Multi-Disciplinary Design Optimization exploiting the efficiency of ANSA-LSOPT-META coupling

Korbetis Georgios, Siskos Dimitrios,

BETA CAE Systems S.A,

Thessaloniki, Greece

Summary:

Simple optimization techniques may serve well for the improvement of product performance at early concept design phases. At final phases though, optimization problems become more complex, with many variables and multiple optimum solutions. This leads to the need for the deployment of multi-disciplinary optimization techniques where many different load cases and analysis types, such as for Crash, NVH, CFD etc., are combined to achieve the optimum solution. The combination of ANSA CAE pre-processor, LS-OPT and mETA post-processor, offers an efficient and reliable tool for solving multi-disciplinary optimization problems.

In such a process, starting from a common initial model, multiple outputs for different load cases and disciplines can be defined in ANSA. Design Variables that handle model shape and parameters are controlled in a centralized manner by the dedicated Optimization Task tool that is integrated in the core ANSA functionality.

Further more, the newly released coupling between LS-OPT and mETA, provides a valuable tool for the definition of multi-disciplinary optimization scenarios, as mETA is able to extract responses from numerous solvers and load cases and feed them to LS-OPT.

Keywords:

optimization, multi-disciplinary, shape, parameter, morphing

1 Introduction

The present paper demonstrates a suggested process for the definition of multi- disciplinary optimization problems. The process is able to control the shape and parameters of multiple models which correspond to the different disciplines. The direct coupling of ANSA LS-OPT and META Post enables this process without the need of scripting and customization. The suggested process is demonstrated through an example of optimizing the behavior of a BiW in crash and torsion stiffness analysis.

The shape changes of the FE-Models are performed by the Morphing Tool of ANSA which provides to the user enormous potential for the global dimension modification and also to local feature definition and control.

The Task Manager of ANSA is used in this example for two purposes. The definition of different load cases which correspond to the different disciplines beginning from geometrical model. Furthermore, the Task Manager is used for the definition of the actions that will be executed in every optimization iteration. A special tool for this purpose, the Optimization Task, controls the shaping and parameter modification which are common in all disciplines.

The new version of LS-OPT supports the connection with used defined post- processors which is a great advantage for the definition of multi disciplinary optimization problems. Now LS-OPT can drive different solvers and extract responses from any solver results. Furthermore, LS-OPT supports with a specific TAB the direct connection with META Post. After a baseline run, META Post is able to extract responses from the 3D or 2D model results. The Graphics User Interface of the later, facilitates the selection or the right values while complicated calculations like noise filtering, user defined functions, HIC criteria, etc.. can be applied to the solver results before extracting responses. A special tool of META Post defines responses and real or complex histories from selected values or curves. The histories and responses are saved in an ascii which is recognized from LS-OPT.

2 The optimization problem

For the demonstration of the optimization problem set up, a case study of two analyses will be performed on a BiW model definition. The first analysis is a front crash of the BiW on a rigid wall while the second analysis is the torsion stiffness of the BiW. The target of the analyses is to reduce the maximum acceleration and intrusion that appears during the crash while keeping the torsion stiffness and mass of the model within specific ranges. The testing model is shown in figure 1.

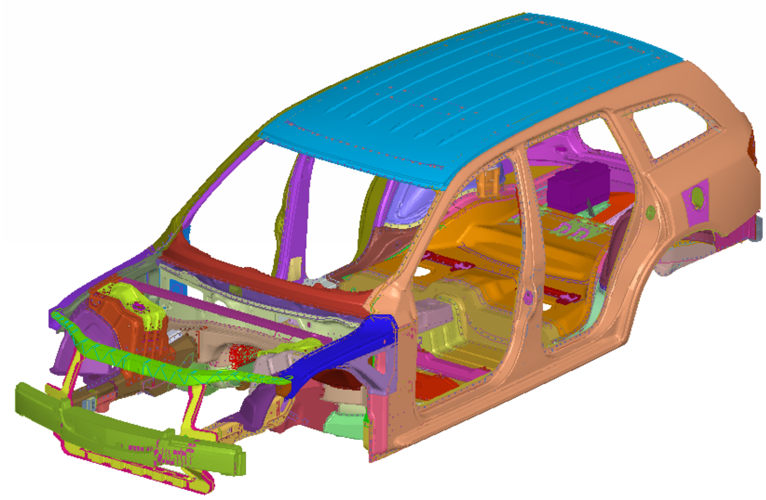

Figure 1: The BiW model

The design variables that will be used to improve model behavior are the thickness of the front rails, and suspension tower parts. Also as design variables will be set the dimensions of the front rails and the definition and modification of beads on them. All the design variables are shown at figures 2, 3 and their type and bounds are listed at table 1.

