GEOMETRY PARAMETRISATION WITH MORPHING BOX AND INTEGRATION INTO A MULTIDISCIPLINARY OPTIMIZATION

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TASK MANGER
PART MANAGER
BATCH MESHING
MULTI-DISCIPLINARY DESIGN OPTIMIZAZION (MDO)

ABSTRACT –

The complexity of the development of the BIW's parts increase year after year. The material mix, the introduction of platforms, the different fabrication processes, the weight, the constant increase of load cases are all factors that a mechanical engineer today have to take into account. The amount of parameters is so huge that is almost impossible to find an optimum. Getting a working solution is most of the time a real challenge itself.

The use of part design optimization based on CAE simulation is nowadays very common and widely spread. Those simulation results are of course essential and should be a great help for the mechanical engineer. The drawbacks are often on one side the time delay between the emergence of a new design and its evaluation and on another side the complexity of the preparation of a full automatic optimization process.

This paper will describe a new approach of the way to implement a full automatic optimization process. The focus will be put on the reduction of the complexity and the regular analogy to real processes.

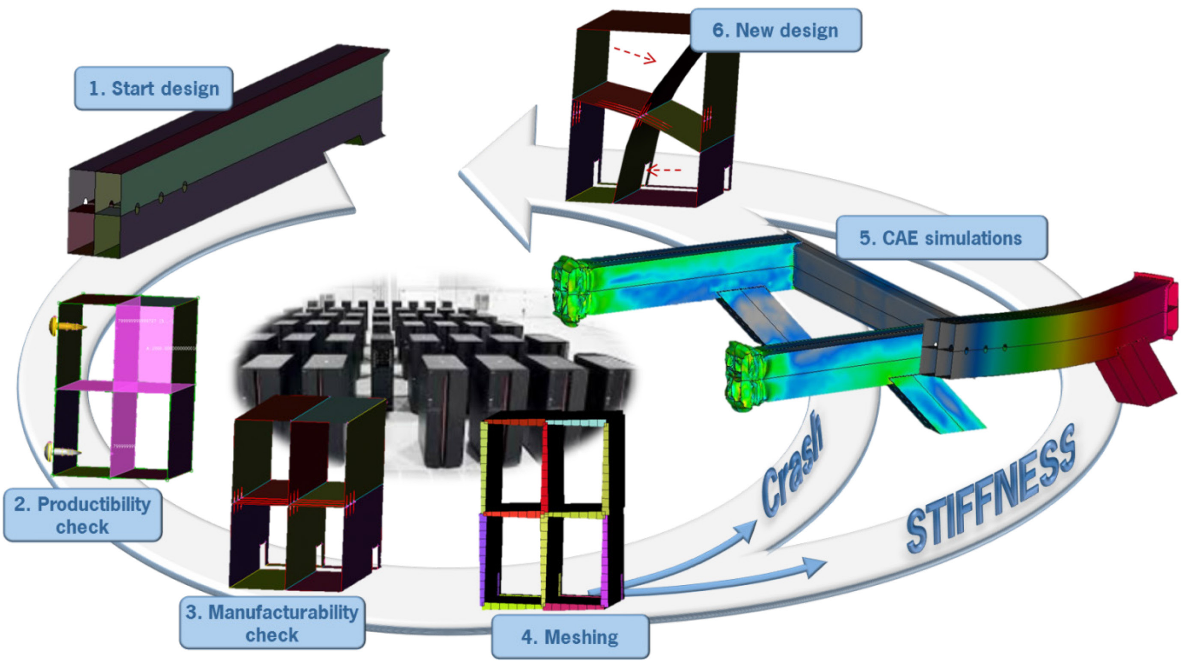

Figure 0 – Multi-disciplinary optimization process

1. CHALLENGE OF A MULTI-OBJECTIVE OPTIMIZATION

The development of a front side member will be taken as example to illustrate the methodology. First of all the boundary conditions and load cases have to be listed in order to isolate the worst cases. In a second step, in order to reduce the complexity, the design, which shows the highest potential, should be chosen as starting point for the optimization. Let now assume that we are in a very early stage of the development and that we were able to reduce the problem the following objectives:

- Producibility: Each valid design must be fabricable. The optimizer has to be aware of the production restriction.
- Manufacturability: The integration of the part into the car should also be considered also. The position of screw holes, fillets or nuts might be fixed from the environment and have to be respected
- Energy absorption: Adjusted crash performance is the main function of a front side member and is essential to ensure the safety of the passengers.
- Stiffness: The modal response of the BIW has a direct impact of the driving confort of the car. Therefore it should also be optimized.
- Weight: Nowadays the weight reduction is one of the most challenging components of the BIW development. Light design should be preferred to fulfil the challenge of a low energy consumption

The challenge of a multi-objective optimization is to design a full automatic process that is capable of taking into account all the listed objectives in parallel. Usually such processes have a high level of complexity and are often develop disregarding the common development process. This paper will show how this complexity can be reduced and how the standard process can taken as basis for the design of a MDO (Multi-Disciplinary Design Optimization) process.

Before starting one important task have to be done: The definition of the reference. Unfortunately this step is often disregarded. In some cases it was afterwards almost impossible to get for it a clear response of the listed objectives. At the end the goal of an optimization is to obtain a better behaviour than before. But without a clear basis, it is impossible to get a comparison. Therefore the adversary has to be well known and have to compete in the same category.

