Erste Erfahrungen mit LS-OPT/Topology

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Overview

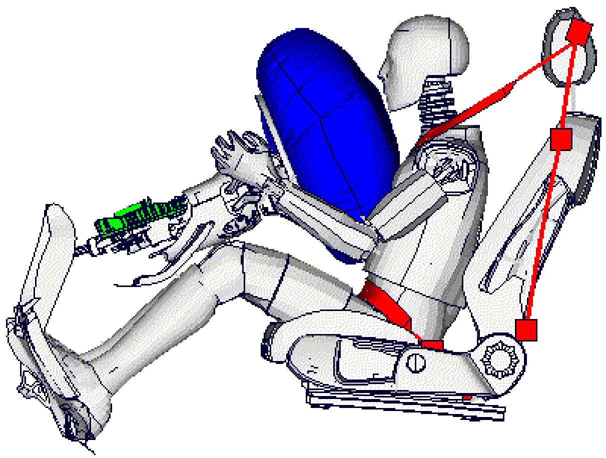
- Introduction
- Topology Optimization for Crash
  - *Equivalent Static Load Method*
  - *HCA Method - Implementation in LS-OPT/Topology*
- Application Example
- Conclusions

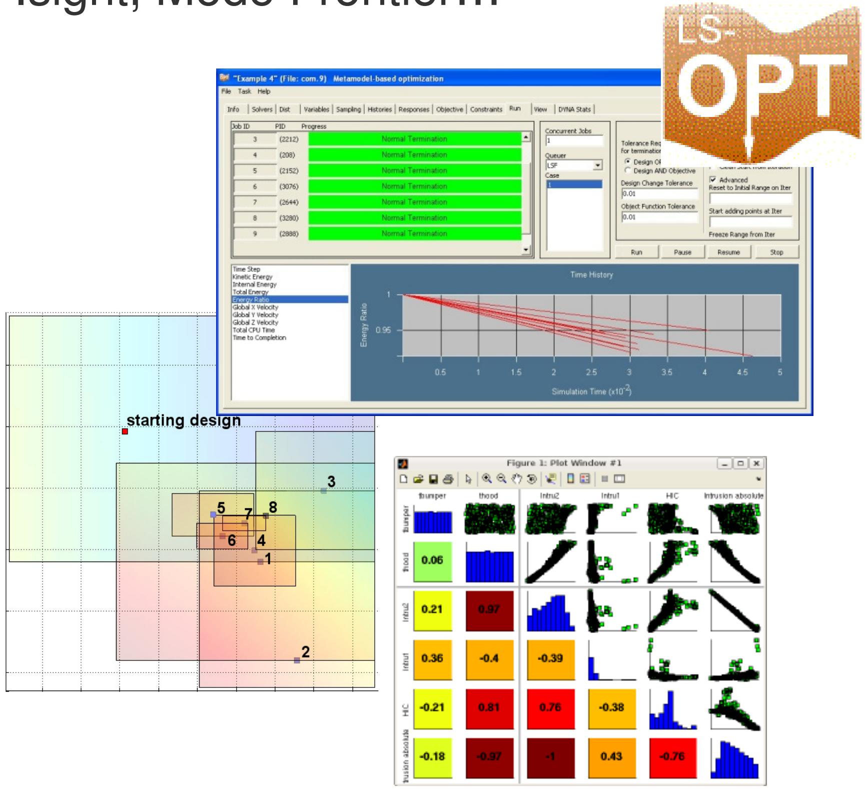
➔ Non-Linear Optimization

- Available Software Products: **LS-OPT,** Isight, Mode Frontier…

Non-linear / Parametric

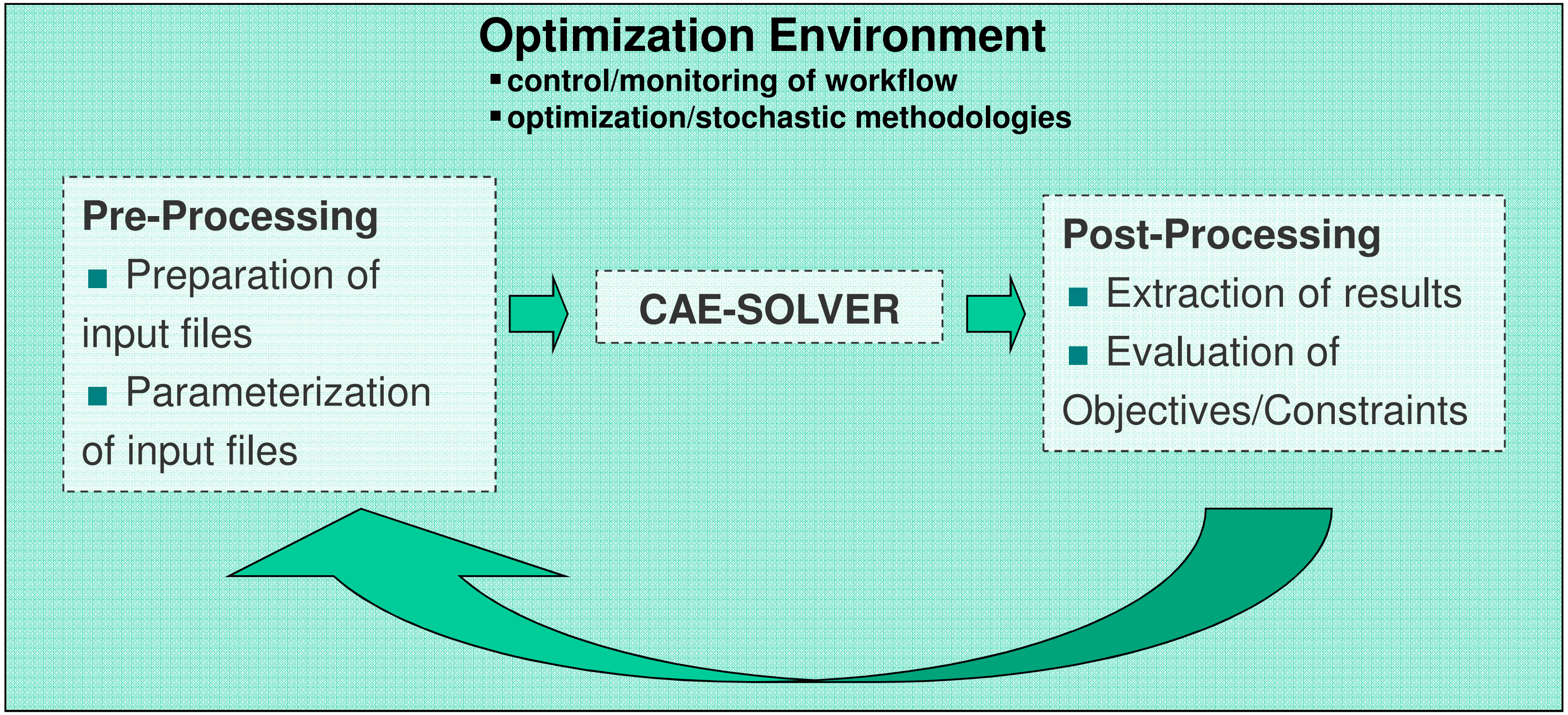
- Parameterization of input files
- Shape/Sizing Optimization