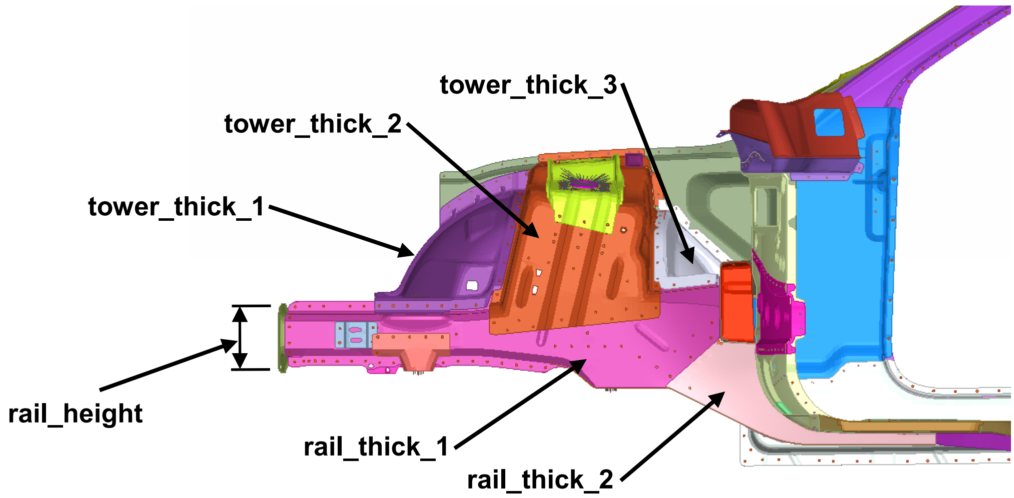

Figure 2: Design variables

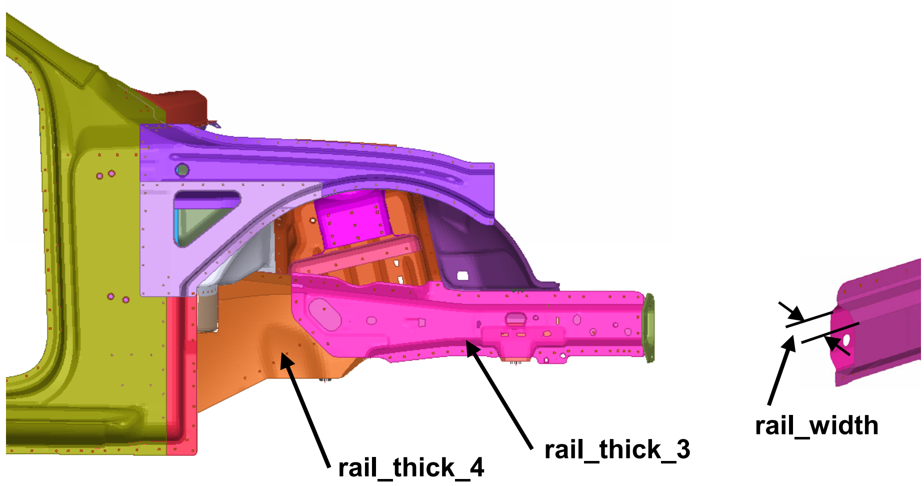

Figure 3: Design variables

Design Variable	Type	Initial Value [mm]	Lower Bound [mm]	Upper Bound [mm]
Rail_thick_1	Discrete	1.6	1.2	2
Rail_thick_2	Discrete	1.8	1.4	2.6
Rail_thick_3	Discrete	1.6	1.2	2
Rail_thick_4	Discrete	2.0	1.6	2.8
Tower_thick_1	Discrete	1.4	1	2
Tower_thick_2	Discrete	2.	1.6	3
Tower_thick_3	Discrete	0.8	0.6	1
Rail_height	Continuous	160	140	180
Rail_width	Continuous	64	60	68
Bead_depth	Continuous	0	0	6

Table 1.

2.1 The load cases

The first analysis is a front crash of the BiW on a rigid wall with initial velocity 17.8 [m/s]. A simplified model of the BiW has been used to make the simulation faster. The rear part of the model has been substituted by a rigid body entity (CONSTRAINED_NODAL_RIGID_BODY) which contains the mass and inertia of the substituted model part. The “rigidize” process is automatically defined in ANSA pre-processor (figure 4). The model will be solved in LS-DYNA.

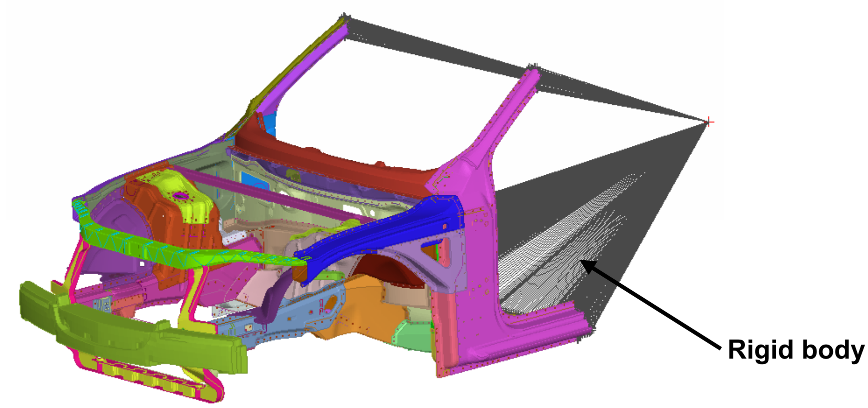

Figure 4: The front crash model

The second analysis calculates the torsion stiffness of the BiW. Nodal loads are applied on both suspension towers in opposite directions to produce torsion, while the rear suspension towers are constrained. For this simulation the full BiW model is used. However, the model is meshed with coarser element length. This will reduce significantly the simulation time and memory cost since for this simulation the LS-DYNA Implicit solver will be used.

2.2 Defining Morphing Parameters

The shaping of the FE-Model is achieved through the ANSA Morphing Tool. This tool provides several ways of morphing FE or geometrical models while ensures smooth and controllable results. Special entities, the Morphing Boxes, are created around the area of the model to be modified. As the shape of the Morphing Boxes can be modified in several ways, the model surrounded by the Boxes follows the modification; the shaping takes place in this manner. Since the model parts which are morphed are symmetrical, symmetry linked Morphing Boxes are used to ensure identical morphing on both sides. (Figure 5).

