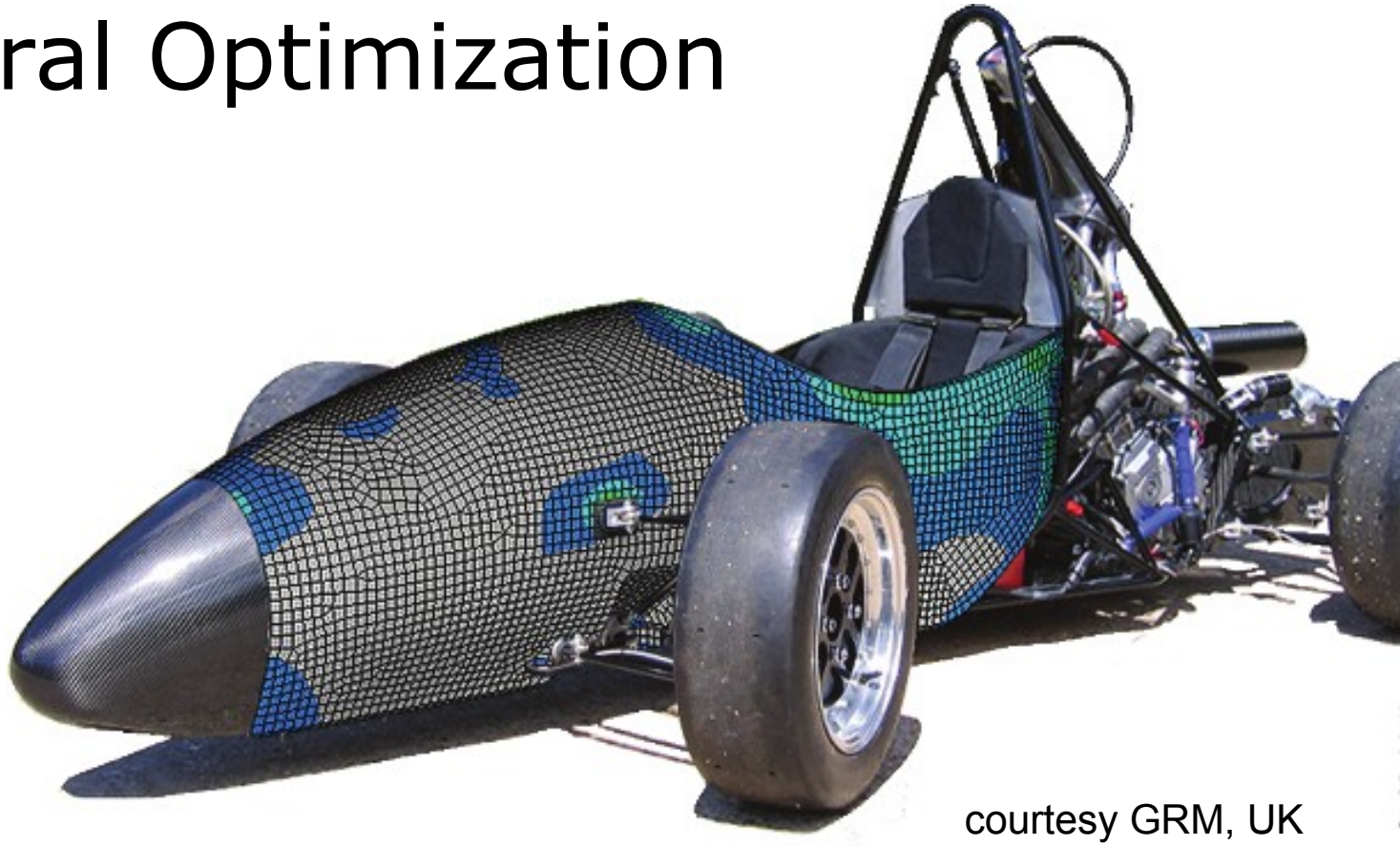
GENESIS
Structural Optimization



courtesy GRM, UK

DYNAmore GmbH, Stuttgart, Germany
http://www.dynamore.de; info@dynamore.de

Outline

Overview

Optimization Capabilities / Examples

- Topology
- Sizing
- Shape
- Topography
- Topometry

Composite Optimization Tools

Coupling Genesis and LS-DYNA

GENESIS

- Product of **Vanderplaats R&D,** 17 years in marketplace
- DYNA*more* Distributor since 2007
- Design optimization by generating new designs based on user criteria
- Large scale analysis and optimization >10^6 of design variables

Genesis features

- fully integrated fast and robust (linear) finite element analysis
- uses standard Nastran input files and
- standard post-processing files
- robust end efficient optimization based on BIGDOT
- almost complete kit of optimization capabilities
- with Design Studio a graphical pre- and postprocessor

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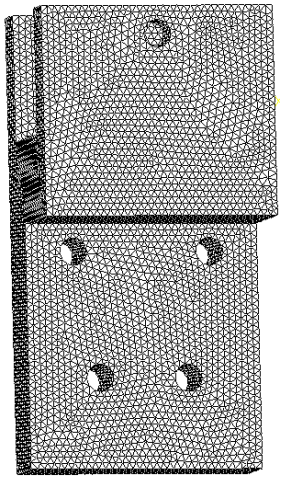
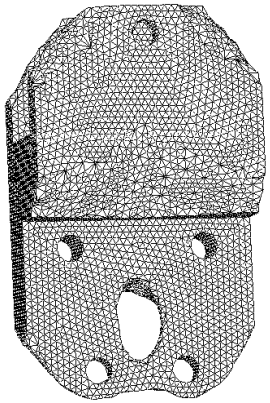
Typical Design Process with Genesis