- Possible for general nonlinear applications: Crash, Fluid Dynamics, Nonlinear Static/Dynamic





➔ Non-Linear Optimization

- Process Flow for Parametric Optimization - Simplified Representation

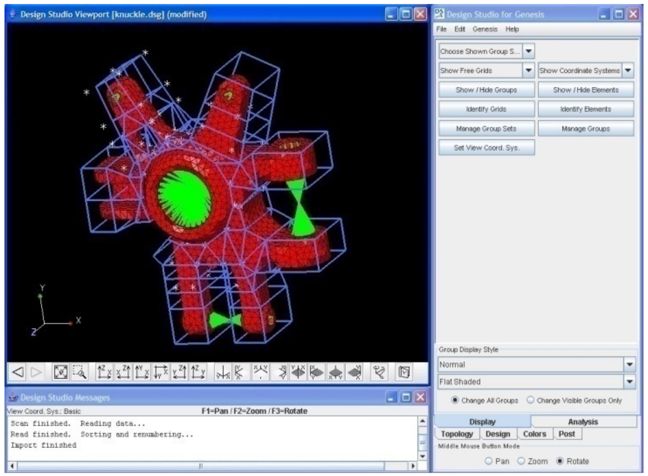


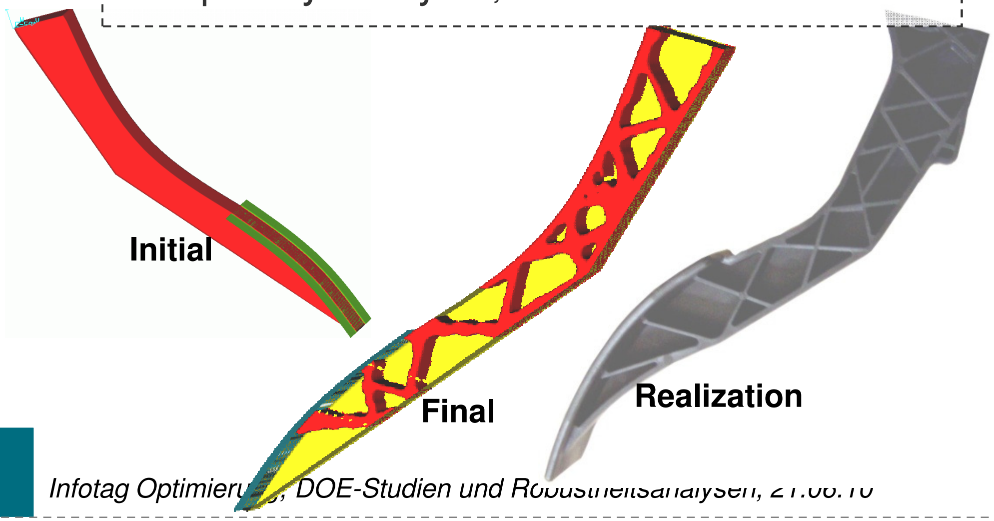
➔ Linear Optimization

- Available Software Products: **Genesis,** Optistruct, Tosca…

Non-Parametric

- Topology / Topometry Optimization
- Usually Linear FE-Problems
- Gradient based solvers – many design variables > 1000000
- CAE-Applications: Static Loads, Frequency Analysis, NVH





