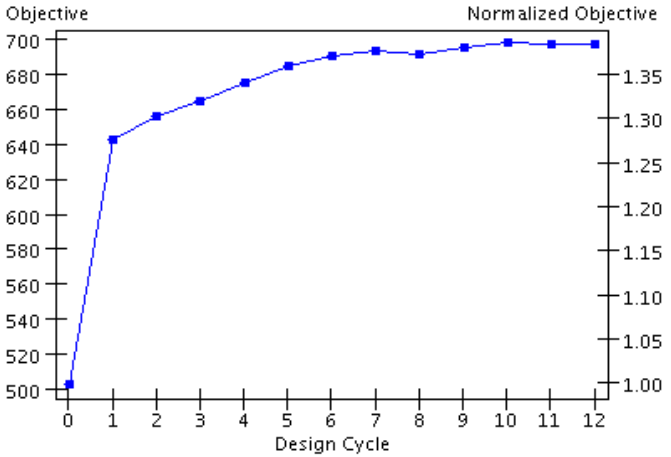


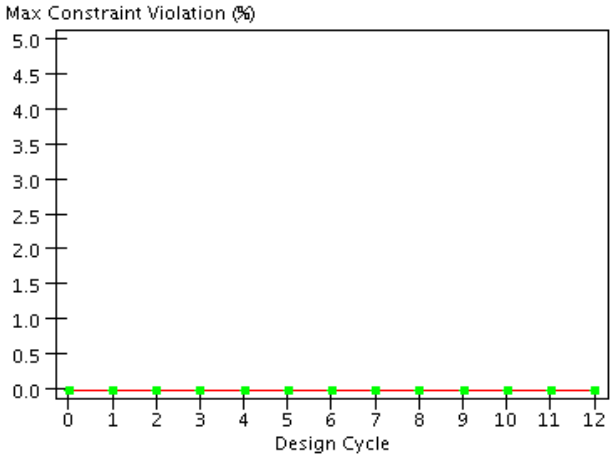
Result:

- 11.2 % increase in torsional stiffness with no mass change

Combined Topometry & Shape Optimization



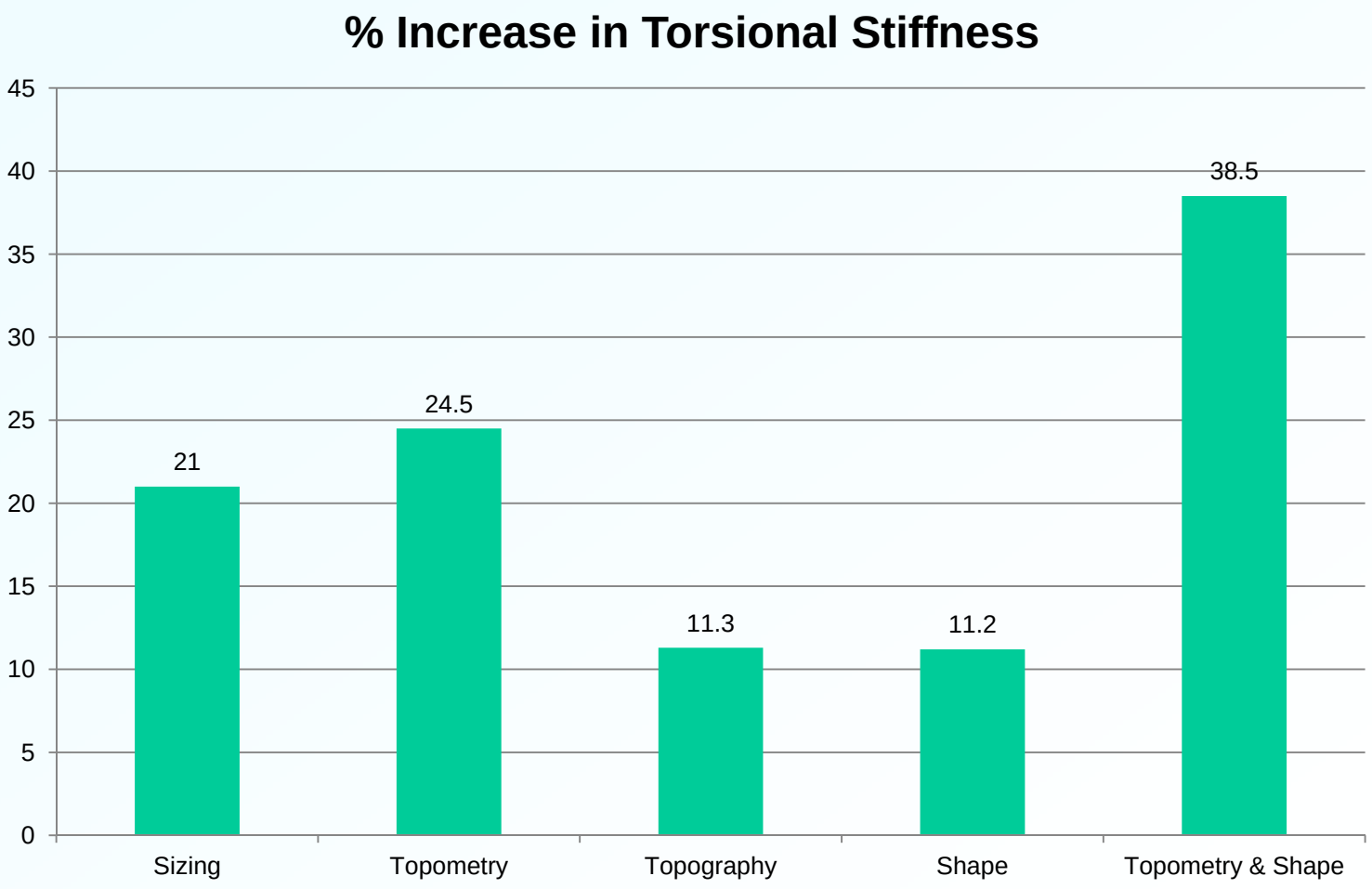




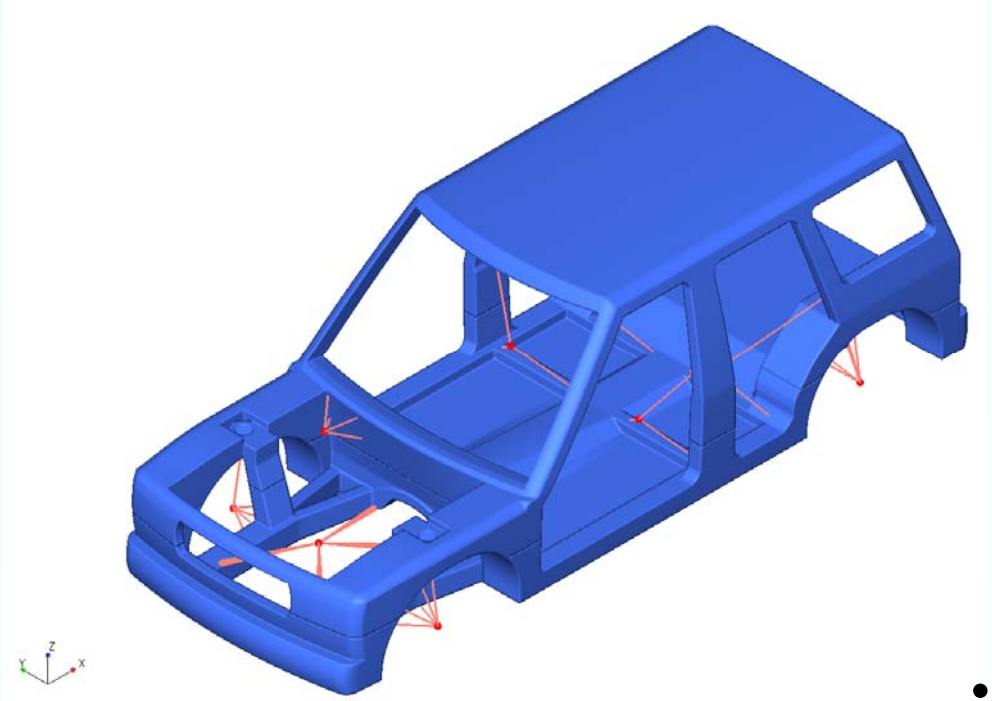
Result:

- 38.53 % increase in torsional stiffness with no mass change

Summary


% Increase in Torsional Stiffness
45
40
35
30
25
20
15
10
5
0
21
24.5
11.3
11.2
38.5
Sizing
Topometry
Topography
Shape
Topometry & Shape

Combined Topology & Shape Optimization



Model:

- 737,836 solid elements
- 5,478,486 DOFs
- 10 static loadcases (4 with SPC and 6 with inertia relief)

- 737,836 Topology design variables
- 1,477 shape design variables

Optimization problem:

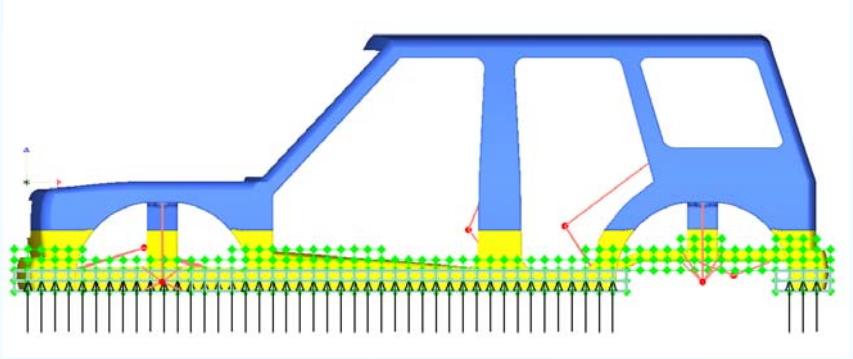
Minimize Strain Energy

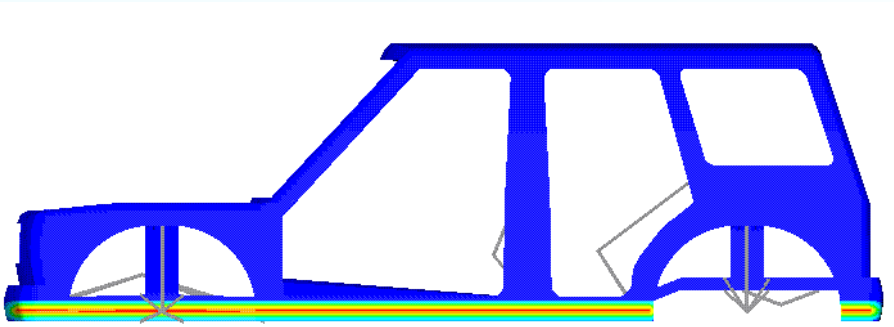
s.t.

