Experience a complete virtual crash and safety laboratory with the aid of the ANSA pre-processor

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1   Abstract

With safety protocols and regulations becoming increasingly enhanced, safety analysts try to keep up replicating all possible crash event scenarios in laboratories using specifications that frequently change. In this pursuit, it is crucial for analysts to have at their disposal accurate and robust digital models that enable the tune and study of any real crash event parameter.

Through the ANSA pre-processor, BETA CAE Systems offers an extensive crash and safety portfolio of automated tools for simulation modelling, to create a complete "virtual crash and safety laboratory". Such tools include this of the seat and the dummy guide, from the identification of HPOINT of the seat to the positioning of the coupled restrained seat-dummy system according to a regulation or a test data position, available not only for standard crash dummies but also for human body models. Pedestrian and Interior tools ensure the proper marking of the exterior and interior of the vehicle but also the accurate positioning of the headform to the desired targets. The Impactor tool enables the positioning of barriers/impactors according to all available regulations. Moreover, the Knee Mapping plugin helps the analyst avoid knee modifier, while Airbag stitching and folding tools set up the pre-crash simulations required for the proper treatment of the airbags.

The current paper presents all the afore mentioned tools and more handy features that crash and safety analysts need to set up detailed and accurate models for different regulations fast, and with the minimum human interaction.

2   Introduction

One of the most important aspects during the design process of a vehicle is the protection that provides to its passengers. As a result, analysts try to test a prototype in several processes that will ensure the production of a successful model as far as safety is concerned. These processes are replicating real life scenarios during car accidents and are applied mostly in laboratories. In parallel, safety protocols and regulations are continuously being updated with different specifications. Thus, the need of reproducing the scenarios above in digital models has become a necessity. For this reason it is very important for engineers to be able to design robust and accurate CAE processes.

But what would be the key for successful CAE simulations? That would be CAE tools that could replicate a real test procedure digitally as close as possible to the reality and with the minimum human interaction.

ANSA the pre-processor of BETA CAE offers a complete suite of safety tools that can set up accurately and quickly a real scenario following the exact specifications of all available safety protocols on a LS-DYNA model. Using the H-Point position tool one can calculate the proper H-Point location of the seat and then can continue to the proper positioning of the dummy-seat system. With the aid of the Knee-Mapping tool a model can bypass the knee modifier. Since human body models are the latest trend in safety simulations, a tool dedicated to positioning them within ANSA, without the need of a pre- crash simulation, is available. Passenger airbag modeling and general airbag folding are really easy through wizards that produce the necessary LS-DYNA loadcases. The tools of Interior and Pedestrian safety provide the ability to set up all the available protocols in the market. Finally extended functionality enable the analyst to position any type of barrier either with the aid of a regulation or on a user defined way.

The current paper explains how one is able to get advantage of the 'virtual crash and safety laboratory' that ANSA provides through its safety suite. Additionally, it dives deep in detail on how all

the tools mentioned above can produce accurate LS-DYNA simulations with the minimum human interaction.

3   H-Point Positioner

The calculation of H-point location (seating reference point) for each seat is essential for the proper positioning of the dummy on it. The process for this calculation in a laboratory follows the steps of EuroNCAP Whiplash test protocol. According to this protocol the H-point machine has to be positioned on the seat and the final position of its hip point is the desired location of the seating reference point. It is a time consuming process that has to follow the exact specifications of the regulation. Digital models for H-Point machines are available in the market for quite some time. Thus, ANSA the pre-processor offers a tool that can set up easily a pre-crash simulation in LS-DYNA in order to predict the H-Point location.
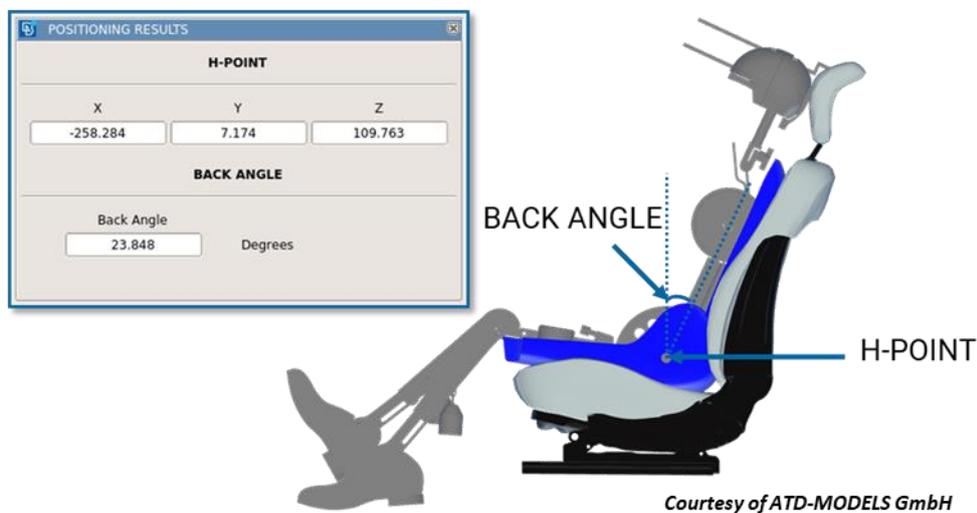
Fig.1:   H-Point and Back Angle calculation in ANSA.