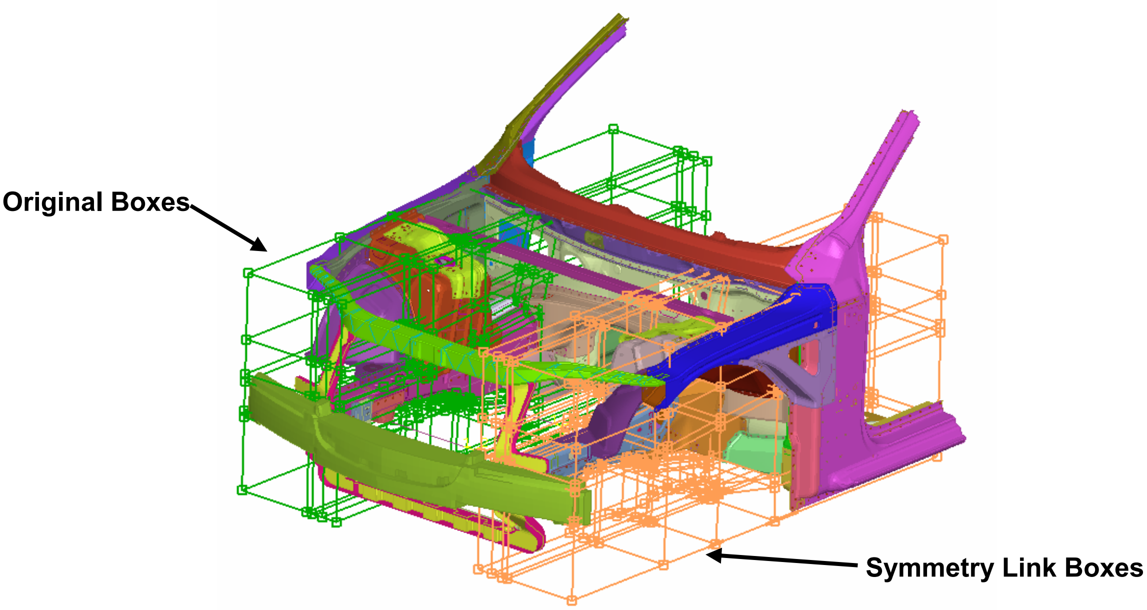

Figure 5: The Morphing Boxes

Since the morphing process should be connected with LS-OPT, the design variables must drive the process. Therefore the modification of the Boxes shape is controlled parametrically by special entities, the Morphing Parameters which later on will be associated with the design variables. The Morphing Parameters hereby defined, control the rail height and width (Figure 6, 7). More Morphing Boxes around the area of the rail work as “absorbing areas” for the shape modification. By this technique, smooth transition among the modified and intact areas it can be achieved. Furthermore, one is able to avoid penetration between the parts and the appearance of bad quality elements.

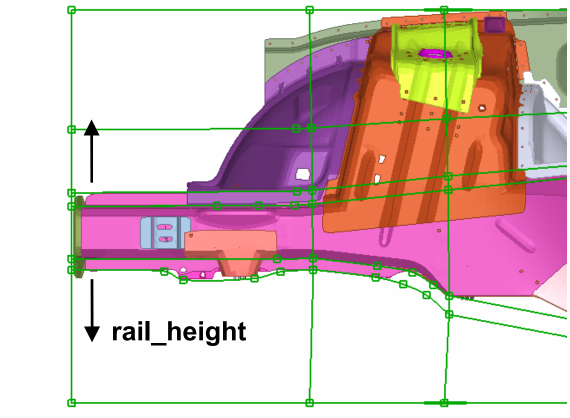

Figure 6: Rail initial shape

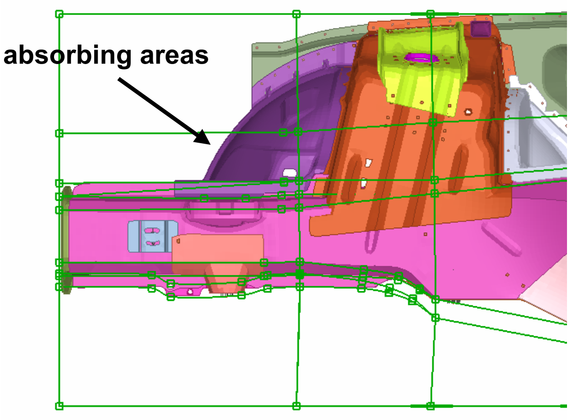

Figure 7: Rail modified shape

Local modifications and feature creation on the FE Model can be defined using small groups of Morphing Boxes. In cases where sheet metal entities have to be modified, the 2D Morphing Boxes can be used which are significantly more simple and easy to be defined and handled (Figure 8). One more design variable will control the bead definition.

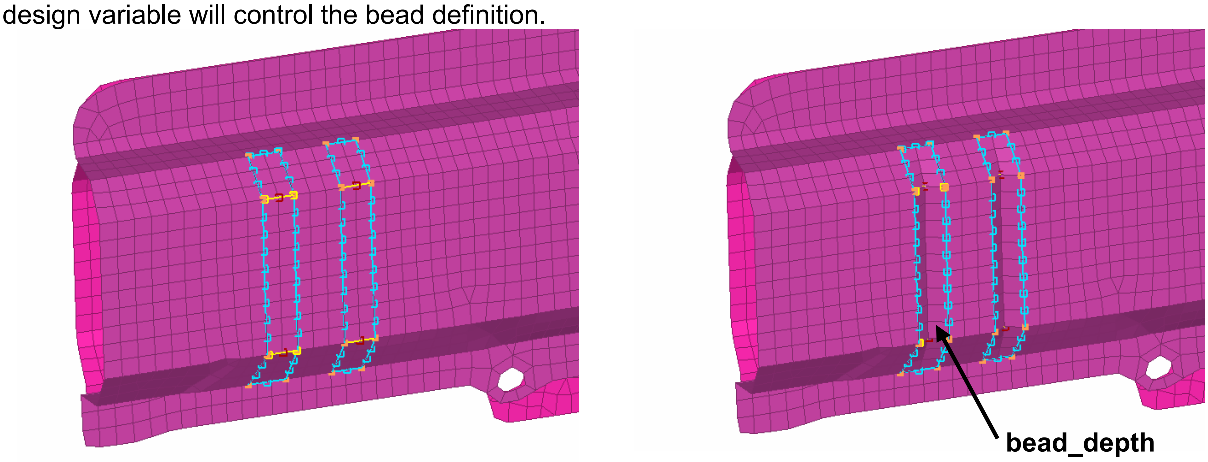

Figure 8: 2D Morphing Boxes

2.3 Defining ANSA Parameters

The thickness of the front rails and suspension towers will be controlled by design variables. For the coupling of the shell thickness to the design variables, a special entity of ANSA pre– processor will be used, the ANSA Parameters. These entities can handle any value on an ANSA card in a parametric way. Thus the shell thickness (T1) of the SECTION_SHELL cards is substituted by an ANSA parameter which later on will be connected to a design variable (figure 9).

