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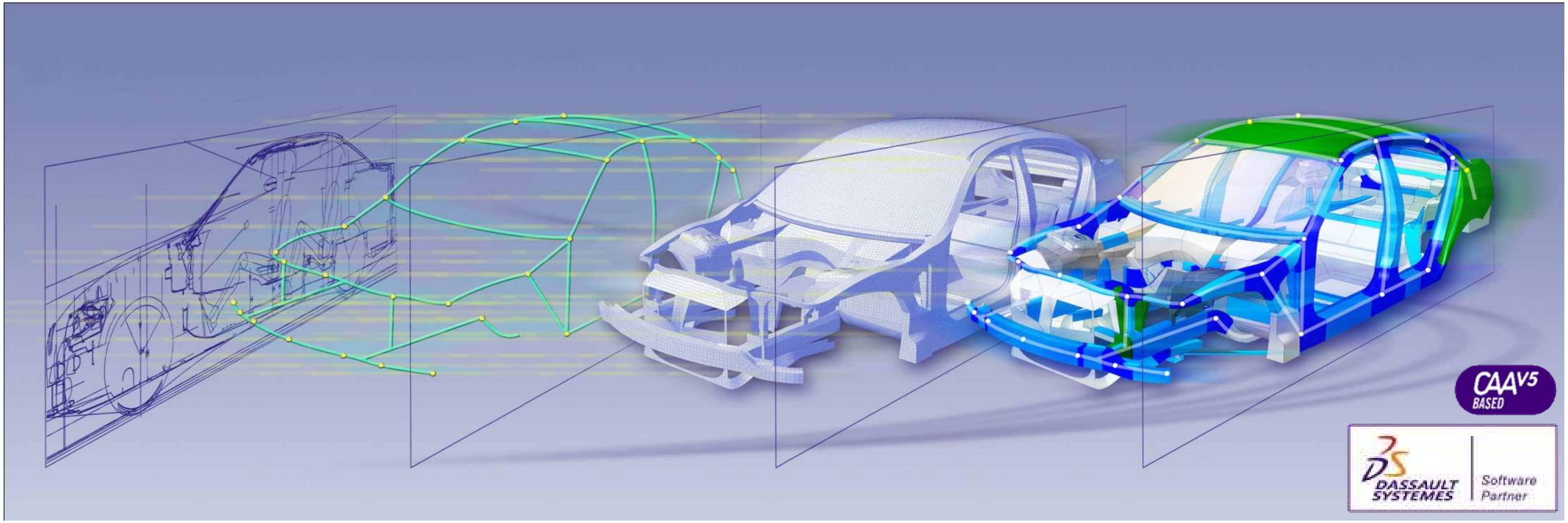

FCM - Fast Concept Modeller©

Optimization of full vehicle concepts using Beam models:
New possibilities for model creation with Fast Concept Modeller

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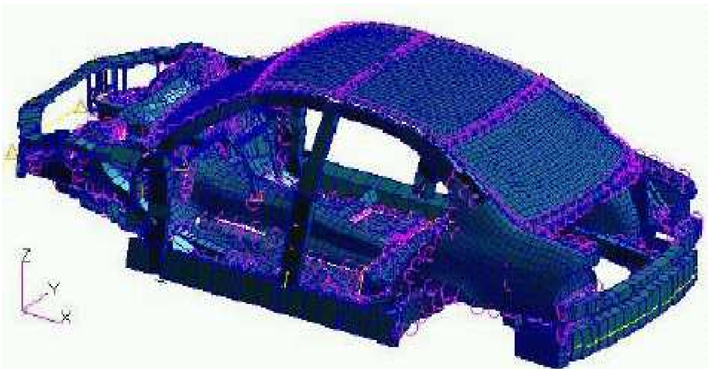
Total Vehicle Optimization using Beam models

- Total Vehicle Optimization using Beam models in the past
- Fast Concept Modeller: CATIA-integrated concept development
- Enhanced Beam Process Using Fast Concept Modeller

Total Vehicle Optimization using Beam models

Application of Beam models

- Beam models are used at BMW in early phase of automotive development (earlier than 60 months before start of production)
- Advantages of Beam models compared to Shell models:
  - Faster solving
  - Shape of carrying structures is described by sizing parameters
- Disadvantage is the higher degree of abstraction
- Goals:
  - evaluate the principal cross section dimensions for new car designs
  - optimize the mass and static and dynamic stiffnesses of the complete vehicle body by varying the cross section dimension



Will, Riedel, Bucher, Raasch: Search for alternative car concepts with OptiSlang. 22nd. CADFEM Users Meeting, 2004

For optimization, gradient-based Nastran SOL200 is used. Different start models are required in order to find optimal design.

Total Vehicle Optimization using Beam models

Hybrid optimization with OptiSlang to find alternative total vehicle concepts

In a successful project presented in 2004 at WOST 1.0, OptiSlang was used together with Nastran in order to find alternative concepts.

The goal of the project was to use genetic algorithms to find “new islands” of valid designs without an extensive increase of weight. Based on several alternative designs, gradient optimization was then used to further reduce the weight.

