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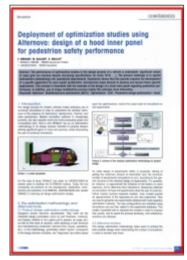

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Deployment of optimization studies using Alternova: design of a hood inner panel for pedestrian safety performance

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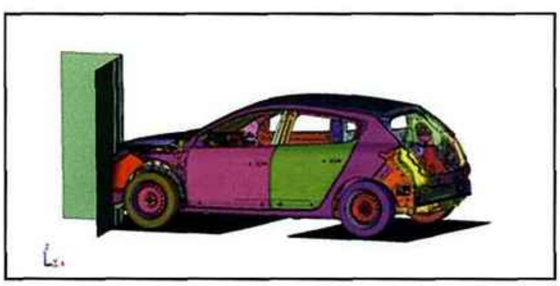
Abstract: The performance of optimization studies in the design process of a vehicle is undeniable: significant values of mass gain are reached despite increasing specifications (in crash, NVH, ...). The present challenge is to spread optimization methodology into operational departments. Experience shows that this process requires the development of a specific application for each expert problematic. Eurodecision helps Renault to develop and spread these specific applications. This concept is illustrated with the example of the design of a hood inner panel regarding pedestrian performance. In addition, use of shape modification process makes this example more interesting.
Keywords: Alternova - Multidisciplinary optimization (MDO) - Optimization - DOE - Parametric design optimisation - Hood.

1. Introduction

The design process for modern vehicles makes extensive use of numerical simulations in order to understand the vehicles' behaviour in the presence of mechanical, aerodynamic, thermal, and other phenomena. Modern simulation software is increasingly powerful, but also requires more and more processing power and computation time. That is why RENAULT set up an optimisation methodology in its design process intended to propose designs offering significant gains in mass and services, while rationalising the use of numerical simulations.



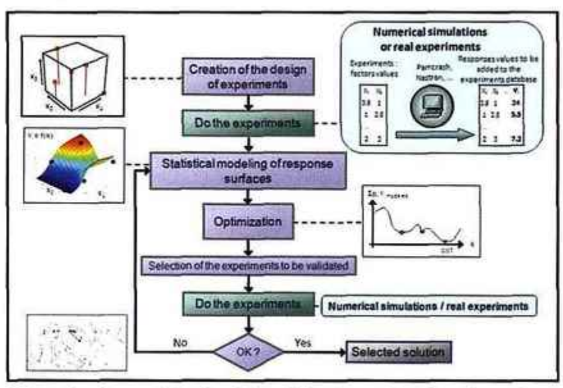
Picture 1: A crash simulation.

For this type of study, RENAULT has relied on EURODECISION for several years to develop the ALTERNOVA toolbox. Today the two companies are partners for the development, distribution, maintenance and evolution of ALTERNOVA. EURODECISION also assists RENAULT in carrying out design optimisation studies.

2. The optimisation methodology and Alternova tools

2.1 Product design optimization methodology

Designers receive technical requirements. They must list the influential design parameters (such as part thickness, materials, and shapes; whether or not a given part is present; an angle, etc.) as well as their level of variation, while factoring in both technical and manufacturing constraints (removal from mould, weldability, etc.). In the methodology, parameters called "factors" correspond to the design decision variables, and "responses" are criteria based upon the specifications, mainly the output data for simulations or real experiments.



Picture 2: schema of the classical optimisation methodology for product design.

An initial design of experiments (DOE) is produced, aiming at getting the maximum amount of information from the minimum number of experiments (simulations to run). According to the specific structure of the selected design of experiments, it is possible, for instance, to approximate the influence of the factors on each response, and to determine their interactions. Responses obtained via simulation of these first experiments allow the user to build statistical models (surface response models). Such models provide an approximation of the responses for any new experiment. They are used to generate new experiments obtained with multi-objective optimisation methods. The new configurations are validated using simulations and are then added to the experiment database. This makes it possible both to reassess the models in order to improve their quality, and to repeat the process iteratively, until satisfactory solutions are obtained.