2. PARAMETRISATION OF THE GEOMETRY

SHAPE PARAMETRIZATION

It will be assumed that the chosen concept for the front side member is an aluminium profile. Instead of trying to parameterize a full finished part with holes, boundary cuts, pressed areas and coving, this methodology will try to parameterize the extrusion process. It is quite simple because it can be reduce to a parameterization in a given plane. The complexity of the extrusion will be also restricted by creating only 4 independent chambers. Each chamber will be built in ANSA with 1 morphing box. After that we will place, on each face of the morphing box, a geometric face with a separated property. The advantage of placing the geometric faces exactly on the boundary of the morphing boxes is that by moving the morphing box edges or corner, the geometric faces won't be morphed, they will be just moved. Using this technique permit to avoid instability problems that might occurred under big distortion or when faces after the morphing get negative areas.

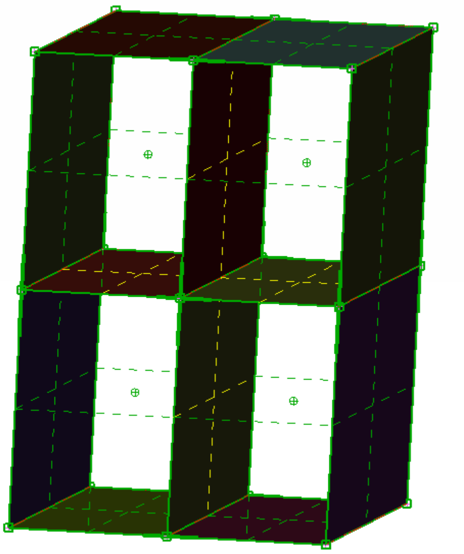

Figure 1 – Geometry of the profile after the extrusion

The parameters that will move the rips can now be defined. One parameter will be defined for the displacement of each rips along the profile contour and two for the position of the rips crossing point.

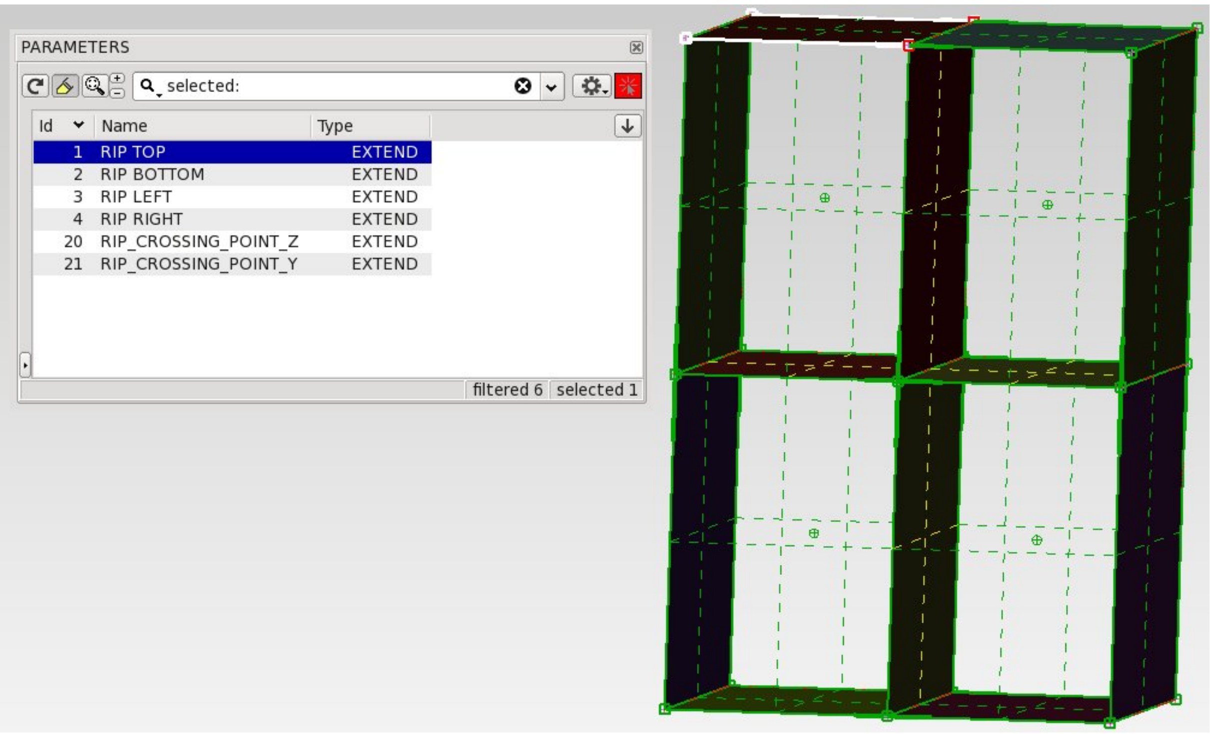

Figure 2 – Definition of the rip parameters

To better control the crash behaviour of our profile, we will choose to drill holes throw the part. This could have following impacts of the profile crash behaviour. It might force it to collapse at a given position and might control the force level over the time. Changing the diameter of the hole or its position along the profile could very be challenging if it's coming in conflict with ribs or other holes. ANSA provides functionalities for this, but there are based on mesh and are sometime instable with complex geometry. Once again it is sometime useful to take distance from the problem and try to think different. Maybe the holes don't need to be moved. This methodology will show that moving the drill machine is easier.