➔ Linear Optimization

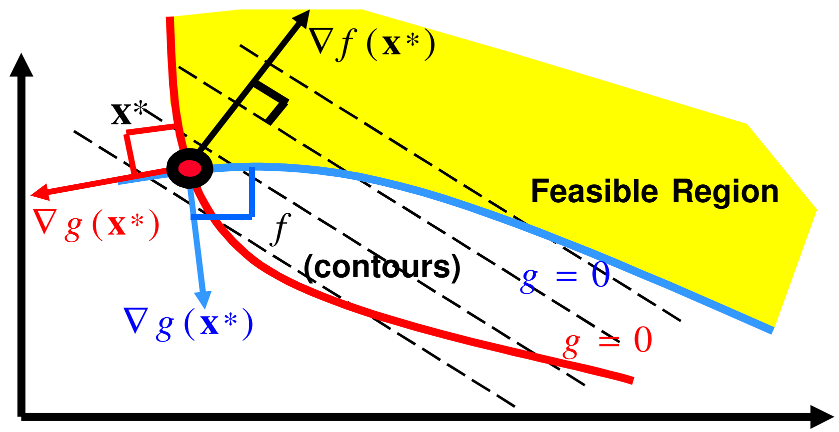
- Usually Integrated FE-Solver

Optimization Environment

- **gradient-based Optimization Algorithms**
- **Usage of internal gradients -> many design variables possible**

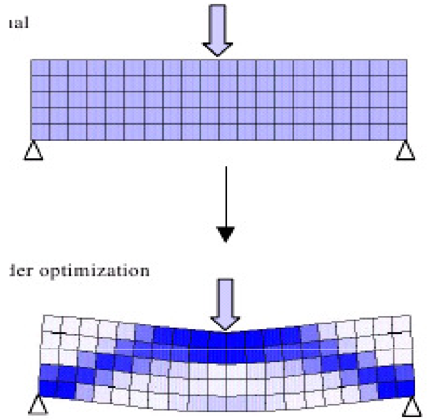
Process

- Specification of Constraints, Objectives
- Iteration
- Result Visualization



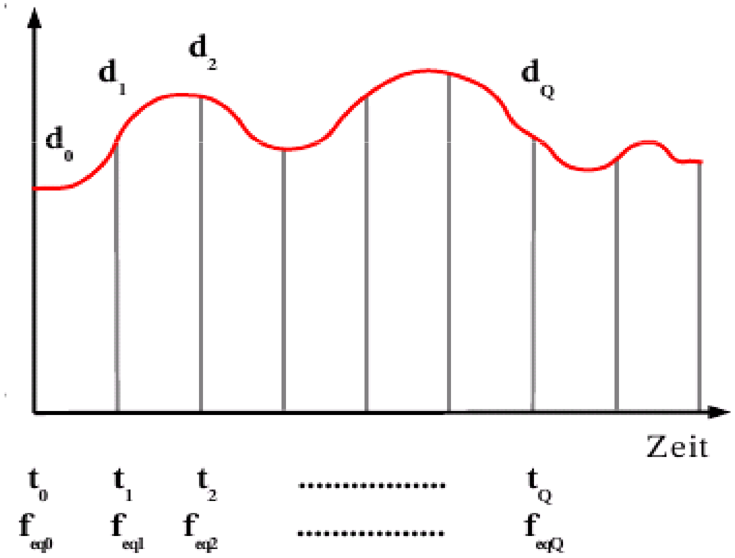
→ Topology Optimization for Crash

- For topology optimization each element is a design variable - can be switched on/off
  → many variables
  - *Can not be solved with LS-OPT (too many variables)*
  - *Can not be solved for crash with gradient based topology solvers like e.g. Genesis (strong non-linearities)*
- Two considerable approaches
  - *Equivalent Static Loads Method – ESLM*
  - *Hybrid Cellular Automata – HCA*



➔ Equivalent Static Loads Method – ESLM

- An *Equivalent Load* is a load in a linear static system that makes an identical response to that in a nonlinear system
- Linear multi load case optimization for each time step t_i with equivalent static loads
- Has to be proven for large deformations such as buckling, folding
- Difficult to account for boundary conditions like reaction forces