The H-Point positioner tool has the 'know-how' of the protocol and guides the analyst through the respective steps. With the minimum input and selections, one can get from the LS-DYNA pre-simulation results, automatically read by ANSA, the H-Point coordinates and the seat back angle.

4   Seat – Dummy system

ANSA has already available a mature tool for positioning the dummy on the seat after having the desired H-Point location in an accurate way. Several tools can articulate the seat and dummy mechanisms, couple them so as to move together, restrain them with the aid of seatbelt but also ensure a fully de-penetrated system. Advanced tools like Marionette and Seat de-penetrate can set up the respective LS-DYNA loadcases if one wants to position the dummy on to the seat with a pre-crash simulation.

4.1   Knee Mapping

Since the dummy seat is well treated by the ANSA functionality there was space for a more sophisticated tool that could offer a solution to a process that till now was applied only in laboratories. This is the Knee Mapping process. Several vehicles after passing the car safety performance assessment programmes, they have to follow the knee modifier process due to the fact that they produce great damage to the area of the knees of the driver/passenger in a possible crash event.

Fig.2:   Knee mapping process in ANSA

The Knee mapping tool of ANSA couples the dummy-seat system, positions the dummy legs properly to the desired position and with the aid of dummy and seat kinematics the system can be positioned so as to match specific locations of the knee on to different positions on the IP area. As a result the tool through a wizard like functionality offers the ability to create quickly ready to run LS-DYNA loadcases for evaluating the instrumental panel against knee impact in different positions.

5   HBM

The advent of autonomous driving with its many out of position loadcases, makes the use of human body models (HBMs) in safety simulations a necessity. Positioning of an HBM though, has always been a challenge. ANSA offers a new tool called HBM that enables the users to deal with this complex problem. Using an integrated Multi Body solver (embedded in ANSA) in combination with morphing algorithms the tool provides real time articulation and positioning of an HBM within an easy user interface. While the user just articulates the human model with the mouse in a most direct way or by typing a desired rotation angle, the biofidelic joint modelling guarantees realistic model movements and a model ready to run without the need of a pre-simulation.
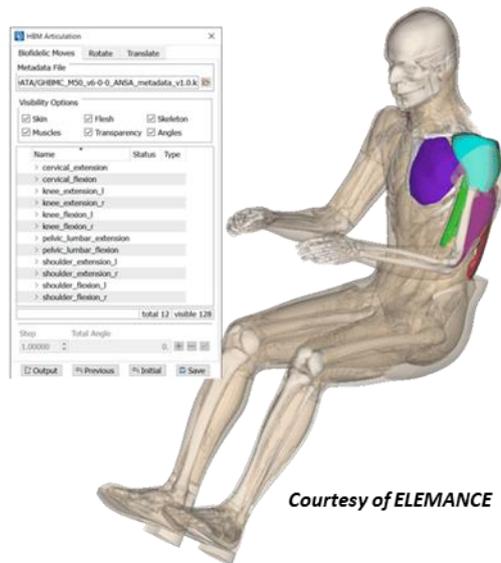
Courtesy of ELEMANCE

Fig.3: HBM articulation in ANSA

All the biofidelic kinematic set up with all the rest necessary information are saved in a metadata file. This metadata file is characteristic for each human body model and it is needed to work properly with ANSA HBM tool. BETA CAE offers for free the desired metadata files to all of its users after request. In case the user wishes to run a pre-simulation in LS-DYNA this can be automatically set up by the program through the Marionette tool.