2.2 Alternova toolbox

This design optimisation methodology helps users to achieve the best possible design while rationalizing the number of simulations in order to shorten lead times.

The ALTERNOVA methodology and tools permit to handle various multi-domain optimization (MDO) cases. For example:

- Mass saving and performance increasing. The aim is to minimize the system's mass or to increase simulated system's performances.
- Failure research: local optimization close to the reference design in order to identify failure behavior. The aim is to find which parameters cause a failure by looking for designs with responses values far from reference responses.
- Numerical model improvement. The aim is to minimize distance between numerical model and real experiment.

Each situation written above corresponds to a specific Alternova application. They are designed to be distributed to people that are not experts in optimization or statistics techniques.

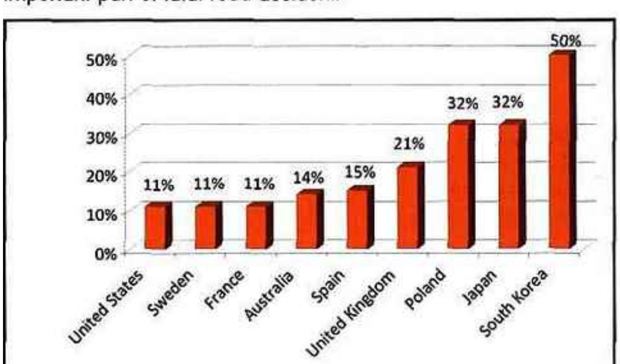
These applications capitalize Eurodecision experience obtained on previous similar studies (Design of Experiments choice, optimization strategy parameters).

They integrate a Human Machine Interface that helps MDO problem definition and post processing operation. They automate every step required for a study:

- Call to Alternova generation of designs executables (designs of experiments and optimization by response surfaces loops),
- Run of the entire simulation campaign: automation of calculations with handling of different input parameters and submission of parallel calculations in several simulation environments. If shape modifications are required, Alternova applications contain automatic design creation and automatic meshing,
- Post processing and calculation output data retrieving,
- Alternova Multi criteria analysis to help the choice of relevant solutions.

3. Pedestrian safety

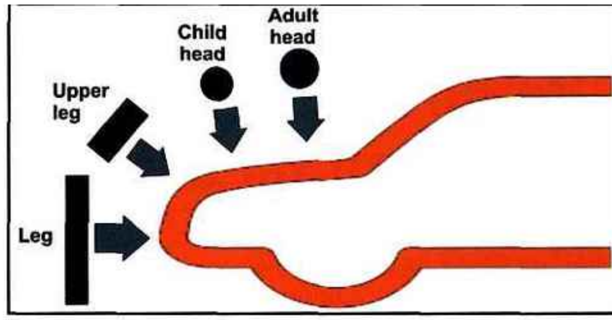
Real accidentology analysis shows that pedestrian represents an important part of fatal road accident.



Picture 3: Pedestrian fatalities.
[JSAE Impact Biomechanics workshop 2008]

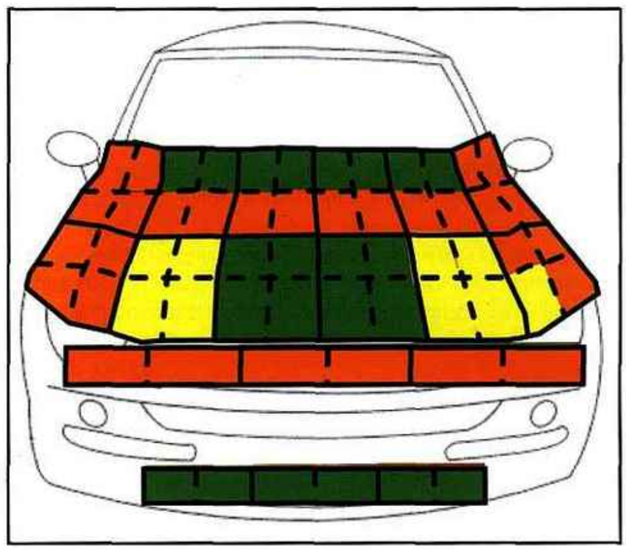
Since 2009, EuroNCAP decided to stop making a specific mark to characterize the vehicle's behaviour regarding pedestrian safety. Instead EuroNCAP included it in its global mark, which was previously a synthesis of important crashes.