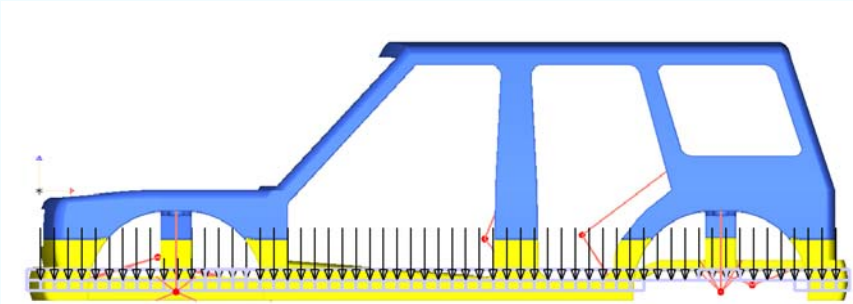
Mass Fraction <= 0.1

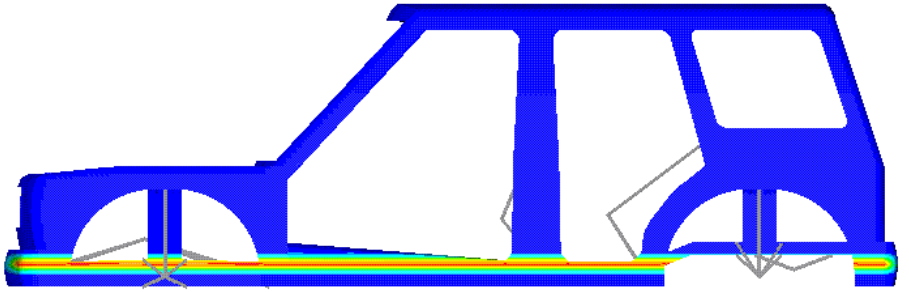
Symmetry about XZ- plane of local CSYS

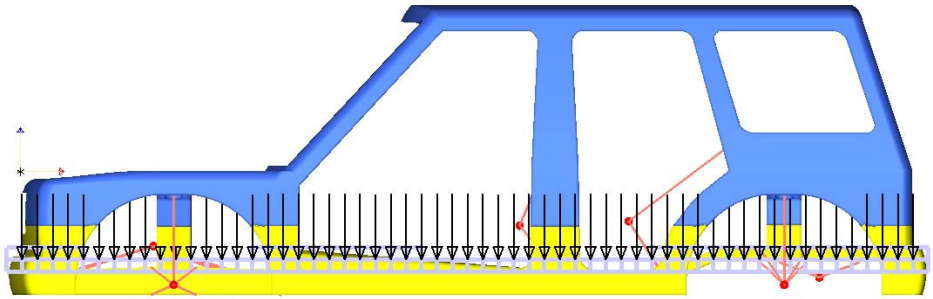
Floor Shape Domains

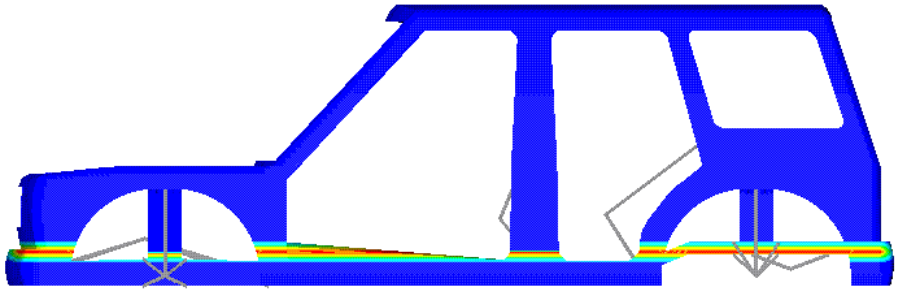