Now the problem seems to be quite simple. The drill machine will be represented in a simple cylinder with a parameterized position and diameter. The depth of the hole could be changed by moving the cylinder along its principal axis. Once in position, the only thing that still needs to be done is a boolean operation between the cylinder and the profile. At this point we have a simple process that is completely independent of the position of the ribs and of the position of the other holes. Let now parameterize the cylinder with morphing boxes and create the corresponding morph parameters

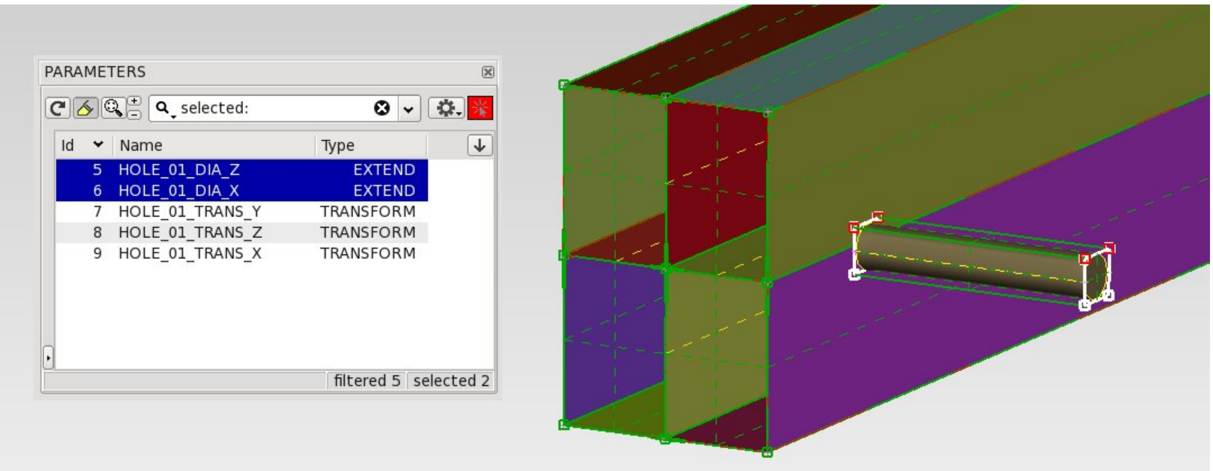

Figure 3 – Diameter parameters of the drill machine

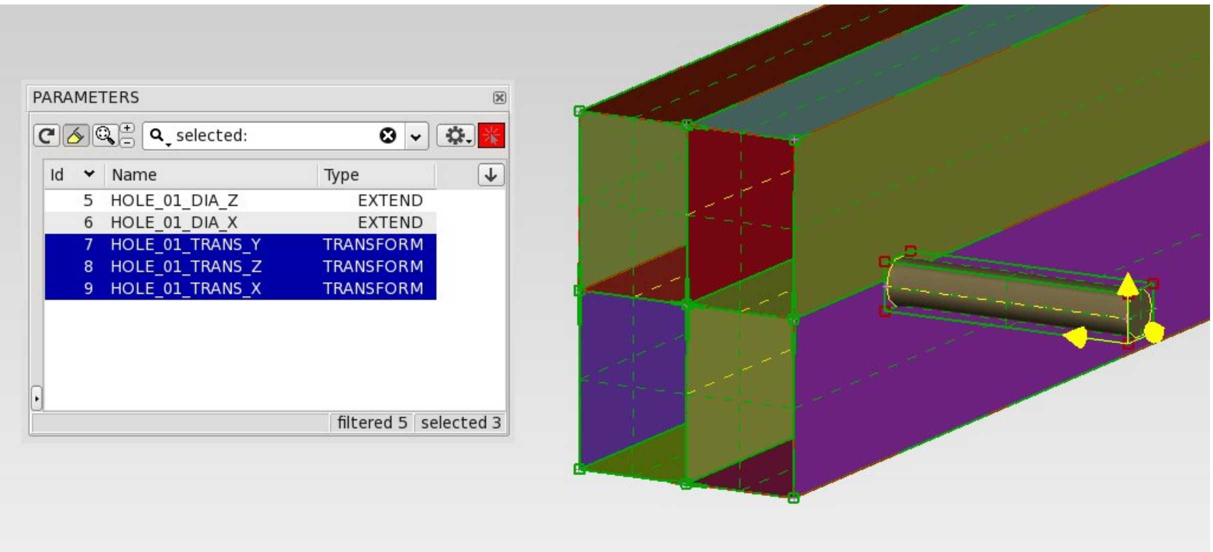

Figure 4 – Displacement parameters of the boring machine

Each hole has three displacement parameters and one for the diameter. Assume that we want to integrate three of such holes in the profile. The results will be 12 independent parameters.

THICKNESS PARAMETRIZATION

For the definition of the thickness parameters, a well-known functionality of ANSA will be taken: A_PARAMETER (1). On the outer surface we will define 2 parameters one for the start and one for the end thickness of each geometric faces. By defining 2 independent parameters the thickness can increase or decrease along the surface.