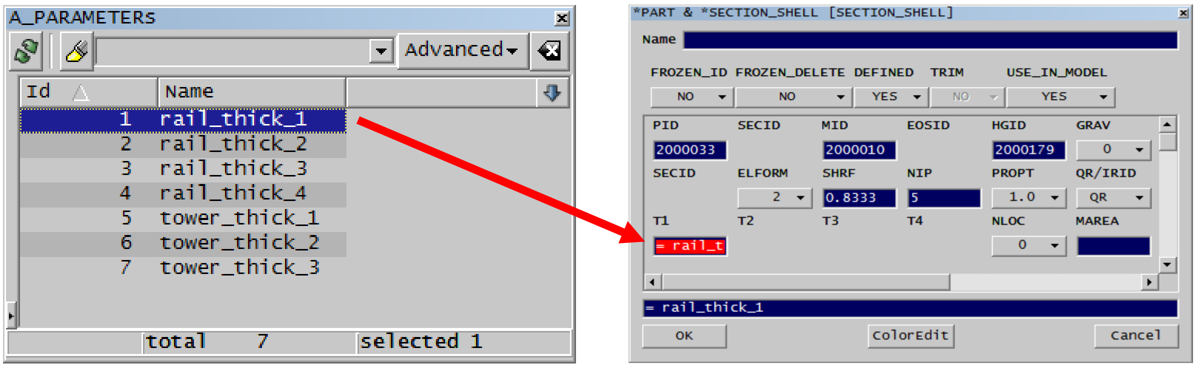

Figure 9: ANSA Parameters

2.4 The Task Manager

The Task Manager of ANSA is a powerful tool which organizes and automates the definition of pre-processing tasks. Here the Task Manager is used for two purposes. The definition of the two load cases beginning from an initial geometrical model and the definition of the Optimization Task.

2.4.1 Defining the load cases

All the actions needed, to define the two FE models are set in the Task Manager in a step-wise sequence. Running the Task Manager sequence, ANSA realizes every Task Item and performs the relative action on the model. The user is prompted to interact when is needed. The process starts from the geometrical model which is common for both analyses. The meshing parameters and quality criteria are prescribed for each discipline. Additionally, all entities that are needed for every discipline are defined at the Task Manager. Such entities are the rigid wall positioning, initial conditions, spotwelds realization, model checks and control keywords. The Task Manager checks if every entity is correctly defined and help the user to complete the model set up (Figure 10).

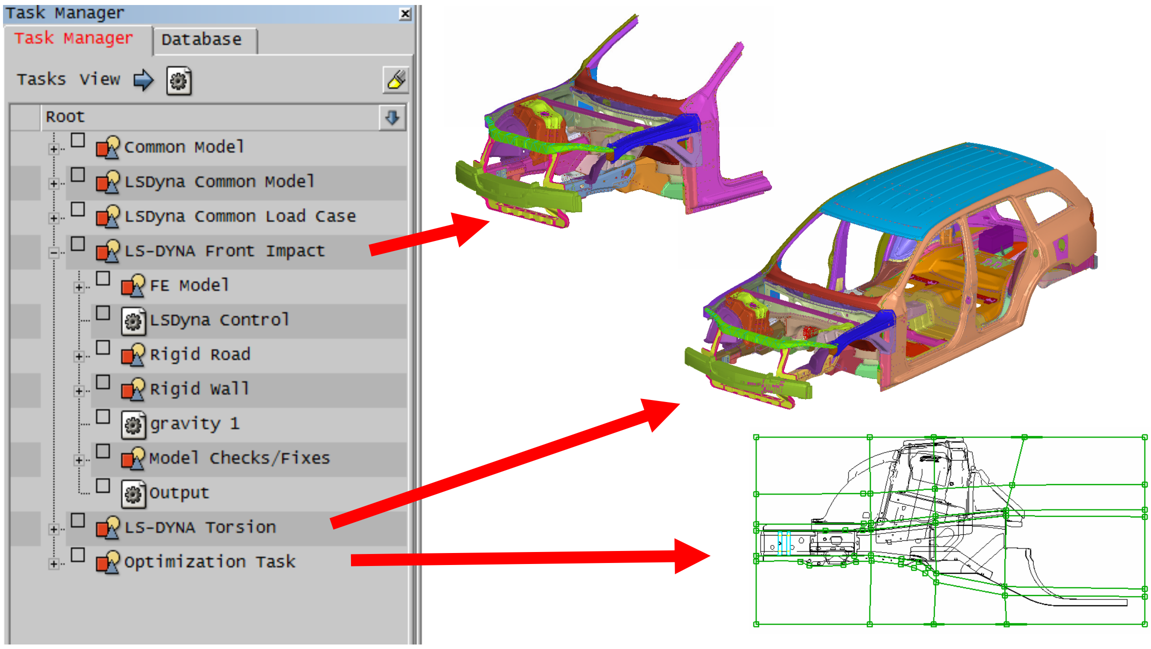

Figure 10: The Task Manager

2.4.2 Defining the Optimization Task

A third Task is defined in the Task Manager. Here, the user can define the sequence of every action that will be executed in each optimization loop. The design variables and their properties and bounds are defined in this Task. These design variables are connected with the Morphing Tool, the ANSA

Parameters or user defined scripts to perform complicated actions. User scripts can also be added to the Optimization Task to create model reports, to apply element quality improving algorithms or to apply model checks before the final output.

The Morphing Parameters that control the model shape are connected to the design variables of the Optimization Task through a simple correlation. Now any change in the current value of the design variables will drive the morphing parameters and hence the morphing action (Figure 11).

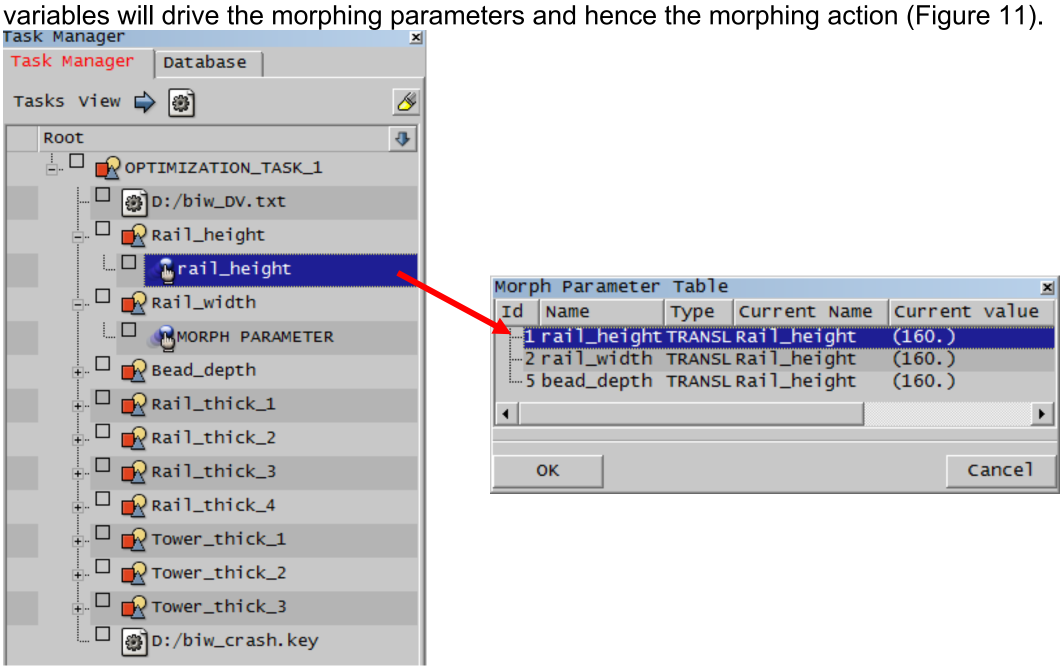

Figure 11: Connecting design variables

Then, the design variables that control the shell thickness of the model parts are connected with the defined ANSA Parameters (Figure 12).