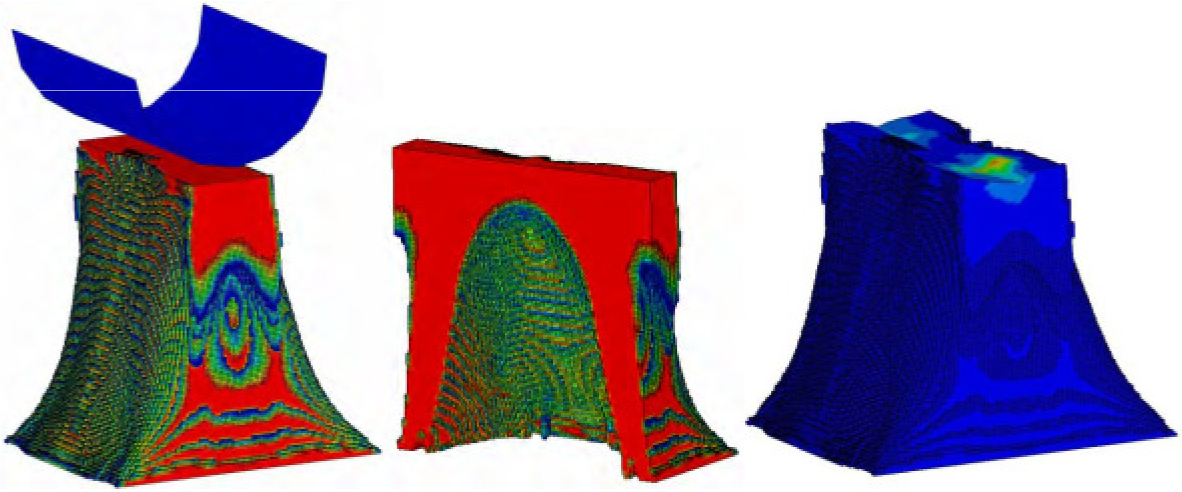


- References

▪ M.K. Shin, K.J. Park, G.J. Park (2007), "Optimization of Structures with Nonlinear Behavior Using Equivalent Loads," Computer Methods in Applied Mechanics and Engineering, Vol. 196, pp. 1154-1167
▪ Kosaka, I. (Vanderplaats R&D) "Improvement of Energy Absorbation for the Side Member using Topography Optimization" LS-DYNA World Conf. 2010

➔ Hybrid Cellular Automata – HCA

- Implemented in LS-OPT/Topology
- Gradient free, heuristic method
- Objective is to achieve a uniform internal energy density (IED) distribution

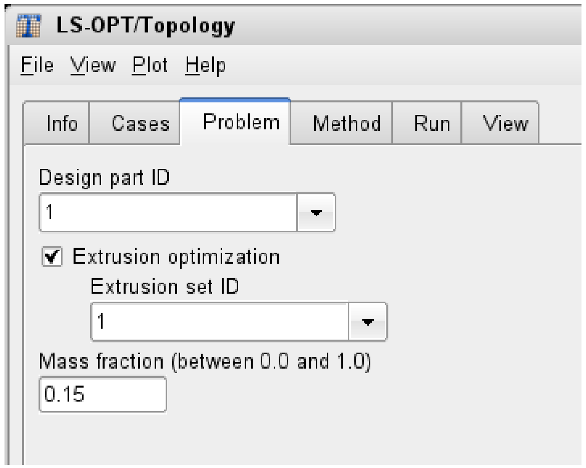


Final geometry | Sectional View | Internal energy density (IED)

- Reference
  - T. Goel, W. Roux, N. Stander; "A topology optimization tool for LS-DYNA users: LS-OPT/Topology" 7th European LS-DYNA Conference, Salzburg, 2009