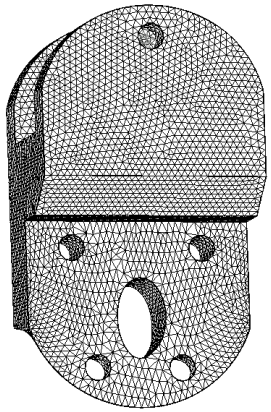


Preliminary design

Topology

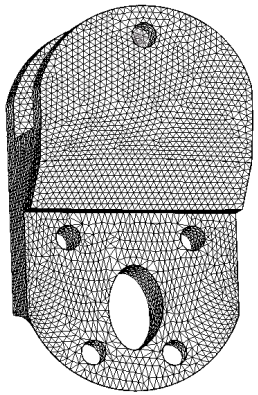


Designer's Interpretation



Final Design

Shape

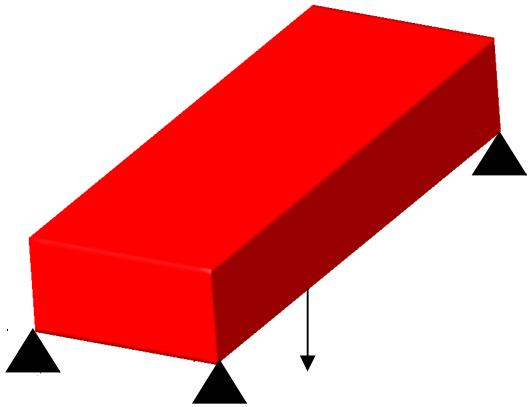


GENESIS Optimization Capabilities

- **Topology** best distribution of material
- **Sizing** best dimensions of any designable elements
- **Shape** best shape possible
- **Topography** location and shape of bead patterns to stiffen panel structures
- **Topometry** optimal distribution of sizing dimensions over the structure (element by element)
- **Composite** layer thickness, shape, angle, ...

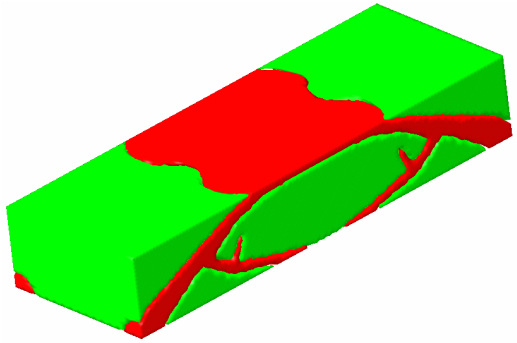
Topology Optimization

Initial Design



reducing mass

Final Design



No. of Design Variables= 1,003,520

Number of Elements = 1,003,520

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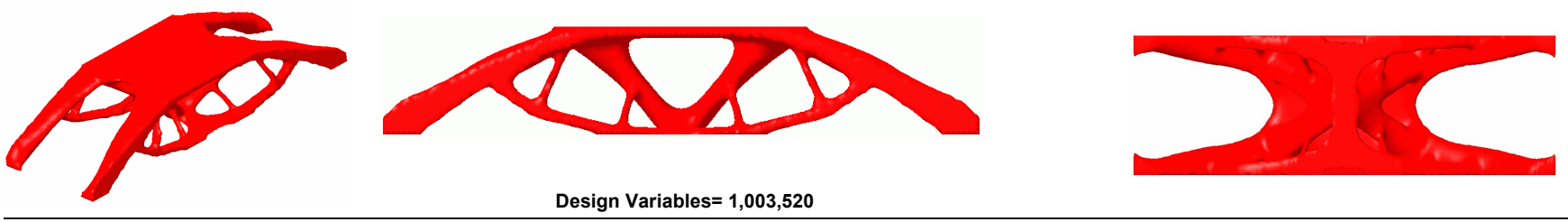
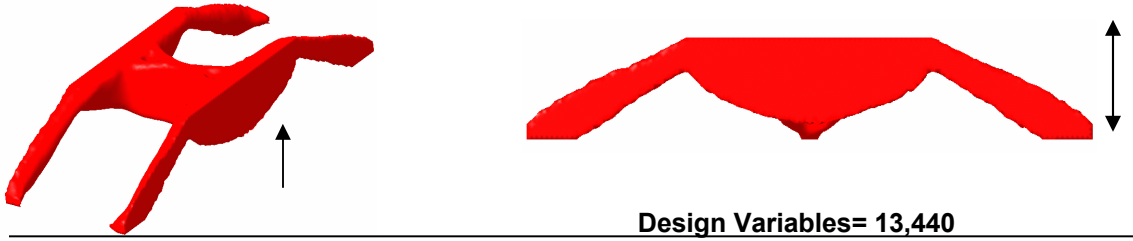
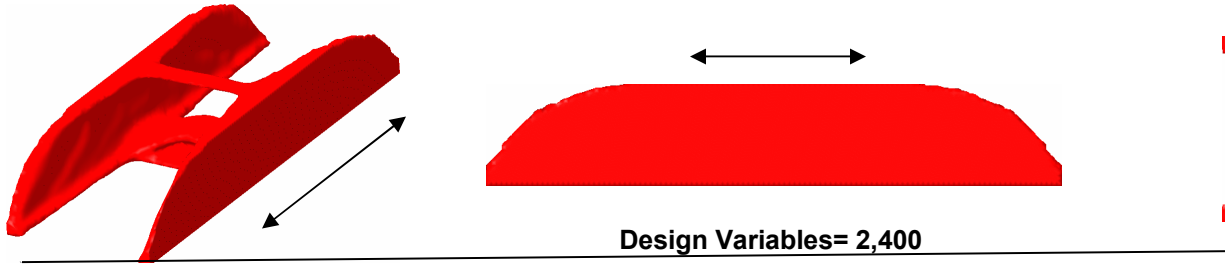
Topology Optimization: Fabrication Constrains