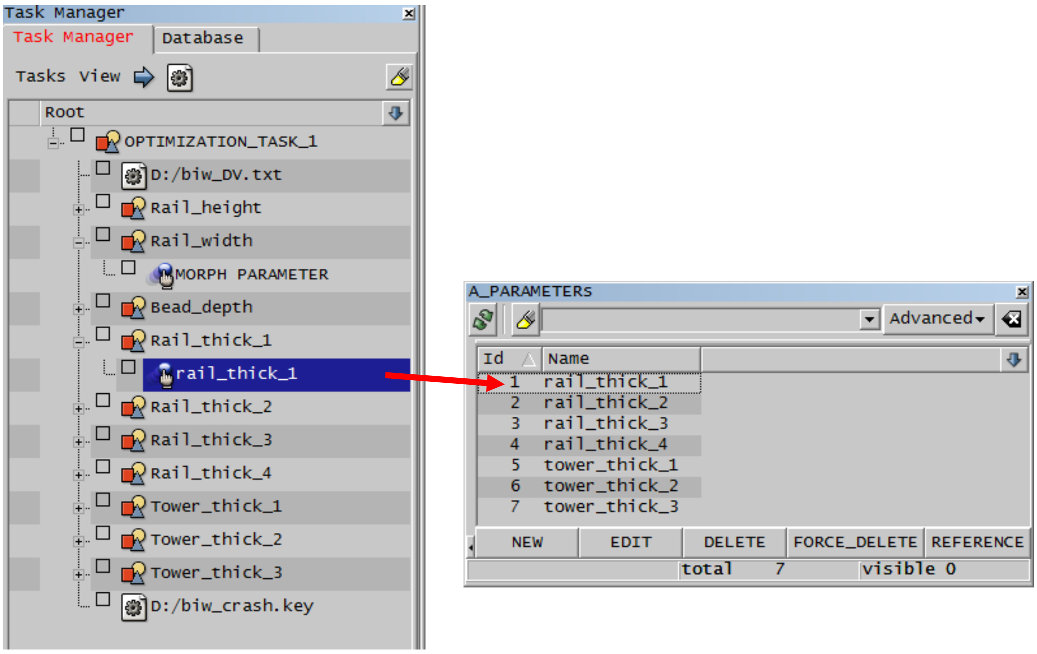

Figure 12: Connecting ANSA Parameters

2.5 Input / Output

The communication among ANSA and LS-OPT is achieved with the use of two ascii files which are defined in the Optimization Task. The first file is the DV File which contains the design variables, their bounds and current values (Figure 13). LS-OPT reads this file and extracts the design variables values. The optimizer will change the current values and the models will be updated in every optimization loop. The second file, the FE Output, contains the FE-Model that will be the input for the solver. The FE-Model is output at the end of the optimization sequence so it contains all the actions that took place in this sequence. One FE Output is created for each discipline.

```
#
# ANSA_VERSION: 13.0.1a
#
# file created by  A N S A  Mon Mar 30 17:26:15 2009
#
# Output from:
# C:/Workspace/biw.ansa
#
# DESIGN VARIABLES
#------------------------------------------------------------------------------------------
# ID | DESIGN VARIABLE NAME | TYPE | RANGE | CURRENT VALUE |  MIN VALUE -->  MAX VALUE | STEP
#------------------------------------------------------------------------------------------
 8,  Rail_height,  REAL,          BOUNDS,  160., 140., 180.
 9,  Rail_width,  REAL, BOUNDS,   64., 60., 68.
 1,  Rail_thick_1,  REAL,         LIST,               1.6,1.2,1.4,1.6,1.8,2.
 2,  Rail_thick_2,  REAL,         LIST,               1.8,1.4,1.6,1.8,2.,2.2,2.4,2.6
 3,  Rail_thick_3,  REAL,         LIST,               1.6,1.2,1.4,1.6,1.8,2.
 4,  Rail_thick_4,  REAL,         LIST,               2.,1.6,1.8,2.,2.2,2.4,2.6,2.8
 5,  Tower_thick_1,  REAL,        LIST,               1.4,1.,1.2,1.4,1.6,1.8,2.
 6,  Tower_thick_2,  REAL,        LIST,               2.,1.6,1.8,2.,2.2,2.6,3.
 7,  Tower_thick_3,  REAL,        LIST,               0.8,0.6,0.8,1.
#------------------------------------------------------------------------------------------
```

Figure 13: The DV file

2.6 The Optimization Task for multiple models

The Optimization Task should control both models for the crash and torsion analysis so as to set up the multi-disciplinary process. The two models should be modified in exactly the same way, in every iteration, even if the meshing or defined entities in the two models differ.

The two FE-models are created by running the Task Manager for each load case. These models can be saved in separate ANSA files. Also, the Optimization Task can be saved as a separate ANSA file which contains the Task Items of the sequence and any entity that is connected to them. So, the Morphing Boxes, Morphing and ANSA Parameters that are connected to design variables will be saved in this file. Also, any user scripts or commands that are defined as Task Items will be saved at the same file too. Finally, the Optimization Task is merged to each one of the previously defined ANSA files, producing the final ANSA files that will be connected to the LSOPT (Figure 14). Both models will be controlled by a unique design variables file ensuring identical modifications.

