

GENESIS und LS-DYNA

Effiziente Struktur Optimierung für nichtlineare Probleme

Heiner Müllerschön, Martin Liebscher

DYNAmore GmbH

David Salway

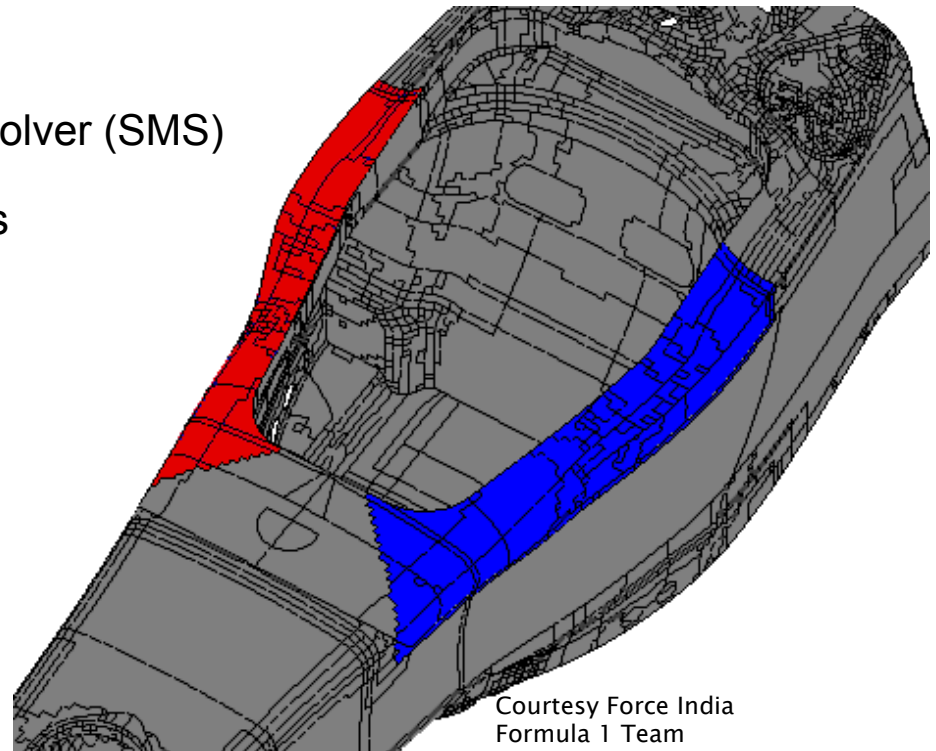
GRM Consulting Ltd.

- **Genesis Overview**
- **Coupling Genesis and LS-DYNA**
- **Coupled Optimisation Examples**
- **Current Status & Future Developments**

- Complete linear solver following NASTRAN input format
 - Linear Statics
 - Dynamic Modal & Frequency Response
 - Linear Buckling Analysis
 - Heat Transfer Analysis
 - Sensitivity Analysis

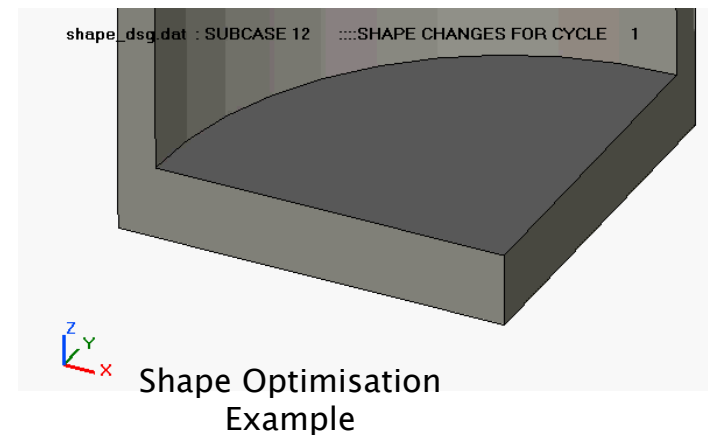
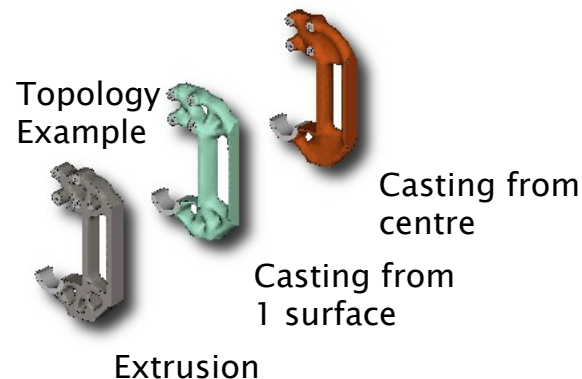
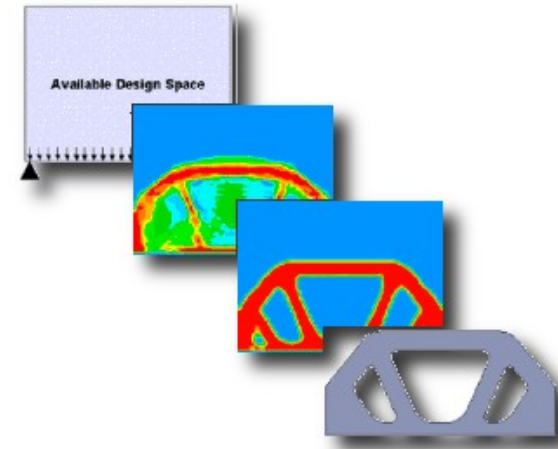
 - Integrated very fast EigenValue Solver (SMS)