Pedestrian safety analysis is done through impacts simulation such as leg, upper leg, child head and adult head impact, as shown on the picture below.



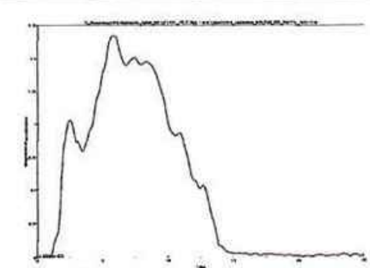
Picture 4: Pedestrian points of impact.
[Euro NCAP website]

Impacts velocity will be 40 km/h. Impacts zones will then be measured and evaluated as good, adequate or marginal.



Picture 5: Pedestrian mark construction.
[Euro NCAP website]

This paper presents more specifically the head impact, which represents 90% of fatal injuries and which is one of the disciplines integrated in Hood/Pedestrian Alternova application. Head impact is characterized by the HIC (Head Injury Criterium) criteria. This criterion corresponds to the maximum value of a floating average of the head impactor center deceleration.



Head Injury Criterion

$$HIC = \max\left[(t_2 - t_1)\left(\frac{1}{(t_2 - t_1)} \cdot \int_{t_1}^{t_2} \gamma_{res}\, dt\right)^{2,5}\right] avec\ t_2 - t_1 \leq 15ms$$

Picture 6: HIC calculation.

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Head impacts are located on the hood, fenders, windshield and windshield pillars.

EuroNCAP partial mark is estimated in the application from HIC value measured on each hood impact.

4. The pedestrian safety software (design of hood inner panel)

The pedestrian safety software is one of the expert applications in the Alternova tools.

4.1 Perimeter of the studies

The hood and its positions in space are strongly dependant on the design of the vehicle, so generally the hood outer-panel will be a fixed input data of the problem and we will search the best solution for a given design.

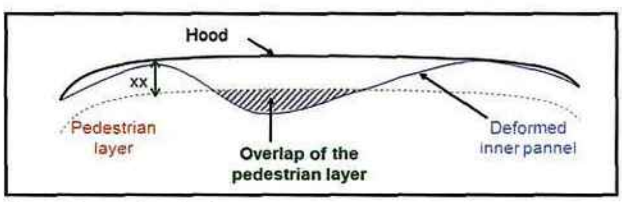
Besides the hood outer-panel, which will be invariant, the hood model is composed of the inner-panel, latch with maybe latch reinforcement and all boundary conditions: springs (position-holding, shock), fender and windshield zone, etc.

Different configurations of the hood inner-panel will be obtained by form modification.

4.2 Concerned disciplines

The main performance is the head impact. Due to the planning of projects, when the study begins some choices are not decided; mainly the choice of the motorization.

HIC evaluation is under estimated due to the lack of the motor. That is why we introduce a second criterion: intrusion of the hood during the impact in the theoretical area of the motor. This area will be called pedestrian layer.



Picture 7: Intrusion criterion.

Besides Pedestrian safety disciplines, engineering of the hood is impacted by other performances such as static rigidity and overrunning.

In static rigidity, objective is to have a sufficiently rigid hood in various conditions (lateral, torsion, bending…) and to preserve it from plasticity.

In overrunning, we don't want the hood to impact its neighbourhood or to permanently deform when closed violently.