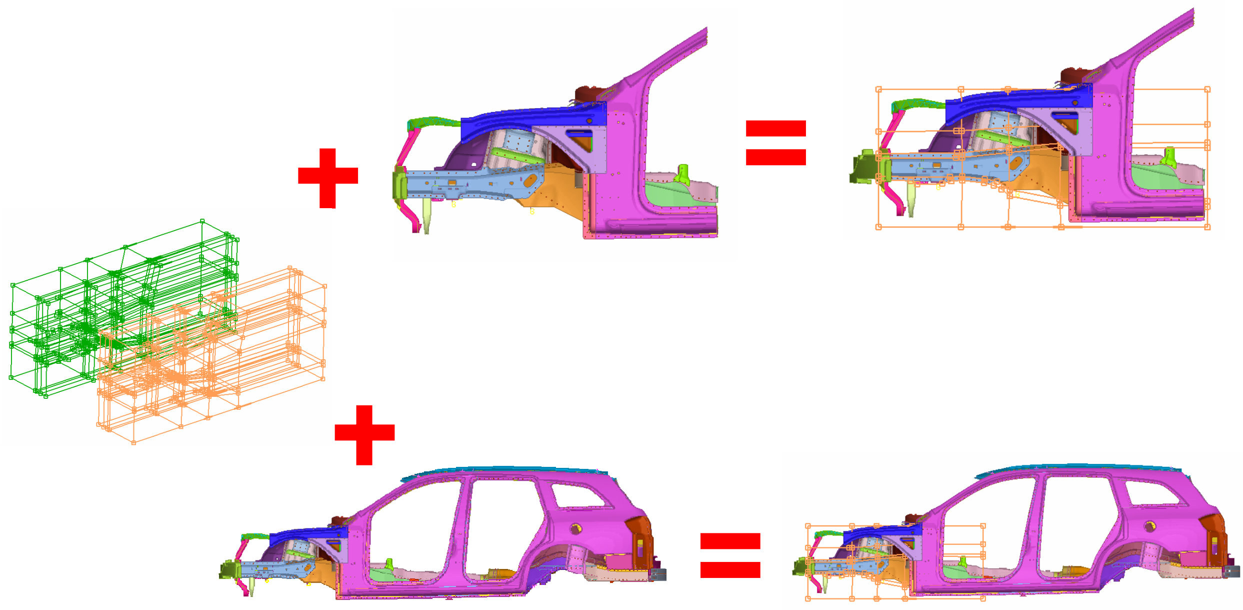

Figure 14: Merging ANSA files

3 Extracting responses from META Post

The latest development of Meta Post-processor allows the extraction of responses and histories from many solver result data and prepares all needed files for the easy connection with an optimizer. Furthermore, the capability of META Post of reading ascii or binary results of many solvers and creating sophisticated reports and statistics and the advantage of the graphics interface makes this post- processor a very important tool for the optimization problem set up.

After a baseline run the solver results can be read in META Post and the user can select the responses or histories that will be extracted. By reading the results of the crash model, the intrusion t used as objective parameter can be identified. An Annotation for the intrusion value is defined from the relative tool, which points at a selected entity and it is updated for every time step (Figure 15). The defined annotations will be used for the definition of the responses later on.

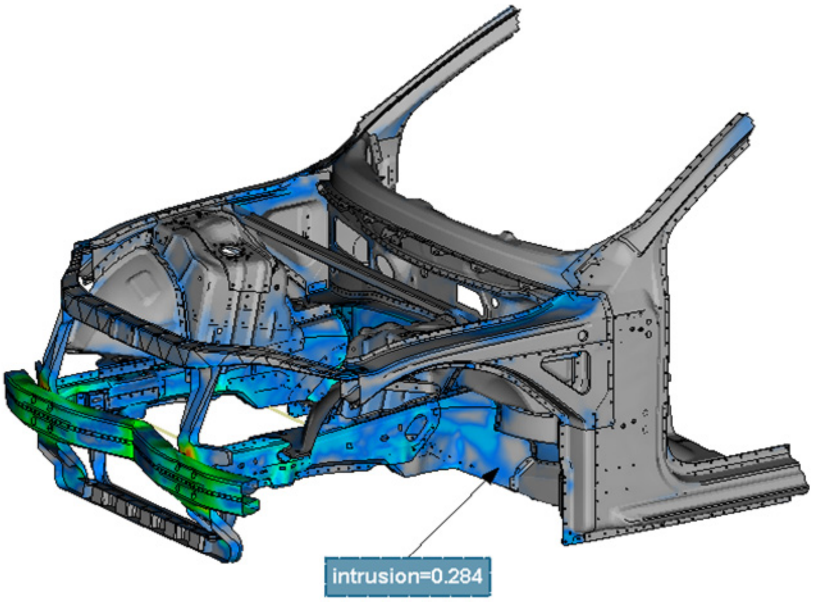

Figure 15: Extracting intrusion

The maximum acceleration which will also be used as objective parameter will be extracted through the 2D Plot capability of META Post. A velocity curve from the result files is read in and a SAE filter is applied to eliminate noise creating a new smooth velocity curve. Though the user functions of 2D Plot the new curve is differentiate to produce an acceleration curve. An annotation is created for the maximum value of the curve (Figure 16).