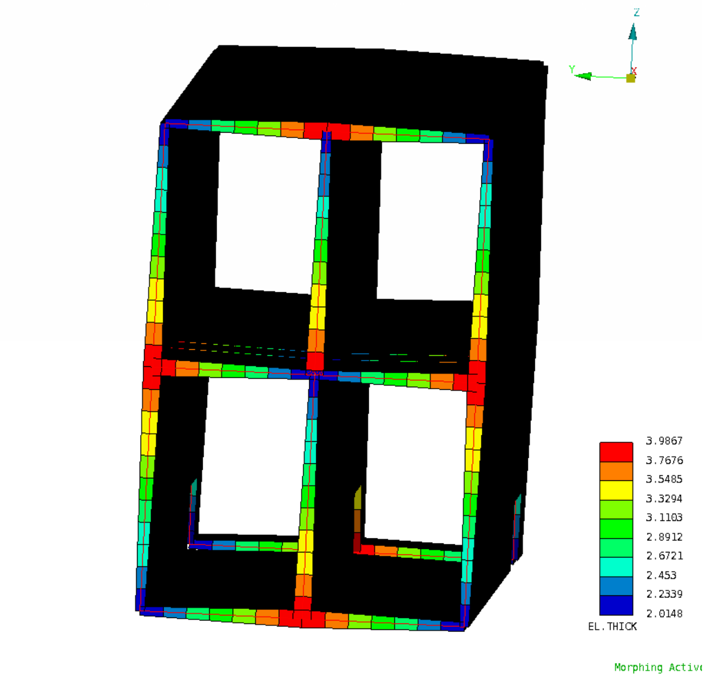

Figure 5 – Example of a possible thickness distribution

2. INTEGRATION OF THE PRODUCIBILITY AND GEOMETRICAL BOUNDARY CONDITIONS

<u>PRODUCTIBILITY CONDITION</u>

One major restriction of the productibility of aluminium profile is the minimum size of the chamber. This minimum size depends from the material and from the dimension of the profile. In the case of a front side member a minimum area from 300 mm² should be respected. For a future integration in an optimization process is essential that the size of the chambers could automatically be measured. Another important point is to have to possibility to export this area measurement from the model to the optimizer. The optimizer needs the exact value of those areas. A signal valid or not valid is insufficient. In that way it will be able to analyze the system and after a learning period it will be able to avoid non fabricable profile by itself. For the measurement of those areas, MEASURMENT ENTITIES (1) can be used. The extraction of the measurement values can be done with python scripts.
In the example, one area for each chamber will be defined in order to measure the productibility condition

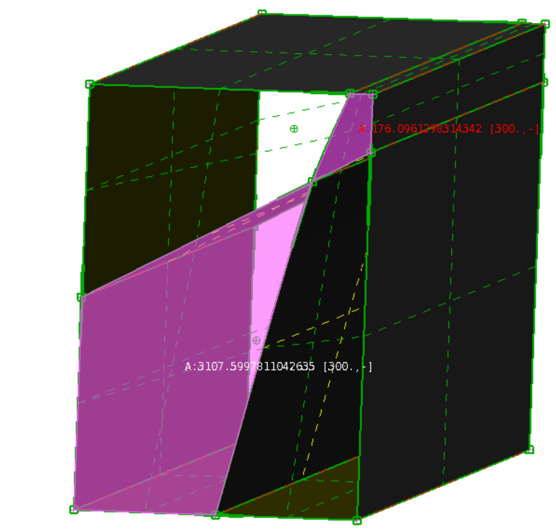

Figure 5 – Example of a no valid design: the camber right up is too small

GEOMETRICAL BOUNDARY CONDITION

One of the geometrical boundary conditions are the potentially collision with parts that lie in the neighbourhood of the profile. Considering the production of real profiles those problem areas will be removed or pressed just after the extrusion. Most of the time, this process is independent of the inner rips and of the outer contour. A possible solution to simulate this production process is to integrate into the model the “No show faces” from the CAD model. Those faces can be considered as negative volumes or as negative blocks to remove. Alike the boring machine cylinder we will use a boolean operation to remove the collision faces from the profile.

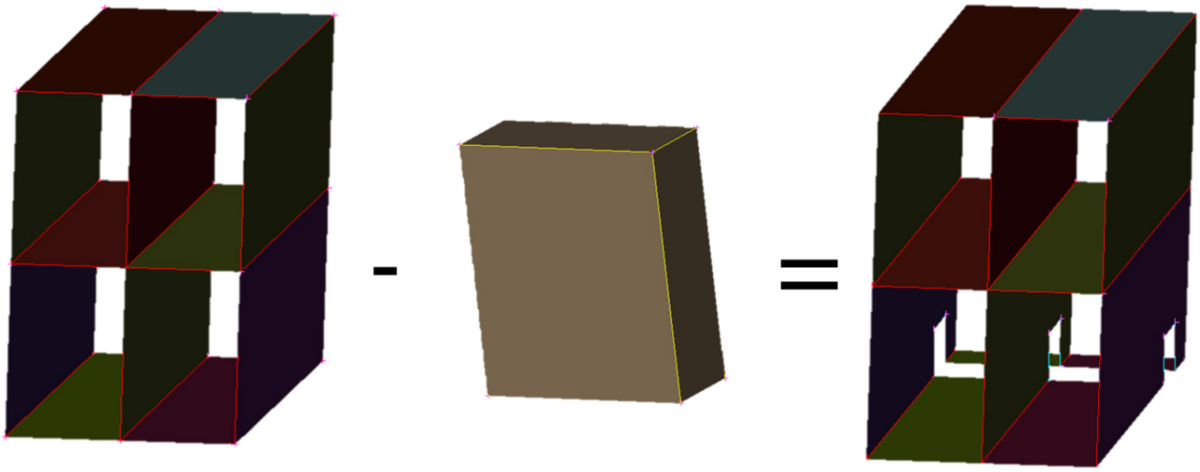

Figure 6 – Example of a boolean operation

Other boundary conditions are the fastening like rivets or flow drilling screws. For both it is essential to reserve a free volume around the welding point. Therefore the distance between the welding points and the inner rips have to be recorded. In case of a conflict the profile has to be marked as invalid. But once again for the optimizer is a boolean signal not enough in order to learn the problem. A signal in form of a double value is much better. To solve this, we will integrate into the profile model the real CAD geometry of the rivets or of the flow drilling screws. Then MEASUREMENT entities can be defined between the rips and the fastening. After each change of the geometry the remaining distance can be exported to the optimizer.