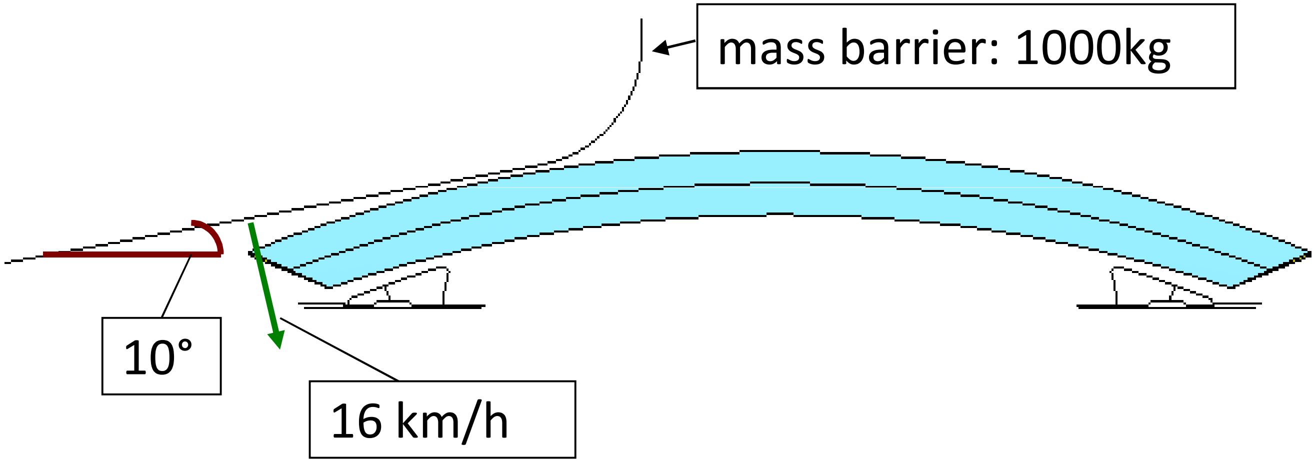
➔ LS-OPT/Topology

- Current Version is V1.0 – released end of 2009
- For now available settings within the LS-DYNA model
  - Element type: eight-noded solid elements
  - Material model: *MAT_PIECEWISE_LINEAR_PLASTICITY
  - Contact types: *CONTACT_AUTOMATIC_SURFACE_TO_SURFACE and *CONTACT_AUTOMATIC_SINGLE_SURFACE
- Objective is fixed in obtaining uniform internal energy density in the structure
- For now two types of constraints are available:
  - Mass fraction
  - Extrusion



➔ Problem Description

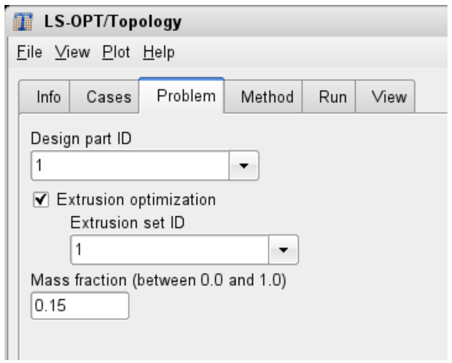
- Optimization of a Crash Management System

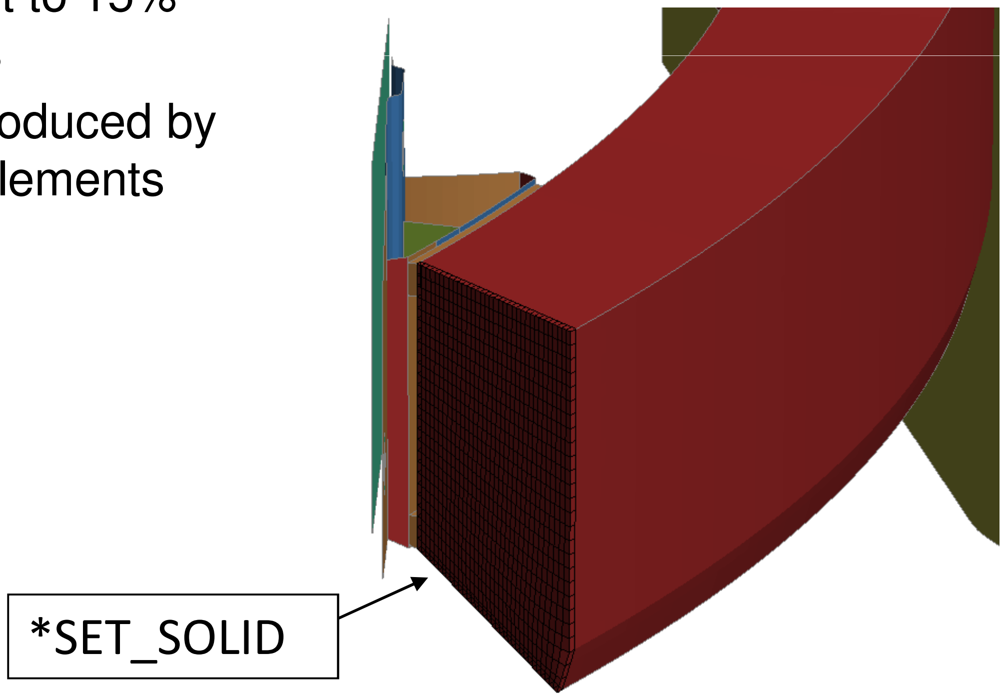


- Objectives are
  - *to absorb the impact energy by plastic deformation without exceeding a specific force level*
  - *reduce the mass of the bumper*

➔ Problem Description / Settings

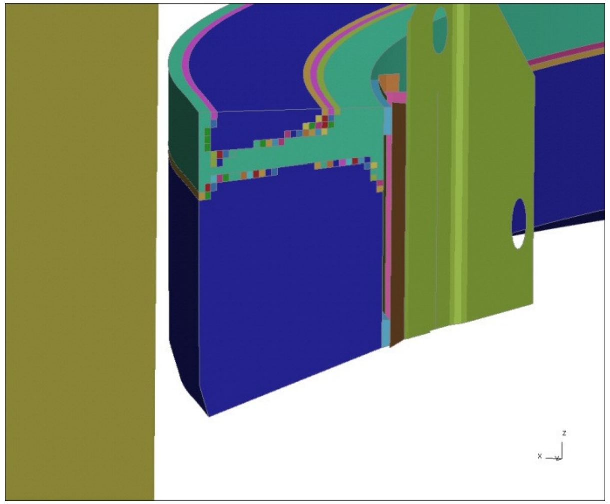
- Installation space for the bumper is defined by an extruded section of solid elements
- In total 565.800 solid elements for the initial model are used
- Mass fraction constraint is set to 15% of the initial (full volume) mass
- An extrusion constraint is introduced by specification of a set of solid elements