Mind that all the available functionality that is applicable in ATDs is available also for HBMs, such as depenetration from the seat, coupled movement with the seat and restraints with seatbelts.

6   Airbags

Airbags are one of the many protection systems that ensure the safety that a vehicle offers to its passengers. They are one of the most commonly used safety systems in laboratory tests. Over the last decades airbags are also a crucial part of the digital crash and safety models. Significant time though is needed for the creation of a digital airbag model but also for the airbag folding process. LS-DYNA is a standard for the airbag models. BETA CAE has come up with tools that deal with the airbag creation and folding based on pre-crash simulation set up for LS-DYNA.

6.1   Passenger airbag modelling

The usage of an airbag model in a crash simulation requires as a first step the creation of the airbag. Airbag stitching, especially the passenger's one, is one of the tedious tasks for a simulation engineer and consumes lots of time to complete a model with a proper shape. ANSA offers a tool that enables the user to stitch the airbag within a few minutes by preparing the LS-DYNA pre-crash simulation of this process within few simple steps.
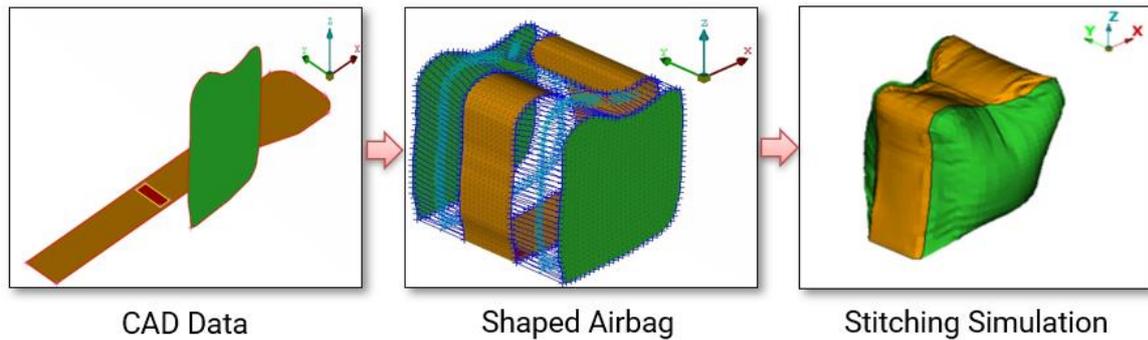
Fig.4:   Passenger airbag modelling in ANSA

The tool can export a file that contains the desired ***AIRBAG_SHELL_REFERENCE_GEOMETRY** keywords. It also provides a solution, with the aid of morphing algorithms, to quickly fit the created airbag within a module of a vehicle.

6.2   Airbag folding

Once the analyst has the desired airbag stitched and unfolded the outermost goal is to move to the folded status. This process is really complex not only in the laboratories but also when it comes to the simulation set up. The folding process in CAE can be done in two different ways, geometrically or through a pre-crash simulation in a solver like in LS-DYNA. The setup of such a loadcase, may include the definition of several LS-DYNA keywords.
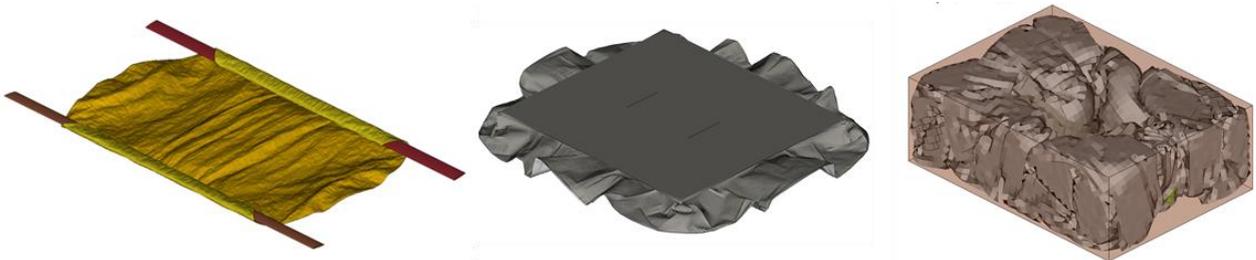
Fig.5:   Generic, tuck and BPFG airbag folding set up in ANSA