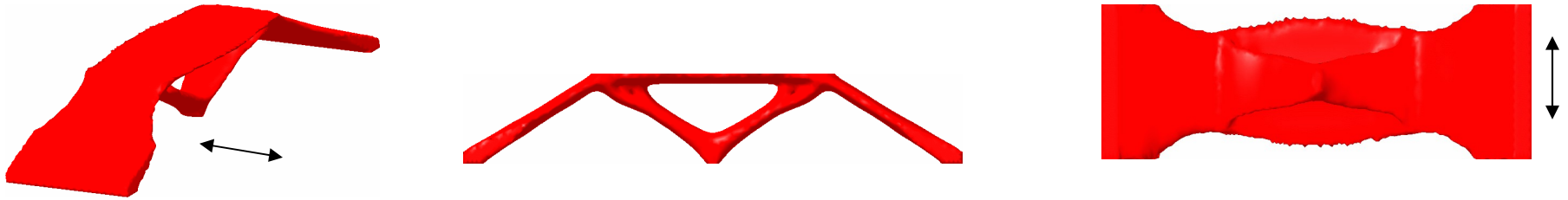
Design Variables= 1,003,520



Design Variables= 13,440



Design Variables= 2,400



Design Variables= 6,720

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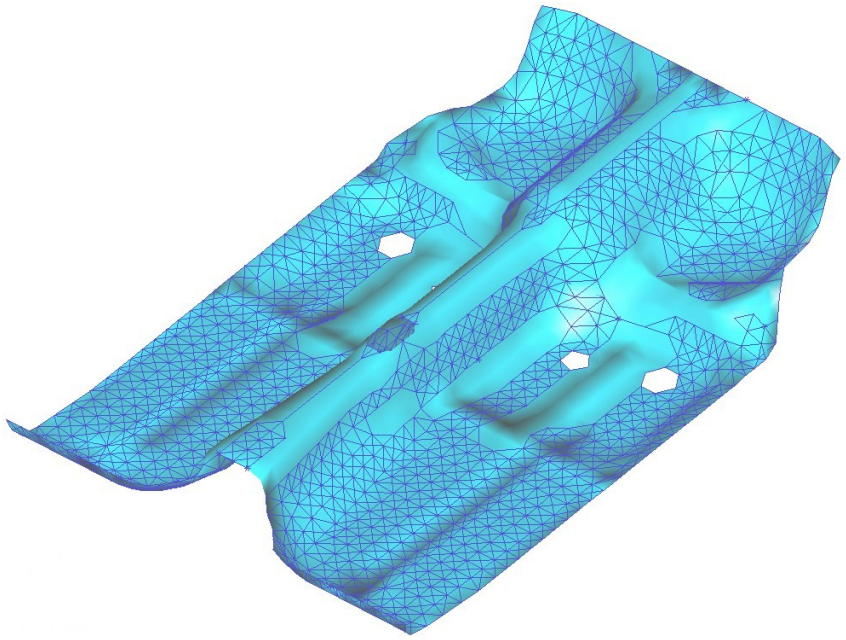
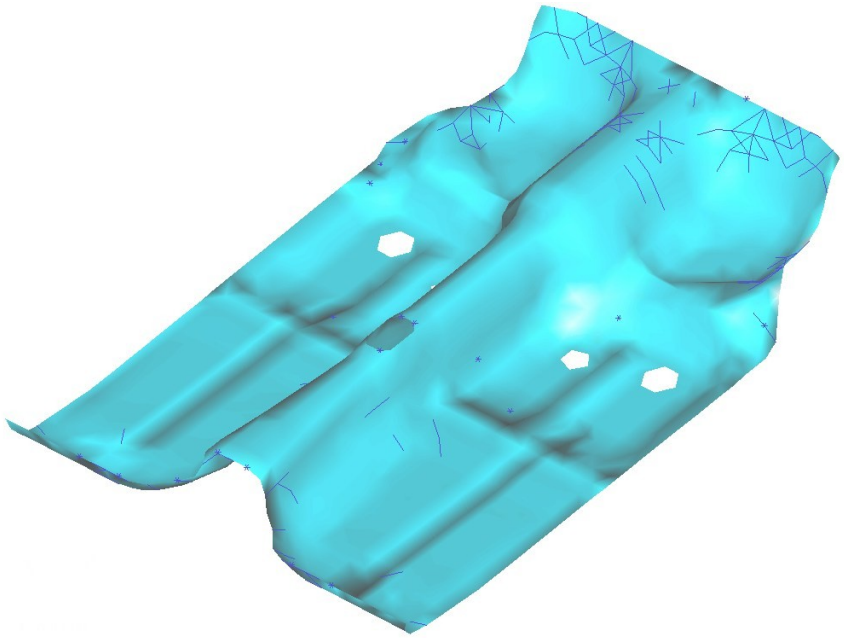
Topology Optimization: Autorib Application



