GENESIS und LS-DYNA

Effiziente Struktur Optimierung für nichtlineare Probleme

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Outline

- **Genesis Overview**

- **Coupling Genesis and LS-DYNA**

- **Coupled Optimisation Examples**

- **Current Status & Future Developments**

Genesis Overview

- Complete linear solver following NASTRAN input format

  - Linear Statics
  - Dynamic Modal & Frequency Response
  - Linear Buckling Analysis
  - Heat Transfer Analysis
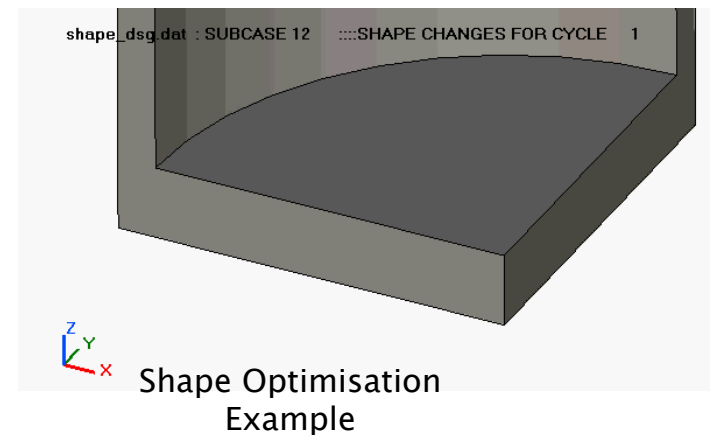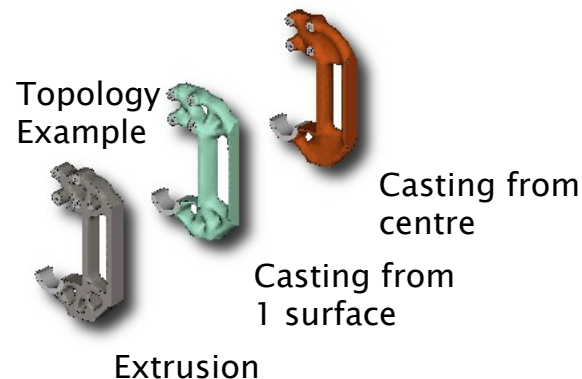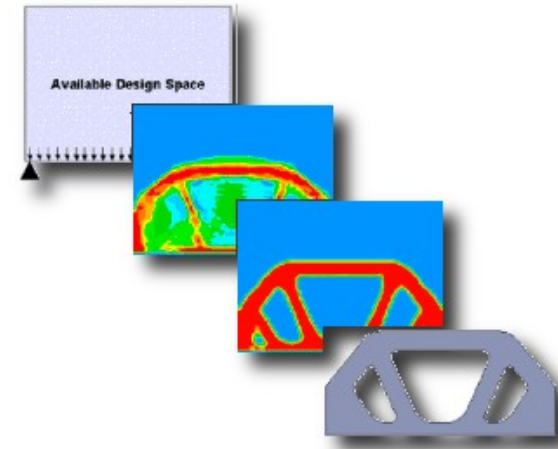 - Sensitivity Analysis

  - Integrated very fast EigenValue Solver (SMS)

  - No non-linear analysis capabilities such as
    - Contact
    - Material non-linearity
    - Pre-loads / Interference fits
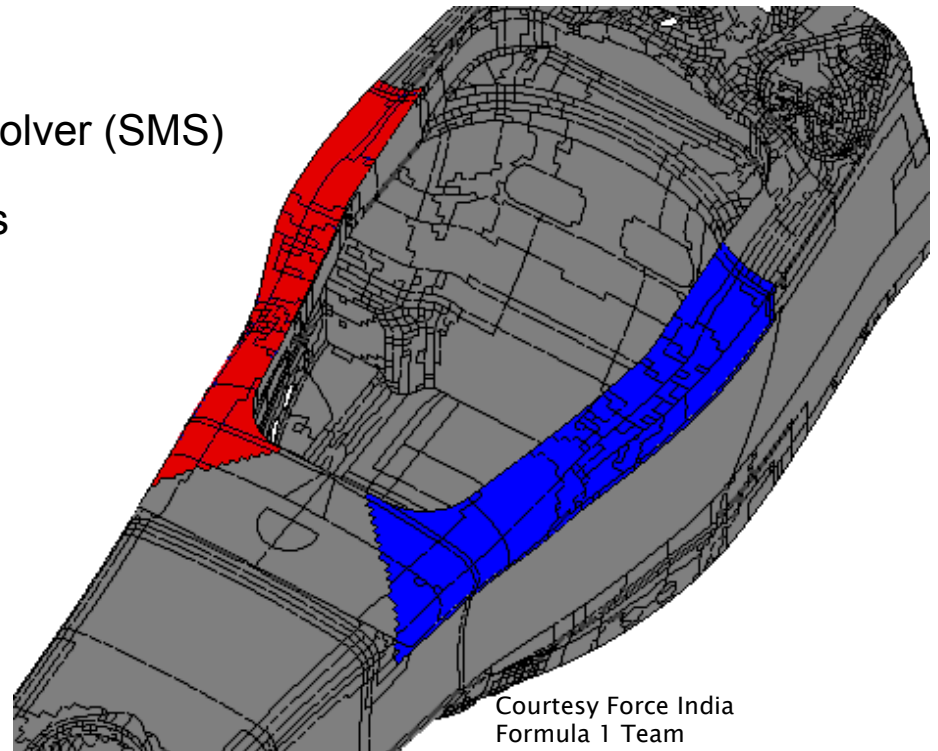
Courtesy Force India
Formula 1 Team

GENESIS Optimisation Capabilities

- GENESIS provides the most complete suite of optimisation capabilities, including:
  - Concept Topology
  - Topography
  - Concept Topometry
  - Size and Shape
  - Discrete Size and Shape
  - Discrete Composite Lay-up for
    orientation and thickness

