

An Automated Process for Interior Head Impact Analysis

Thanassis Fokilidis, Anneli Hoegberg, Antonis Perifanis

BETA CAE Systems SA, VOLVO CAR Corporation, BETA CAE Systems SA

1 Abstract

During the last decade, the Occupant Protection legislation requirements on interior safety properties of automobiles have become considerably more demanding. The US standard laboratory test procedure FMVSS201U regulates the tests for the head protection against the event of its impact on the upper interior roof. The procedure involves the identification of the most critical target zones and headform target angles. To minimize the need for physical tests, the product performance evaluations are, as far as possible, performed with numerical simulations involving CAE software. However, covering all possible load cases would require an infinite number of simulations.

In order to automate the generation of input data and to assist in finding the critical load parameters, Volvo Cars Safety Centre and BETA CAE Systems employed a process that involves ANSA pre-processor and μ ETA post-processor, extended with special tools. This automated process starts with the model file input to ANSA and concludes with the assessment of the LS-DYNA results within μ ETA, requiring minimum human interaction.

An advanced algorithm, for the automatic headform positioning, which identifies the areas where the maximum vertical angle can be reached, has been developed. The process also involves a robustness analysis for each target point, and thus reduces the uncertainty of the problem. This has been successfully deployed within Volvo Cars Safety Centre, leading to great reduction of modelling time

2 Introduction

One of the most substantial issues that Safety engineers have to deal with is the occupant protection during a car accident. In particular, head protection against the event of its impact on the upper roof zone of the vehicle, demands complex safety analysis processes. As a result, the simulations in CAE software have been increased in order to cover the continuously increasing number of the corresponding loadcases. The need for automated and robust tools is mandatory to minimize the human interaction. Volvo Corporation in collaboration with BETA CAE Systems SA has employed a process that simulates a complete test for the Interior Head Impact Analysis according to the FMVSS201U test procedure. The process begins in ANSA pre-processor with the automatic identification of the Target Points in the Upper Roof Zone of the vehicle. It continues, using the same software, with the positioning of the headform impactor on the identified Targets and the creation of the corresponding keyword files which are solved by LS-DYNA. At the end, the process involves the presentation and the evaluation of the respective results in μ ETA post-processor.

3 Identification of Target Points

Upper Roof Zone covers the 70% of the roof of the vehicle. According to FMVSS201U test regulation there are no specific Target Points suggested for it, but only the calculation of its boundaries is presented. Therefore, an infinite number of Target Points exists in this area. However, the discretization of Upper Roof Zone in Targets has been accomplished by calculating the *Discrete, Distribution and Robustness Target Points*

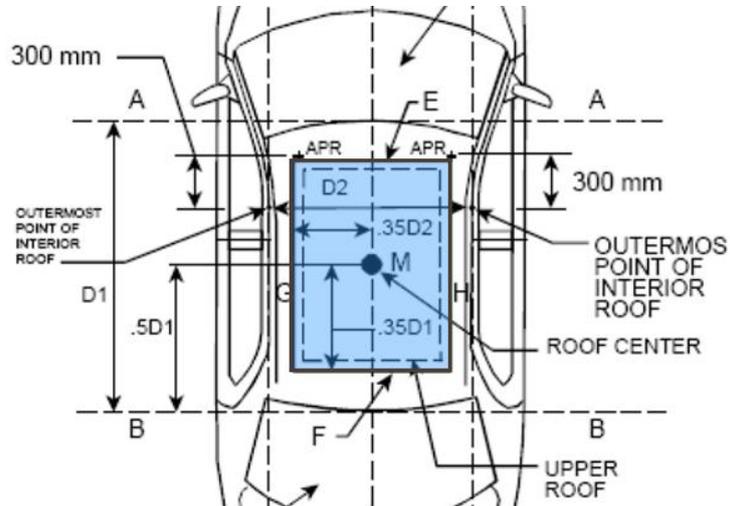


Fig. 1: Upper Roof Zone

3.1 Discrete Target Points

The first analysis that has been made for the study of the Upper Roof Zone is the calculation of the *Discrete Target Points*. In every section of the Upper Roof Zone in the ZY plane, three Targets are created. Two of them are coincident and created on the outer boundaries of the Zone, closest to the BiW of the vehicle. From those two, one (a) is free to rotate in Vertical angle limits $0^\circ - 50^\circ$ to reach the maximum value and one (b) makes a conservative maximum vertical angle positioning of 50° . The 3rd point (c) is created on the place of the section where the highest z' coordinate stands. In the latter case the headform has undergone a conservative vertical angle positioning of 50° . In all cases Horizontal angle is steadily depending on the side of the vehicle where each Target Point exists. Front side corresponds to 180° , left to 270° , Rear to 0° and Right to 90° .