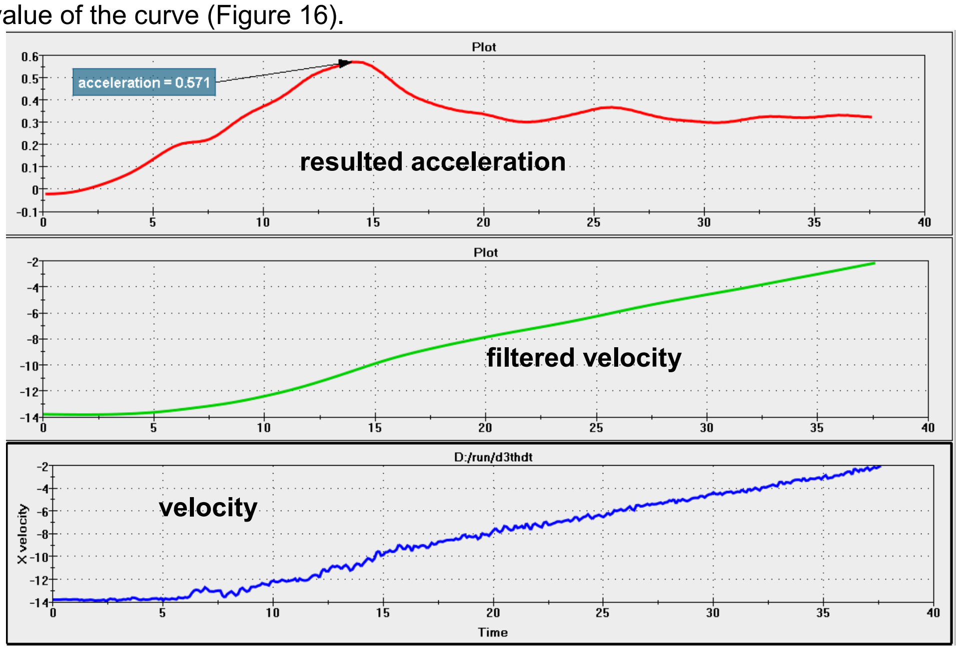

Figure 16: Extracting the acceleration

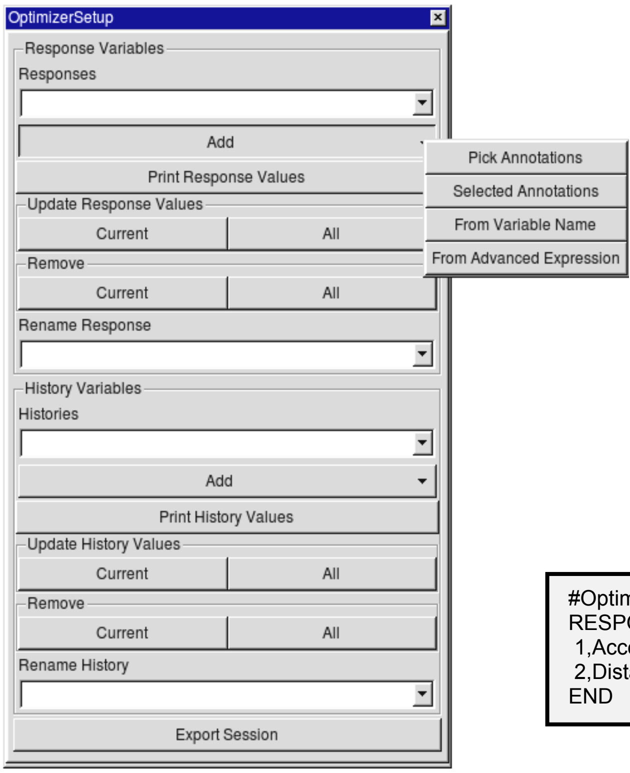

Figure 17: The Optimizer Setup

```
#OptimizerSetup Response & history File created by META post
RESPONSES
 1,Acceleration,0.571
 2,Distance,0.2191
END
```

Figure 18: The responses file

A special toolbar, the Optimizer Setup, will extract responses from the defined annotations. Upon saving, the responses are stored in a text file with a specific format which is recognized by LS-OPT. At the same time all the actions that the users have made in META Post until the response creation are saved in a session file. Using this session file LS-OPT can reproduce the response extraction through META Post in every optimization iteration.

A new response file and session for META Post will be created for the second model. Here the maximum displacement at the suspension towers will be set as response (Figure 19).

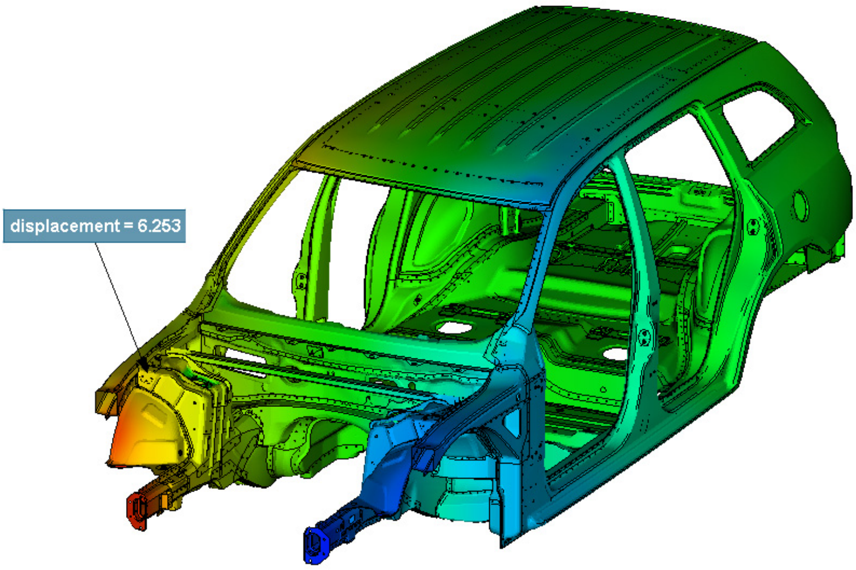

Figure 19: Extracting maximum displacement

4 Connect ANSA and META Post to LS-OPT

The optimization sequence that is defined in ANSA and the response extraction through META Post can be easily connected to LS-OPT to provide a complete solution for optimization. LS-OPT provides special functionality for this connection without the need of scripting and customization.