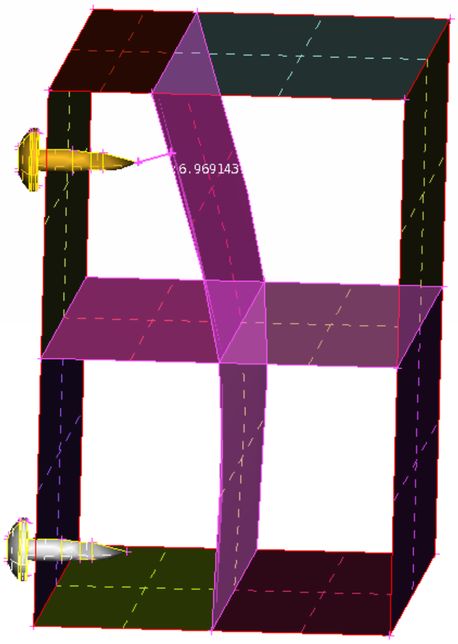

Figure 7 – Example of fastener / rip measurement

3. AUTOMATISATION THROUGH THE OPTIMIZATION TASK

This paragraph will describe how the building steps of the profile could be put together in a single process. At the end this process should be capable to redesign the profile only knowing the new design variables values.

CREATION OF THE DISIGN VARIABLES

The creation of the design variable is a very simple step within ANSA. The only thing to do is to create an optimization task and then to select the defined parameters of the model you want to transform into design parameters. ANSA integrates them automatically into the TASK MANAGER (1) and gives the possibility to define ranges for each variable.

With the creation of the design variable, the geometry of the profile can now be triggered from a simple text file.

TRACKING OF BOUNDARY CONDITIONS

In a second step just after that the geometry gets its new design, the boundary conditions have to be checked. Python scripts will be used for that purpose. They will extract the card values of the measurement entities and export a simple text file for the optimizer. If the current profile design crosses a boundary condition limit, the task manager will send a warning message in order to stop unnecessary CAE calculations.

GEOMETRY CLEAN UP

At this stage all the negative blocks will be removed. The geometry will be checked in order to be sure that all penetrations or failures are removed. This step is essential for the preparation of an automatic mesh generation. At the end of the clean procedure, the geometry will be saved as STEP or IGES: In case of good calculation results this design can be directly send to the CAD department.

BATCH MESHING

A batch meshing session will be prepared and triggered from the TASK MANAGER (1). After the meshing, the quality will be checked and reported. If the quality doesn't match the requirement after many attempts of batch improvement, the task manager will send a warning message. The next processes will be automatically stopped and this design will be marked as no valid. Once the part is meshed, the node thickness can be assigned and the mass can be calculated.

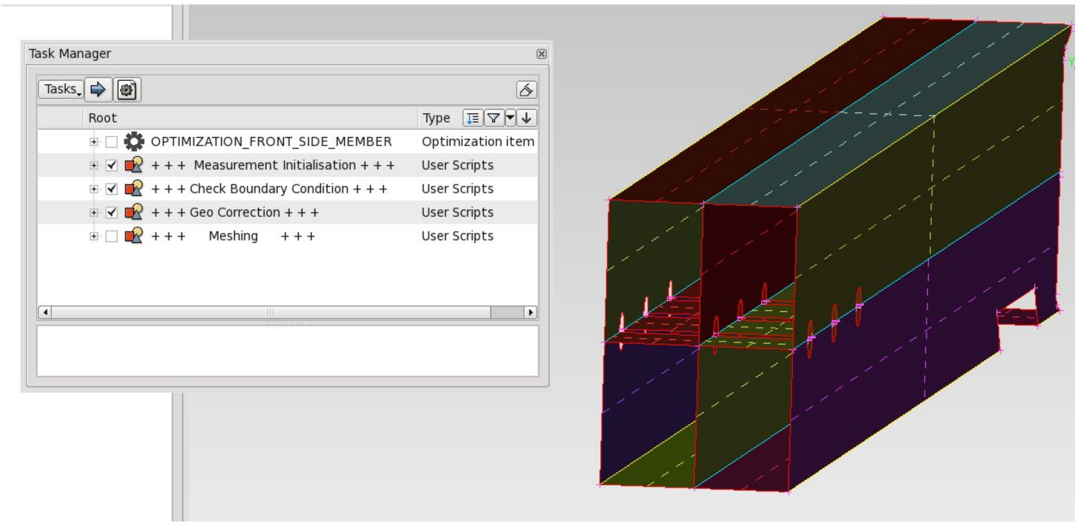

Figure 8 – The implemented task manager sequence

STABILITY CHECK WITH A DOE SIMULATION

A functionality of the TASK MANAGER (1) is very useful and is worth to be mentioned. After turning the optimization to ready to execute, the user have the possibility to run a DOE. In the described case it is very useful because it give the possibility to check the stability of the geometry parameterisation without the integration into an optimizer.