- Use genetic algorithms to find islands of multiple valid designs
- More than 1500 design variables
- Two optimizations were performed: first: Generation size: 50, number of generations: 100; second: Generation size: 100, number of generations: 100
- Objective function: weight and design space
- Constraints: Stiffness, eigenfrequencies, distance between eigenfrequencies, stresses, accelerations
- 1018 valid designs could be found
- Perform cluster analysis in order to identify clusters of similar designs
- Use one design with best constraint fulfillment from each cluster to perform gradient based optimization with Nastran SOL200

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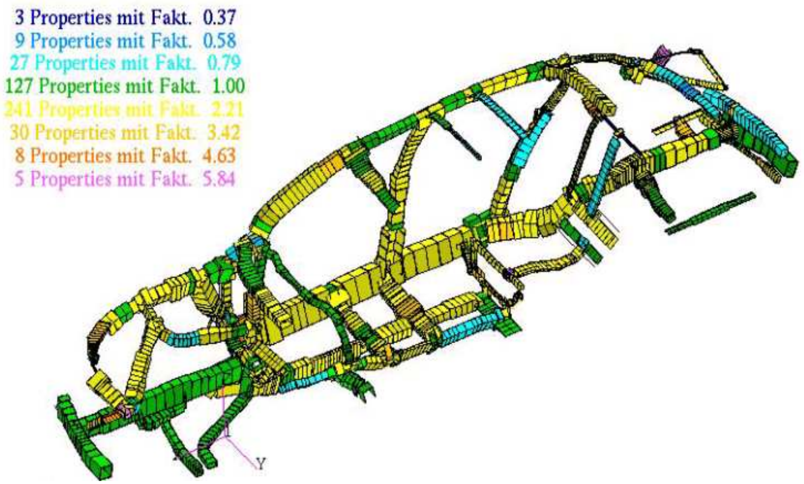
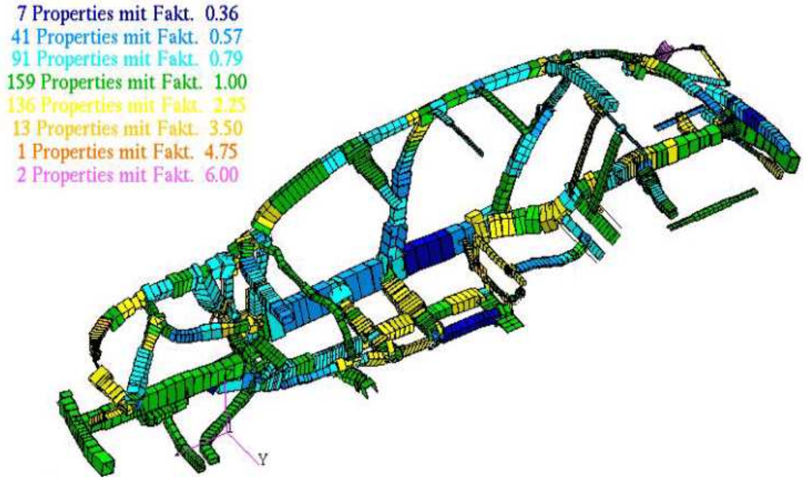
Total Vehicle Optimization using Beam models

Results of hybrid optimization project

Traditional optimization with gradient based SOL200 and different start values:	1096 kg
New design with hybrid optimization: OptiSlang and SOL200	**1037 kg**



Construction Space difference hybrid optimization compared to gradient-based only



Weight difference hybrid optimization compared to gradient-based only

Will, Riedel, Bucher, Raasch: Search for alternative car concepts with OptiSlang. 22nd. CADFEM Users Meeting, 2004

Besides the extensive weight reduction, the results showed that the new design differed a lot from the original design. Especially in the rear of the car and along the sill, the weight and construction space could be reduced significantly.

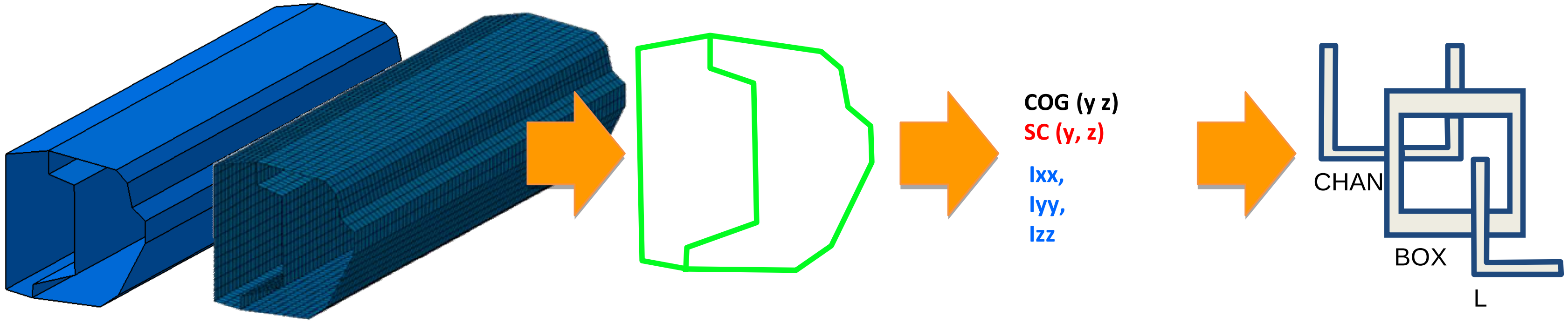
From: Will, Riedel, Bucher, Raasch: Search for alternative car concepts with OptiSlang. 22nd. CADFEM Users Meeting, 2004