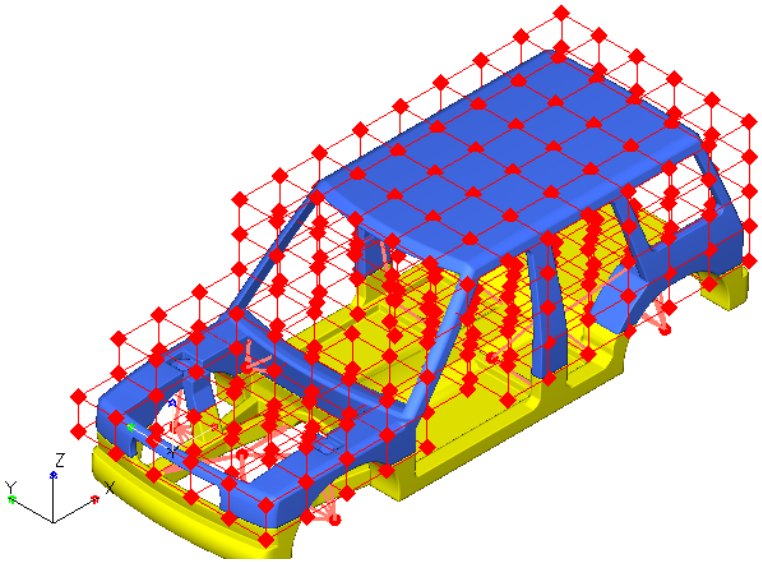


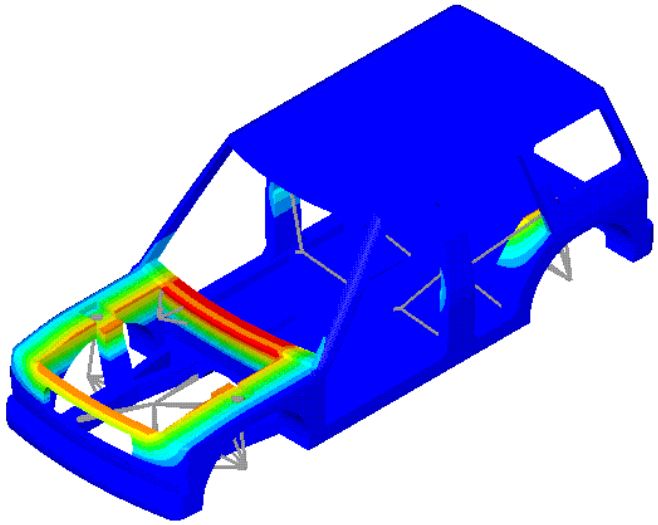


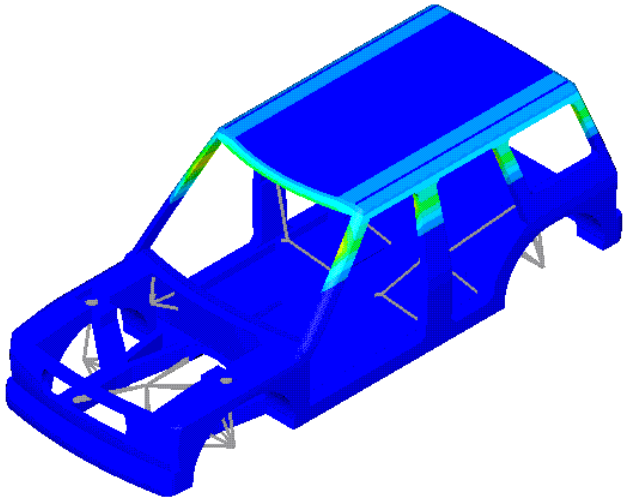


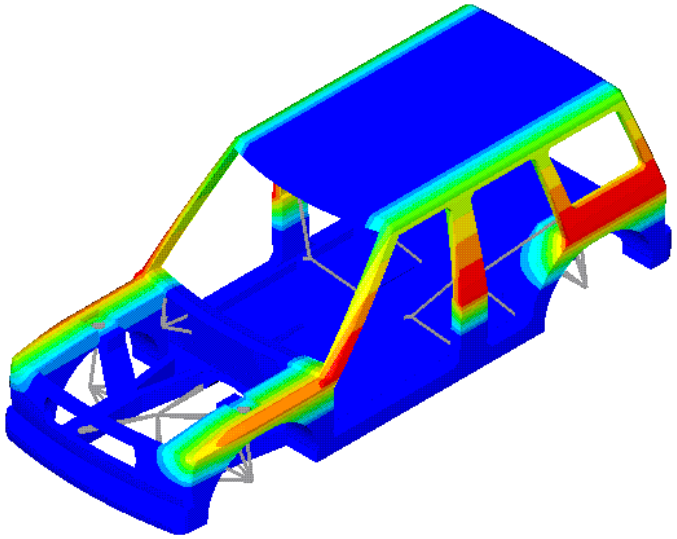
Freeform: Each perturbation is controlled by a separate design variable