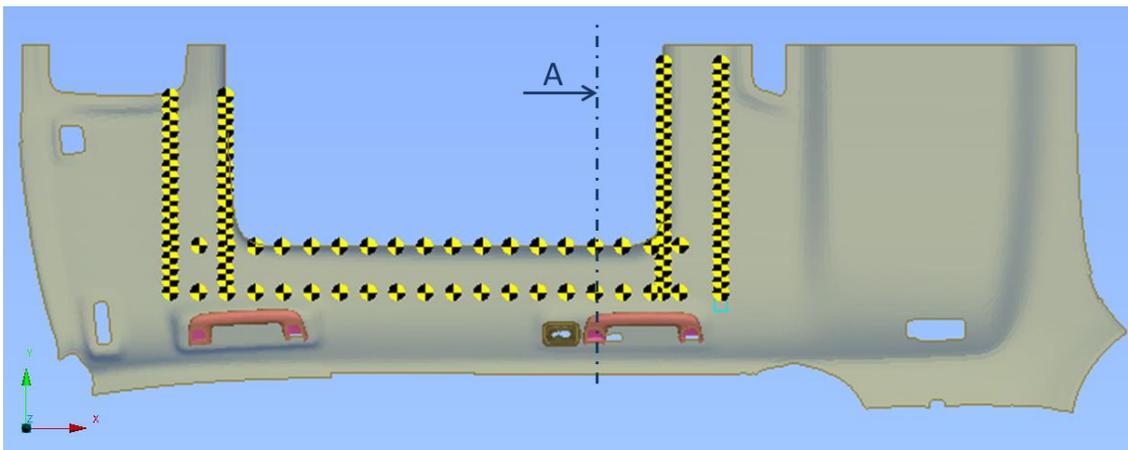


Fig. 2: Discrete Target Points (Down View)

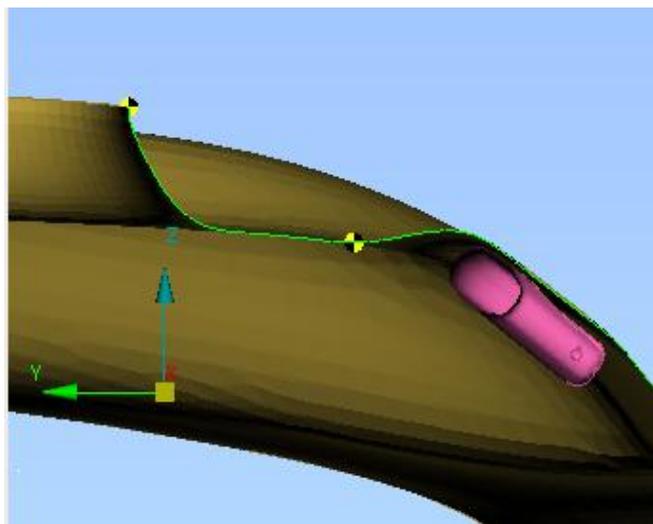


Fig. 3: Discrete Target Points (Section A)

3.2 Upper Roof Distribution Target Points

The *Distribution* Target Points has been created through an advanced tool which divides the whole Upper Roof Zone in possible positions for a headform impact. In this case the analyst can select what kind of positioning parameters, Horizontal and Vertical angle limits, should be applied in each Target Point.