4.3 The multidisciplinary optimization problem

Optimization problem is expressed as a two objective problem: Minimizing, for different positions of the head, HIC and intrusion, under the constraint of other simulations (such as static and overrunning).

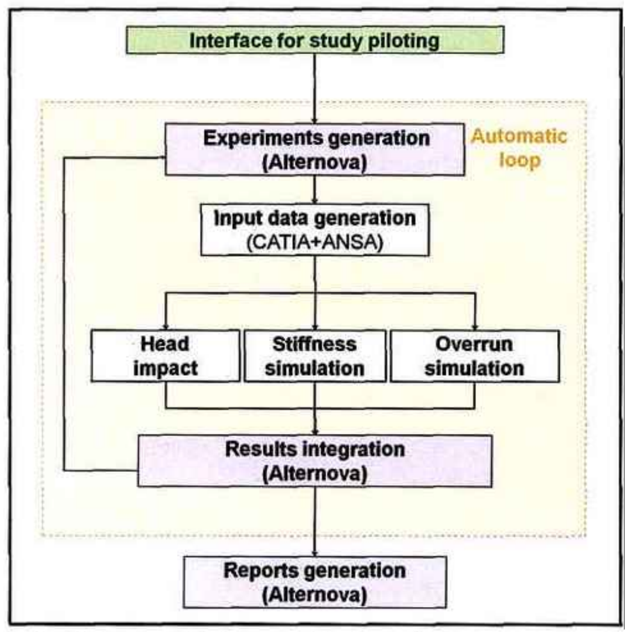
User can describe his optimization problem in this interface:

Strategy 1		
Budget *		
5		
Active Simulations		
Head		
Overrunning		
Objectives *	Direction *	
EuroNCAPNote	MAX	
Pedestrian_Layer_overrunning	MIN	
Constraints	MIN_TARGET	MAX_TARGET
Overrunning_Spring_G		500
Overrunning_X_1002		2
Overrunning_Z_1002	-6	
...		

Picture 8: Interface of optimization description for hood application.

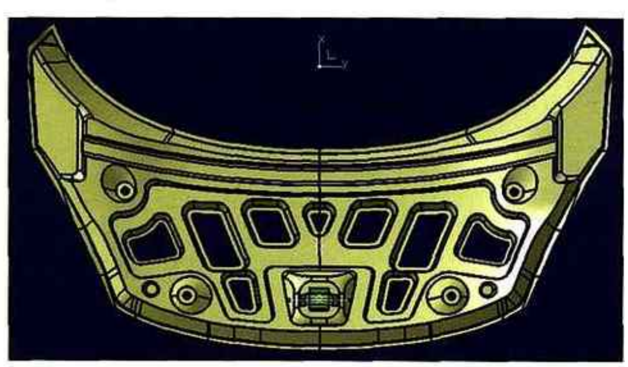
4.4 Application steps

Following diagram shows the sequence of the jobs executed by the application, detailing the steps relative to simulation launching. Experiments are generated according to the methodology presented **Picture 2**.



Picture 9: Sequence of jobs executed by the application.

Starting with the parameterized model given by the user, CATIA reconstructs geometrical configurations of the inner-panel for the different experiments that will be evaluated.



Picture 10: Configuration constructed by CATIA.

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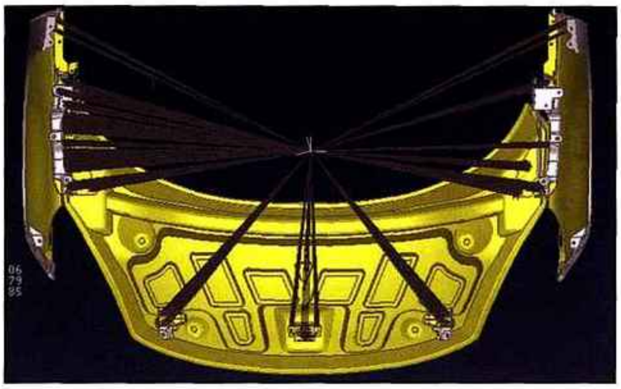
Geometry is then meshed and assembled by an ANSA script. This phase allows introducing the inner-panel to the other constituting parts of the model. Rigid bodies, hemming and glue ensure the links with fenders, outer-panel, hinges... Assignment of thicknesses is also done during this phase.