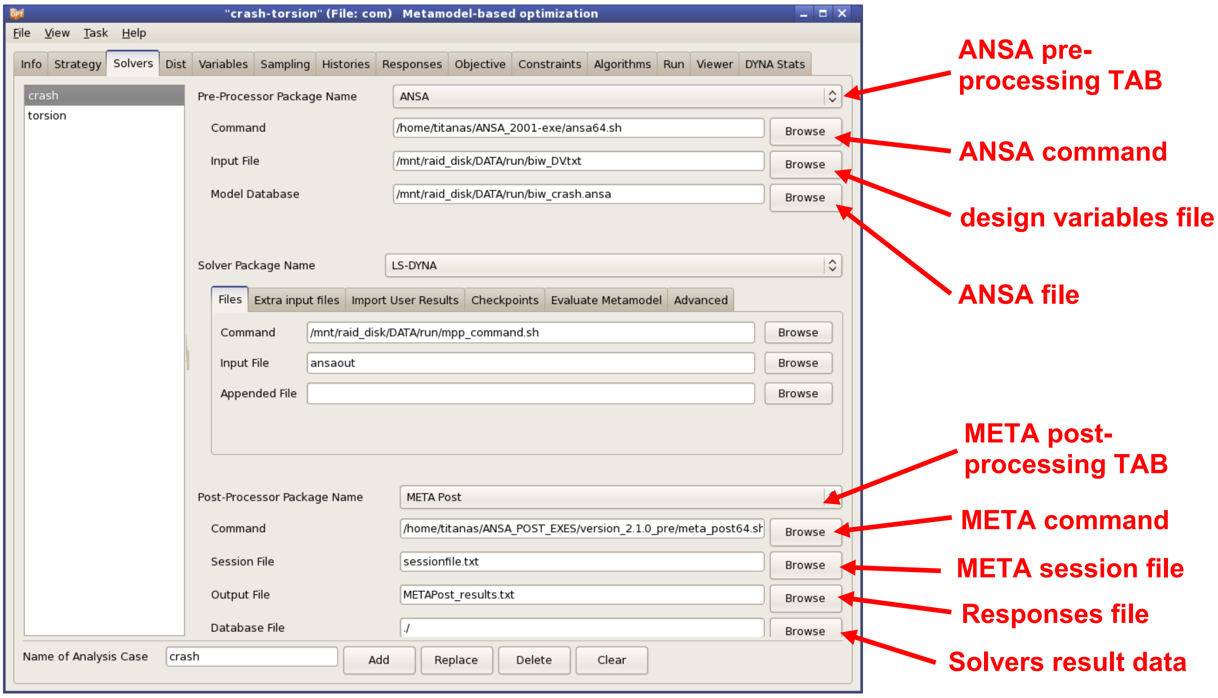

Fig. 20. The ANSA and META tabs in LS-OPT

LS-OPT provides a special pre-processing Tab for ANSA where the user can define the ANSA command, the ANSA file and the design variables file (Figure 20). All the information contained in the design variables file is recognized from LS-OPT so the design variables with the correct name, type, bounds and initial values are defined automatically as shown in figure 21.

META Post is connected to the brand new TAB for META Post processor of LS-OPT. The META Post command, the response file and the session file are entered to the relative fields (Figure 20).

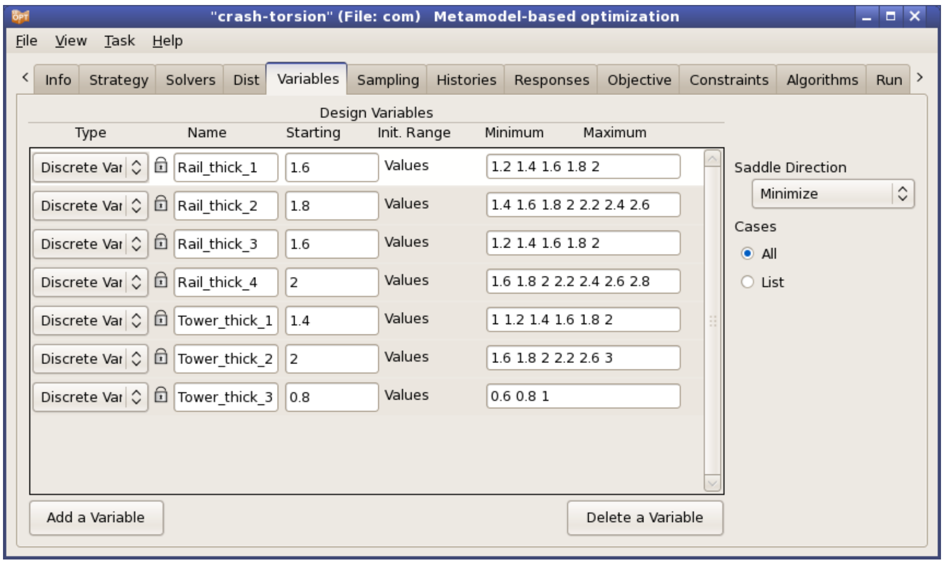

Fig. 21. The design variables in LS-OPT

All responses and histories are recognized and imported to the relative tabs of LS-OPT as shown in figure 22. The above process is defined for both disciplines.

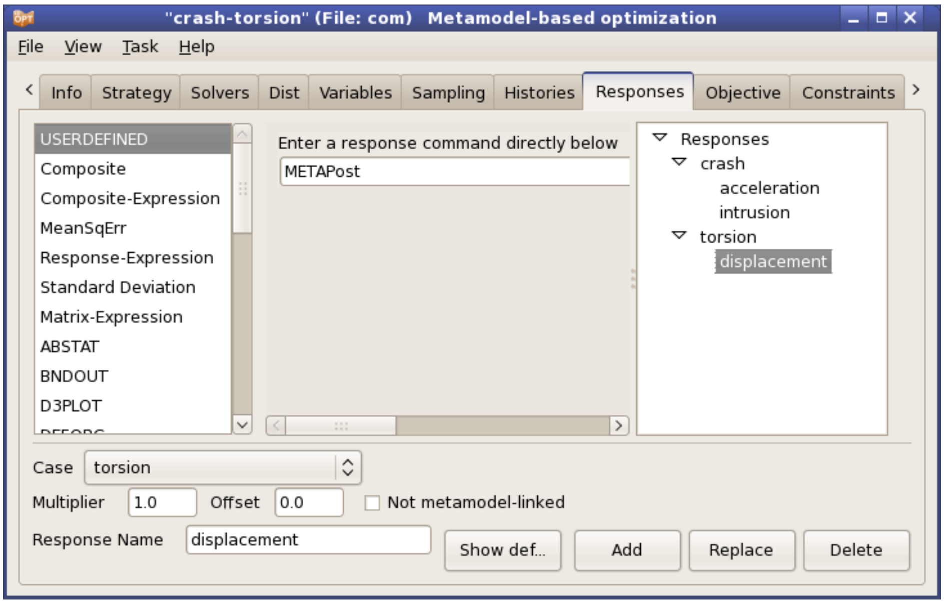

Fig. 22. The design variables in LS-OPT

5 Summary

The Morphing Tool provides powerful functionality for shaping FE or geometrical models. Global and local modification on the model's shape can be controlled from the design variables which are used for shape optimization problems.

The coupling of ANSA, LS-OPT and META Post provides a complete solution for optimization problems. Different solvers can be controlled through LS-OPT while histories and responses can be extracted from META Post and feed the optimizer. The capability of ANSA to define multiple models for different analyses starting from an initial geometry and controlled by a unique optimization sequence, facilitates the set up of multi-disciplinary optimization problems. The definition of the multiple models and the optimization sequence is automated and standardized through the Task Manager.

6 Literature

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