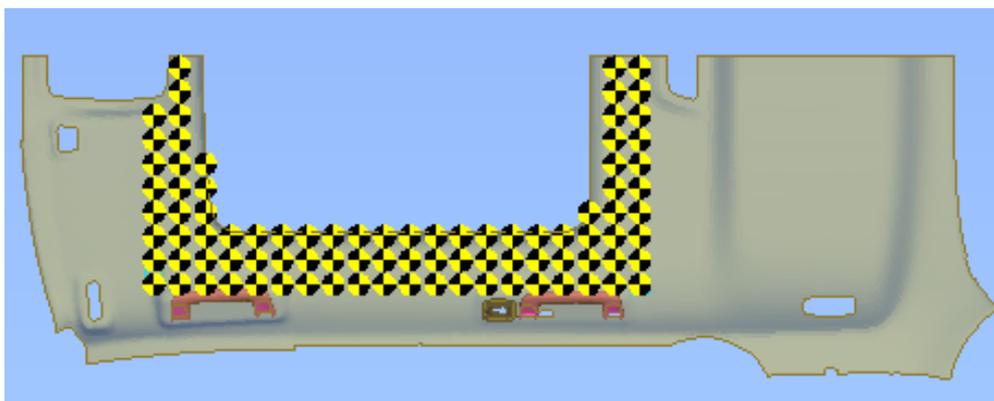


Fig. 4: Upper Roof Distribution Target Points

3.3 Robustness Target Points

Another way of targeting the Upper Roof Zone, was the creation of Robustness Target Points. Their utility was to apply Robustness studies for the identification of the worst case scenarios.

Having as anchor the original Target, *Discrete* or *Distribution*, according to a user specified distance and the number of the desired Points, an advanced script created a circle of Points around the original Target Point. Robustness Target Points are copies of their original Target Points (same positioning parameters) but placed in different position around them.

Furthermore, Robustness analysis took place having as criterion the Horizontal angle. A number of Robustness Target Points were created in the same coordinates with the original, but each one held a different Horizontal Angle in a user specified range. This way the analyst could check the influence that Horizontal Angle had on a specific position in the Upper Roof Zone considering the maximum vertical angle positioning.

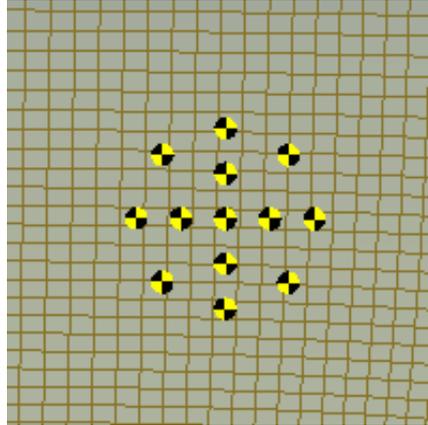


Fig. 5: Robustness Target Points (Circle)

4 Position the Headform

The positioning of the Headform is a really perplexed process. Moreover, the FMVSS201U test regulation is not totally clear about how exactly the impactor should be positioned on a Target. The solution was to rely on the experiments and try to simulate exactly how the FMVSS201U test positioning is done in the laboratory. The maximum vertical approach for the Upper Roof Zone is determined according to the regulation.

4.1 Positioning in ANSA

A special algorithm has been developed which works in consistency with the real tests. First of all, the lowest point on the meridian of the Forhead Impact Zone of the Headform was selected as the coordinates which should be matched with the Target Point.

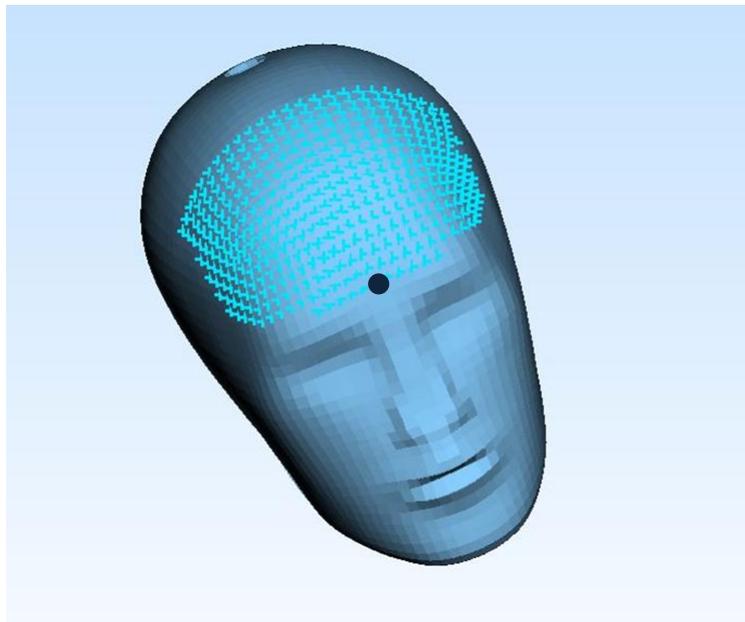


Fig. 6: Forhead Impact Zone and the lowest point on its meridian

The algorithm ensured that the headform has been positioned with the aim to reach the maximum vertical angle in the respective Target Point, including the rebound angle in each case. Also the minimum contact distance has been achieved in really narrow areas of Upper Roof zone. In several Target Points, conservative 50° positioning was applied, either directly on them or after an

optimization process in the area around the Target. The optimization is performed automatically by the positioning algorithm. It is applied in cases where the Headform cannot be positioned with 50° on a specific Target Point, but a conservative positioning might be possible in a position nearby it.