 - No non-linear analysis capabilities such as
 - Contact
 - Material non-linearity
 - Pre-loads / Interference fits



Courtesy Force India
Formula 1 Team

- GENESIS 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

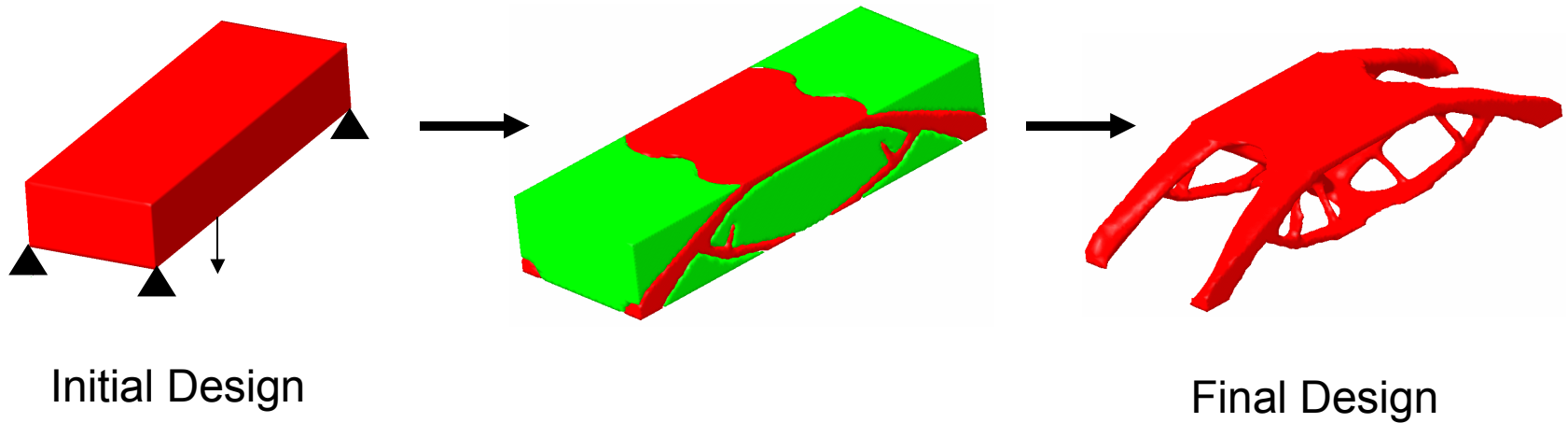


Application of Genesis is limited due to applied methodology in topology optimization.

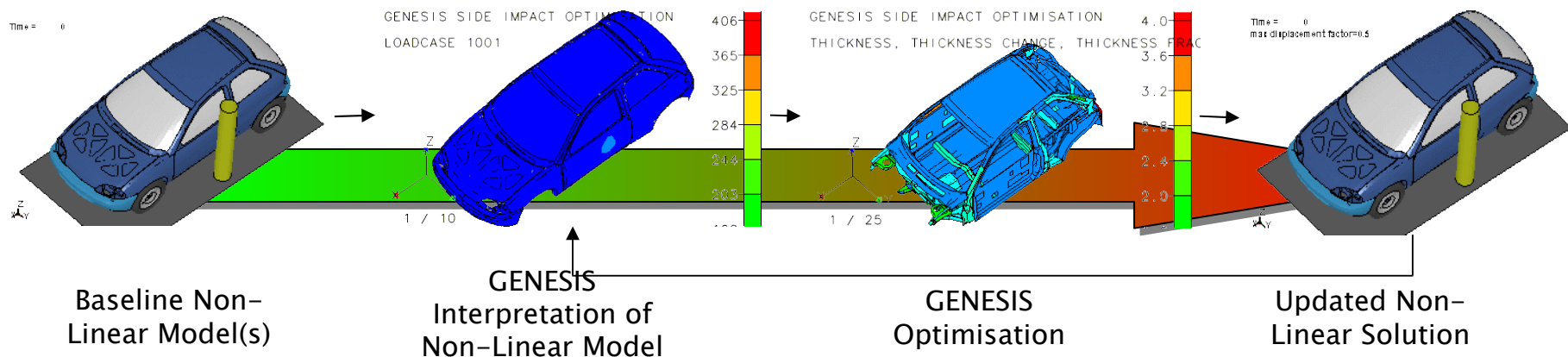
Limited to:

- 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:

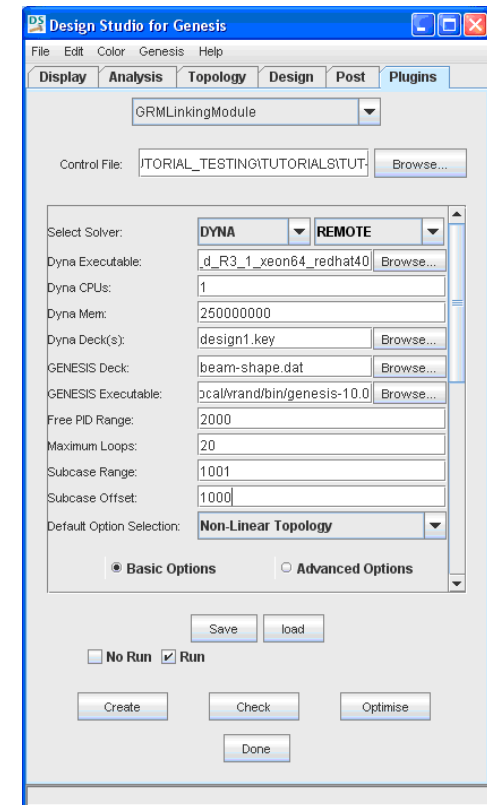


- Method developed to provide non-linear loading in GENESIS optimisation studies
- Approach allows GENESIS to optimise considering for non-linear loading
- No requirement for non-linear analysis to determine design sensitivities