For this reason ANSA has a dedicated tool which through an assistant streamlines all the necessary steps to set up properly an LS-DYNA pre-simulation for airbag models. It offers three basic ways of folding in order to cover all the different folding types, the 'generic', the 'BPFG' and the 'tuck'. In the 'generic' folding type the user can set up a loadcase for folding the airbag with the use of any kind of tool (e.g. cylinder). 'BPFG' folding type contains all the steps in order to create the entities needed to fit the airbag in its case with the creation of ***BOUNDARY_PRESCRIBED_FINAL_GEOMETRY** LS-DYNA keyword. Finally using the 'tuck' folding type one goes through all the steps for preparing the tucking of different airbag areas.

7   Interior safety

As it has already been highlighted there are several protocols and regulations which the analysts have to follow in order to achieve the desired occupant protection that a vehicle offers as far as its interior is concerned. Different tests are being applied in the laboratories and each has its own complexity. Consecutive steps should be taken where different parameters have to be tuned and measurements have to be taken. This has made the necessity of simulations inevitable in the prediction of safety in

the interior of a vehicle against the head impact. ANSA offers a complete suite of tools that cover FMVSS201U, ECE R-21 and FMVSS201, FMVSS226 and others for seat impact like FMVSS201, FMVSS202A, ECE-R21, ECE-R17.

7.1 FMVSS201U

The ANSA tool offers an interactive and an automated way of marking the vehicle according to the homonym regulation. It can apply any customized marking but also offers marking ways for robustness analysis on the desired areas. Following the exact specifications, one can either quickly mark the complete vehicle in one pass but can also interactively focus on specific target points applying single point analysis. In a single point analysis the user can modify auxiliary data (curves, points, planes) and check the influence of the updated target point coordinates and its dependencies too. Through a table one can get an overview of all the Target points that are needed according to FMVSS01U and check the dependencies among them. A complete vehicle marking process can be applied since both sides can be marked (left and right).

The ANSA positioning algorithm is contact based and ensures that no penetration between FMH and interior trim exist. During the positioning process, minimum contact distance and maximum vertical angle are the criteria that are taken into account. Conservative positioning of 50 degrees is applicable so as to identify where exactly the headform can be positioned with the maximum vertical angle. Special functionality is offered for relocation in cases of non-contactable target points but also in positioning cases for respecting hard parts so as to predict the worst case scenario. Bulk positioning process for all target points is applicable and simultaneously all the respective LS-DYNA loadcases are created with the use either of ***NODE_TRANSFORM** or ***INCLUDE_TRANSFORM** keywords.

7.2 IP impact

Following FMVSS201 and ECE-R21 the IP Impact tool can first mark the vehicle. The marking process includes the creation of the curves and the target points either on each contact point (of the curve) or on a specified by the user distance. The tool works for all types of seats (moving ones and not). Debug entities are created for the user to evaluate the validity of the marking process.

The positioning process on IP is a process that is mostly customized at each laboratory. For that reason the ANSA tool offers several ways to position the impactor. Z-level and pivot node can be defined separately so as to have the x and z coordinate of the pendulum rotation center irrelevant. Additionally the headform can be positioned following a vector normal to the target point (underneath surface), along a vector that is tangent to the pendulum trajectory, on a specified by the user vertical angle, or with a fixed arm length. Bulk positioning process is applicable and simultaneously all the respective LS-DYNA loadcases are created with the use either of ***NODE_TRANSFORM** or ***INCLUDE_TRANSFORM** keywords.
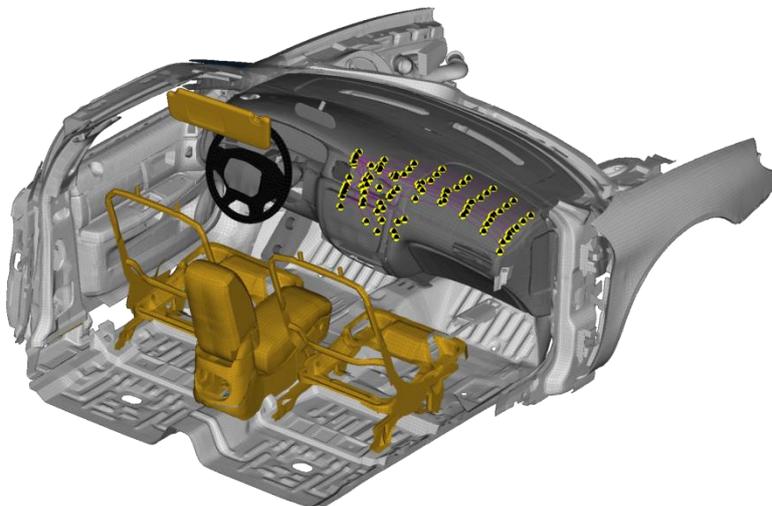
Fig.6:   Marking the IP in ANSA