Automatically Generated
Candidate Rib Stiffeners



Best 5% of Ribs for Increased
Torsional Natural Frequency

Sizing Optimization

Problem

Objective

Max sum of 12 lowest frequencies

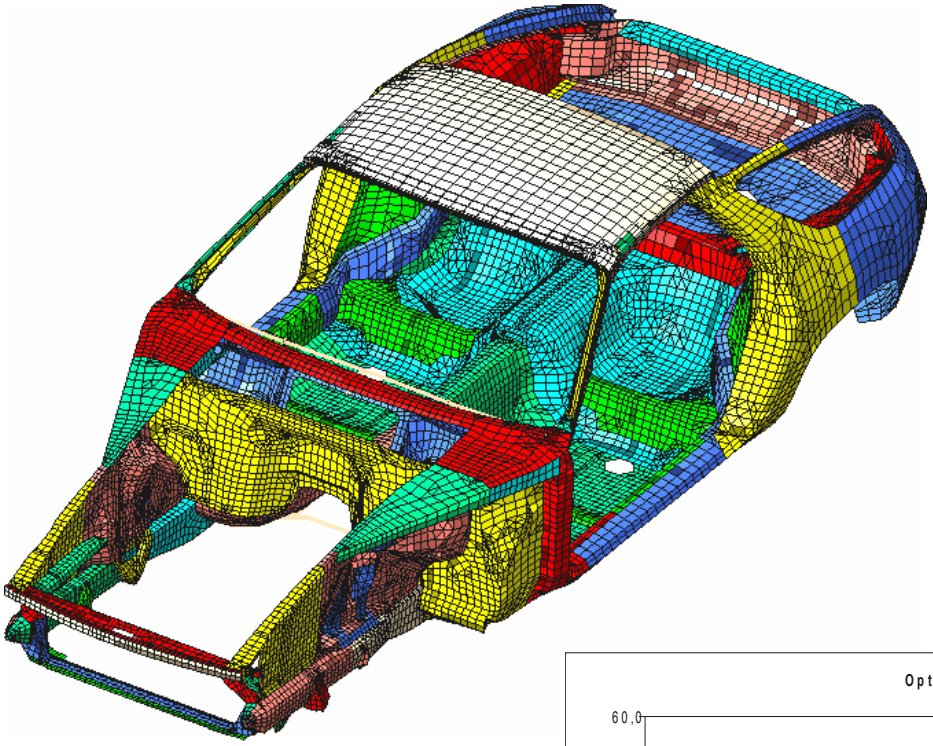
Constraints

Mass can increase up15kg

Design Variables

63 sizing variables, sheet thicknesses

1.0 <= X <=2.0 mm



Results

Objective

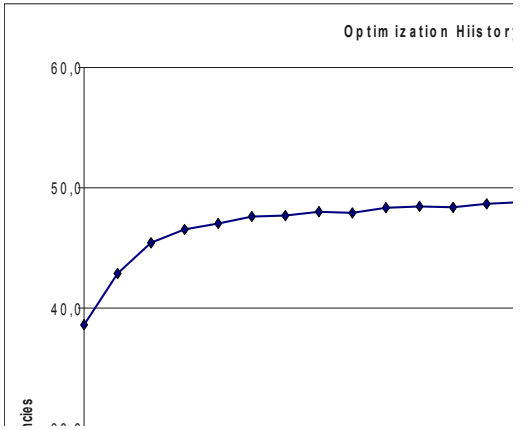
Frequency increased from 38.6 to 48.9Hz (10 Hz, 27% Gain)

Constraints

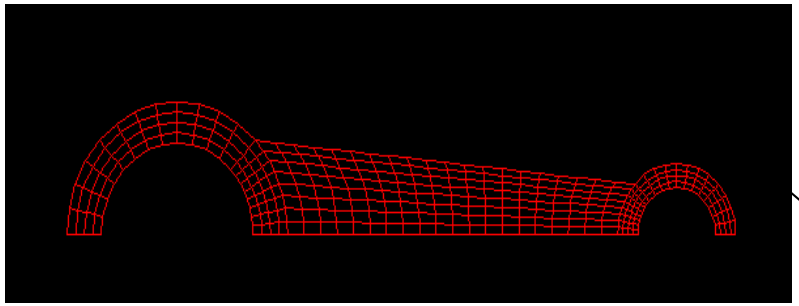
Mass Increased 15kg

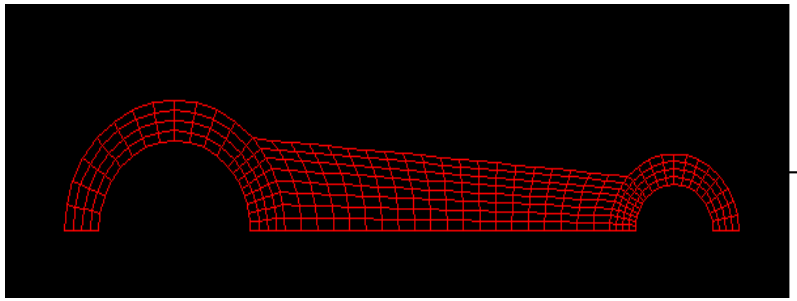
Number of Design Cycles

15

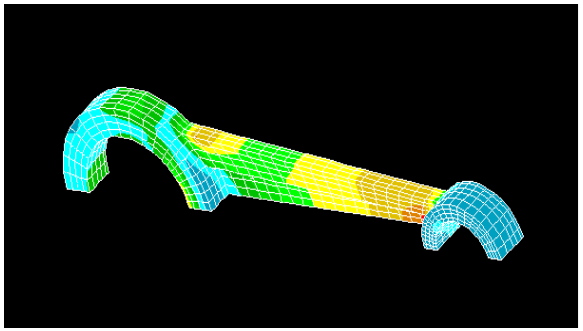


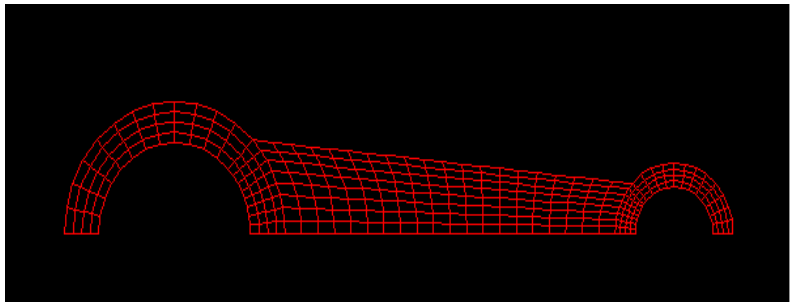
Shape Optimization





$$X_i = X_{io} + \sum_j DV_j * PX_{ij}$$
$$Y_i = Y_{io} + \sum_j DV_j * PY_{ij}$$
$$Z_i = Z_{io} + \sum_j DV_j * PZ_{ij}$$





Optimization

Perturbation Vectors

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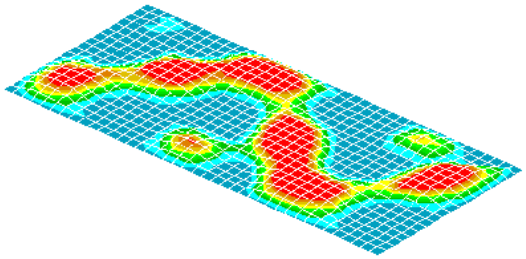
Topography Optimization

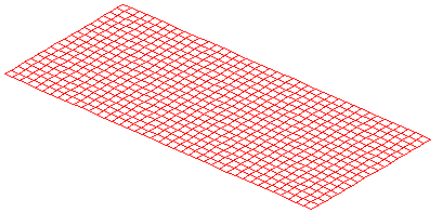
Available to develop optimum swaging patterns in sheet metal formings