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 solves
- Remote Submission of Coupled Optimisation using SSH protocol
- Provides automatically updated objective / constraint plotting and live progress reporting



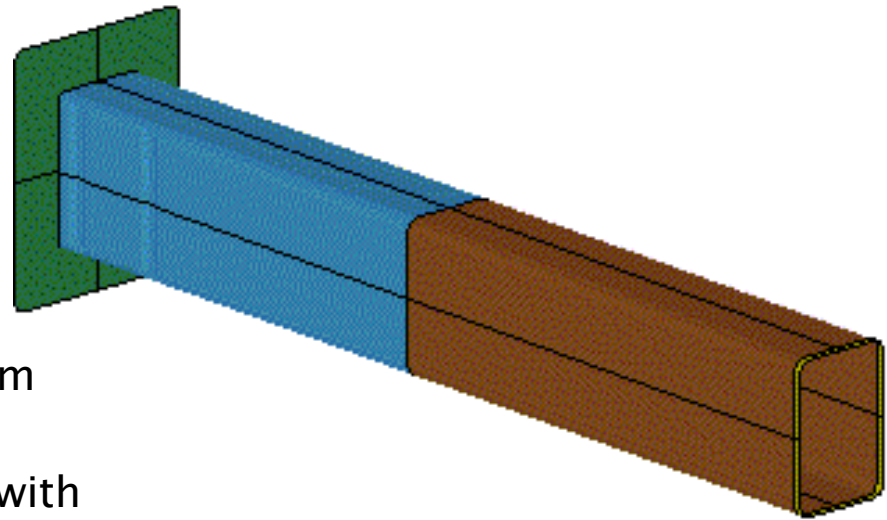
Design Studio LS-DYNA interface

Loading

- Tube Crush
-

Design Problem

- Objective = Minimise Mass
- Constraint = 600mm Maximum Displacement of loading plate
- Variables = Optimisation run with various design variables