7.3 Seat impact

The seat impact tool is similar with the one above since it covers the same protocols but also some additional ones (ECE R-17, FMVSS202A). The marking process is applied on the seat and the user has either the necessary area produced to focus on or the exact target points.

The positioning algorithm is the same with IP impact in terms of the vector normal to target and the vector tangent to the pendulum trajectory. Bulk positioning and LS-DYNA loadcase creation is applicable for all target points either with the use of ***NODE_TRANSFORM** or ***INCLUDE_TRANSFORM** keywords.

7.4 FMVSS226 – Ejection mitigation

This tool is used to evaluate the possibility of partial or complete passenger ejection through the window glazing. It marks the windows with the possible target points either in an automated way or manually.
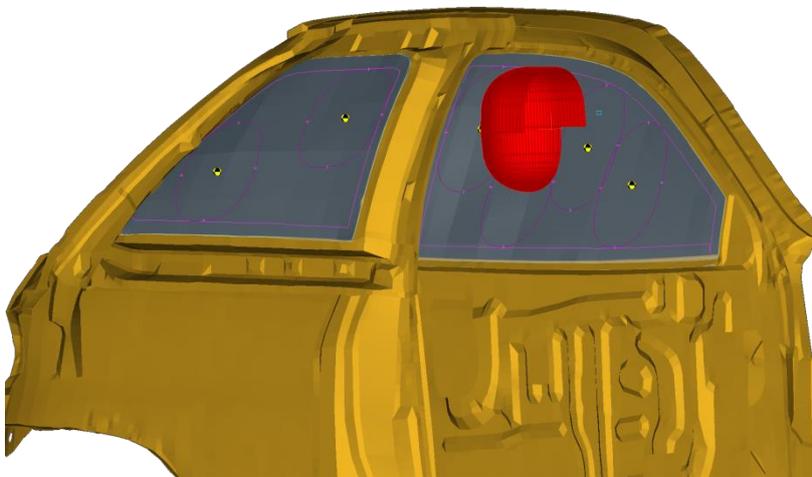
Fig.7:   Positioning of the impactor according to FMVSS226 on to specified targets in ANSA

The positioning process ensures no penetrations between glazing and impactor and is applied either in a single or bulk mode. Simultaneously all the respective loadcases for each positioned target are created with ***NODE_TRANSFORM** or ***INCLUDE_TRANSFORM** keyword.

8   Pedestrian safety

ANSA provides a tool for covering the complete process that takes place in a laboratory for pedestrian analysis. The first step of setting up a simulation for pedestrian analysis has to do with the marking of the vehicle. The ANSA tool covers all the available protocols in the market but also those that are in a proposal phase. 3D curves are created on the outer trim of the vehicle and Target points in the cases that the protocol suggests specific targets. In cases that only the creation of areas is taking place according to a protocol the user has several ways either from the main ANSA pedestrian functionality or from extended tools to mark the vehicle. Flat and inclined ground is supported. The tool also has the ability to deal with active bonnet, since it can move it from its original position to the desired one and mark on it (according to each protocol). The handy feature to check the most dangerous areas based on hard parts placed under the hood in a contour plot is applicable. Debug entities are created in every marking process so as to evaluate the created results.

Positioning of ANSA in pedestrian ensures no penetration between the headform and the outer trim of the vehicle. The main algorithm respects the specifications of each protocol for positioning (EuroNCAP, GTR9). Bulk positioning on all targets and LS-DYNA loadcase creation can take place with the use of ***NODE_TRANSFORM** or ***INCLUDE_TRANSFORM** keywords.

