Automated Injury Metrics Evaluation and Visualization for the Hans HBM using Generator4 and Animator4

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1 Abstract

The Hans Human Body Model (HBM) is a high-fidelity structural human body model designed for use in LS-DYNA simulations, enabling the biofidelic analysis of occupant injuries in crash scenarios. With growing demands for accuracy and efficiency in safety assessments, automating pre- and post-processing steps has become crucial for improving simulation workflows and ensuring consistent results.

This work presents an automated framework for visualizing and evaluating injury metrics for simulations using the Hans model, with the software Generator4 and Animator4.
Generator4 facilitates efficient pre-processing through a user-friendly GUI, enabling rapid model positioning and setup in crash test environments.
Post-processing is handled in Animator4 using the **Human Body Model (HBM) GNS Tool**, which automates the extraction of injury metrics such as the Head Injury Criterion (HIC), Brain Injury Criterion (BrIC), rib fracture assessment, and other key indicators. The tool also supports detailed visualization and customizable report generation. This framework enhances handling and visualization of complex models, whether involving a single body part or multiple components, through an automated process.

By reducing manual intervention and minimizing user error, the workflow improves analysis speed, reliability, and repeatability. The integration of Generator4 and Animator4 provides a robust solution for engineers and researchers performing occupant injury evaluation and iterative safety design within LS-DYNA environments.

2 Introduction to HBMs such as Hans

The possibility of new forms of travel, opened by the implementation of new automotive technologies such as autonomous driving, is no longer a vision of the distant future, but a reality.

New autonomous driving systems, made possible by improvements in sensor systems, data analysis, and AI, have opened the door to new vehicle interior configurations, expanding the previously limited number of passenger positions to an infinite range.

The uniqueness and novelty of these possible arrangements within the vehicle make it particularly necessary to evaluate them in terms of safety. It is necessary to develop new restraint and shock absorption systems that have little or nothing to do with current devices. Changing these systems means entering new design territory, where there is generally less experience. However, advances in passenger comfort must not compromise safety within the vehicle. It is therefore essential to evaluate, test, and simulate possible scenarios in these environments to ensure the suitability of the new designs.

However, traditional dummies are limited when it comes to evaluating the safety of these new spatial arrangements. These sophisticated test pieces feature unidirectional sensors specifically designed for conventional postures. In some cases, such as zero-gravity seats, classic models even present problems in the positioning of the hardware within the vehicle due to their high rigidity compared to a human being.

Human models are the answer to these new needs. Advances in modeling and simulation techniques have made it *possible to faithfully represent the most complex part involved in road safety related situations: the human body.*

2.1 Hans Human Body Model

In recent times multiple HBMs have been introduced in the market. One of these models is Hans.

Fig.1: Hans model overview [1]

Hans is a high technical quality model that has been developed by DYNAmore (an Ansys company)©. As indicated in their portfolio, the model has been defined with state-of-the-art LS-Dyna definitions and various features and highlights, such as[1]:

1. Level of detail: Realistic modeling of the musculoskeletal system for detailed analysis of the skeleton and musculature at the geometric and material level.
2. Robustness: Includes robustness considerations during meshing and material card generation.
3. Efficiency: Moderate element count and moderate use of “expensive” solver functions.
4. Ease of use: Supporting the entire workflow with positioning concepts, pre- and post-processing tools and user assistance.

2.2 Working with HBMs. Related difficulties

Using HBMs in safety simulations is a great step forward when it comes to flexibility and biofidelity of the results, offering a huge range of possible outputs for evaluation. However, these improvements come at a cost. They are accompanied by an increase in the complexity of model management, both during pre-processing and simulation definition, and in the post-processing of the obtained results. An increase in simulation times is also to be expected for this large models.
Therefore it is vital to work with them with the correct tool, that ensure an accurate handling of the model while easing the task avoiding possible errors.

2.2.1 Preprocessing difficulties

To use an HBM, the model must be correctly positioned to the posture that needs to be evaluated.