Total Vehicle Optimization using Beam models

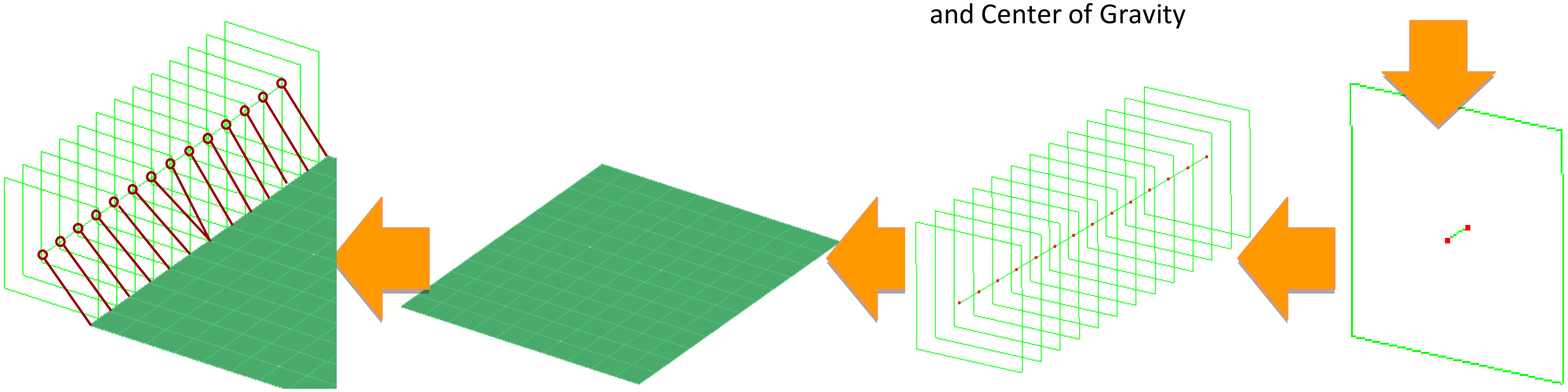
Conventional Creation of Beam Models

Despite the proven successes of optimization of beam models, the biggest drawback is the high time consumption of model creation, which has been a manual task in the past.

The following steps were required in order to convert geometry or meshes into beam models:



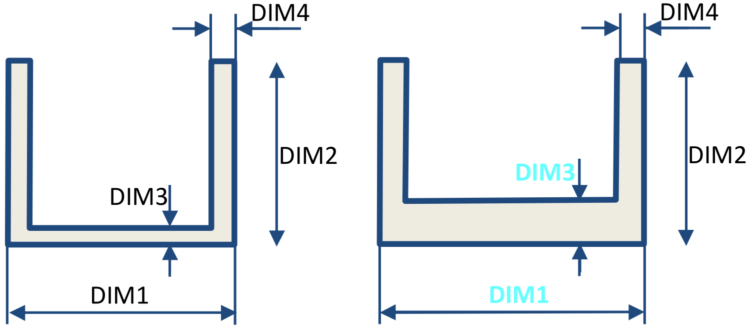
Structural parts as CAD-Geometry or FE-Mesh — Cut through mesh — Calculate physical properties, Shear Center and Center of Gravity — Search for an equivalent standard cross section



Create beam element and property — Repeat these steps for all carrying structures — Create Shell meshes for sheet metal parts — Add rigid connections between beams and Shells

Total Vehicle Optimization using Beam models

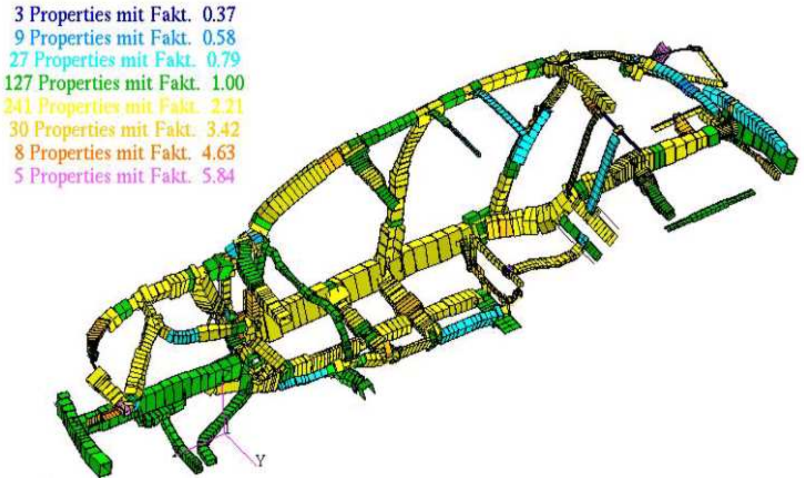
Information Transfer from CAE to CAD department



Design variables are the dimension of beam properties. The final model contains about 1500 desvars.

Optimization target is to minimize the model mass while static and dynamic stiffnesses of the complete vehicle should not fall below certain values

Optimization results are documented in ppt and passed to the design department. The results are then applied manually to the CAD model, which has evolved in the meantime.



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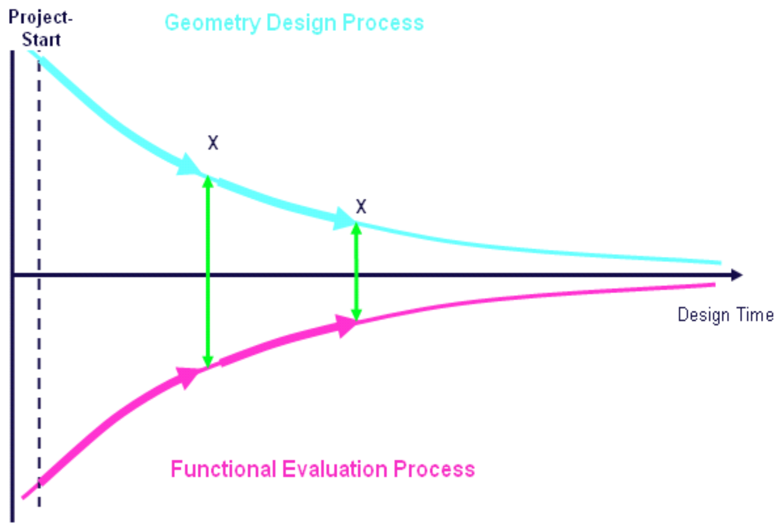


As a consequence, at certain times X, a synchronization of geometric models and optimization results has to be performed, which is time and resource intensive.