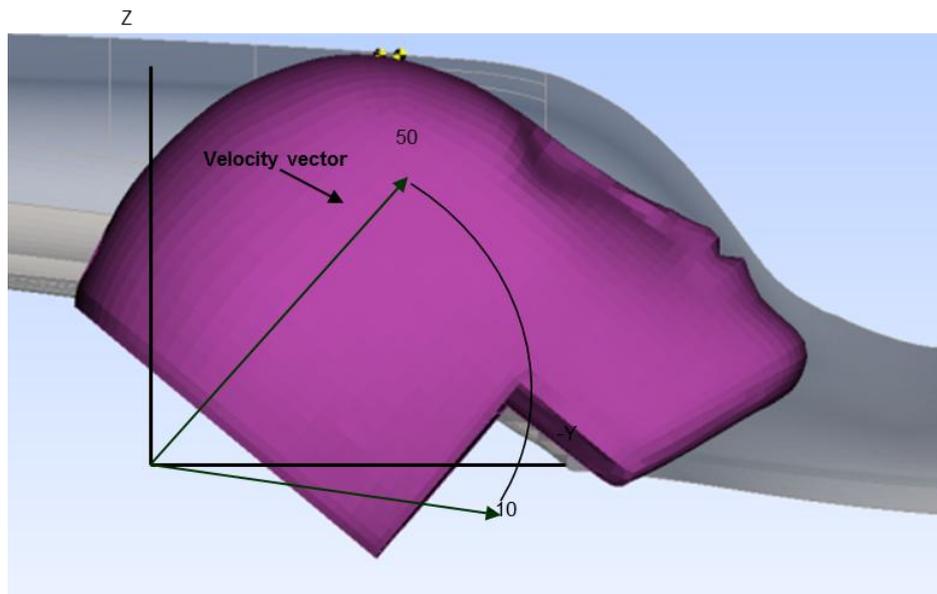


Fig. 7: Headform positioned in 50° Vertical angle (Conesrvative Positioning)

4.2 Automatic Massive positioning

Apart from the validity of the positioning process, another issue that is generally crucial for such complex processes was its duration. The automatic multi positioning tool of ANSA gave the ability to position the headform massively to all the Target Points that have been identified respecting the corresponding parameters in each case.

5 LS-DYNA keyword files

The Post-Processing of the current analysis was accomplished with the production of the files that would be solved by LS-DYNA. These files included the transformation matrices of the movement that the Headform has undergone to be positioned in each Target Point. *DEFINE_TRANSFORMATION keyword was used in order to pass the movement information to LS-DYNA. Specifically the options TRANSL and ROTATE have been used not only to pass the information to LS-DYNA solver, but also to offer the analyst a clear overview of the roatation of the headform in each angle (Horizontal and Vertical).

The huge amount of identified Target Points, Descrete or Distribution, Robustness, circle and Horizontal agle ones, was critical considering the time consumption. However, the FMVSS201U tool of ANSA applied a massive output of the respective LS-DYNA keyword files for all the Target Points, contributing this way in the reduction of the process duration.

6 Post-processing in μ ETA

The high number of target points in combination with robustness studies for each point resulted to a vast amount of simulations to be evaluated. The significant multiplicity of repeated, otherwise, results and the strict frame imposed by the regulations has created the need for smart automation and overview solutions. These needs were addressed efficiently by the FMVSS201U tool of μ ETA, the post-processor of BETA CAE Systems.

6.1 Post-processing results in 2d and 3d

The FMVSS201U tool of μ ETA offered functionality to manage and streamline all the post-processing actions needed for the evaluation of the results. An interface provided information of the simulations regarding the existence of results files from LS-DYNA, the position coordinates of the impact, the horizontal and vertical angle of the impact. When HIC values had been calculated in previous sessions of μ ETA, the values appeared next to the simulation to allow the direct selection of the new, unprocessed results.

Through the 2d post process functionality of the tool the HIC(d) value, the HIC time interval, and additional history results were calculated and stored automatically for each simulation. Acceleration to time and displacement graphs in compliance with the regulations were plotted without the need of manual interaction of the user. Through the 3d post process functionality videos were extracted to demonstrate the impact for each simulation. The videos were generated again with no need of manual interaction, while inherent μ ETA functionality was utilized to improve the display and focus on the impact;: cut planes were created automatically on the center of the head parallel to the vertical / horizontal angle of the impact and the area of impact was isolated. The above data were presented directly from the tool inside a ready-to-save PPTX report.