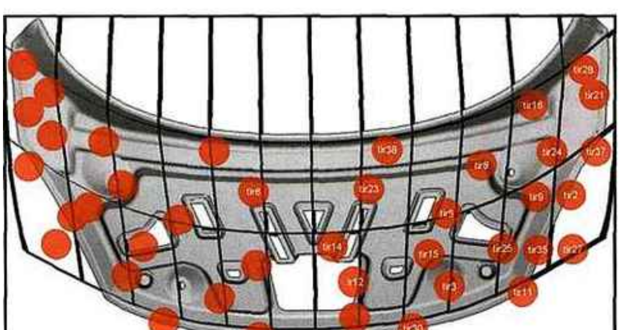
Picture 11: Configuration assembled by ANSA.

Transfers of input data to the server and automatic launches of simulation (including head positioning) is done by the application. Results are post-processed and integrated to the database of the application. Reports include the analysis of most satisfactory configurations. These reports are composed of cartographies and Pareto graphs for different criteria.

4.5 Difficulties

In case of parameterized geometry, not all sets of parameters are feasible. Failure happens during the construction of geometry in case of incompatibility between values of parameters. Others failure can happen during the meshing process. Consequently, we must plan, in the initial phase of the design of experiments, supplementary tests to compensate these failures. In the optimization phase, if we have a good statistical model of the feasibility (answer 0 or 1), it is possible to guide the optimizer towards solutions that seems to be feasible.

For HIC evaluation, 40 impacts positioned in the hood area respecting euroNCAP are defined. In order to spare runs, impacts are divided in three levels.



Picture 12: Example of localization of the 40 impacts.

Impacts of the first level are systematically run. They are used to obtain first evaluation of the configurations. Only promising configurations are run with the second level positions. Likewise, depending on the results, configurations are evaluated with the third level positions.

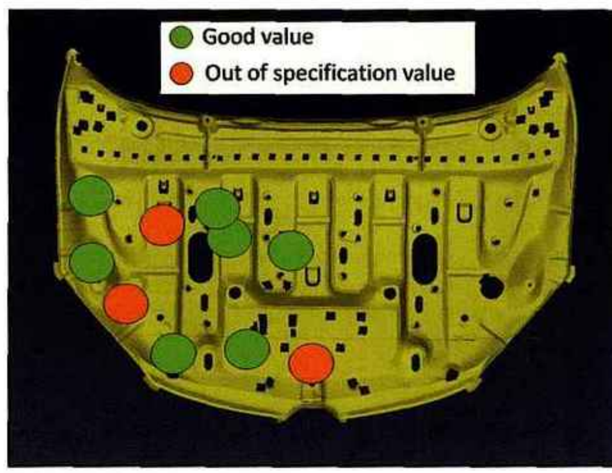
As a final remark, optimization is a difficult task because it consists in finding solutions which are compromises between many criteria. All problems of great dimension optimization apply here: sequencing of criteria, multi-criteria comparison of the solutions, difficulty for the algorithm to converge, etc.