- Optional direction of swages
- Minimum bead size definitions

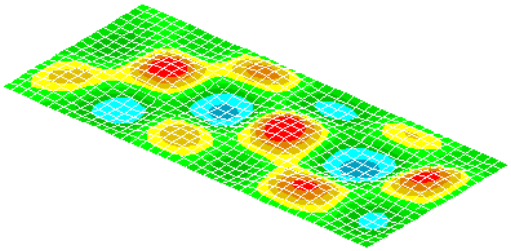
Particularly suitable for solving NVH problems



Grids allow to only move up



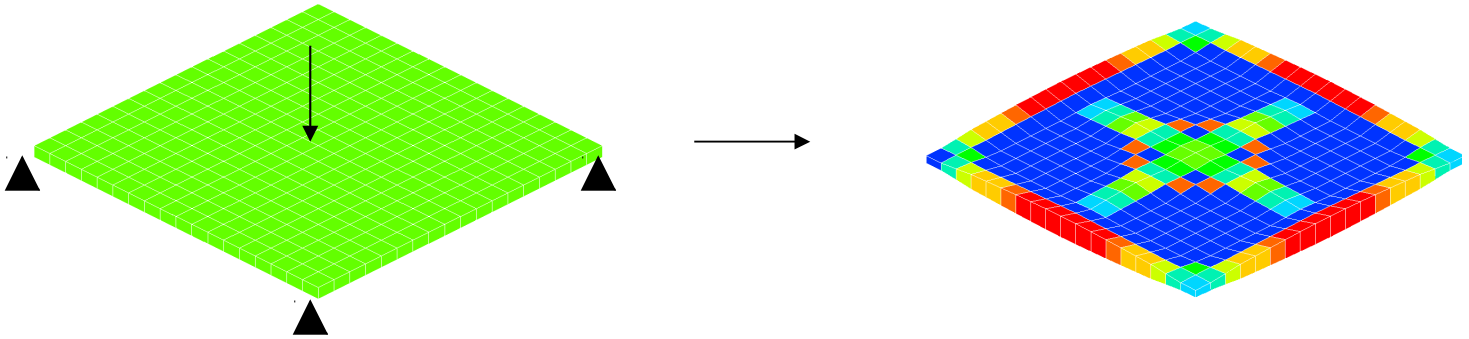
Initial Design



Grids allow to move up/down

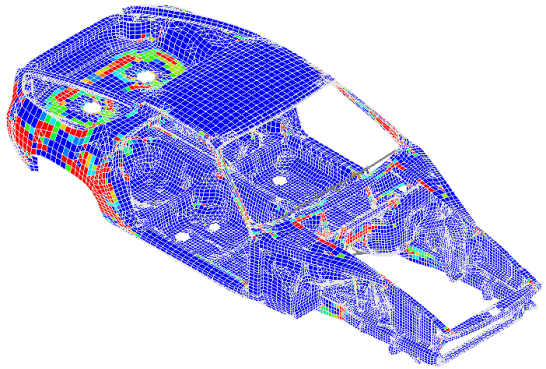
Topometry Optimization

- Element by element sizing optimization
- Works with any element that can be size optimized
- Works with all type of load cases in GENESIS
- It can be mixed with shape and topography
- Easy to set up



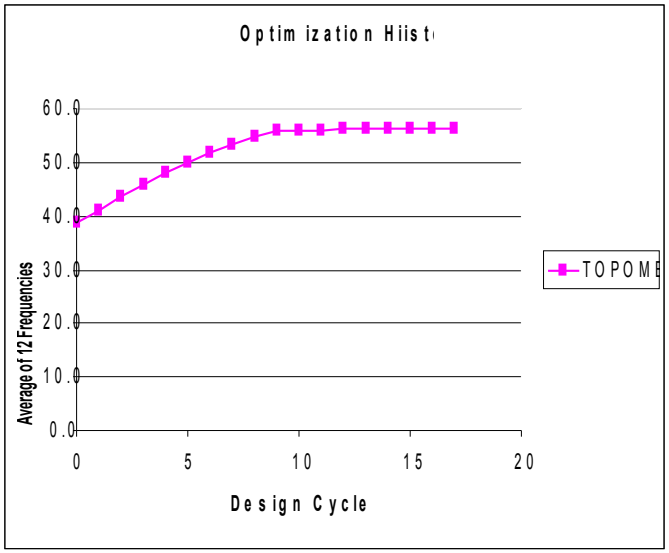
Objective	**Constraints**	**324 Design Variables**
Minimize Strain Energy	Mass	Each element thickness

Topometry Optimization



Problem

- **Objective:**
  - Max Sum Of 12 Lowest frequencies
- **Constraints:**
  - Mass can increase up 15kg
- **Design Variables:**
  - 34,560 sizing variables
  - 1.0 <= X <=2.0 mm



Results

- **Objective:**
  - **Frequency increased from 38.6 to 56.3Hz**

    (18 hz, 46% Gain)
- **Constraints:**
  - **Mass Increased 15kg**
- **Design Variables:**
  - **34,560**
- **Number of Design Cycles**
  - **15**