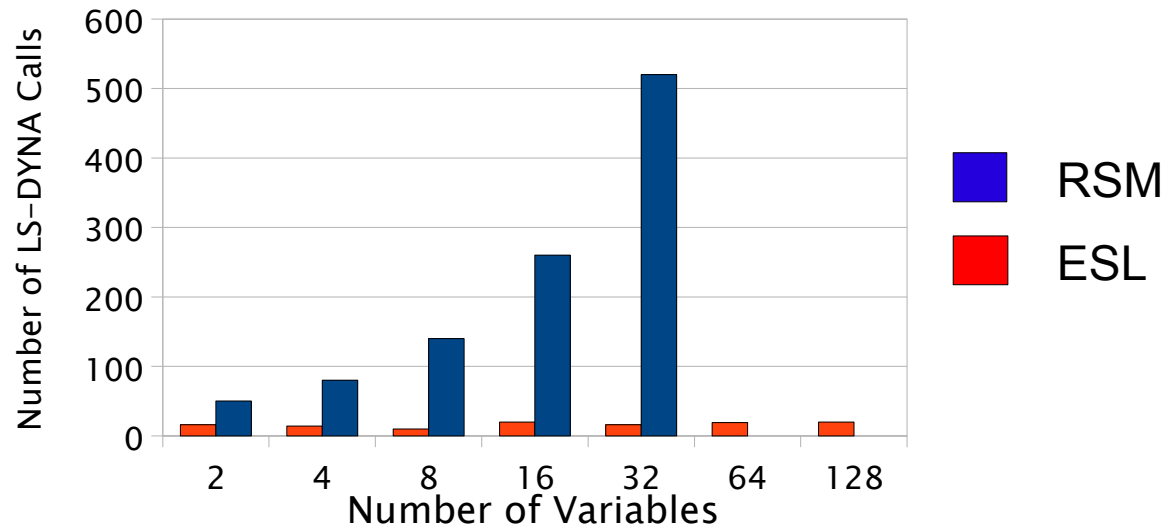


Objective

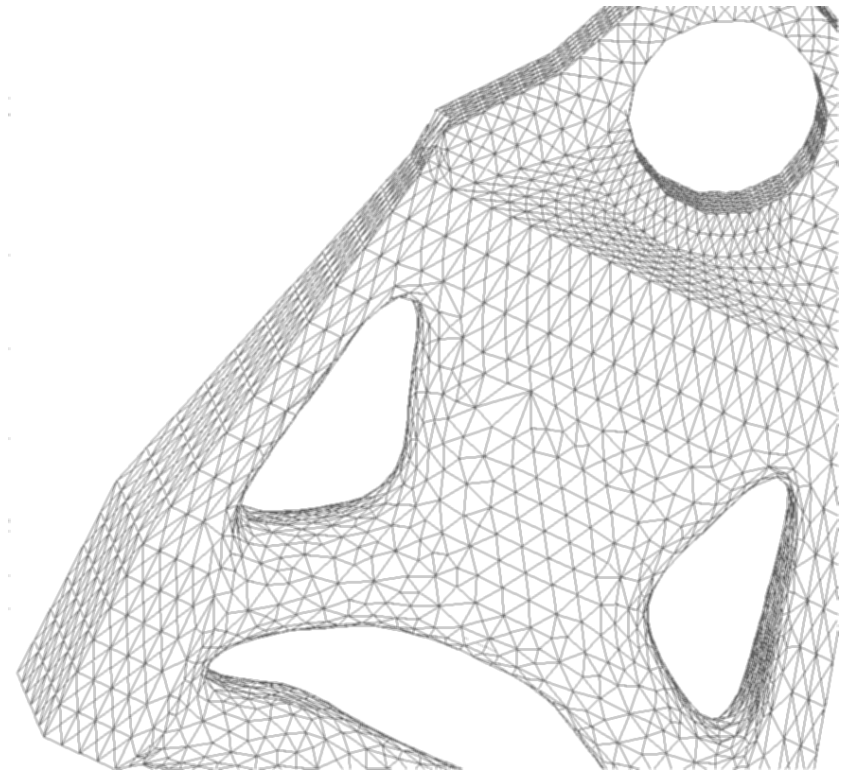
- To investigate link between the number of design variables and function calls