Top Shape Domains



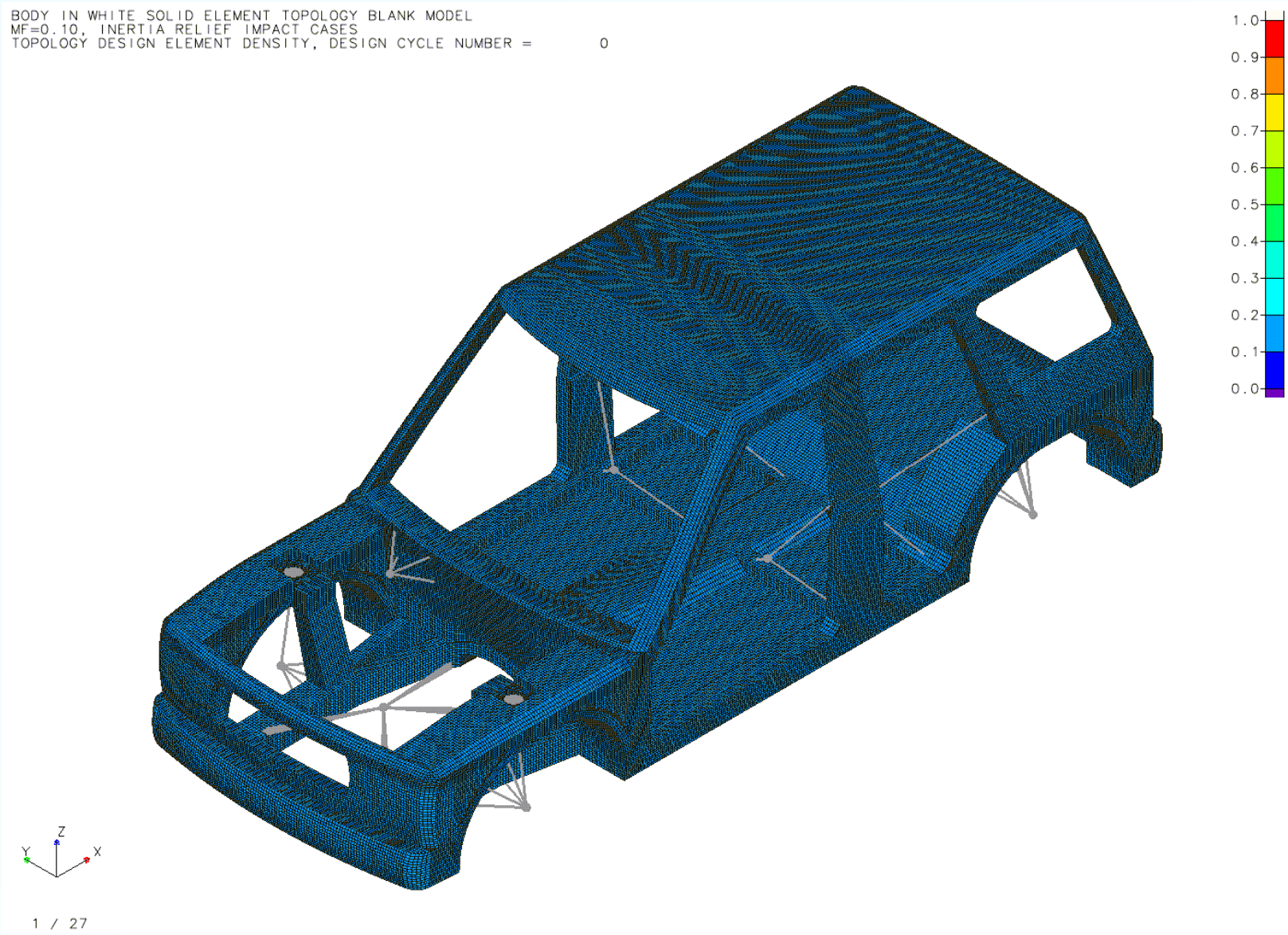




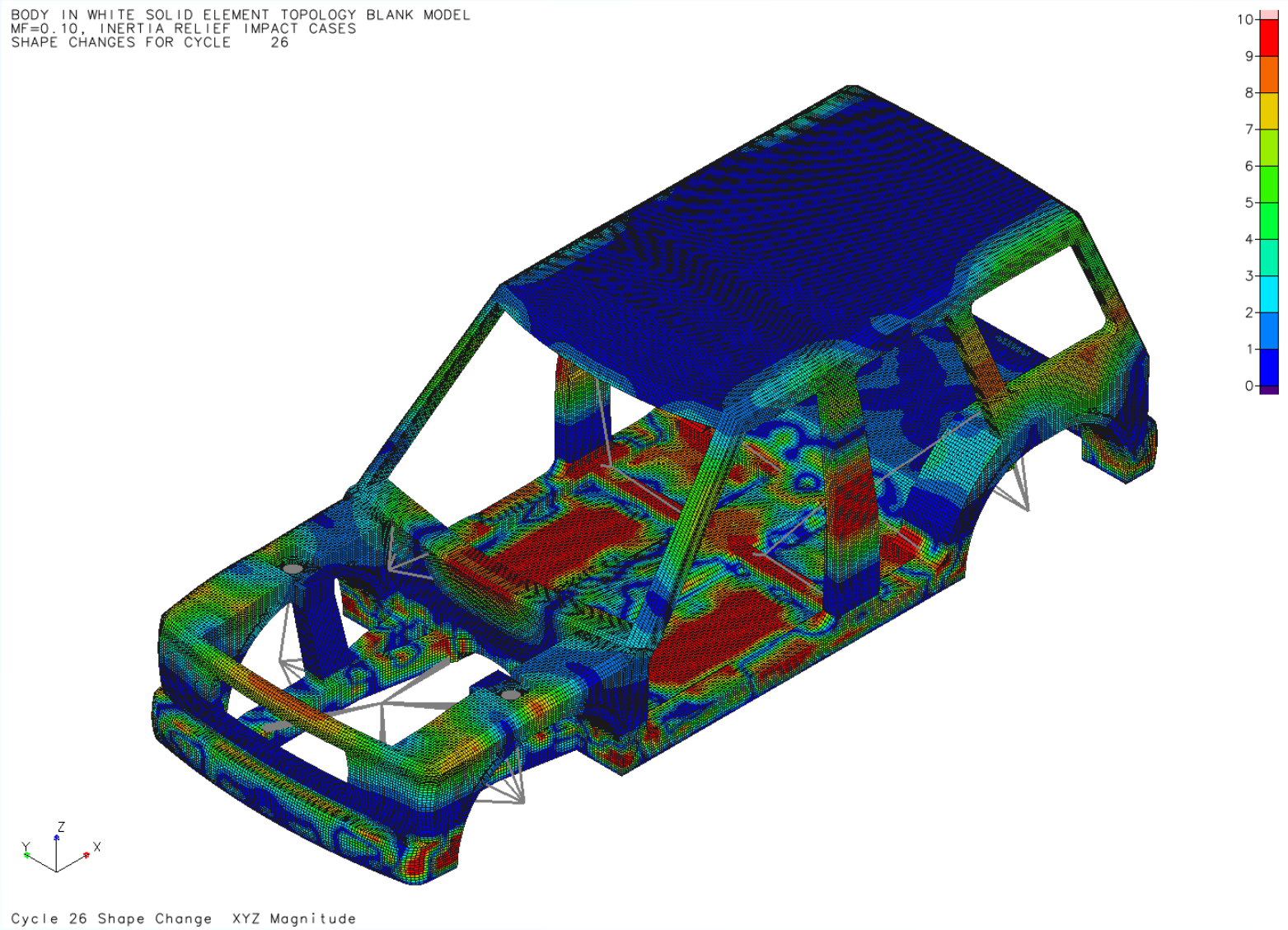


Freeform: Each perturbation is controlled by a separate design variable

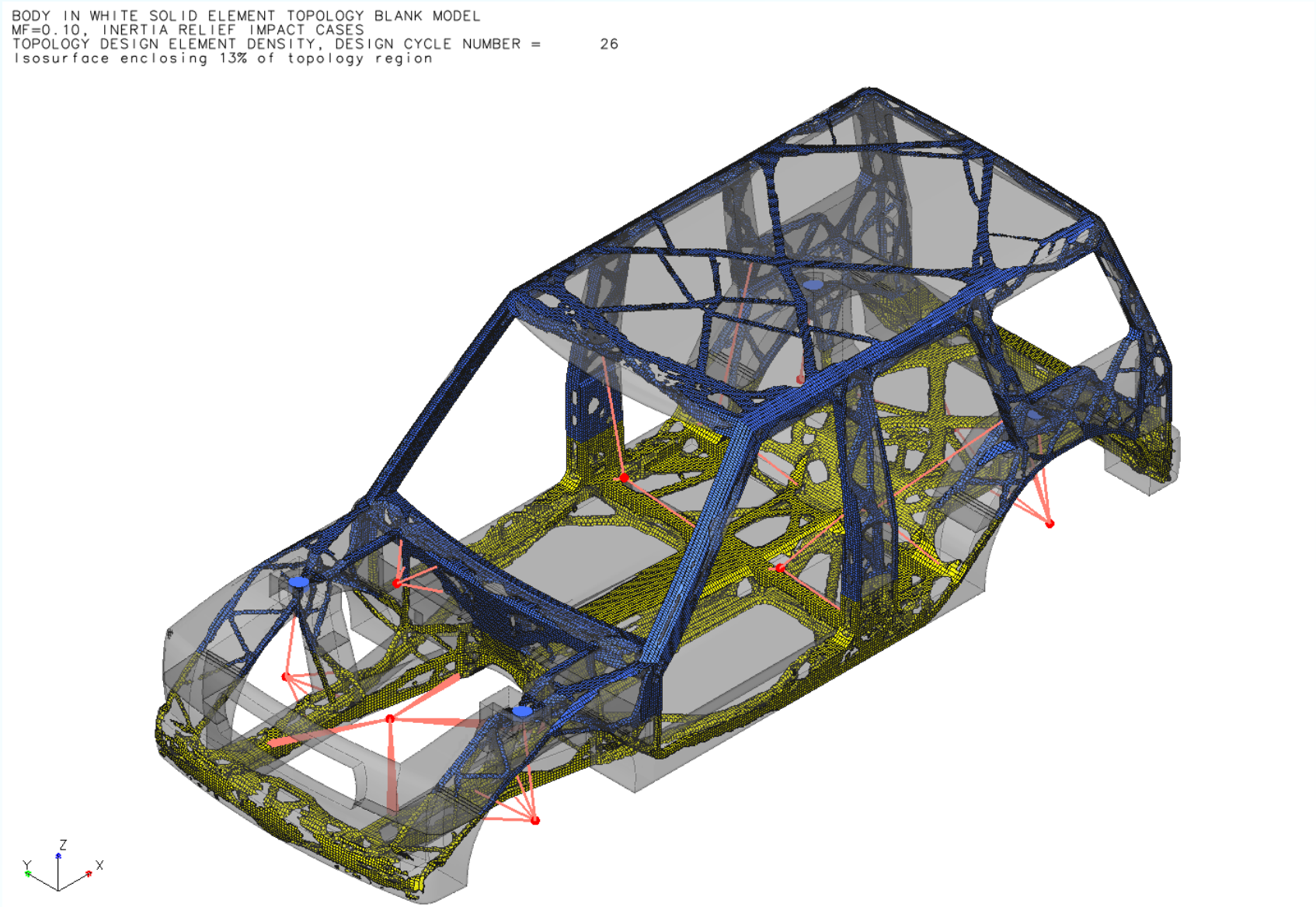