Available Design Space

Topology Example

Casting from centre

Casting from 1 surface

Extrusion

shape_dsg.dat : SUBCASE 12   ::::SHAPE CHANGES FOR CYCLE   1

Shape Optimisation Example

Genesis Limitations

Application of Genesis is limited due to applied methodology in topology optimization.
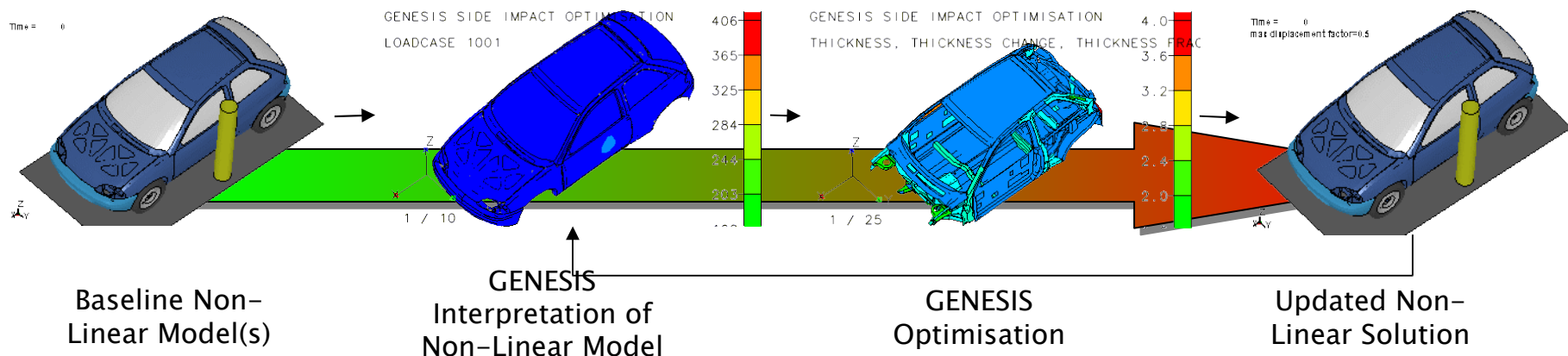
Limited to:

- to linear structural analysis
- limited to a few dynamical aspects (Modal & Frequency Response)
- optimization of arbitrary dynamic problems is not supported

Typical use case topology optimization:

Initial Design

Final Design

Coupling Optimisation Methodology
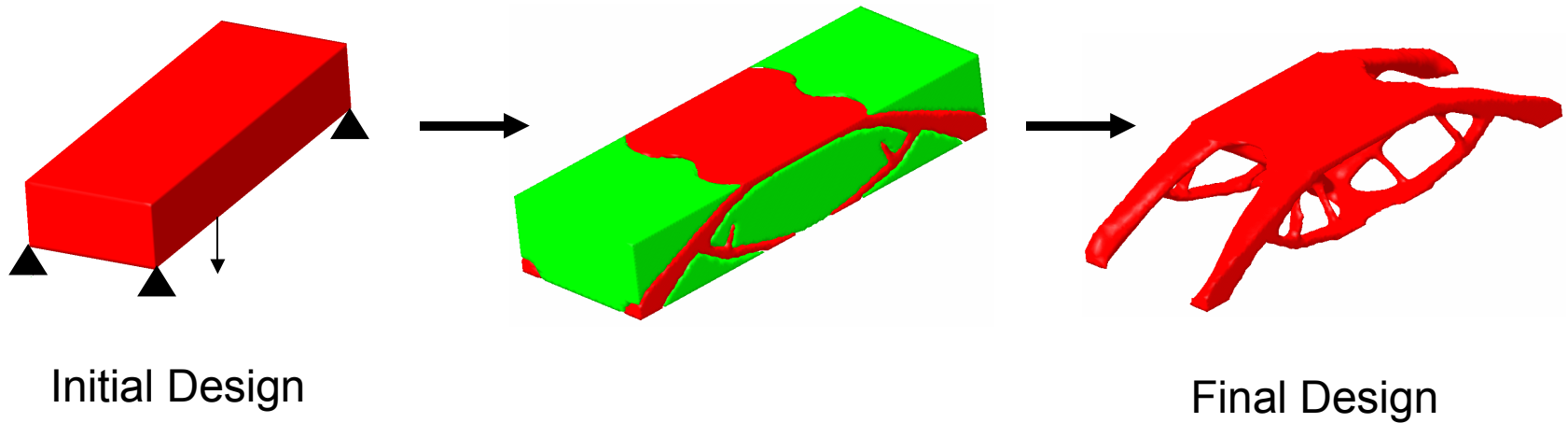
- Method developed to provide non-linear loading in GENESIS optimisation studies

- Approach allows GENESIS to optimise considering for non-linear loading

- No requirement for non-linear analysis to determine design sensitivities

Baseline Non-Linear Model(s) → GENESIS Interpretation of Non-Linear Model → GENESIS Optimisation → Updated Non-Linear Solution

Interface Development

- Interface developed as additional module to GENESIS Pre/Post-Processor environment, Design Studio

- Intended to simplify process to remove user interaction by automatically updating and submitting LS-DYNA and GENESIS solves