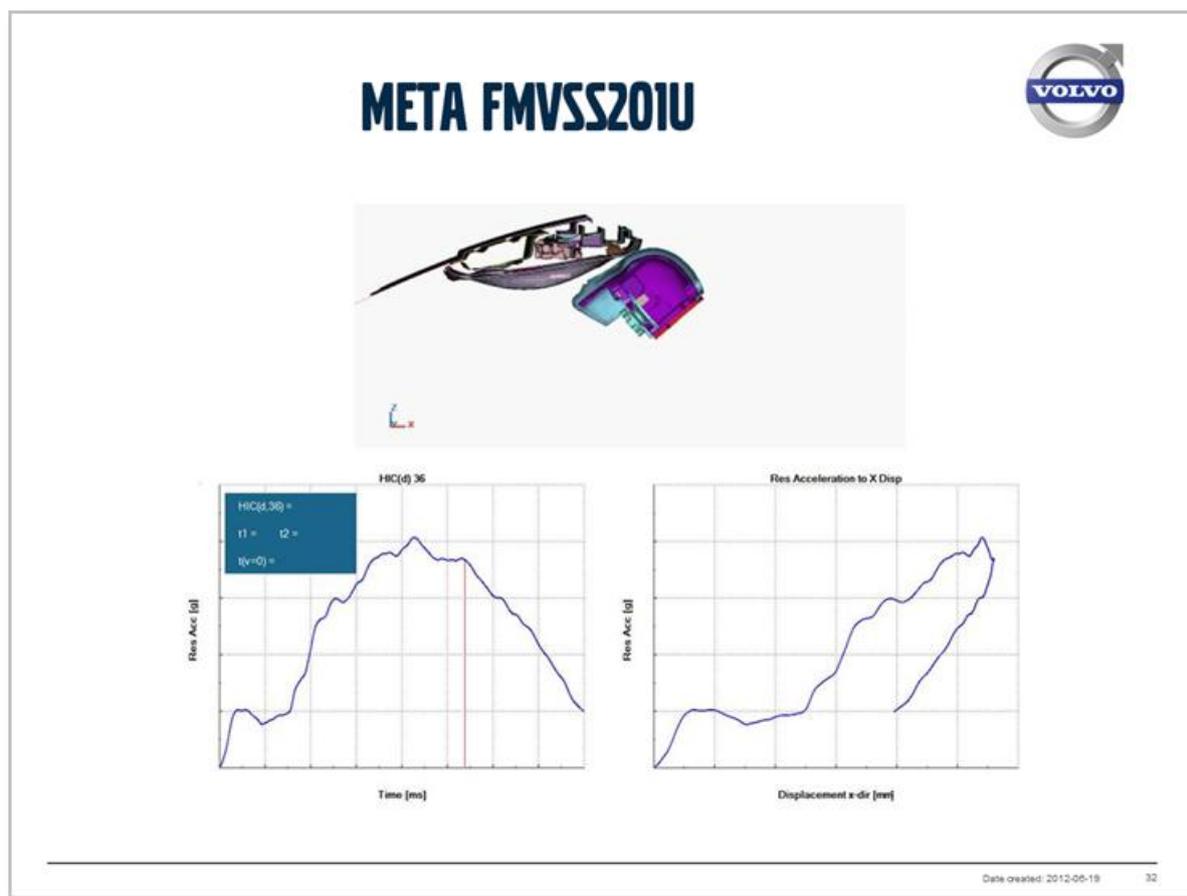


Fig. 8: Post Process Report Slide

Different options were available to process each simulation separately or to overlay plots and 3d models of the robustness studies. In the first case, one report slide with the graphs and the corresponding videos was generated for each simulation. In the latter case, simulations that belong to the same target point were grouped automatically. History results data of each group were placed in a single graph, whereas horizontal and vertical sections of each model were extracted and inserted in one common window with an offset to facilitate the simultaneous animation of the impacts. A custom palette was used by the tool to color the curves and the respective sections.