BIW Topology & Shape Result



Shape Change

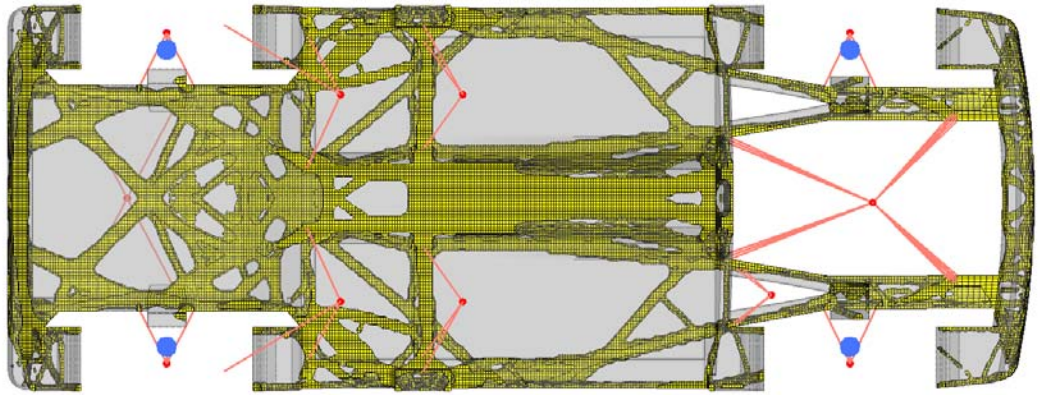


Combined Shape & Topology Isosurface

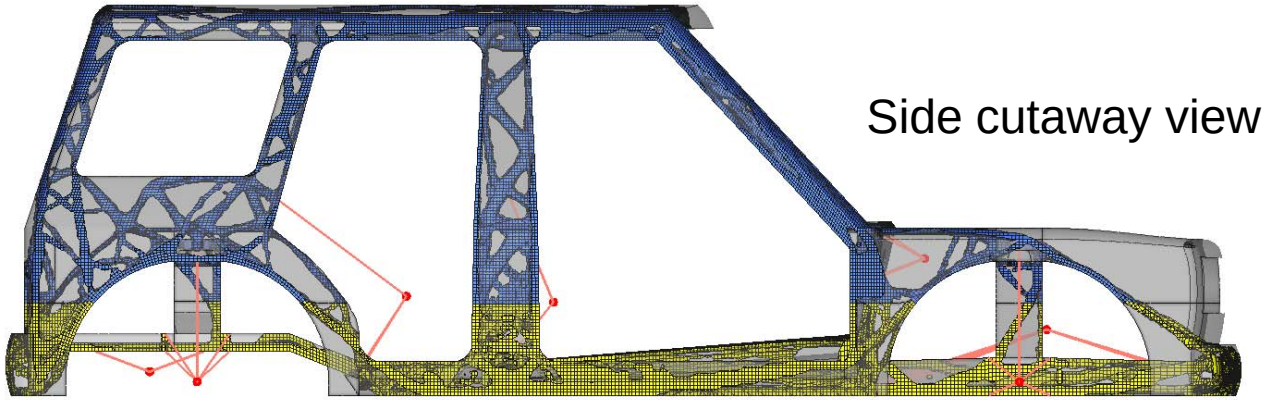


Combined Shape & Topology Isosurface

Roof cutaway view



Floor cutaway view



Side cutaway view

Closing Remarks

- **GENESIS provides powerful methods for optimization**
- **GENESIS can efficiently solve large scale structural optimizing problems in industry**