- Automatic management of GENESIS and LS-DYNA solvers

- Remote Submission of Coupled Optimisation using SSH protocol

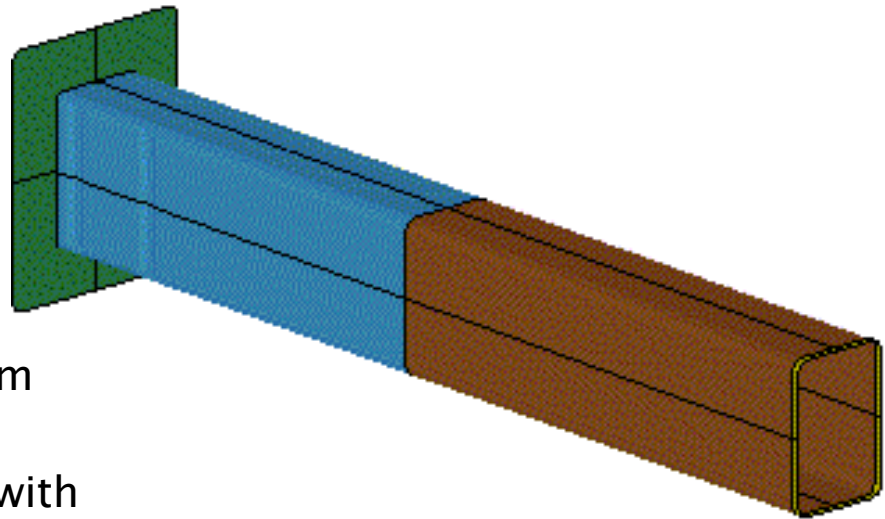- Provides automatically updated objective / constraint plotting and live progress reporting
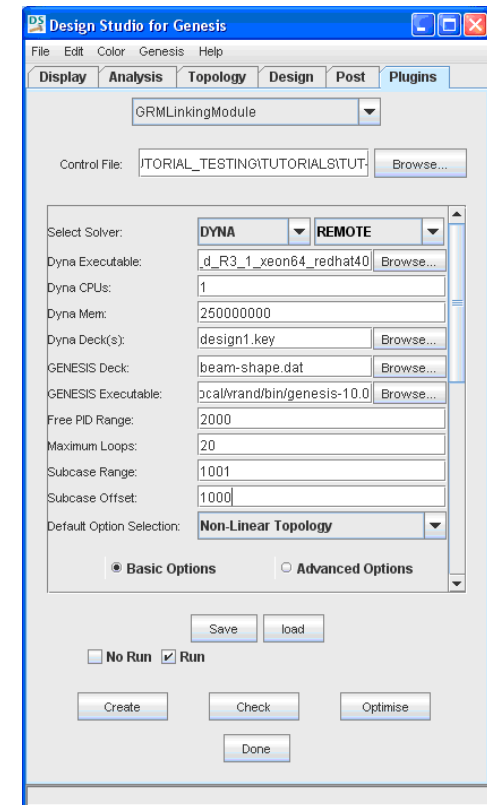
Design Studio LS–DYNA interface

Loading

– Tube Crush

Design Problem

– Objective = Minimise Mass

– Constraint = 600mm Maximum Displacement of loading plate

– Variables = Optimisation run with various design variables
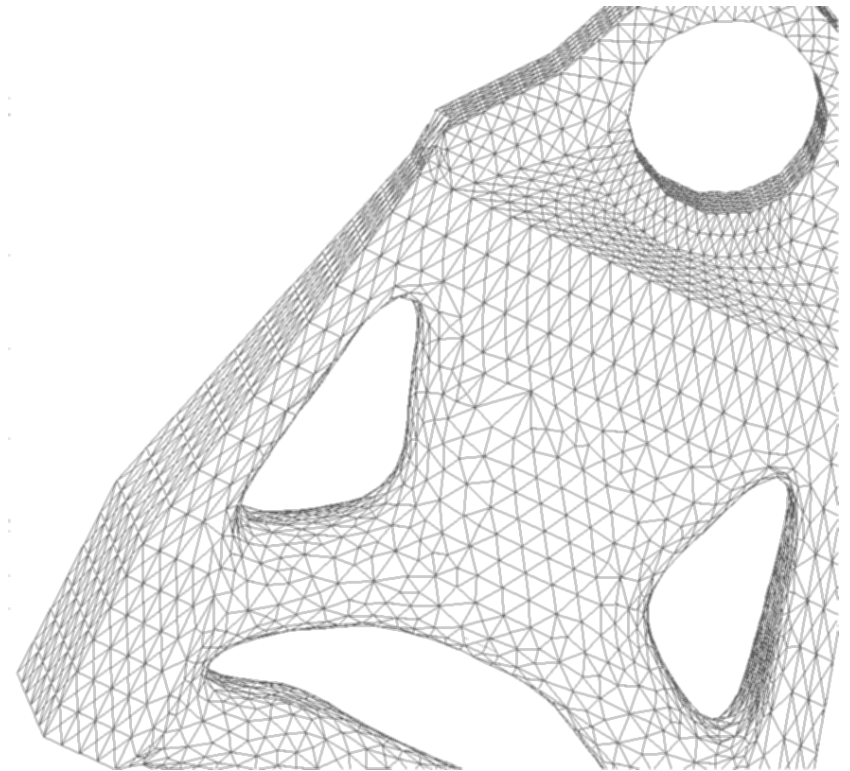
Objective

– To investigate link between the number of design variables and function calls

Benefits of Coupling

- Internal sensitivity calculations break the link between the number of design variables and analysis calls

- Allows multiple non-linear and linear load cases to be considered in one optimization