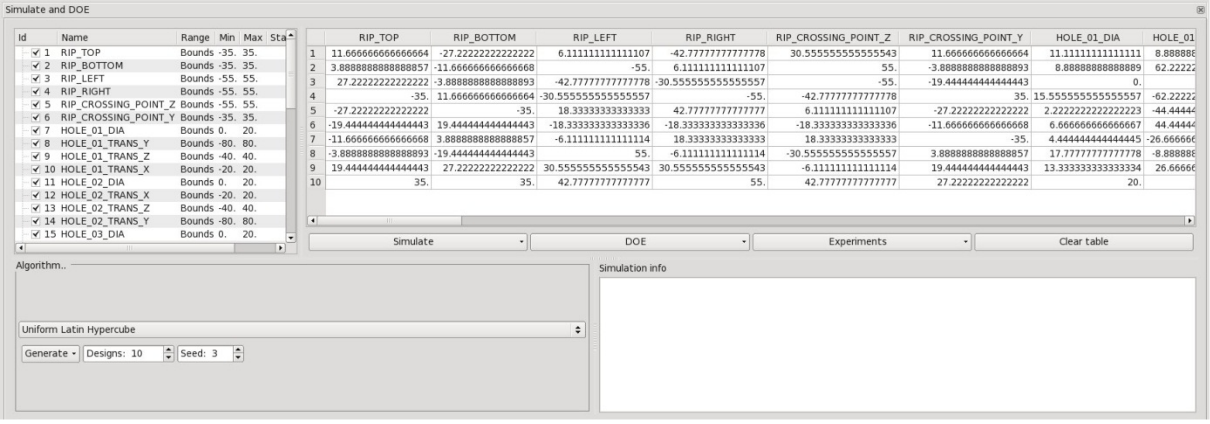

Figure 9 – Preparation of DOE simulation

4. INTEGRATION OF THE GEOMETRY INTO DIFFERENT LOAD CASES

STARTING POINT

Let now resume the situation. First a list of design variables must be defined, that have the capability to create new geometries of the front side member and then to mesh them automatically. The producibility, the manufacturability and the weight of each design can also be extracted. All of those simple steps are bundled in a single straight forward process controlled by the TASK MANAGER (1). Actually this is not far away from the normal development process. The only difference is that in the presented methodology the designer is a single text file. But the result is the same: a new geometry that has to be integrated in different simulation models. In the example of the front side member, a front crash and a NVH simulation have to be started. To achieve this, the CRASH department will be asked for an already running crash simulation and the NVH department for a validated modal analysis calculation. This optimization process will use exactly those input files, the same solver and the same post-processing method.

The next paragraph will describe a way to automatically recognize the old part within the model and then changing it with the new design. A big advantage of this method is that it acts like a surgeon. The focus is put on that part and the rest stays unchanged. This reduces the complexity and increases the stability.

At this point it is important to notice that the described process is based on CAE simulations, which were already validated from the corresponding CAE discipline. This methodology differs from other MDO processes that try to integrate the parameterisation and the creation of the load cases into one step. By comparison those processes suffer from the following disadvantages:

- Sometime the completely model have to be meshed. This leads to poor quality compare to the model coming from the CAE department
- The build of the different load cases have to be fully implemented in order to run in batch mode. This increase the complexity and decrease the stability
- Most of the time the resulted simulation cannot be directly compared to simulation from the CAE department.

AUTOMATIC PART REPLACEMENT

The automatic replacement of the part is principal based on the part manager functionalities from ANSA. One fundamental requirement is to have a clean and updated part structure on the both sides. The new incoming part should have a clear id and version. The same old part should also be clearly assigned to the product structure in all given CAE models. This is the condition needed from the process to be able to automatically recognise the part in the CAE model.