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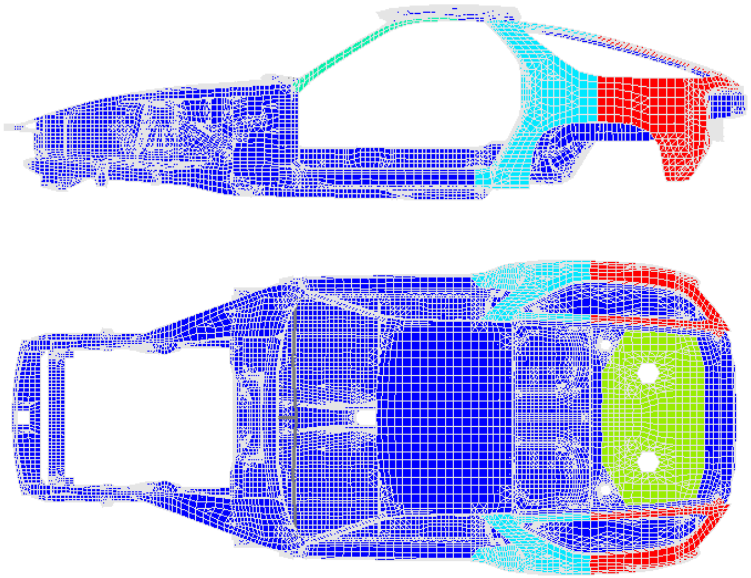
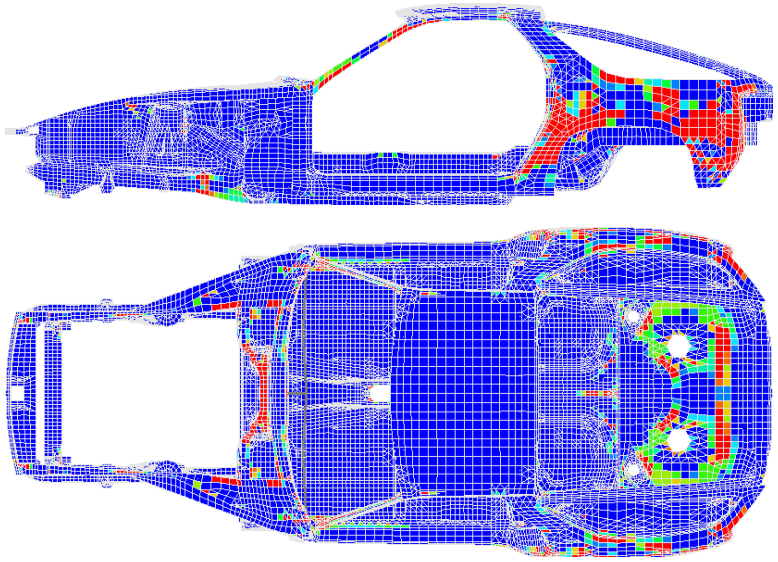
Sizing vs. Topometry

Sizing



+15 kg => 10 HZ Gains

Topometry

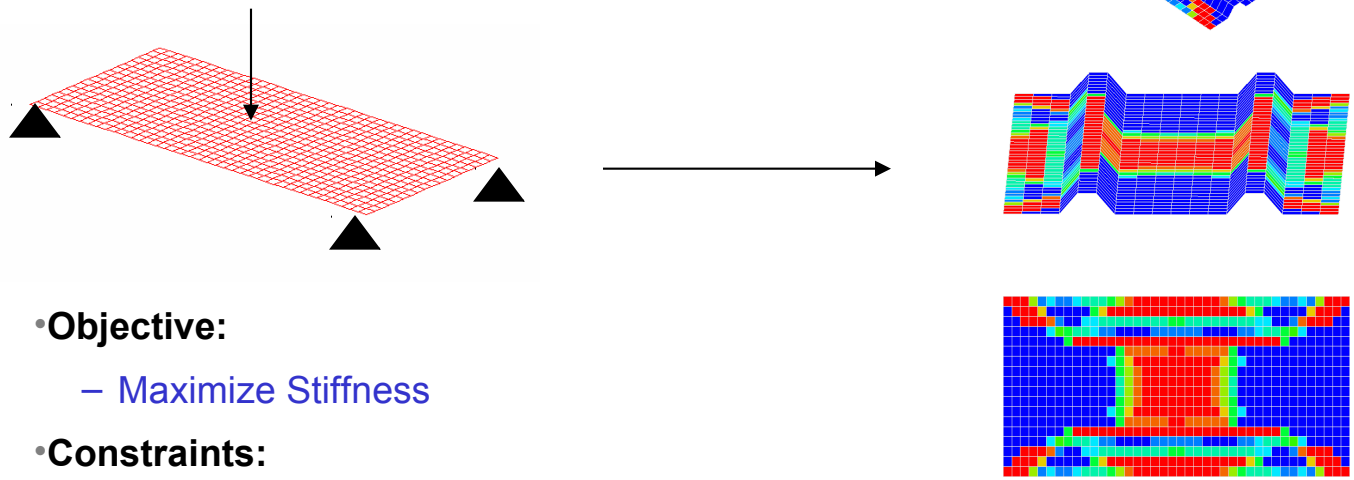


+15 kg => 18 HZ Gains

Topometry helps to set targets and understand limits

Topometry work with Other Types of Optimization

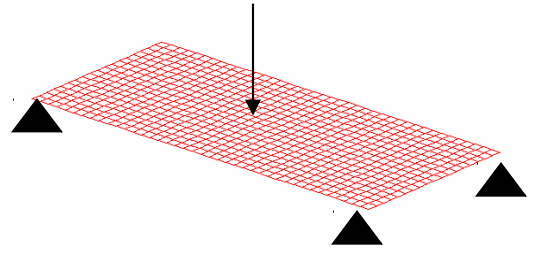
Topometry + Topography

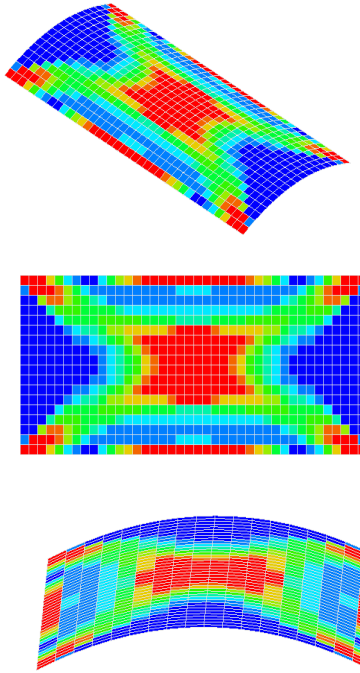


- **Objective:**
  - Maximize Stiffness
- **Constraints:**
  - Volume <=600mm^3
- **Design Variables: 726**
  - 720 Element thickness
  - 6 Topography