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

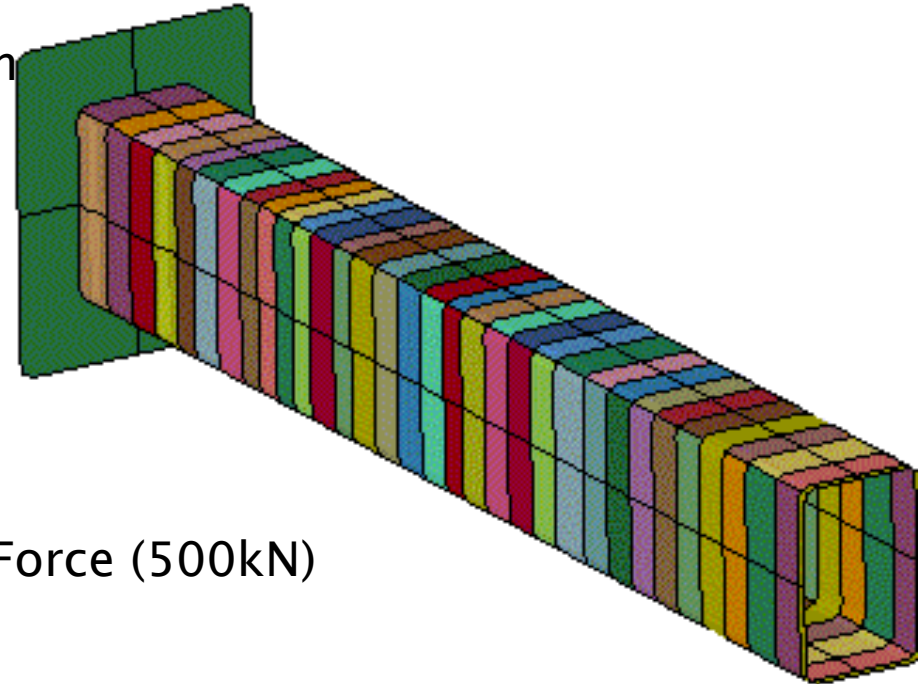


Coupled Optimisation Examples



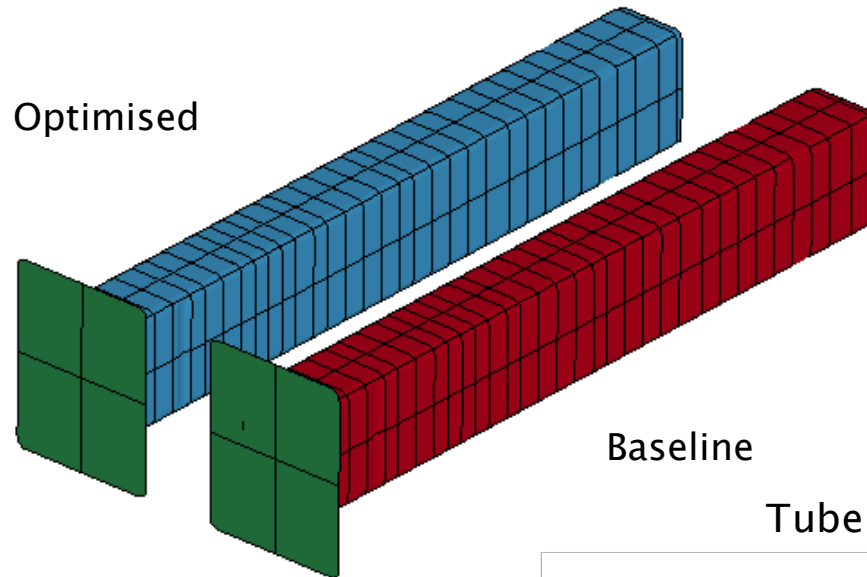
Loading

- One loading condition Tube Crush



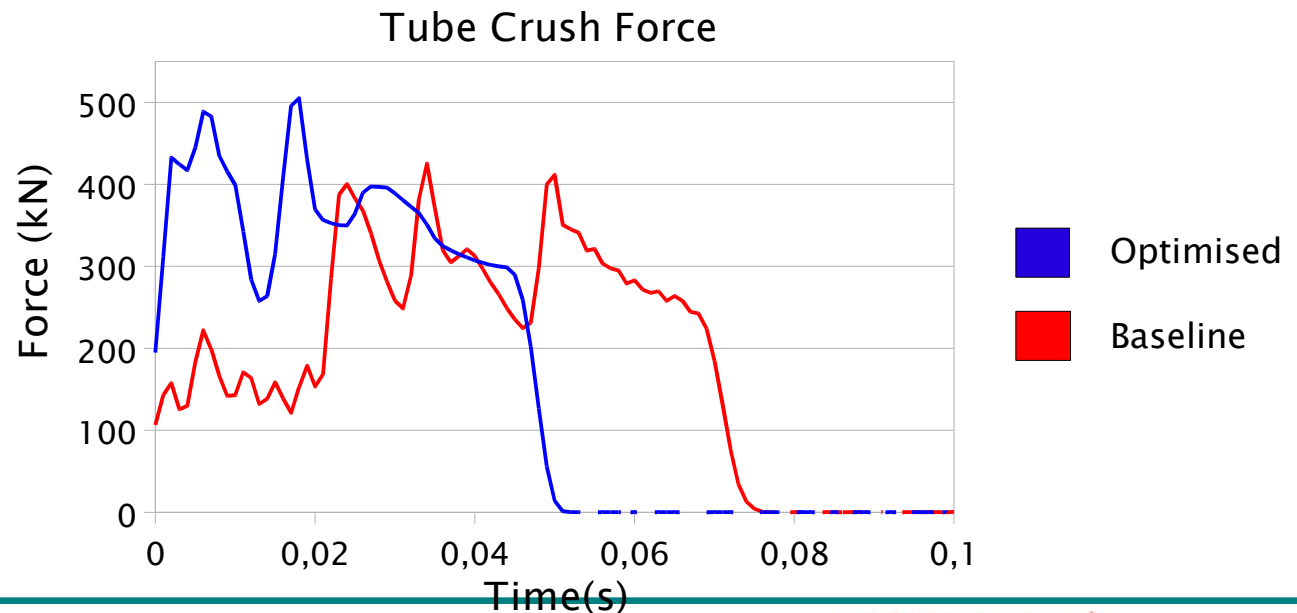
Design Problem

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



Solution

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



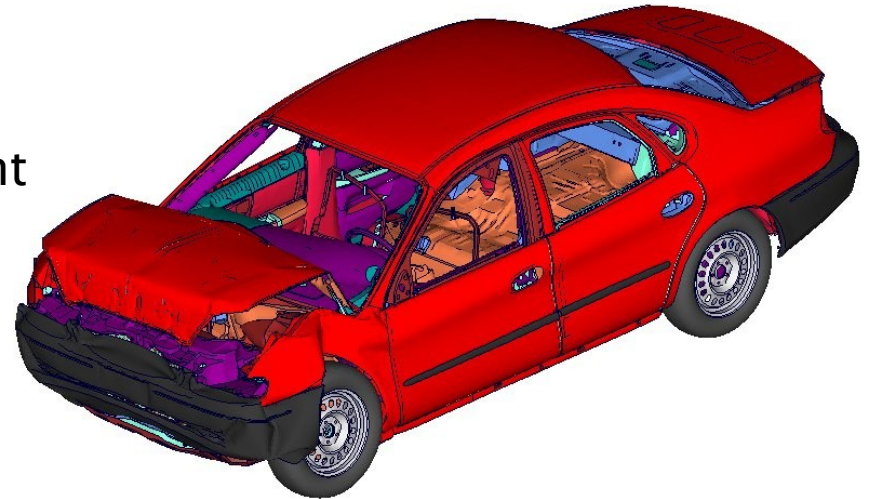
- To be able to optimize for force it is necessary to calculate this in the linear solver, the coupling code takes care of this
- Force/acceleration method is working as can be seen by this example, but further work is still required to improve the robustness of the solution
- It is necessary to have high frequency output to be able to optimize for force, which results in large quantities of data, this is a key area of improvement

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)