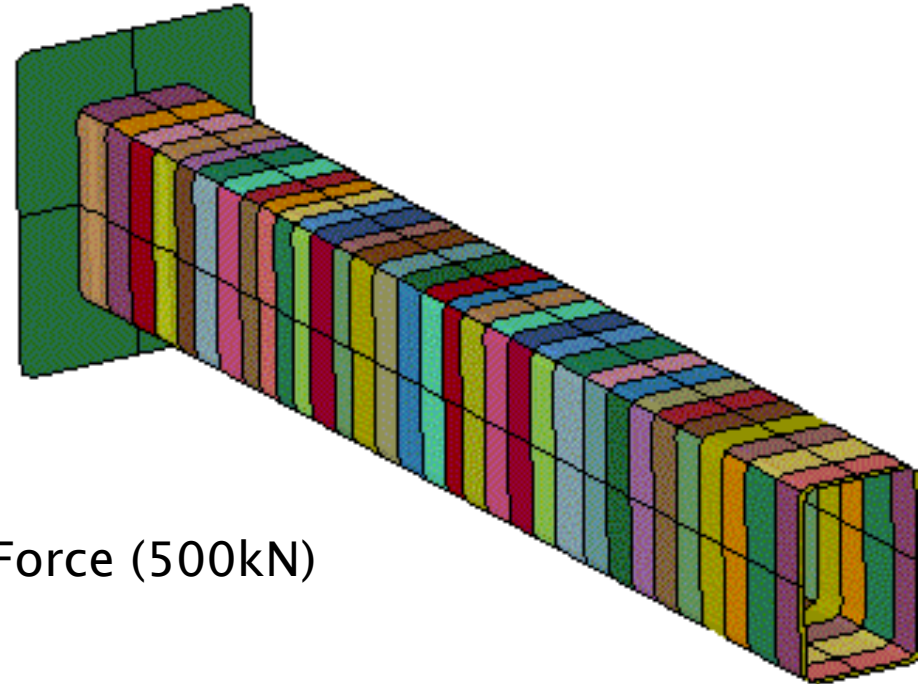- Provides a quick route to the 'optimum' answer, without fully interrogating design space
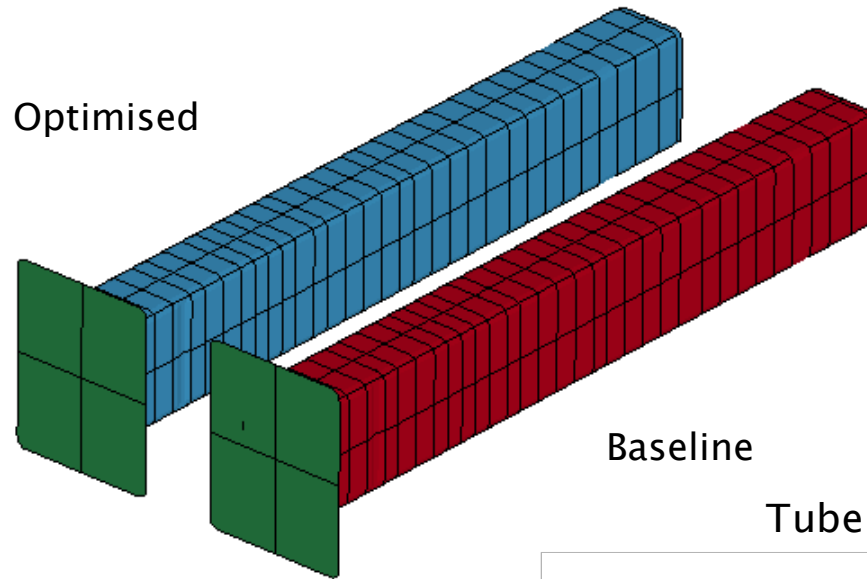
Coupled Optimisation Examples

Longitudinal Crush Force Optimisation
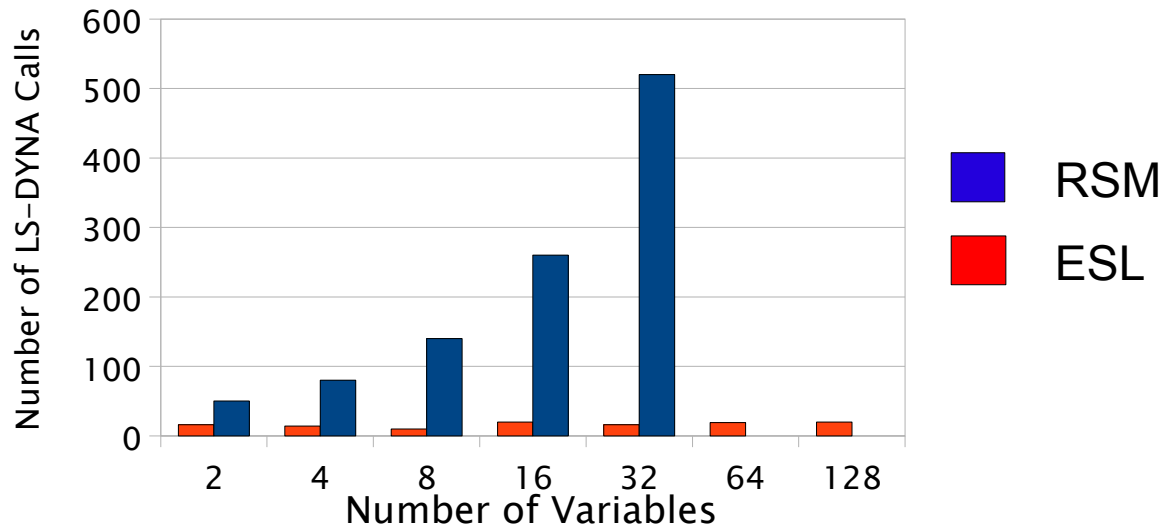

Loading

- Axial crash impact on tube

Design Problem

- Objective = Minimise Intrusion
- Constraint = Maximum Reaction Force (500kN)
- Variables = 64 Sizing Variables

Longitudinal Crush Force Optimisation

Optimised

Baseline

Solution

- Intrusion decrease = 43.2%
- Mass change = 0.2%
- 99 GENESIS iterations
- **34 LS−DYNA simulations**