FCM: CATIA-integrated concept development

- Total Vehicle Optimization using Beam models in the past
- Fast Concept Modeller: CATIA-integrated concept development
- Enhanced Beam Process Using Fast Concept Modeller

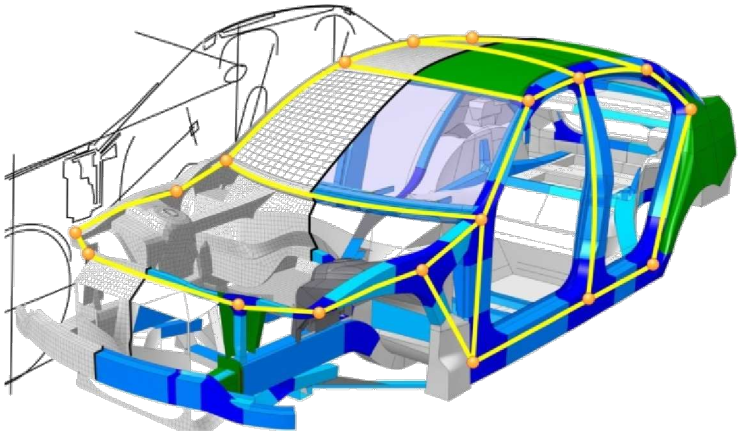
Total Vehicle Optimization using Beam models

Goals of FCM development

In 2007, ForceFive started the development of a software called “Fast Concept Modeller” based on BMW’s requirements.

The main goals of the project were:

- Implement a software for concept development that is integrated into CATIA V5
- Provide interfaces to common CAE-Pre-Processors
- The concept-model is the master for all CAE-processes

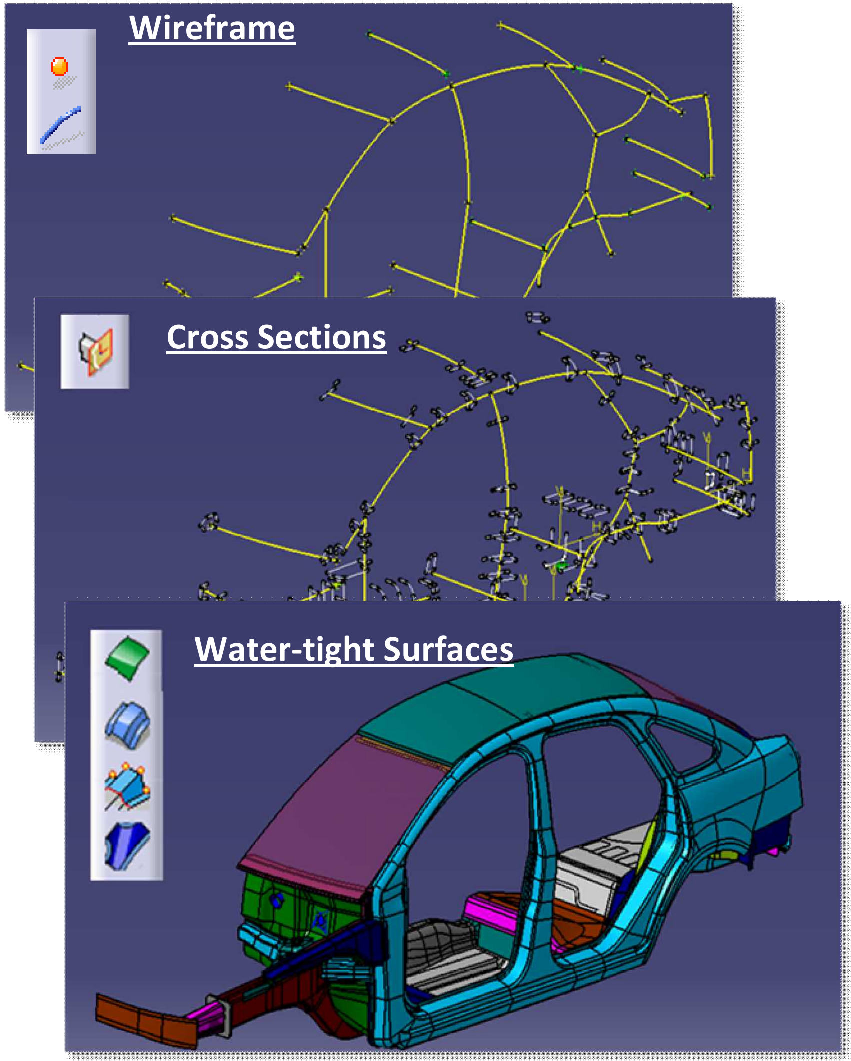


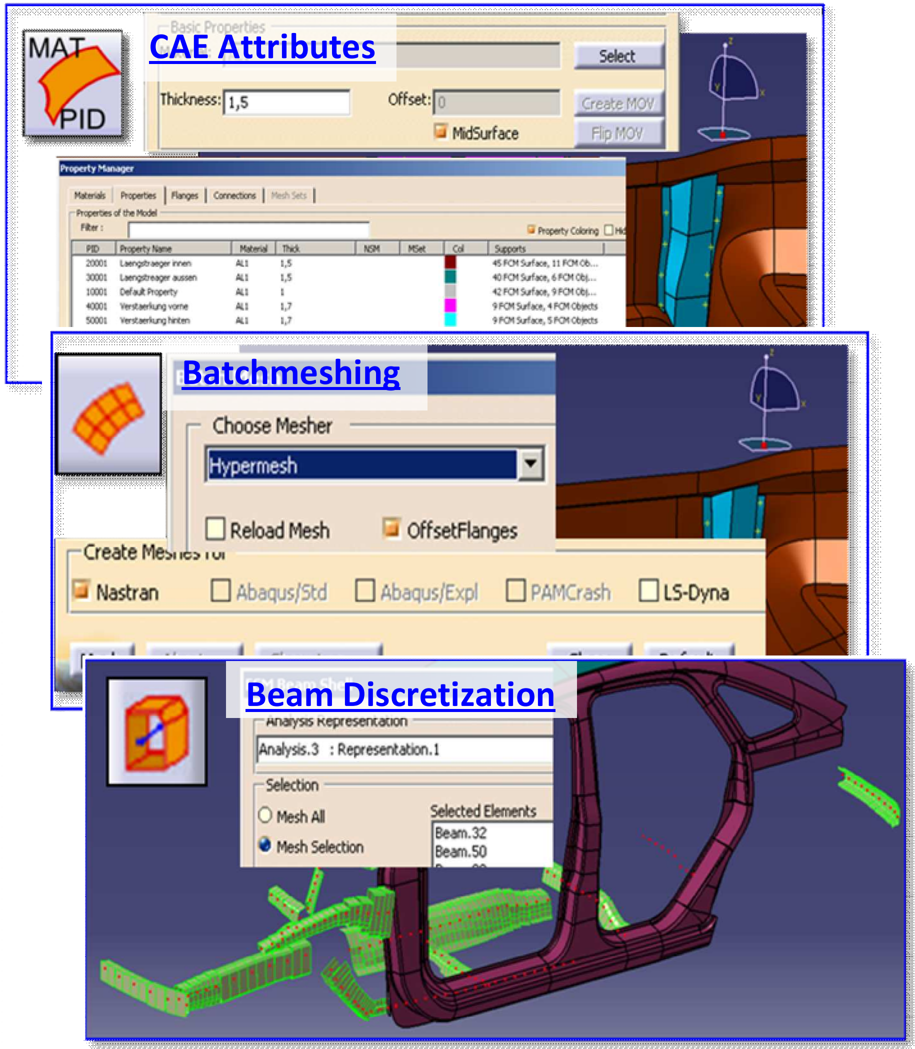
Additional Requirements of Complete Vehicle Department:

- Provide a fast way to derive Beam-Shell FE-models from CAD geometry by a rule-based beam mesher and a high degree of automization
- Implement functions to apply optimization results from CAE-world to CAD-models in order to minimize synchronization efforts
- Reduce usage of CAE-applications and interfaces

FCM Functions and Modules

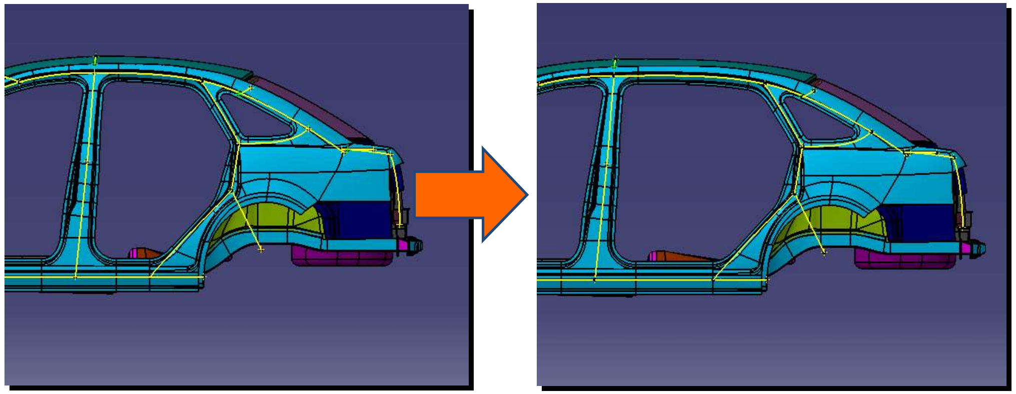
Create concept models fast and easy with surfaces ready to mesh





FCM Parametric Modeller and Analysis Preprocessor

Fundamental design changes can be performed without update errors



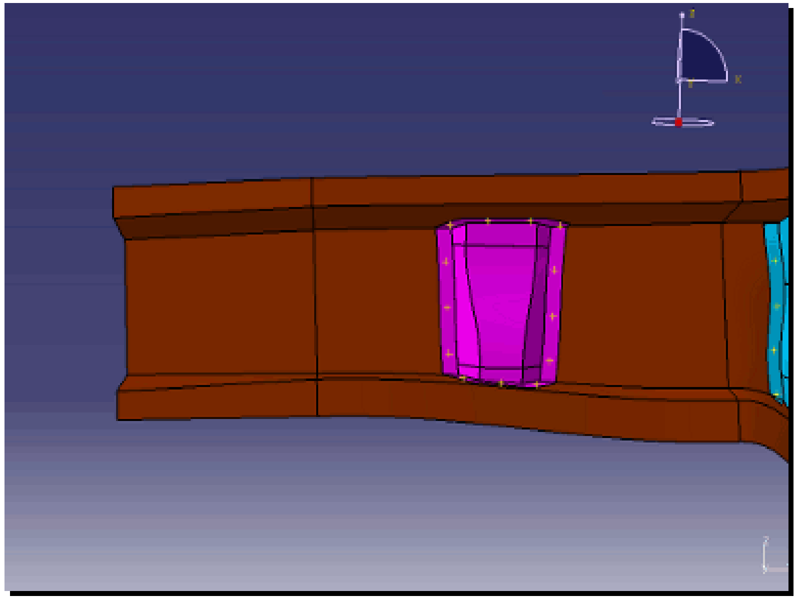
Example for stable FCM parametrics: stretching the whole rear of the vehicle

Make fundamental changes to your concept:

Flat FCM parametrics allow stable changes

Modifications can be easily performed also for non-CAD-experts.

Model remains water-tight all the time.



Stable parametrics play hand in hand with CAE attributes and Batchmeshing. This enables the user to set up automatic optimization loops.

Create optimal design by using FCM in the loop with optimization software:

FCM parameters can be manually changed from within CATIA or from outside.

Optimizers as Optislang can access geometry and CAE parameters

For each new design, shell meshes can be created automatically through Batchmeshing.