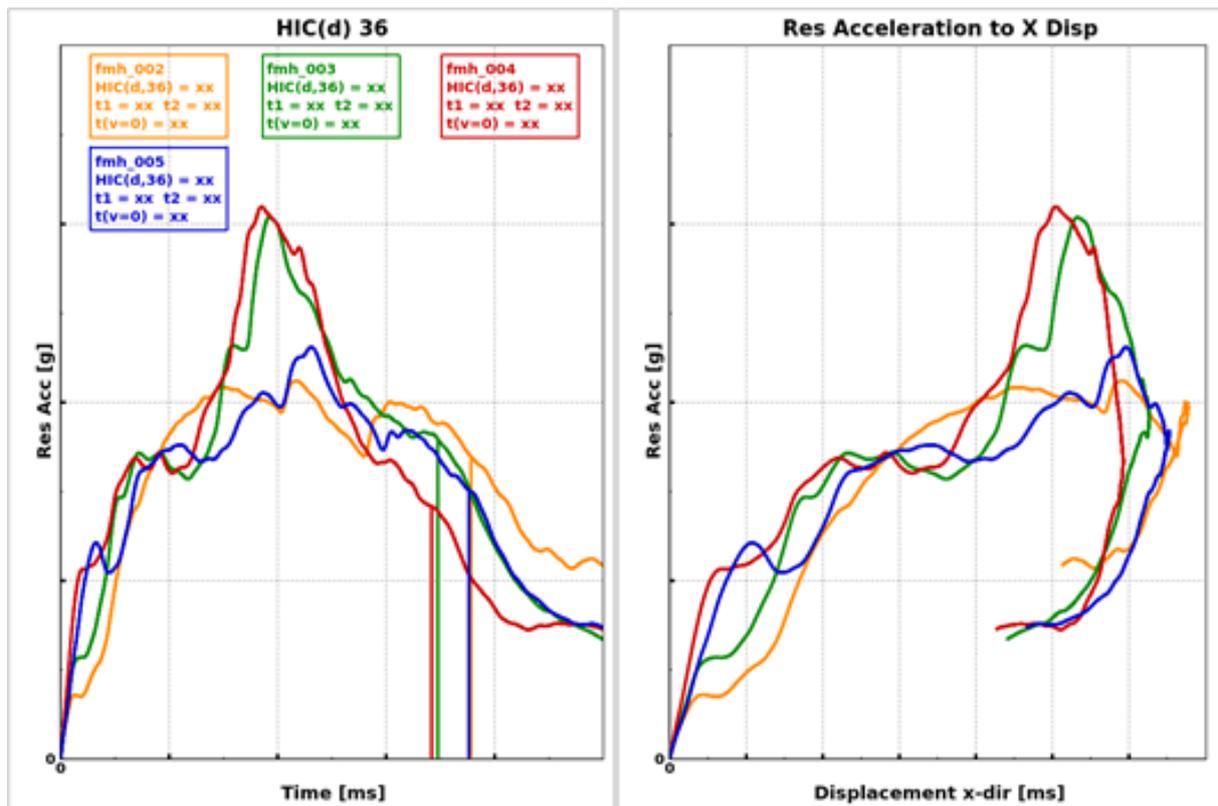


Fig. 9: Overlay Robustness Study History Results

6.2 Overview of results

The challenge for efficient overview of the numerous HIC values calculated in Volvo Cars Safety Center for a model variant was addressed through functionality of the FMVSS201U tool which was dedicated to present these values in a supervisory form. Rectangular annotations, colored according to the value, could be created for each impact with the target point name and HIC(d) value information. Circular annotations were used to visualize a high number of results on nearby locations.



Fig. 10: Results Overview – Circular Annotations

Lines facilitated the display of the impact angles, where the lines length and coloring matched the value. In the case of robustness studies, the results were grouped automatically in order to extract the worst case value of each group.



Fig. 11: Results Overview - Lines

7 Summary

A complete CAE process has been presented which simulates in a very precise manner the FMVSS201U test for Interior Head Impact analysis. The ANSA and μ ETA functionality as far as their extended special scripting tools, lead the analyst from the file input in ANSA to the assessment of the LS-DYNA results in μ ETA with the minimum human interaction.

The identification of Target Points in the Upper Roof Zone which used to be a bottleneck has been facilitated and now requires minimum effort. The robust and precise positioning algorithm guaranties the consistency with the FMVSS201U test procedure as it is determined in the laboratory. μ ETA post processing tools offered the ability to evaluate the results in 2d, 3d and overview mode simplifying the extraction of the conclusions of such a complex analysis. Volvo Corporation has successfully deployed the process in their workflow decreasing the duration of the modelling time up to 100 times.

8 Literature

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