Topometry work with Other Types of Optimization

Topometry + Shape

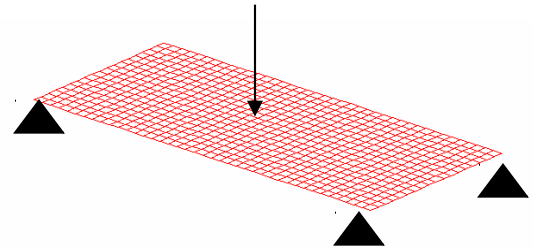


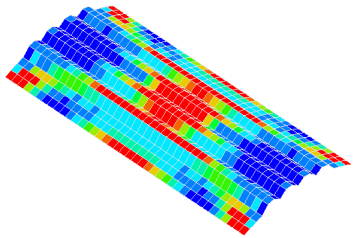


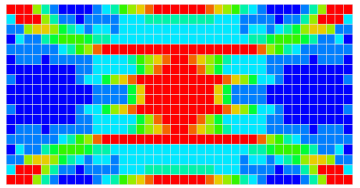
- **Objective:**
  - Maximize Stiffness
- **Constraints:**
  - Volume <=600mm^3
- **Design Variables: 726**
  - 720 Element thickness
  - 1 Shape

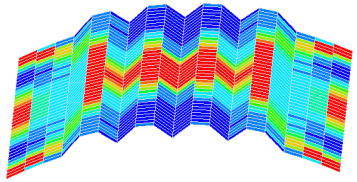
Topometry work with Other Types of Optimization

Topometry + Topography + Shape









- **Objective:**
  - Maximize Stiffness
- **Constraints:**
  - Volume <=600mm^3
- **Design Variables: 726**
  - 720 Element thickness
  - 6 Topography
  - 1 Shape

Genesis: Composite Optimization Tools

Design Variables:

- Thickness
- Angle
- Shape

Objective Function:

- Any response

e.g. reduce mass or cost

Constraint Function:

- Any response

e.g. prevent buckling, Constrain failure indices, displacements, torsional/bending frequencies

Failure Theories Available:

- Hill Theory
- Hoffman Theory
- Tsai-Wu Theory
- Maximum Strain Theory

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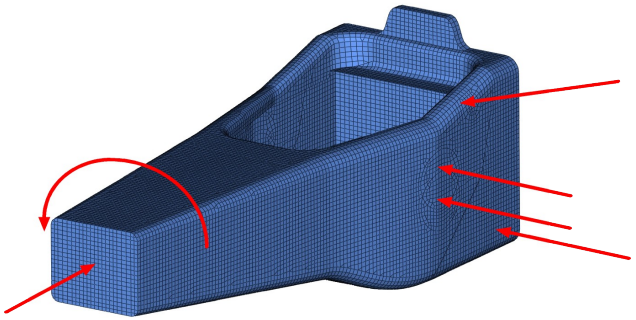
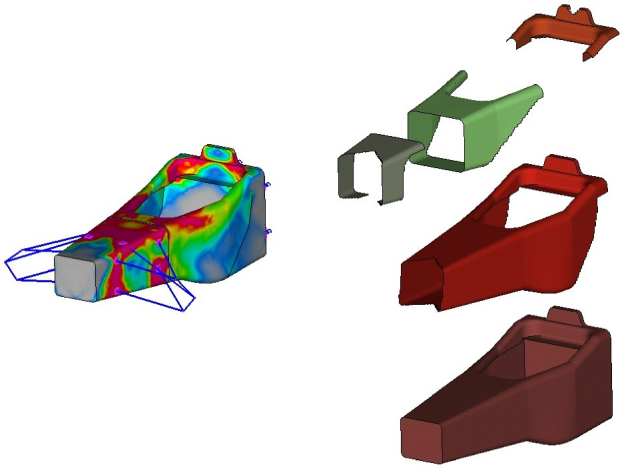
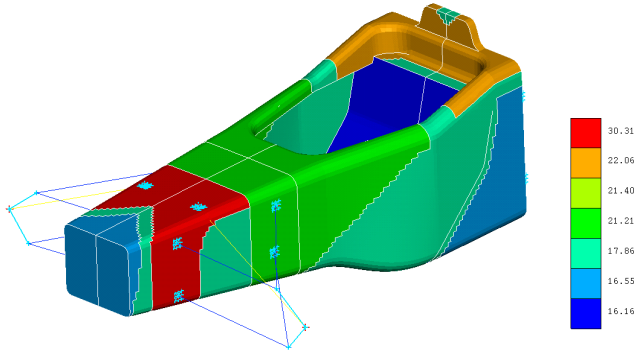
Genesis: Composite Optimization Tools



Loading Conditions



Designable Areas



Designable Areas

Mass reduced by 18%

Courtesy GRM Consulting and P+Z

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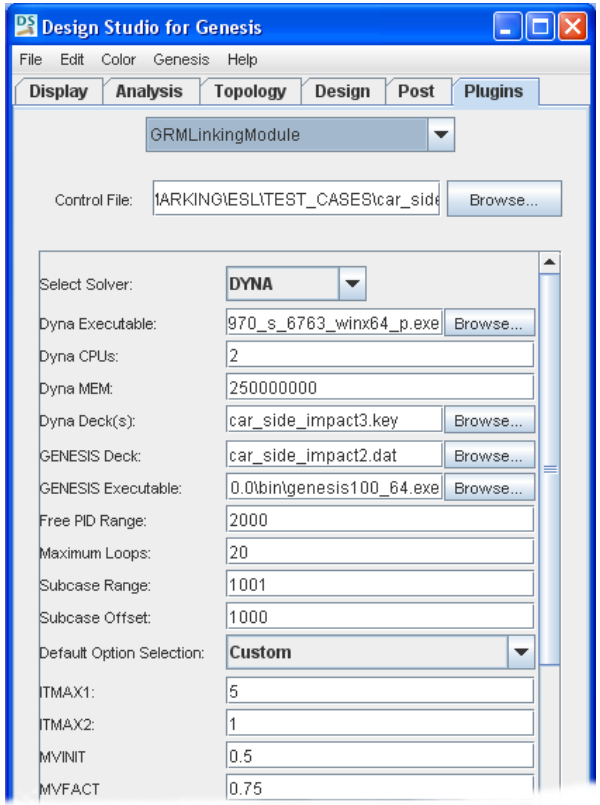
Coupling Genesis and LS-DYNA