Enhanced Beam Process Using FCM

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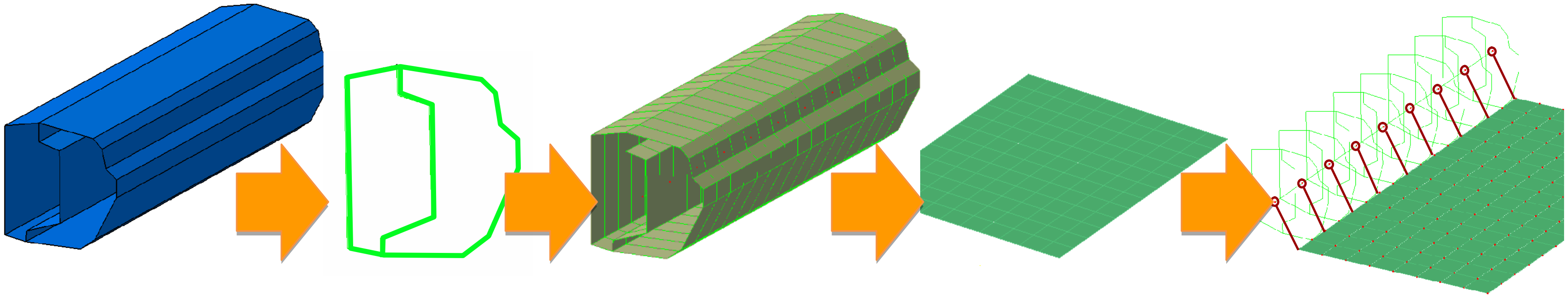
Creation of Nastran Beam Models with FCM

Automatic conversion into Beam Models using Nastran Arbitrary Cross Sections

Fast Concept Modeller along with Nastran Arbitrary Cross Sections allows to convert the concept geometry directly into Beam Meshes.

The sections are created based on a given element length normal to the geometry and converted according to the rules of Beam Meshes. They are directly visualized in FCM and can be exported to Nastran straight away.

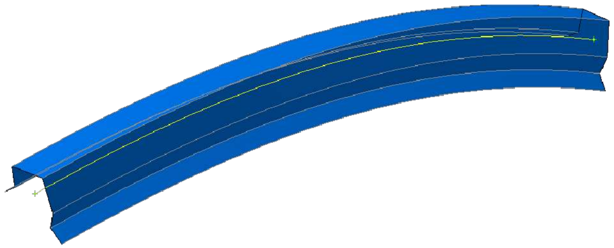


FCM-Geometry | Section of geometry (automatic) | Nastran Beam elements with ABCS properties | Shell Meshing (automatic) | Connection of Beams and Shells with RBEs (half-automatic)

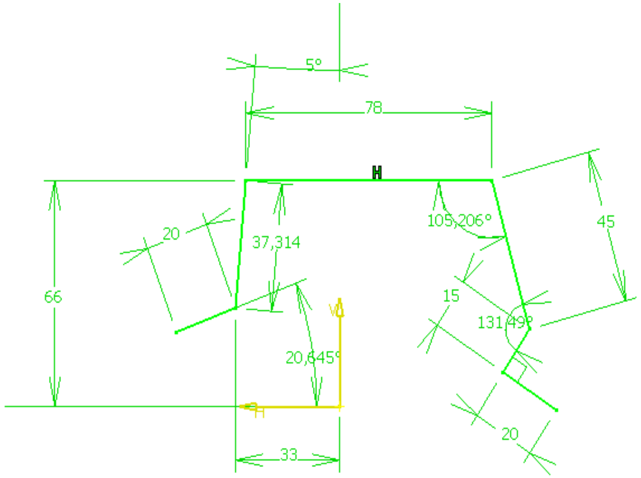
The meshing follows basic rules. The model topology is analyzed and accordingly converted (discretized) in a beam model.

FCM – Automatic conversion from CAD to CAE

Discretization converts CAD Surfaces and Parameters into FE Input Data

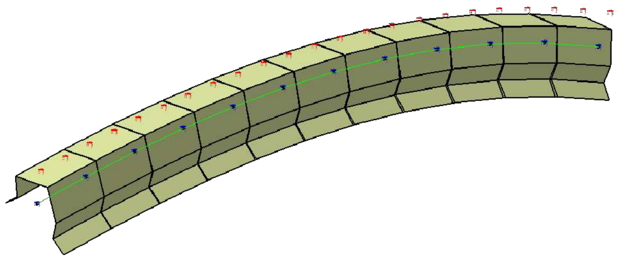


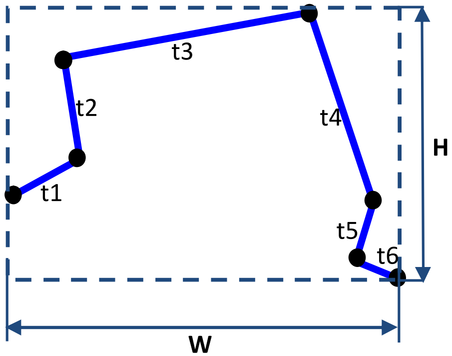
Conversion of n geometry parameters into m FE parameters



Parameters of FCM Geometry are:

- Position of start and end points
- Sketch Orientation
- Dimensions of start and end sketches
- Spline tangents
- Thickness (one or more)





Implicit Parameters of discretized Model are:

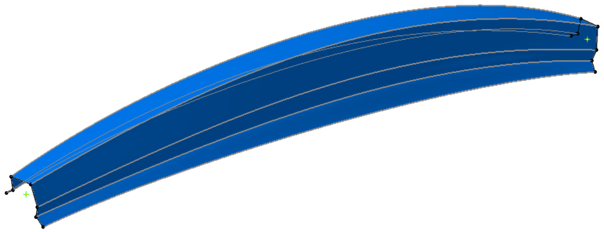
- Position of start and end node of each element
- Element orientation
- Coordinates of edge points of each property (2d)
- Thickness of each segment

Explicit Parameters are:

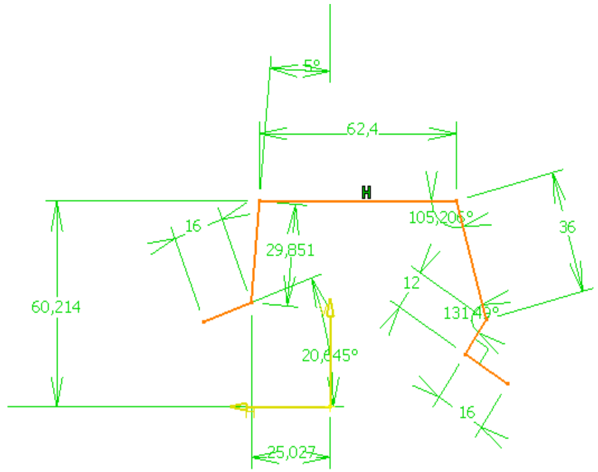
- Height and Width of each element

FCM – Apply optimization results to concept geometry

Feedback converts FE input data back into geometry parameters

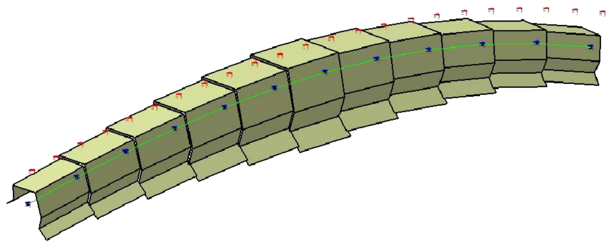


Extrapolation of m FE parameters back to n geometry parameters



Parameters of FCM Geometry are:

- Position of start and end points
- Sketch Orientation
- Dimensions of start and end sketches
- Spline tangents
- Thickness (one or more)



Implicit Parameters of discretized Model are:

- Position of start and end node of each element
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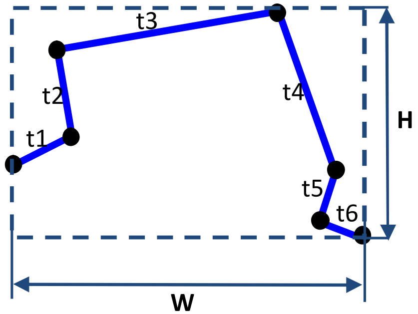
- Coordinates of edge points of each property (2d)
- Thickness of each segment

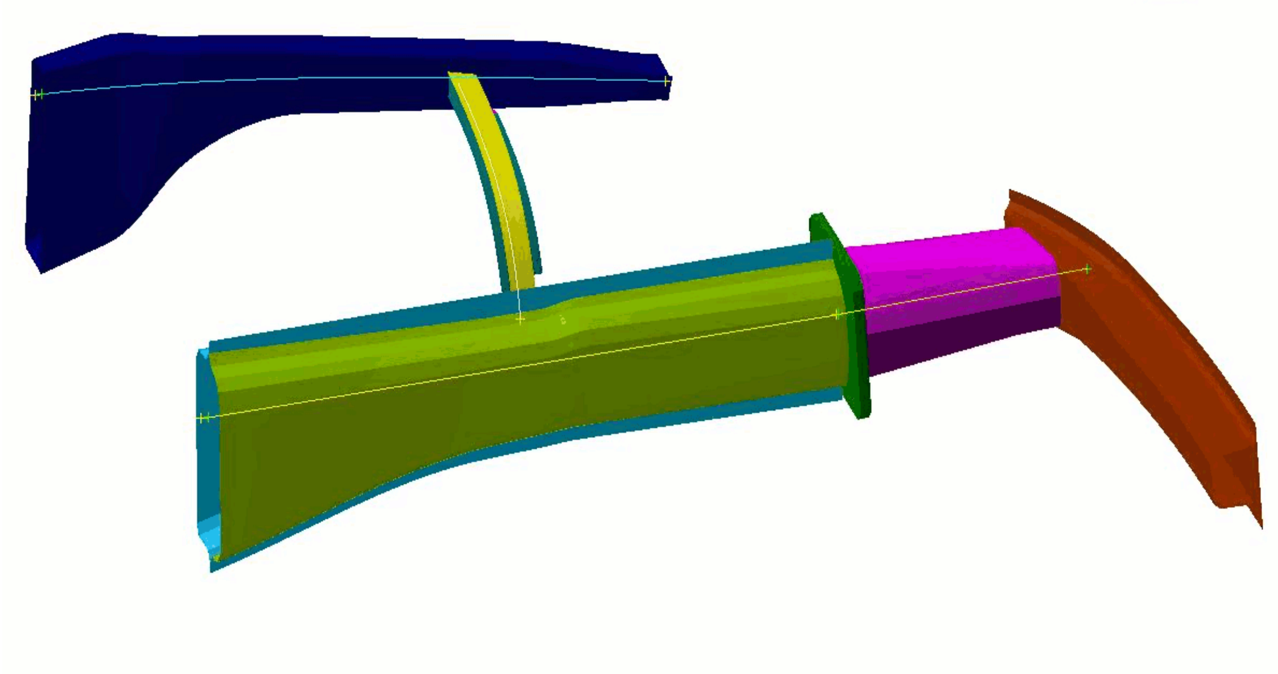
Explicit Parameters are:

- Height and Width of each element



FCM – Apply optimization results to concept geometry

Example



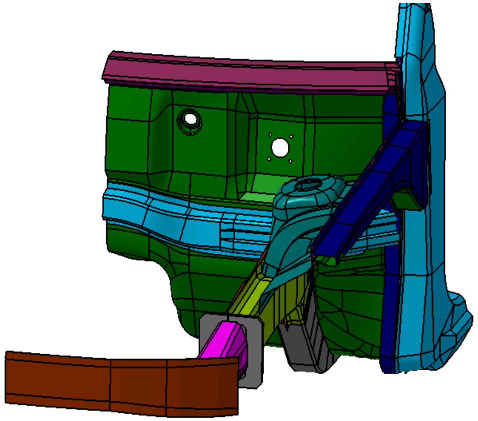
Subsequently the optimized cross sections can be incorporated into the FCM geometry. There are different options available to update the FCM geometry, either select the objects individually or the complete model.