5. B95 study with the Hood/ Pedestrian application

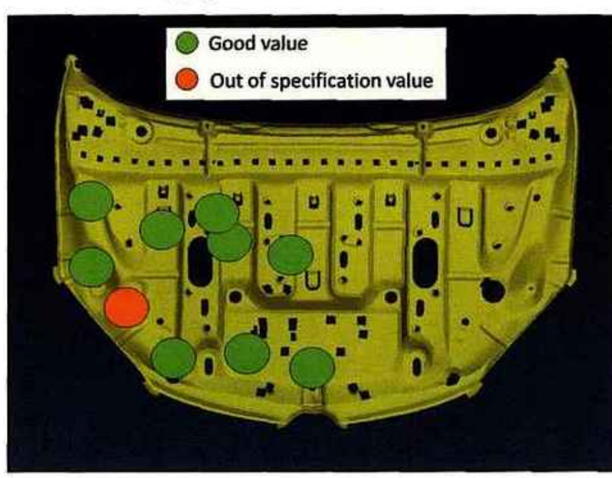
B95 study goal was to assess the performance of a hood inner panel inspired from other car manufactures in the Renault context. This panel, called "A inner panel" is tested on a crash performance: the child head impact. The results are compared to the B95 reference design shown below.

5.1 B95 reference

The initial inner panel is composed by 5 aligned omegas.
As shown on the HIC mapping and on the layer over running mapping (**Picture 13**, **Picture 14**), B95 hood inner panel is globally good on the first 10 level impacts. From the HIC point of view, some raise some issues: it concerns impacts located near springs or near the latch.



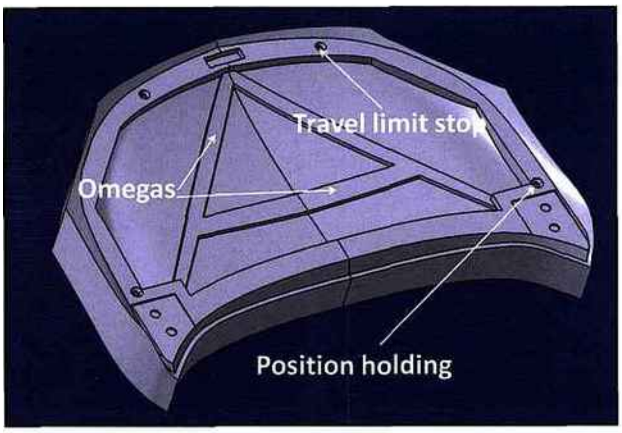
Picture 13: HIC mapping for B95.



Picture 14: B95 layer over running mapping.

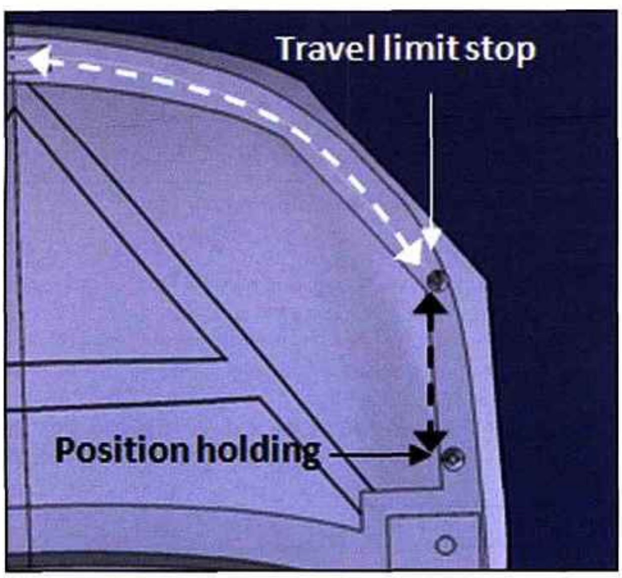
5.2 Study perimeter

The important question to answer is: « Is the hood inner panel geometry shown in **Picture 15** better for head impact performance?".

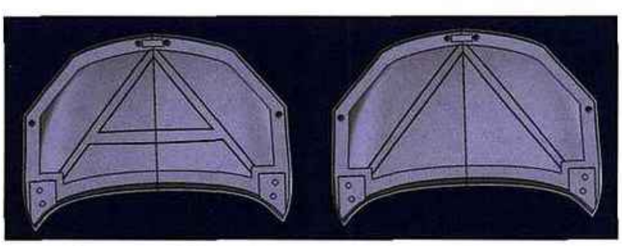


Picture 15: CAD model of A inner panel.