Tube Crush Force

- Optimised
- Baseline

# Longitudinal Crush Force Optimisation
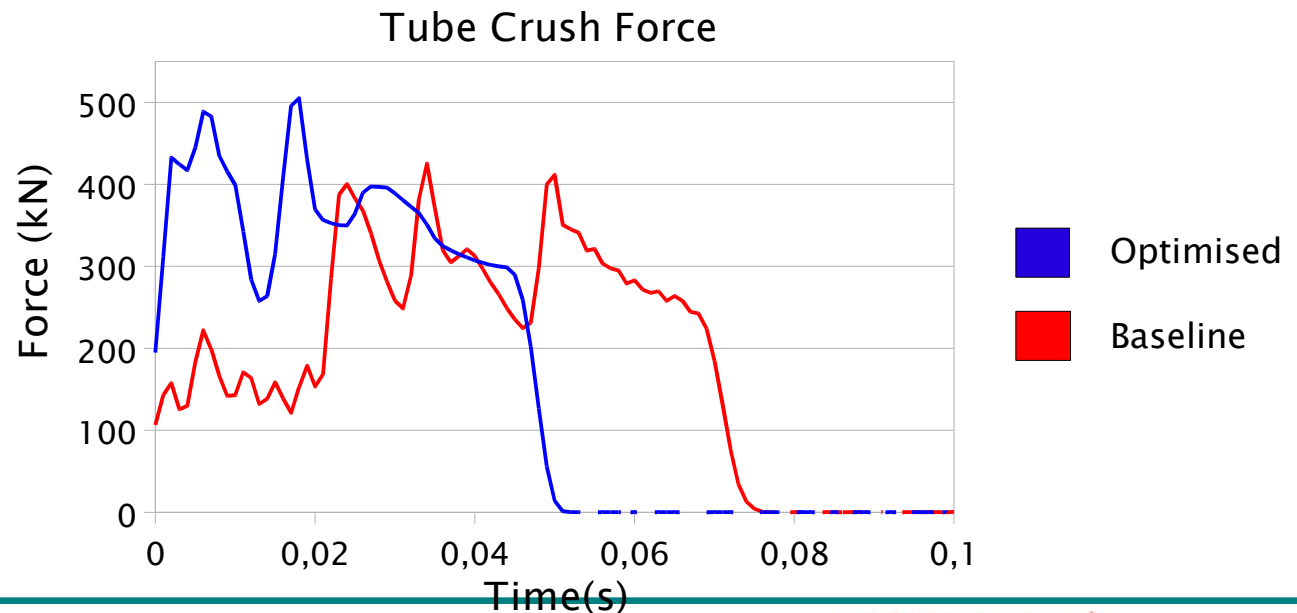
- To be able to optimize for force it is necessary to calculate this in the linear solver, the coupling code takes care of this

- Force/acceleration method is working as can be seen by this example, but further work is still required to improve the robustness of the solution

- It is necessary to have high frequency output to be able to optimize for force, which results in large quantities of data, this is a key area of improvement

Ford Taurus Front Impact

Loading

- Two loading conditions
  - LS–DYNA FFB impact
  - GENESIS BIW Modal Assessment

Design Problem

- Objective = Minimise BIW Mass
- Constraint =
  - 100mm Intrusion of bulkhead at transmission tunnel
  - First torsion mode of BIW
- Variables = 205 Sizing designable elements (symmetry constraint applied)
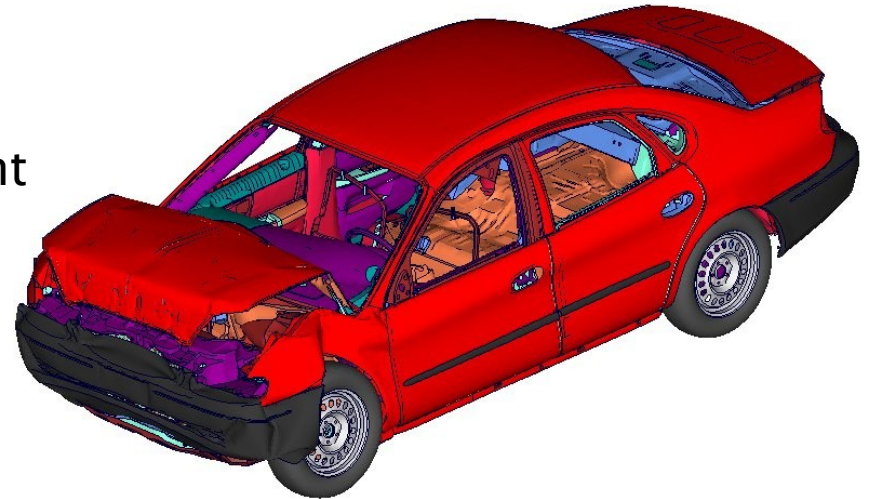
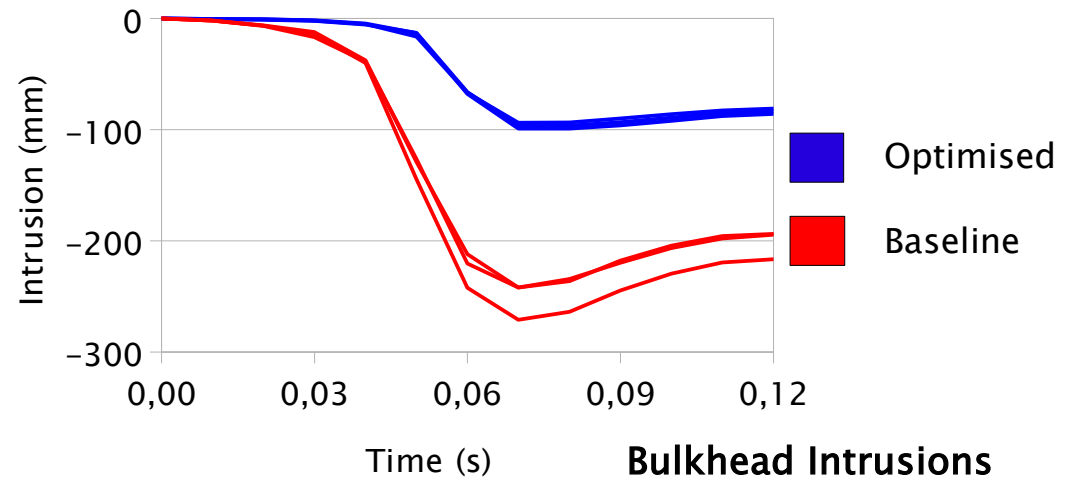# Ford Taurus Front Impact