On the one hand, HBMs require a Structure Tree to be managed within a preprocessor. These structure trees define the possible movements for each joint in the model and their postural relationships. They allow the HBM to be articulated within the preprocessors to change its posture.

HBMs have a bone structure similar to that of a human being. This implies a large number of joints with truly complex movement possibilities. For this reason, the models are characterized by very extensive structure trees that are highly complex to manage.

On the other hand, the model cannot be treated as a simple solid-rigid to be positioned. The materials used reflect the organs and tissues of a real human. Deformations and stress values must be considered, while initial penetrations of any kind must be avoided. Therefore, a presimulation is necessary to move the model to its position of interest. Tissues and organs will be deformed during this simulation in a realistic way, ensuring that no initial penetrations of any kind arise.

These simulations, tend to be time-consuming and quite delicate to define. Although they are not normally the main objective of the design engineer, the success and bio fidelity of the future simulation to be evaluated depend largely on them.
It is vitally important to define a stable, secure process that provides a good basis for subsequent studies.

2.2.2 Postprocessing difficulties

Once the engineer has completed a simulation, the most important step in the design process must take place. The simulation must be evaluated correctly to learn from it and make improvements to the design. Drawing clear conclusions is a key factor in ensuring the safety of vehicle occupants and the successful development process. And doing it with HBM-simulations presents associated difficulties.

The output data to be evaluated differs significantly from that of traditional dummies. Different signals and physical results must be evaluated to obtain equivalent information (i.e. to evaluate possible brain damage). While traditional dummies are hardware models offering different accelerations and force curves from installed sensors that can be directly evaluated against limit values, HBMs represent the human body. Medical knowledge must be applied to obtain information on cumulative damage, probabilities, and possible tissue effects.

The wide variety of models is another factor that makes evaluating human models a complex process. Differences in shape, sex, ethnicity and represented age must be taken into account when manipulating the data, since the probability of damage depends on these factors. For example, elderly bones have a higher risk of fracture than those of a young man for the same strains.

3 Generator4 offers a simple way to position HBMs with accuracy[2]

Generator4 is a general preprocessor that can be used to define finite element models for LS-Dyna© and for the other solvers it offers. The user can access a variety of tools dedicated to the automotive field, especially the safety protocols simulation areas, covering the complete process when it comes to HBM preparation.

In order to prepare a human-body model (HBM) for use in evaluating the safety of a certain environment or vehicle during a simulation, three basic steps must be performed. Firstly, the model must be articulated to define the desired evaluation position. Once this has been done, a pre-simulation must be performed to calculate the movement and deformation implied by this position. Thirdly, it is necessary to consider how the possible restraint systems are adapted to the model while in this position.