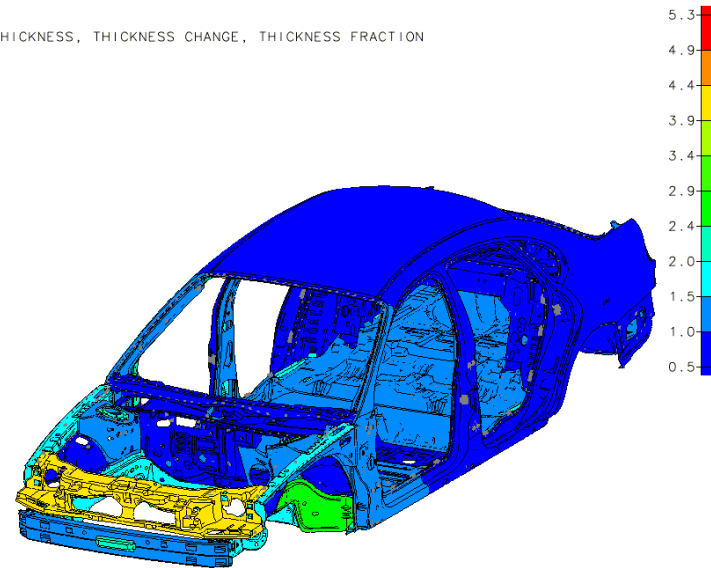


Ford Taurus Front Impact

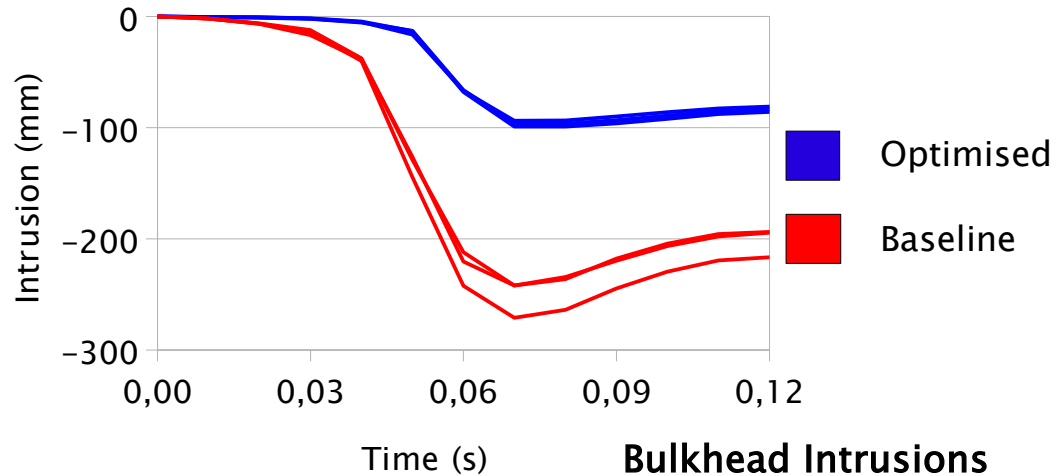
Solution

- 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

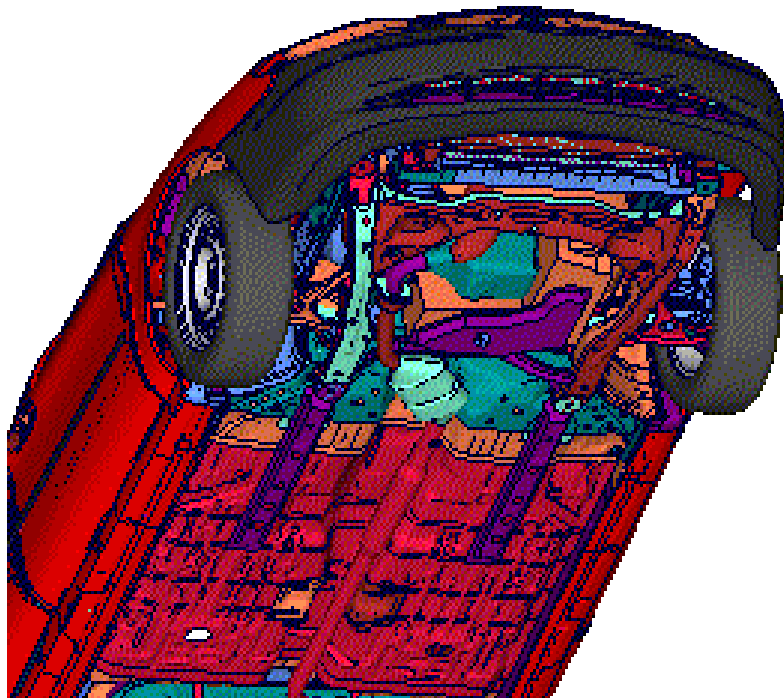
THICKNESS, THICKNESS CHANGE, THICKNESS FRACTION