Solution

- Bulkhead intrusions reduced from ~250mm to 100mm

- Torsion mode increased from 20.3Hz to 25.9Hz

- BIW mass increase = 4.6%

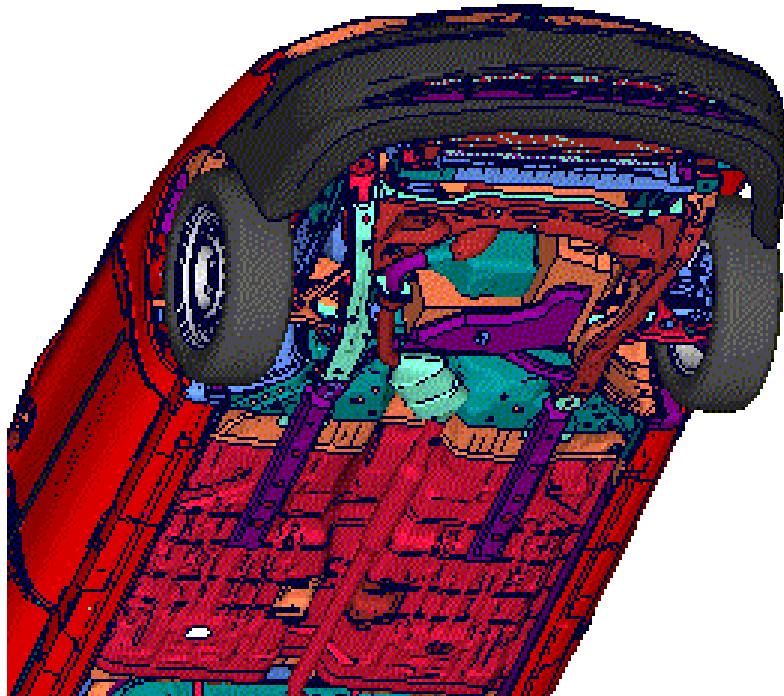- LS-DYNA simulations = 22
- GENESIS iterations = 32

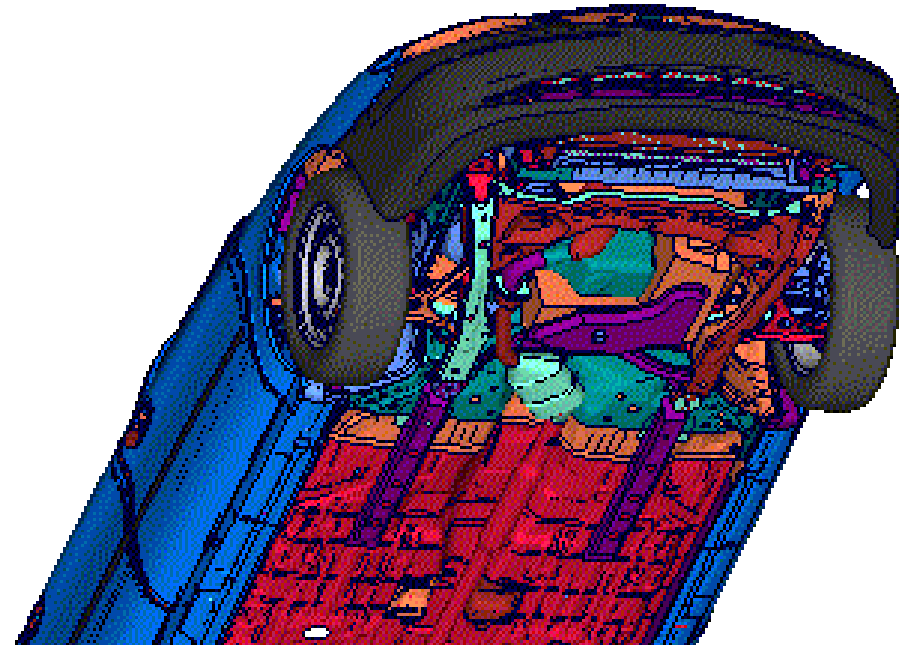THICKNESS, THICKNESS CHANGE, THICKNESS FRACTION

Design History

Intrusion (mm) vs Time (s)

Optimised (blue)
Baseline (red)
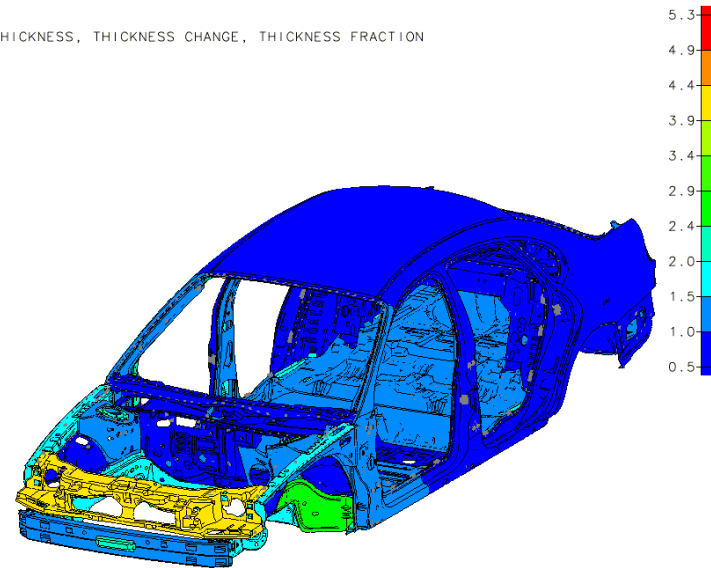
Bulkhead Intrusions