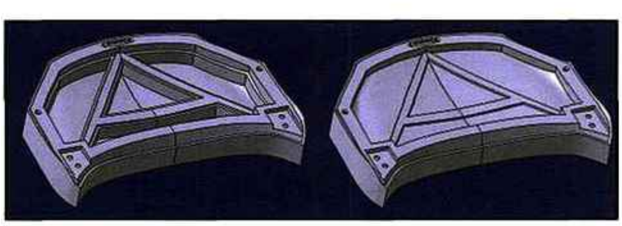
A parameterized Catia model has been used. It contains 8 design factors, as presented below.



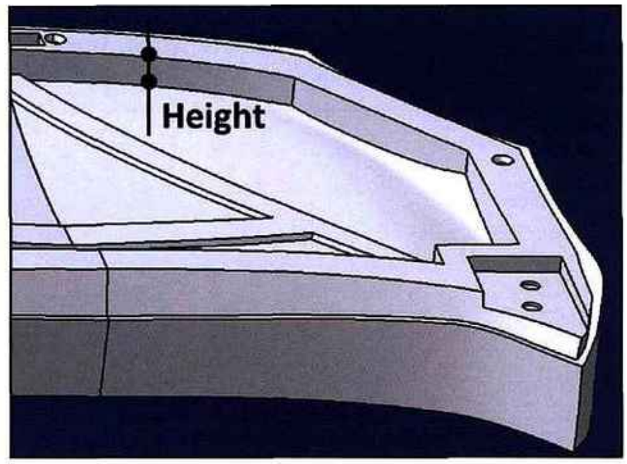
Picture 16: Position holding and travel limit stop position parameters.



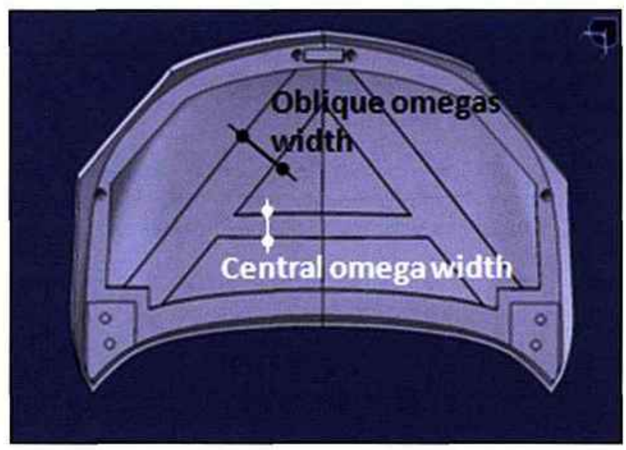
Picture 17: Presence/absence parameter of the central omega.



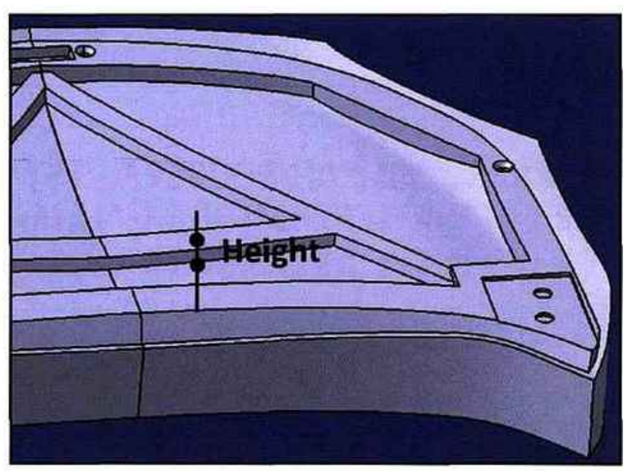
Picture 18: Presence/absence parameter of digging operation.



Picture 19: Inner panel circumference height parameter.



Picture 20: Central and oblique omegas width parameter.