VR&D GENESIS < > LS-DYNA Interface

- Implemented as an add-on to Design Studio an interface to LS-DYNA is available for VR&D GENESIS

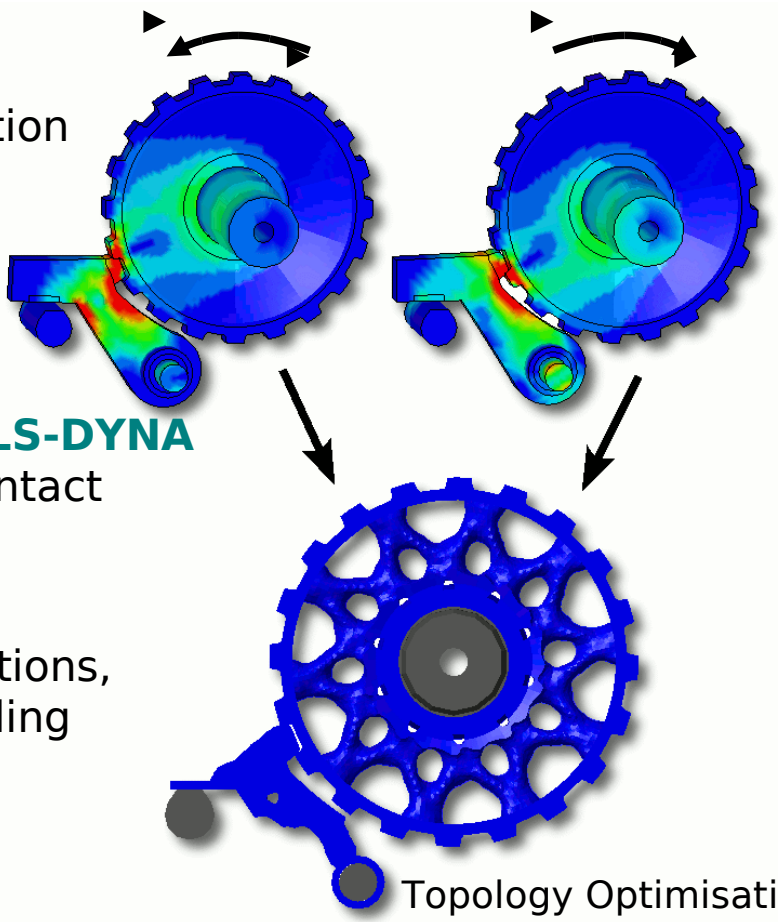
- Interface supports all capabilities of GENESIS optimisation including:
  - Topology
  - Topometry
  - Topography
  - Size & Shape



Coupling Genesis and LS-DYNA

Parking Break Study (two loading directions)

- Topology Optimisation performed to determine optimum material distribution for:
  - Positive gear torque
  - Negative gear torque
- **Optimisation coupled to implicit LS-DYNA** models consider gear and lock-pin contact conditions
- Concept design developed in 39 iterations, optimising for **42,000 variables**, calling **LS-DYNA only 7 times** for each loading direction

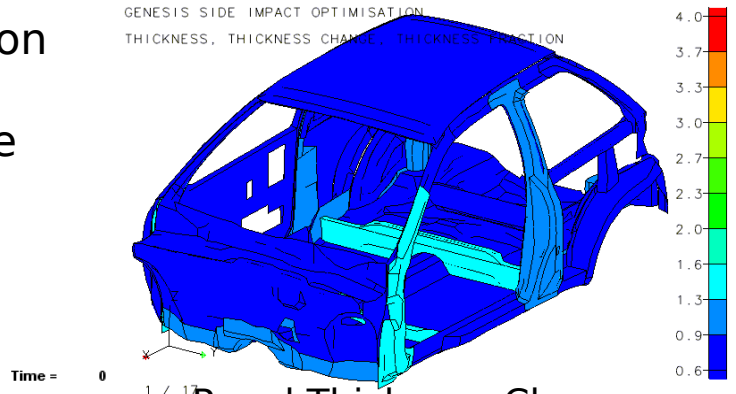


Topology Optimisation Results

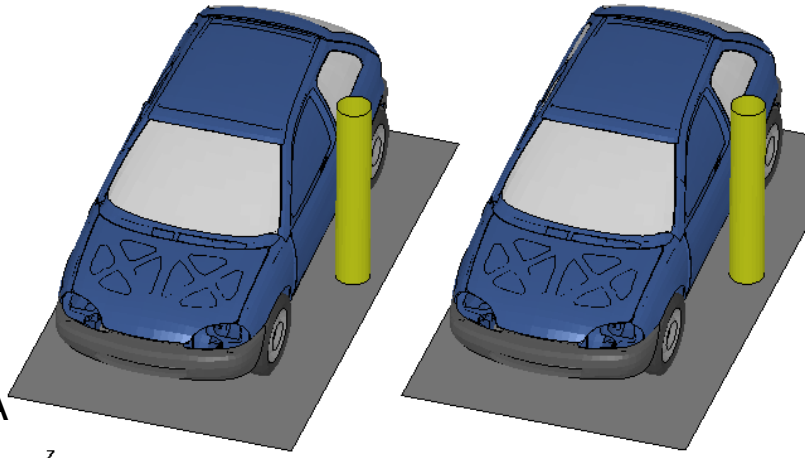
Coupling Genesis and LS-DYNA

Coupled Pole Impact and Static Torsion

- Vehicle BIW panel thickness optimisation performed for both static body torsion (GENESIS/NASTRAN load case) and side pole impact
- Torsional stiffness maintained whilst pole intrusion reduced from 600mm to 300mm.
- Required mass increase only 39kg
- Optimisation considered **59 panel thickness** changes using on **10 function calls to LS-DYNA**
- Method can consider multiple LS-DYNA impacts cases



Panel Thickness Change



Original Optimised

Pole Impact Performance