Taurus Front Impact


Baseline

Optimised

Ford Taurus Front Impact

- Bulkhead intrusion and modal constraint have been met

- Optimization solution does not consider accelerations, which have increased. Accelerations could be considered, as seen from previous example

- Additional loading conditions could be considered. Including the following:
  - Rear impact
  - Side impact
  - Further modal/static stiffness requirements

- This example shows how the method can be applied to examples such as vehicle crash

FSI Coupled Optimisation

Loading

- One loading condition
  - LS–DYNA Underwater explosion

Design Problem

- Objective: Minimize Structure Mass
- Constraint: Relative deck heights
- Variables: 290 Sizing designable elements
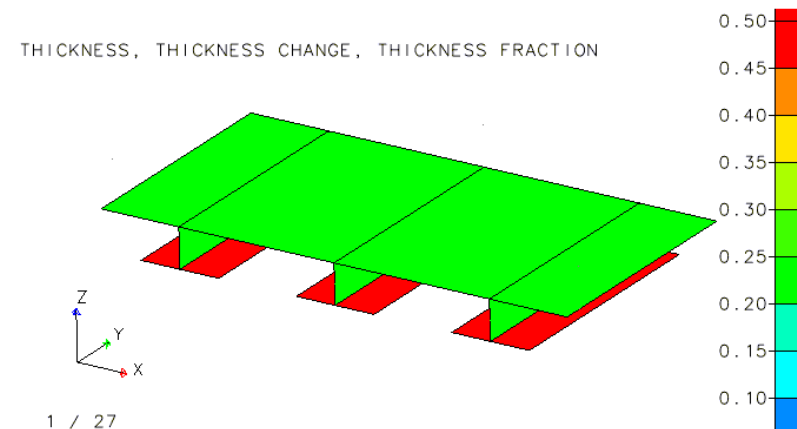
FSI Coupled Optimisation
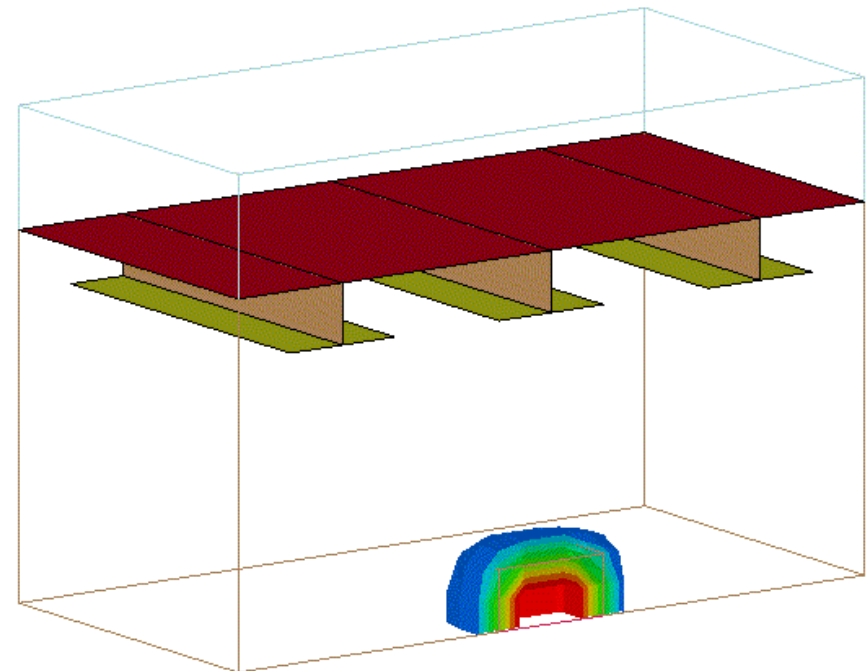
- Relative deck optimized from ~6.2mm to <5mm

- Extrusion constraint applied to design variables. This reduces the independent variables from 290 to 26

5mm
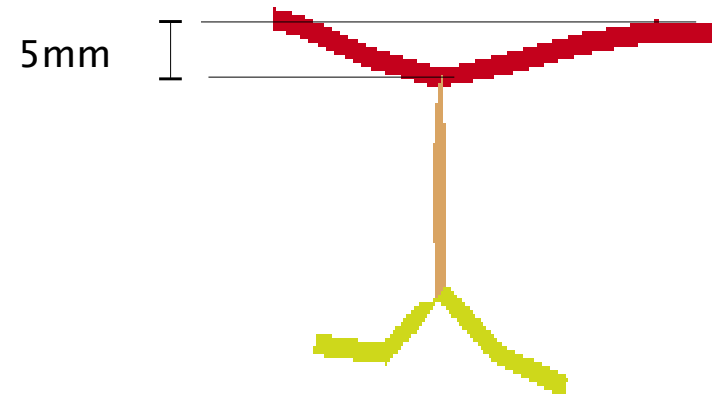
Constraint Definition

Solution

- Mass increase 15.5%
- 26 GENESIS iterations
- **20 LS-DYNA simulations**

THICKNESS, THICKNESS CHANGE, THICKNESS FRACTION

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Iteration Material Thickness

FSI Coupled Optimisation

- Moving structure is optimized using GENESIS, special consideration has be given to boundary conditions in GENESIS

- This example shows a non-automotive problem, and illustrates the capabilities of the coupling

- The coupling can be employed in any problem where structural displacements are occurring. These can be the result of any of the advanced methods in LS-DYNA