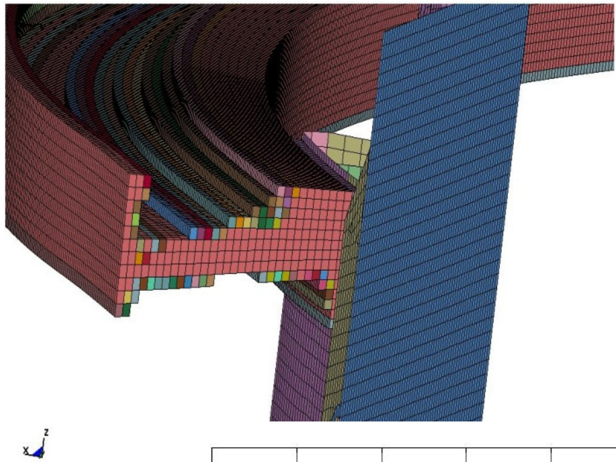




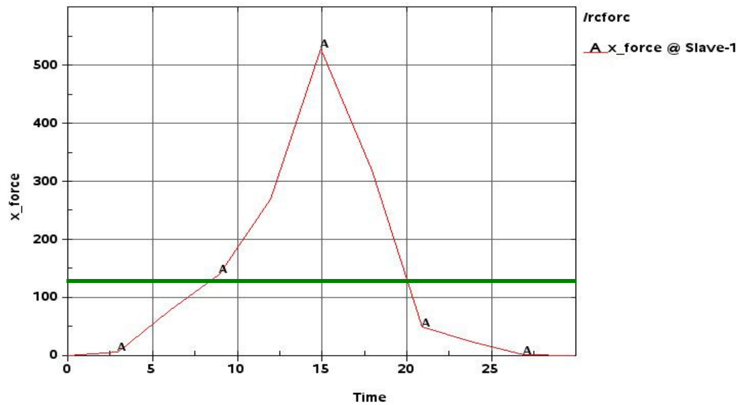
➔ Result Topology Optimization

- Result of the topology optimization after 30 iterations, which means 30 LS-DYNA simulations



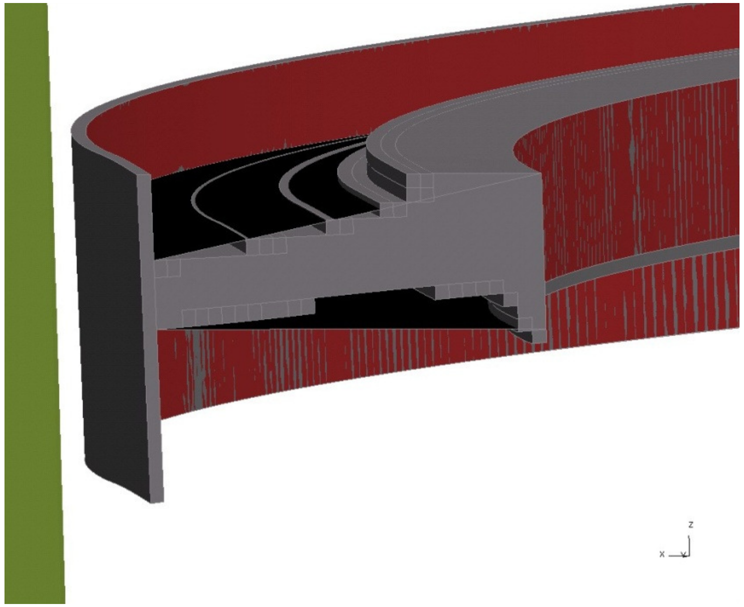


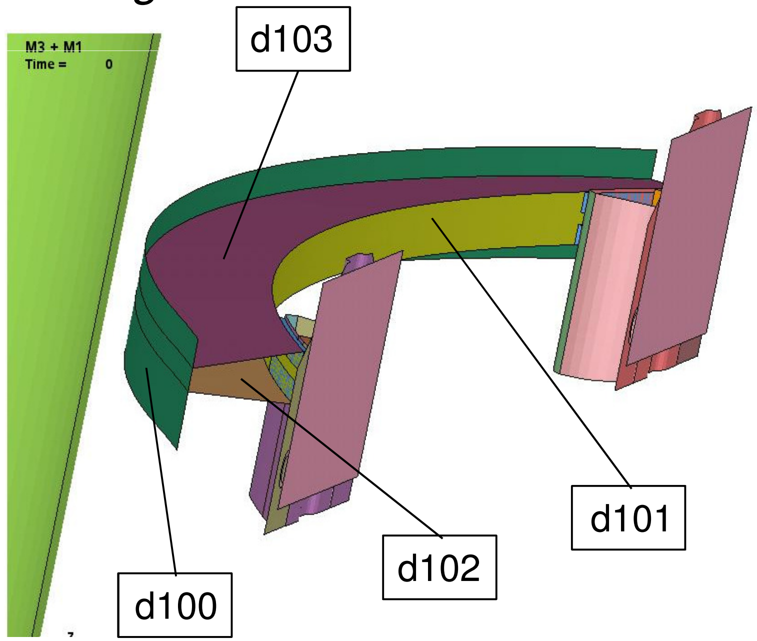
- But contact force is very high and exceeds a required threshold