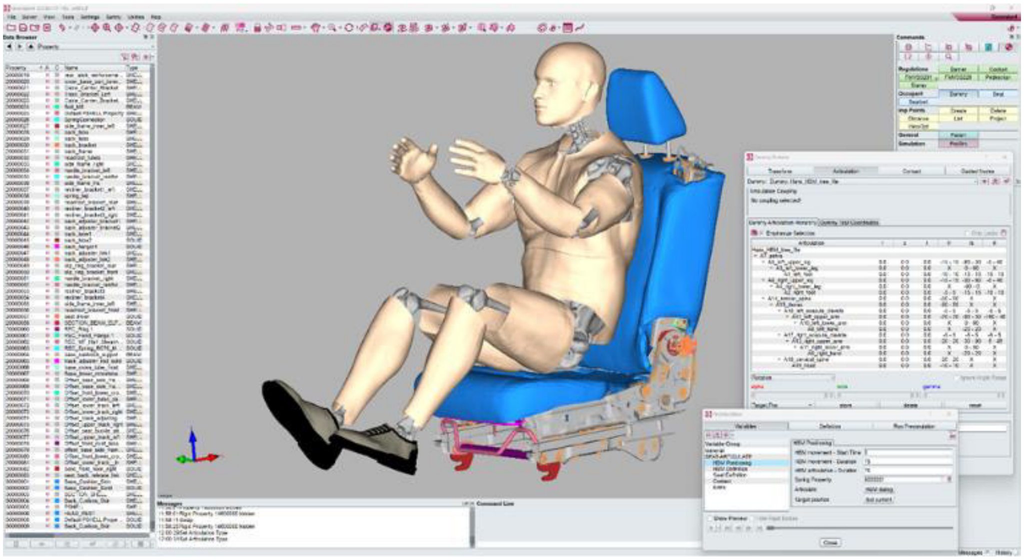

Fig.2: Generator4 layout. Dedicated dialogs for HBMs and Dummies

3.1.1 Model articulation

A dedicated dialogue allows both traditional dummies and complex HBMs to be positioned. Engineers who are familiar with working with dummies won't need to learn any new skills to use the dialogue and work with HBMs.
The straightforward dialogue with on-ground options allows for easy articulation and definition of the desired target posture. Different options for articulating the HBM are offered depending on the user's needs and preferences:

1. Rotating the different joints, thus defining the exact angles needed for each articulation.
2. Defining the location in space of any node in the model, for which the user may have some coordinate requirements.
3. Setting the position of any articulation by setting the exact coordinates.

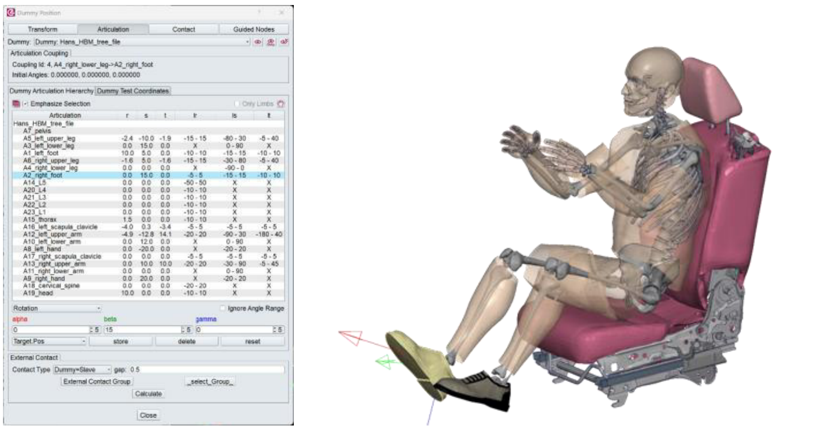

Fig.3: Generator4 dialog for HBMs positioning

The described process is methodical, allowing for great accuracy in defining the target position, and it can easily be reproduced and automated. However, due to the large number of moving parts in the human models, performing this work manually can be time-consuming.
To facilitate the HBM articulation process, the posture of the models can be adjusted using drag-and-drop. Thanks to powerful kinematics evaluation algorithms, users can interactively place the different

parts of the model at the desired location in real time. This saves engineers a lot of time while offering a very simple, intuitive way to adapt the posture of the model and its interactions with the environment.

Apart from this, Generator4 also offers the possibility to directly position the model based on defined test coordinates for predefined model markers. Thanks to a powerful algorithm for processing and evaluating the kinematic structure of the model, it is possible to position all limbs, spine and even the general position of the HBM (pelvis coordinates and rotation angles) with a single click.
To do this, the engineer provides a list of targets for his choice's markers (both in number and location). This option is of interest when real test measurements are available. In the case of HBMs, this can come from biometric measurements of study subjects, X-rays, or even crash test markers on real cadaver tests.

3.1.2 PreSimulation definition

Once the model has been articulated to reach a certain target position in Generator4, it will most likely exhibit penetrations or elements that have been stretched unnaturally. This is due to the way the model is articulated and moves as a rigid solid. In this case, a simulation is always recommended to create a realistic, penetration-free model.
During the simulation, the human model will adapt to the defined target posture. This ensures that all tissue deformations and strains are taken into account. Meanwhile, the user can use the same simulation to calculate seat pan deformations or other environmental interactions that might occur. This kind of simulations imply a lot of boundary conditions and predefined movements that are complicated to handle properly.