Current Status & Future Developments (Sizing Optimisation)
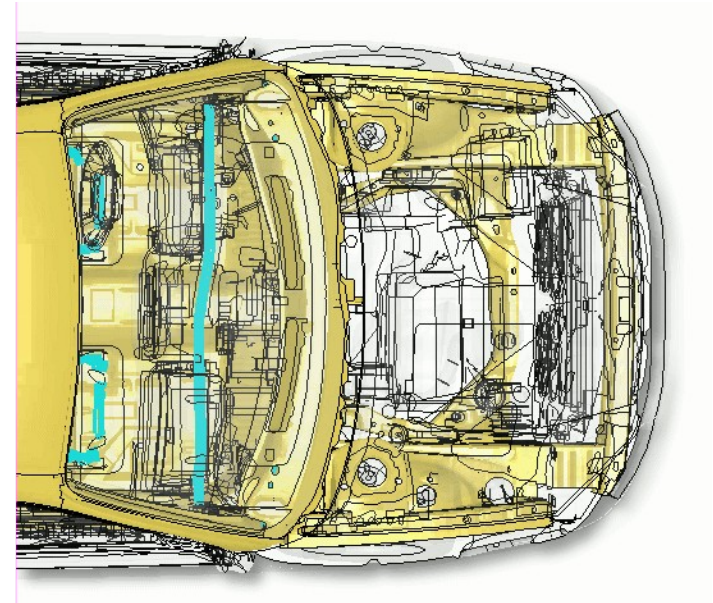
Current Capabilities

- Sizing / Shape / Topometry / Topography functionality

- Intrusion constraints

- Force constraints (Large scale solution still under development)
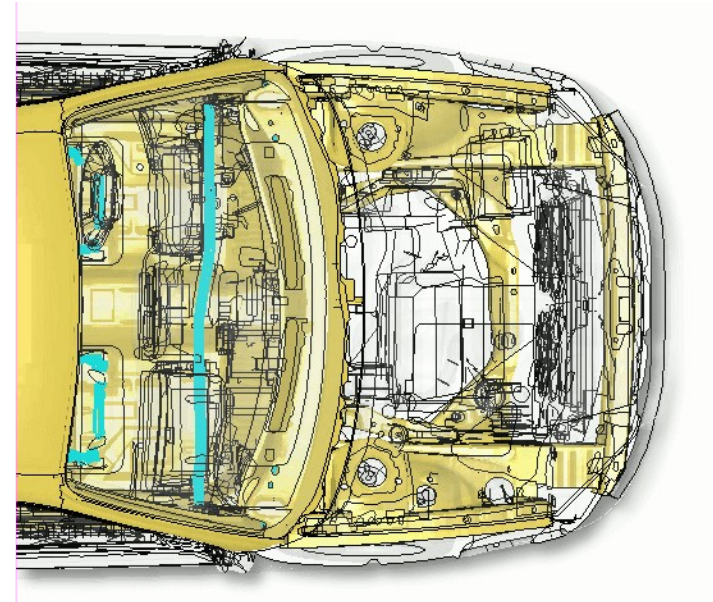
Current Status & Future Developments (Sizing Optimisation)
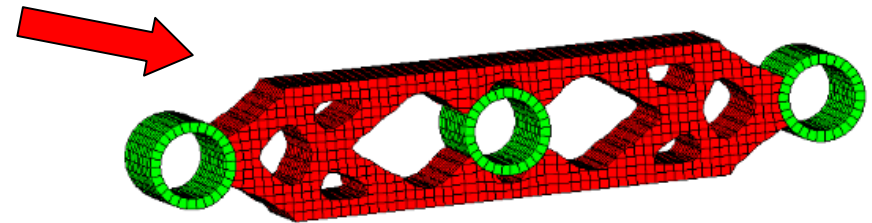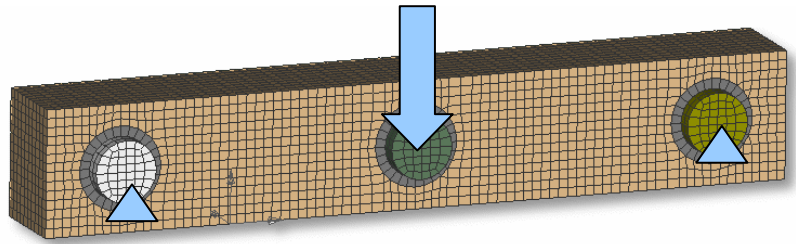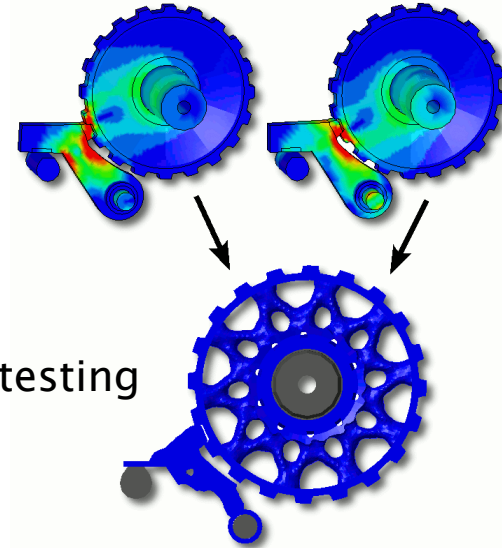
Future Developments

- Support of plastic strain constraints

- High fidelity (1ms) Velocity/Acceleration/Force constraints

Current Status & Future Developments
(Topology Optimisation)

Current Capabilities

- Robust implicit (quasi–static) optimisation with
  - Contact
  - Minor plastic strains

- Explicit crash optimisation
  - Solution developed recently, still undergoing extensive testing

Future Developments

- Robust crash Topology optimisation

- Further development of problem formulations

- Further improvement to reduce number of LS–DYNA calls

TOPOLOGY DESIGN ELEMENT DENSITY, DESIGN CYCLE NUMBER =

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