9 Barrier Positioning

One of the most important aspects during the setup of a real crash scenario in laboratories is the barrier positioning. It is a very demanding and time consuming process. Similarly, in simulations the specific procedure needs accuracy and of course protocol's 'know-how'.
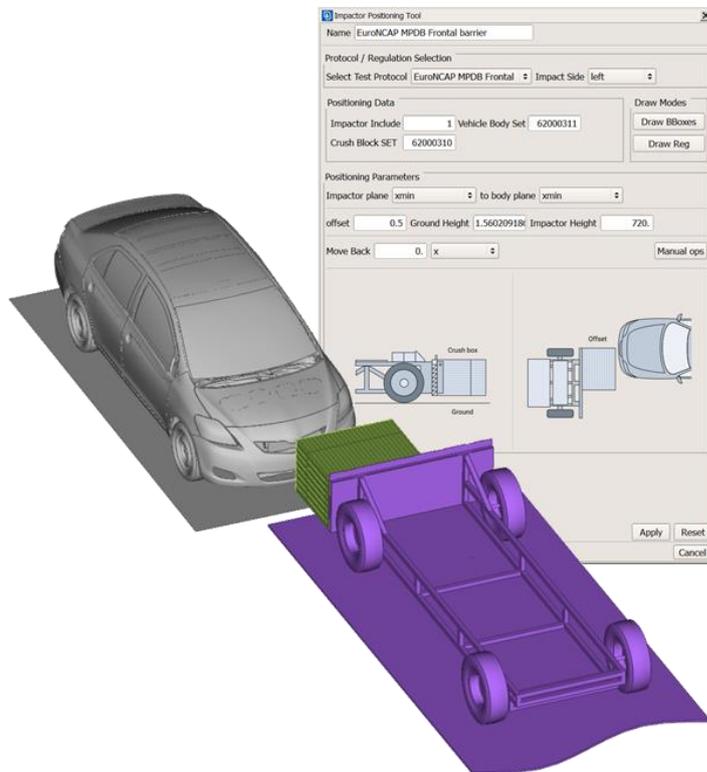
Fig.8: Barrier positioning in ANSA

ANSA has implemented in its safety tools suite a dedicated tool for barrier positioning. It is an assistant functionality that guides the user through each step of the selected protocol. With the minimum input and manual effort one can position the barrier quickly and accurately. ***NODE_TRANSFORM** or ***INCLUDE_TRANSFORM** is automatically created for the barrier (SET or Include).

10 Summary

In order to reach the acceptable levels of safety during the design process of a vehicle several tests are held in laboratories. Over the last decades these tests are combined with numerous digital analyses in order to guarantee the safety of a vehicle. The numerical simulations decrease the number of real tests and consequently the cost for the companies. However, in each case protocols that include really demanding specifications have to be followed. So it is really important to have accurate and robust CAE models and the prerequisite to achieve that is powerful CAE tools.
BETA CAE has come up with a complete suite of safety tools offering to the CAE engineers a virtual crash and safety laboratory. These tools have the needed 'know how' of the protocols and guide the user step by step to the final result producing ready to run LS-DYNA loadcases.
Starting from the seat-dummy system ANSA the pre-processor has a tool to calculate the H-point for the seat for a proper positioning process. Knee mapping tool can help the analysts to position the

dummy-seat system easily and accurately in different cases so as to avoid the knee modifier ensuring a safe instrumental panel. The trend of autonomous vehicles with the numerous out of position cases has made the use of HBMs a necessity. The HBM tool of ANSA can position a human body model within ANSA avoiding the need of an additional pre-simulation. Airbag stitching and folding tools cover all the needs that the airbag modelling demands. With the use of Interior suite and Pedestrian tool of ANSA a safe interior environment and an exterior trim can be achieved. At the end with the use of Barrier Positioning tool all barriers can be easily positioned through a wizard that guides the user to the exact steps of the desired protocol.

11   Literature

[1] ANSA version 21.1.2 User's Guide, BETA CAE Systems International AG, March 2021
[2] LS-DYNA Keyword Users' Manual Version R11, Livermore Software Technology Corporation, Livermore 2019