➔ Remodelling from Solids to Shells

- Introduction of a second stage:
  - *re-model the bumper with shell elements considering the results of the topology optimization, and determine optimal sheet thicknesses by constraint parameter optimization using LS-OPT*



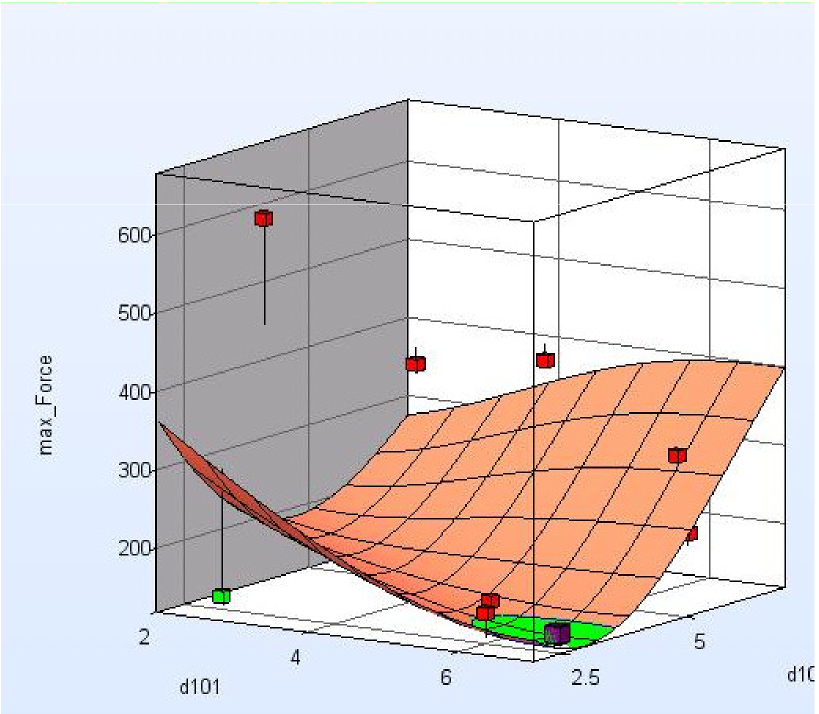


➔ Optimization Problem for LS-OPT

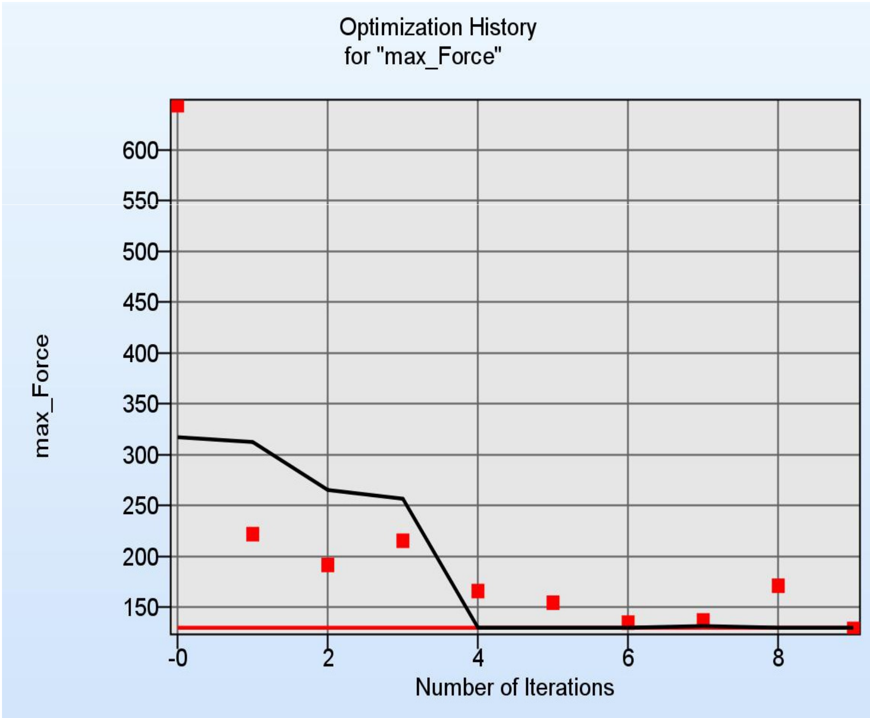
- New optimization problem:
  - *Objective is to minimize the mass*
  - *Subject to the constraint*
    max (ContactForce(t)) < 130kN
  - *Variables: Sheet thicknesses of four parts*
- Successive response surface method (SRSM) is applied in LS-OPT