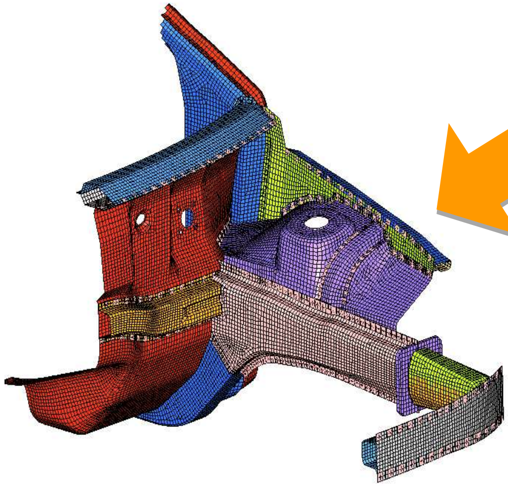
The optimization results are integrated into the construction process with a touch of a button.

Other applications of Fast Concept Modeller

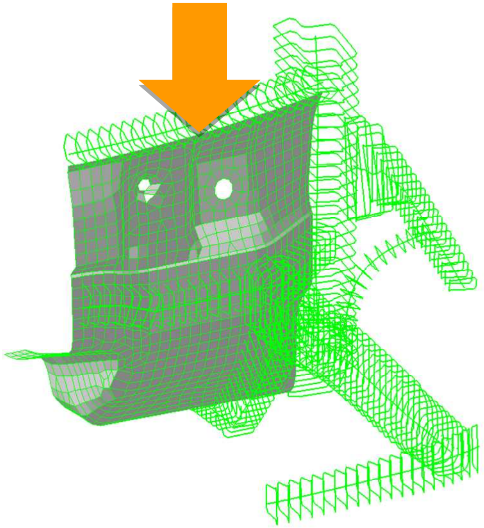
FCM in Loop with linear and nonlinear optimization

Up to now, only linear problems could be treated with Beam Models. By combining FCM's discretization functionality with a newly developed interface to Impact Design's Visual Crash Studio, the crash performance of the vehicle can be investigated in less than a minute.

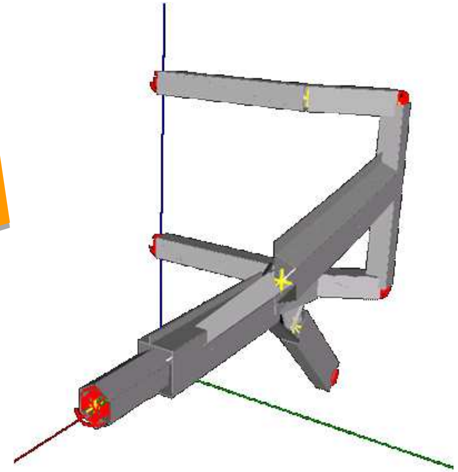




Implicit and Explicit FE Analysis



Linear Total Vehicle Optimization

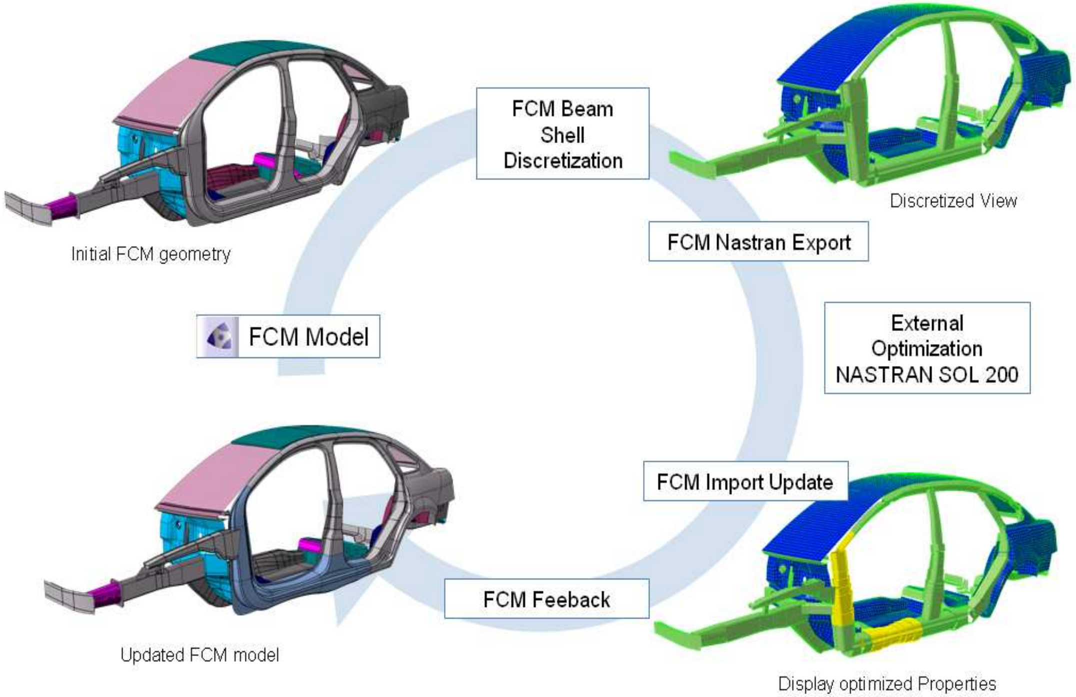


New Possibility: Macro Elements in Visual Crash Studio for evaluation of crash performance in early concept stage

Fast Concept Modeller for Concept Development

Summary

- Beam and Shell Nastran models are used in total vehicle development at BMW for optimization of full vehicle model characteristics
- Hybrid optimization with optislang and Nastran SOL200 has proved to deliver much better results than using gradient based optimization solely
- Based on FCM Models an automatic process to derive beam and shell models from parametric concept geometry has been realized
- The feedback of optimized beam sections on initial geometry helps designers to benefit from results of the CAE-process instantaneous.



The time effort for geometric model creation and FE model derivation can be reduced by a big amount with Fast Concept Modeller. The interfaces to CAE processes deliver new possibilities for optimization of CATIA-integrated concept models.

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