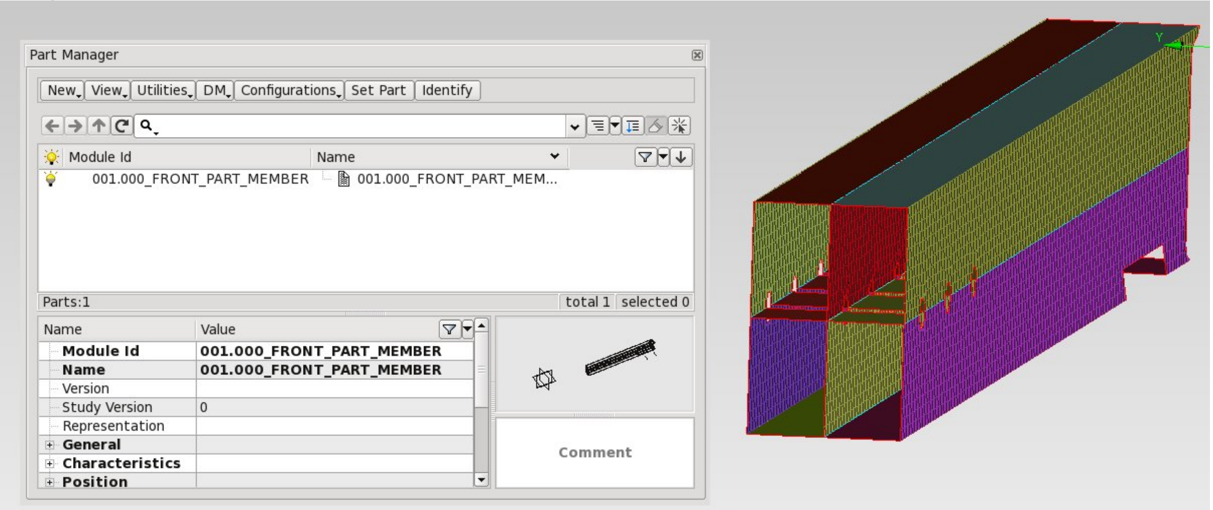

Figure 10 – Part structure of the front side member model

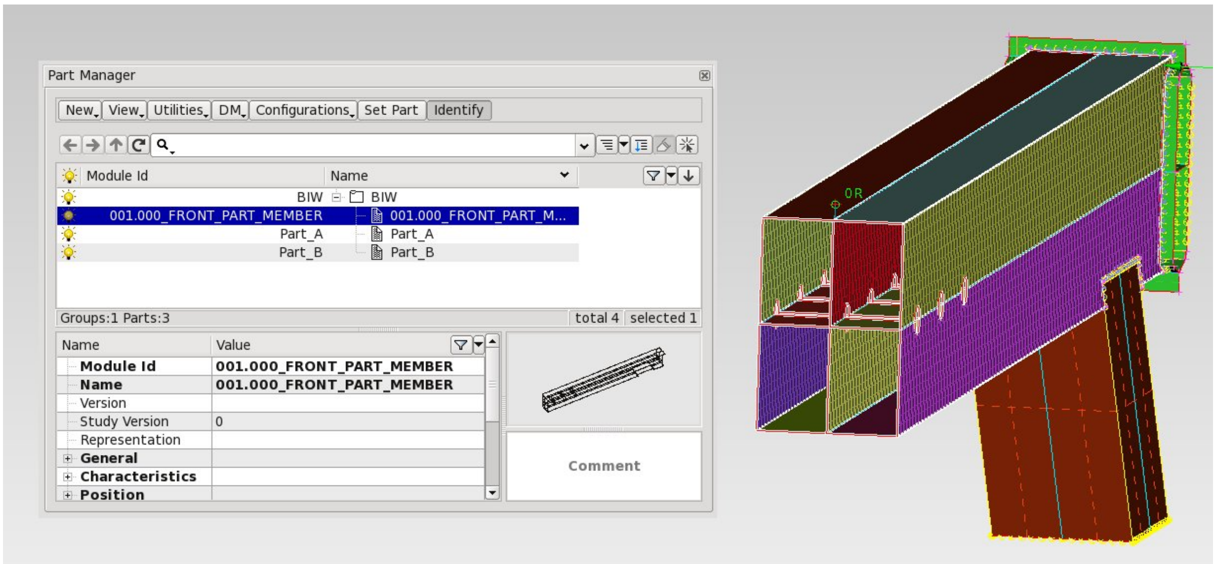

Figure 11 – Part structure of the NVH model

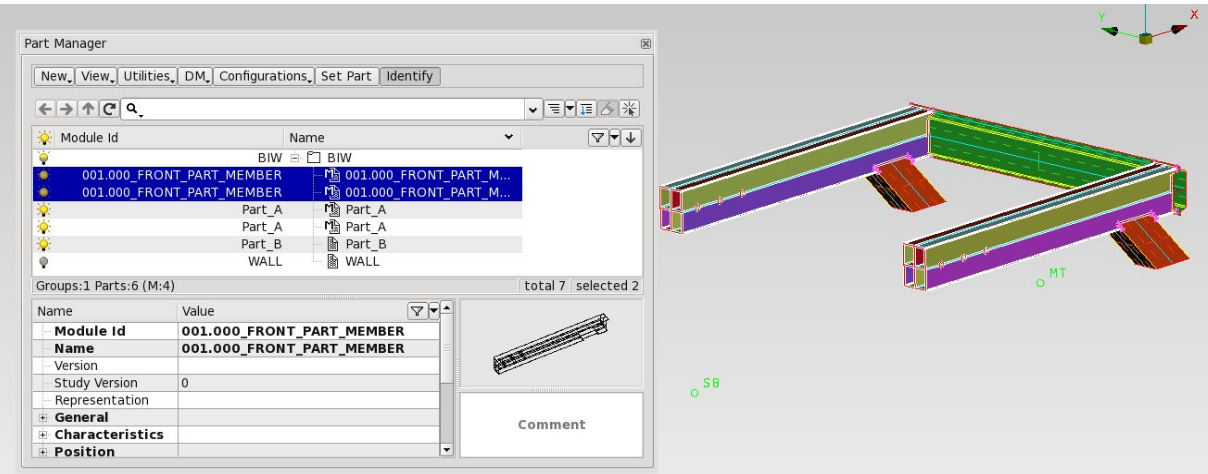

Figure 12 – Part structure of the CRASH model

Another premise is that all fasteners and all post-processing elements have to be defined as generic entities like ANSA connection, connectors or GEBs. In that way it is very simple to reapply those entities after the part have been replaced. In a last step, the corresponding renumbering rules will be called in order to insure that all the input files stay in the correct id range. This condition is unfortunately often not given. Therefore some small changes in the CAE models should be done in order to match these requirements.

This is one of the disadvantages of this method. In order to work straightforward, the process needs to get well-kept CAE models built in ANSA. It is unfortunately not often the case especially if you have to work with models with a long past history.

The big advantage is that you can apply this method independently of the discipline and of the CAE model. Actually the CAE model could be black box. The only requirements that should be given are a part structure and generic entities. Furthermore if the part is present more than one time in the structure it will be also automatically replaced for each positions.