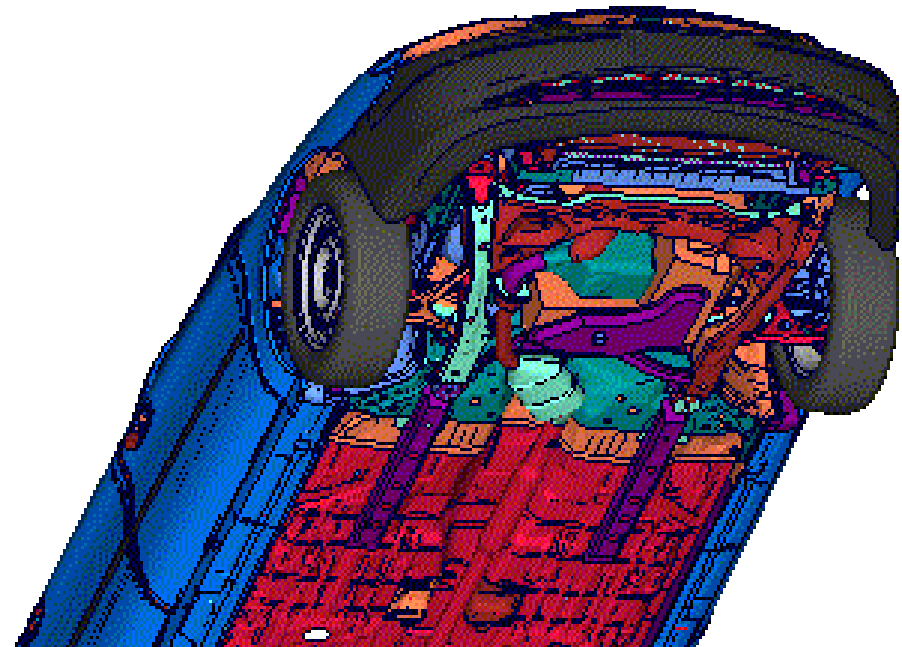
Design History



Taurus Front Impact



Baseline



Optimised

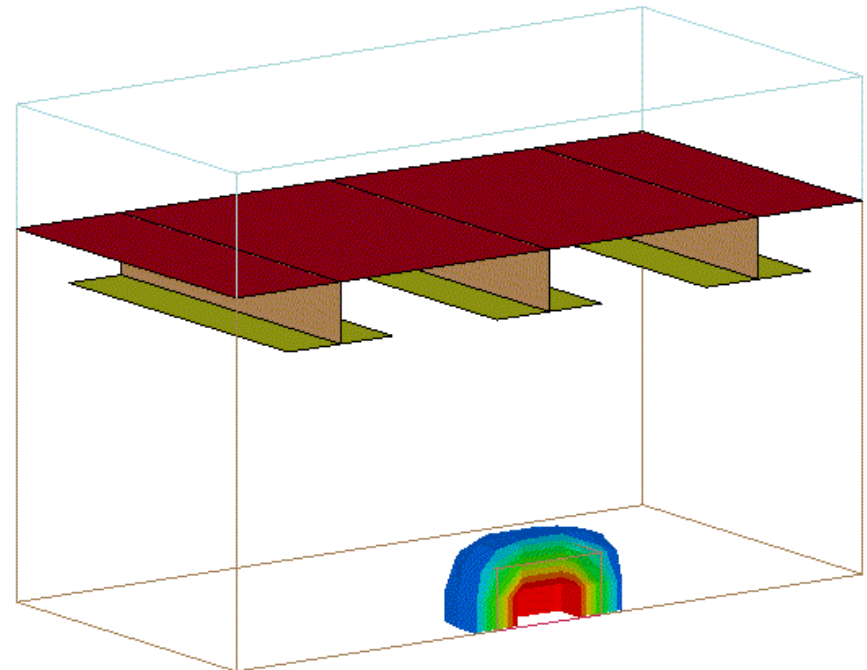
- Bulkhead intrusion and modal constraint have been met
- Optimization solution does not consider accelerations, which have increased. Accelerations could be considered, as seen from previous example
- Additional loading conditions could be considered. Including the following:
 - Rear impact
 - Side impact
 - Further modal/static stiffness requirements
- This example shows how the method can be applied to examples such as vehicle crash

Loading

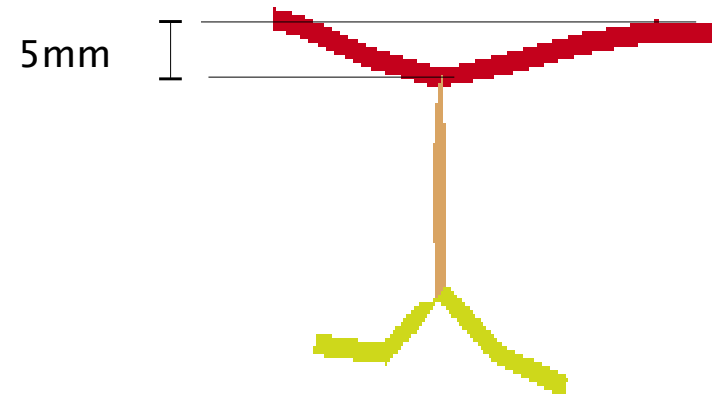
- One loading condition
 - LS-DYNA Underwater explosion

Design Problem

- Objective: Minimize Structure Mass
- Constraint: Relative deck heights
- Variables: 290 Sizing designable elements



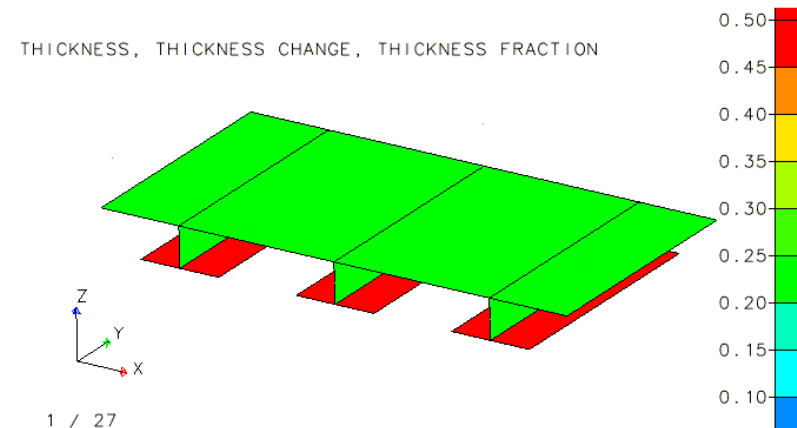
- Relative deck optimized from ~6.2mm to <5mm
- Extrusion constraint applied to design variables. This reduces the independent variables from 290 to 26