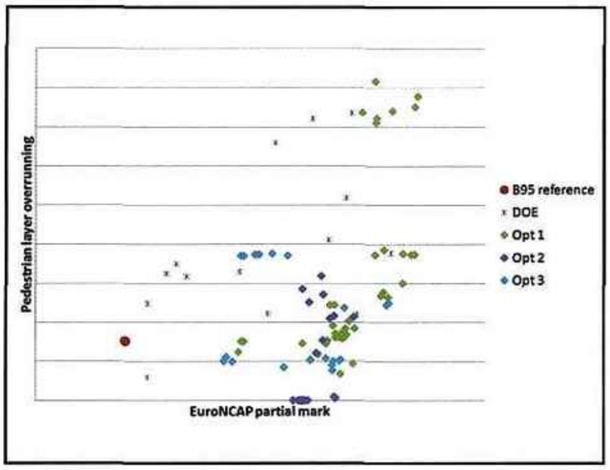


Picture 21: Omega height parameter.

5.3 Optimisation phase

In this study, the optimization problem is quite simple to express: the aim is to maximize EuroNCAP mark while limiting over running of the pedestrian layer.

The classical optimization method has been used thanks to Hood/Pedestrian Alternova application, and 3 optimization iterations have been done. The results found are showed on the **Picture 22** graphic. For all simulated designs, layer over running values are shown according to EuroNCAP mark on 10 impacts.

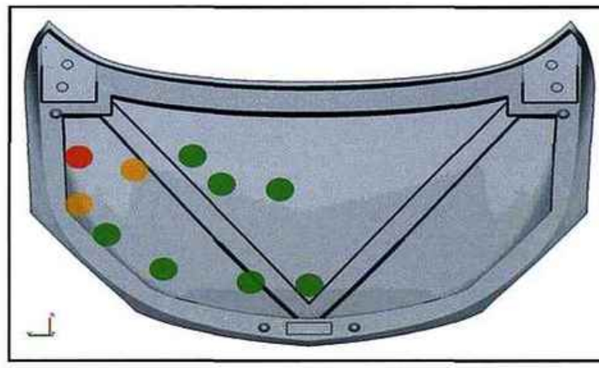


Picture 22: Graphic representation of the results: layer over running vs EuroNCAP mark on 10 impacts.

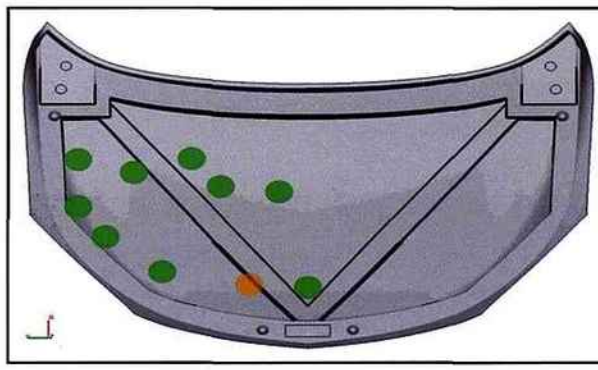
All solution with A inner panel are better than B95 on the EuroNCAP mark criterion. Nevertheless, some designs have high layer over running value. Some designs are better on both criteria.

Pareto graphic allows visualizing how antagonist the two responses are. The better the EuroNCAP is, the worse the layer over running is.
Two extreme configurations can be identified: the best solution without over running and the best mark but with no respect of layer over running specification.

The design number 134 has been selected among intermediary compromise solutions, because of its very low over running and its interesting mark. Its mappings are shown below.



Picture 23: HIC mapping for design number 134.



Picture 24: Overrunning mapping for design number 134.

6. Conclusion

This B95 outer-panel study, realized with the help of Alternova Hood application, allows validating the interest of the application. The good functioning of the tool was verified. It permits the exploitation within a short time period of a parameterized geometry of the inner-panel, relieving the user of all meshing, models assembling, transferring, post-processing and solution searching, and allowing him to concentrate on problem description and results analysis.