→ Optimization Results

- Result of SRSM Optimization - Convergence after 9 iterations each with 8 runs



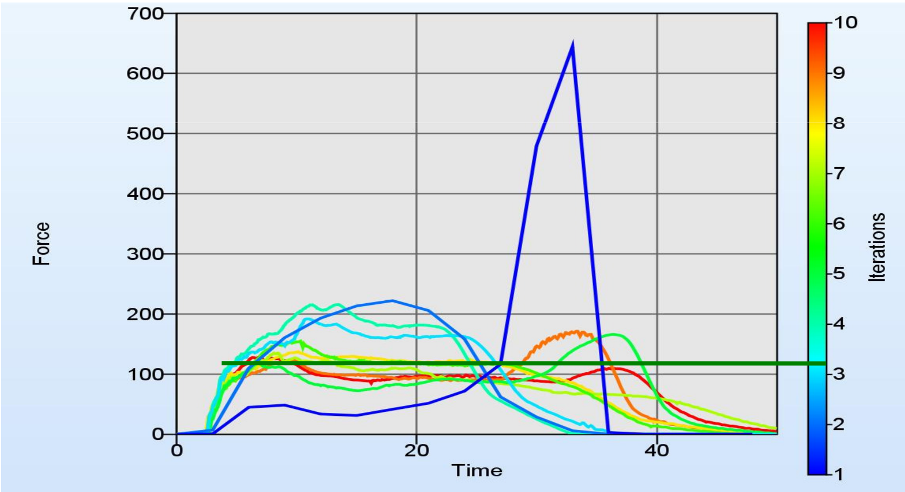
Meta-model used for optimization with feasible and infeasible regions



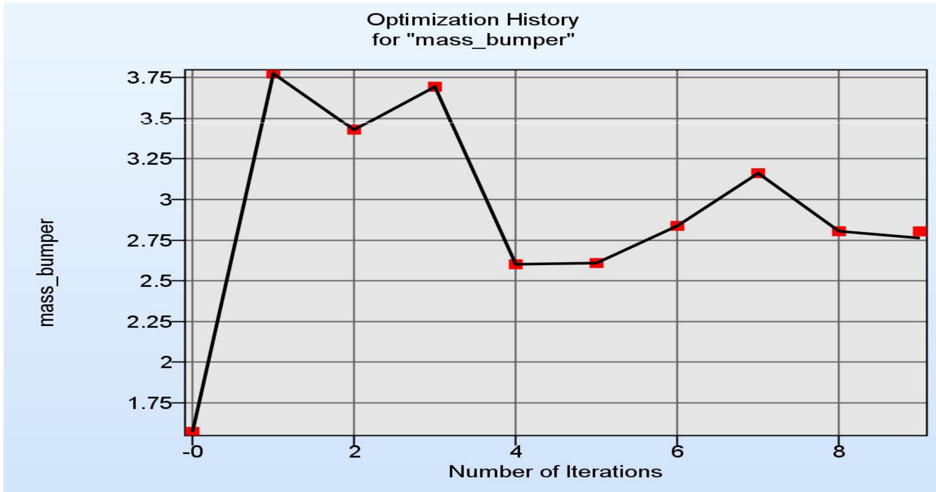
Optimization history of max contact force

➔ Optimization Results

- Result of SRSM Optimization



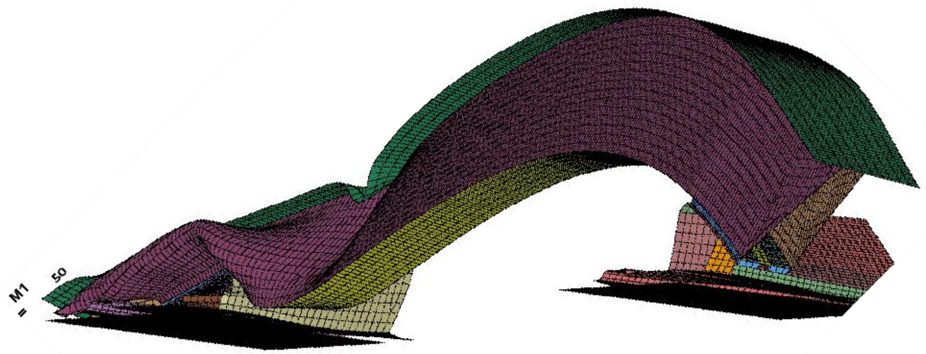
Development of contact force curves during LS-OPT iterations



Optimization history for bumper mass

➔ Conclusions

- Optimization has been performed in two steps
  - *Topology optimization with LS-OPT/Topology*
  - *Size optimization with LS-OPT*
- Two step approach was necessary in order to consider a maximum force constraint and it also helps to refine the optimization on the basis of a shell design that represents a feasible design solution.
- Shape optimization on the shell design might be an additional option, but hasn't been addressed in this study



Thanks for your attention!