Constraint Definition

Solution

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



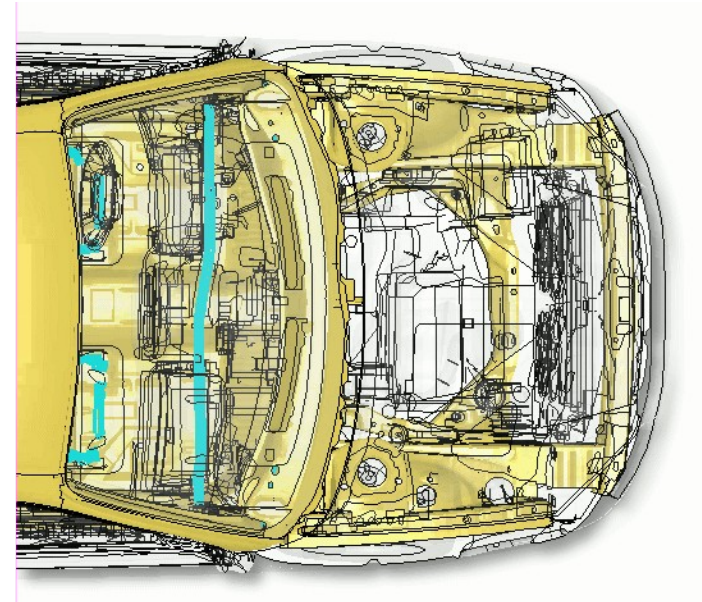
Iteration Material Thickness

- 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

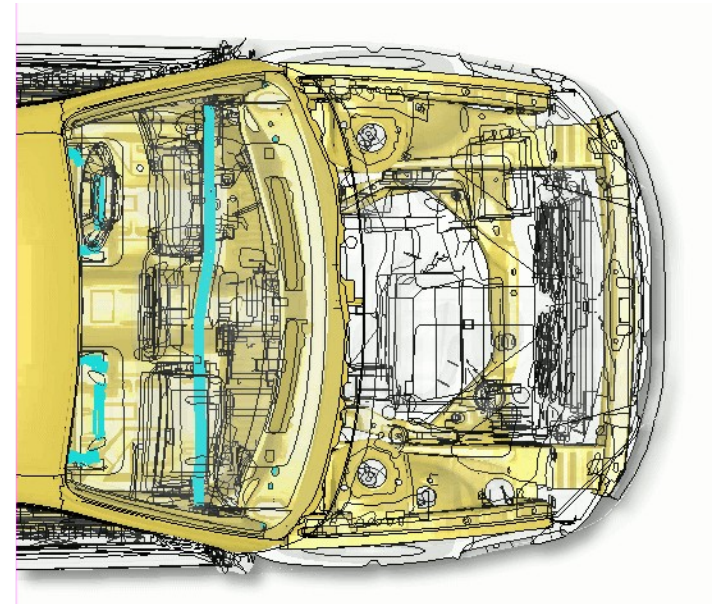
- Sizing / Shape / Topometry / Topography functionality
- Implicit displacement / stress constraints
- Explicit intrusion constraints / targets
- Force constraints (Large scale solution still under development)



Current Status & Future Developments (Sizing Optimisation)

Future Developments

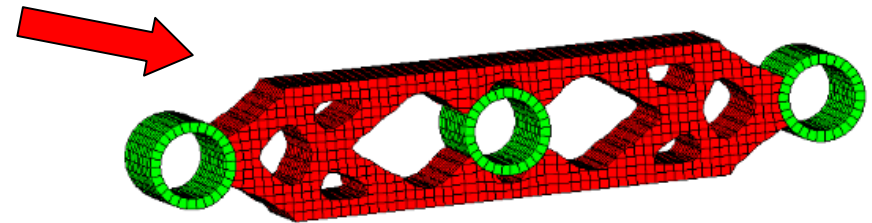
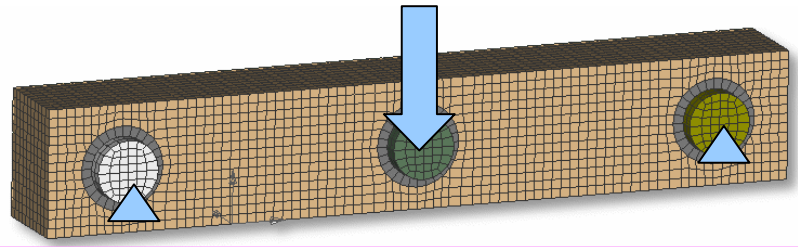
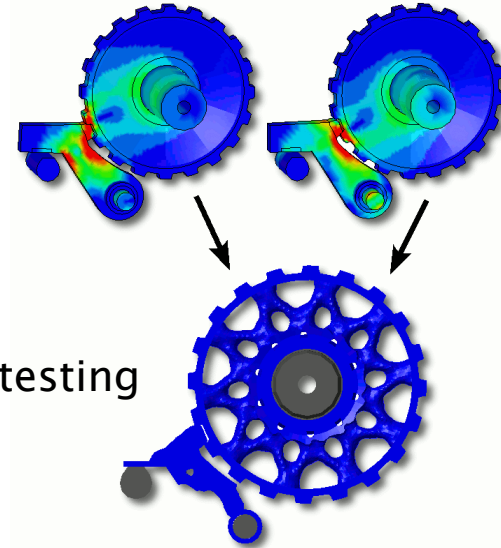
- Support of plastic strain constraints
- High fidelity (1 ms) Velocity/Acceleration/Force constraints



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



Current Status & Future Developments (Topology Optimisation)

Future Developments

- Robust crash Topology optimisation
- Further development of problem formulations
- Further improvement to reduce number of LS-DYNA calls