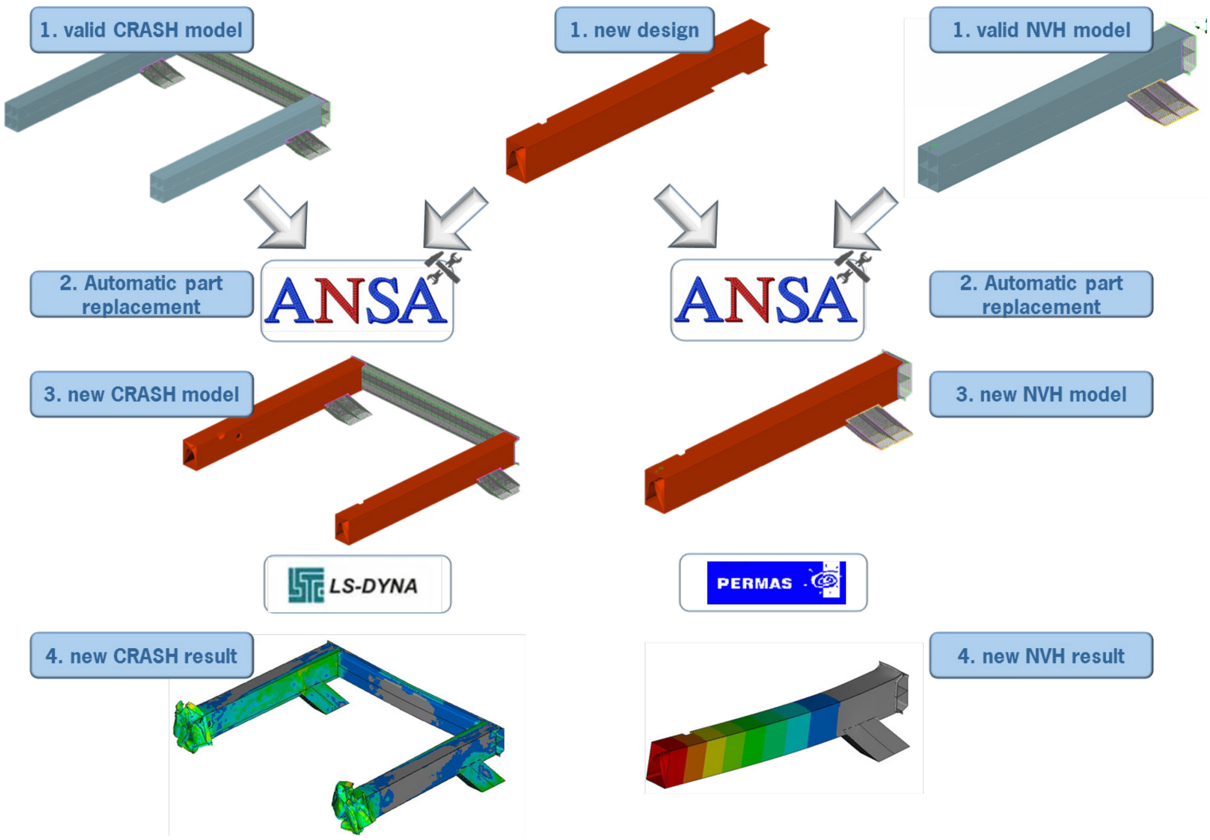

Figure 13 – Automatic part replacement procedure

5. EXAMPLE OF RESULTS

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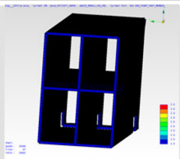
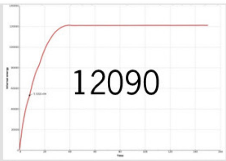
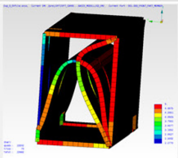
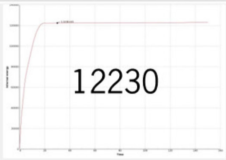
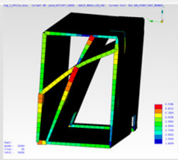
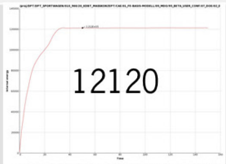
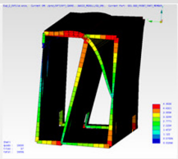
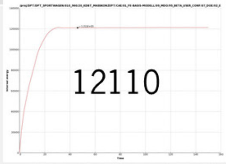
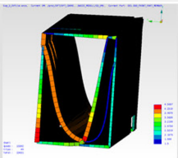
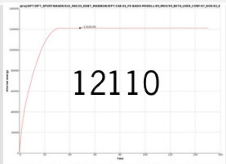
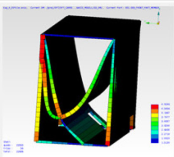
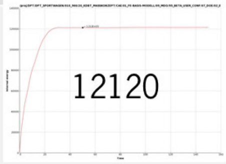
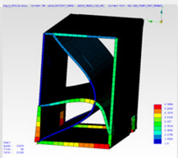
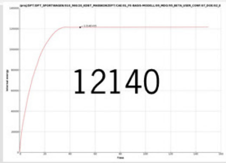
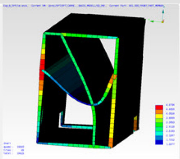
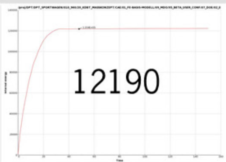
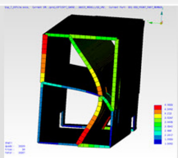
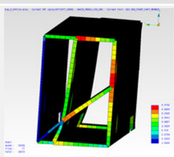
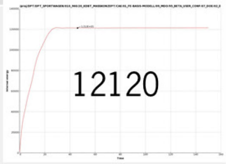
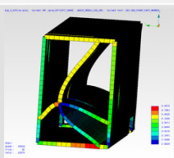
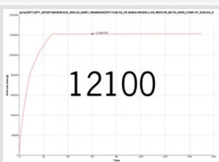
	YES	9.105	85.6	 12090
	YES	19.675	72.7	 12230
	YES	12.642	82.0	 12120
	NO	12.438	76.3	 12110
	YES	13.053	78.9	 12110
	NO	13.857	81.3	 12120
	YES	10.436	86.5	 12140
	YES	11.665	83.2	 12190
	YES	11.904	82.3	 12160
	NO	12.775	81.9	 12120
	YES	15.059	81.6	 12100

CONCLUSIONS

The entire process is based on ANSA functionalities or scripts. The use of the latest ANSA features combined with the old one give the possibility to split complex processes into small and simple entities. ANSA is now growing so fast that to get an overview of all features is very challenging and almost impossible. Therefore asking advices directly from Beta is often very helpful

This paper reduced the complexity of the problem by considering the parameterization of one part only. It was done on purpose. Technically it is also possible to consider a group of parts and to parameterize them as a single entity with its own boundary condition. Once the group isolated, the same process can be use with the only difference that inner connections could also be part of the parameterization.

This methodology was already run in many projects. Lot of experience were gathered. Afterwards it can be said that a robust way was found to define parametric models. But other aspects are still more challenging like the calculation cost and the definition of clear objective values for crash.

By starting such project it has also to be clear that one person alone don't have the capability to bring all the needed knowledge together. Lot of people have to be brought together (designers, researchers, crashers, NVH engineers, optimization specialist). In some cases it lasts months to finalize a multi-disciplinary design optimization.

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