Generator4 simplifies the generation of these input decks, by offering a dedicated module: The PreSimulation module. Here, the user can just select the process or method to position the model. Key variables are offered to adapt the process to his concrete model by selecting a few properties and parameters. The software will automatically create all boundary definitions, described motions and physic definitions to set up the simulation.

But the great advantage of the Generator4 PreSimulation module is its great flexibility and simplicity. The module can be used in any of the following ways:

1. The user can take advantage of pre-defined processes, where only adapting a phew variables is necessary.
2. It is also possible to combine several pre-defined processes to generate a more complex one. For example when using the same simulation for calculating also pan deformations or other interactions with the environment.
3. The last possibility is to define new positioning methods and movements, selecting all boundary conditions and definitions the user whants to use and save it as a template for late usage.

This flexibility is an important point to consider. Users are not limited to a predefined way of positioning their HBMs, but can choose their own way of doing so. This can be very interesting due to the wide variety of possible environments inside autonomous cars in the near future.
Once defined, you obtain a directly automatable and reproducible process for any of your future calculations, accelerating the design workflow.

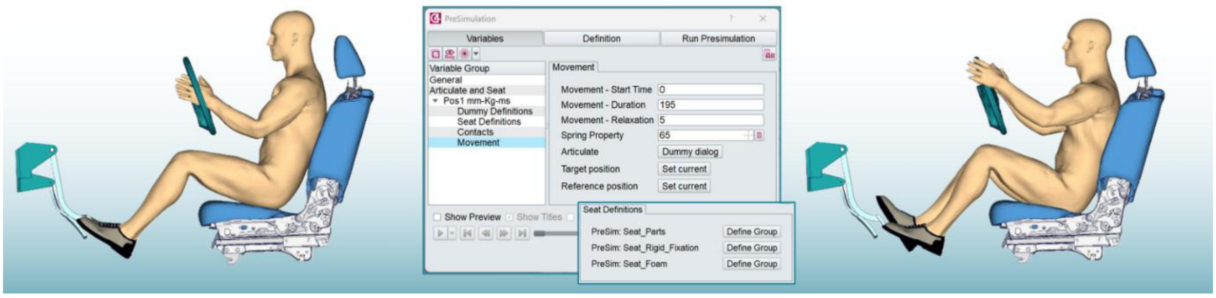

Fig.4: Generator4 PreSimulation module for HBMs and Dummies positioning simulations

3.1.3 Belt adjustment

Restraint systems such as seat belts can be defined in Generator4, where there is a dedicated dialog exclusively for this purpose.
The seat belt is generated automatically, including the typical redirects of the strap at the B-pillar and the buckle.
Once the model has been generated, the band shape can be adapted interactively if the engineer is not satisfied with it and considers that further improvements need to be carried out. The belt bandage can be morphed according to the user's desired settings via drag & drop.

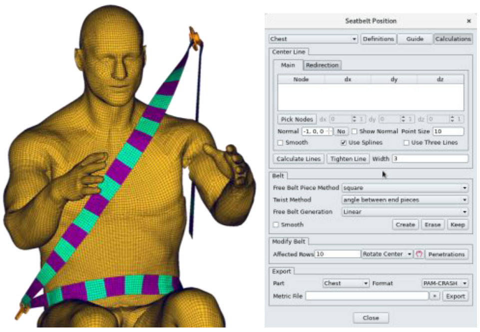

Fig.5: Generator4 dedicated dialog for belt generation

4 Animator4 HBM Tool to enable an automated evaluation of HBMs

Animator4 is a generic postprocessor that has led the automotive industry market for over twenty years. It is renowned in the field of numerical simulation for its exceptional performance in handling large models and vast quantities of result data. Large, complex human body models present no challenge to the software.

However, the large volume of available data and evaluations, as well as the detailed modelling of different human tissues, can make interactive handling of the models and processing of the data quite complicated for engineers with commonly little medical knowledge.

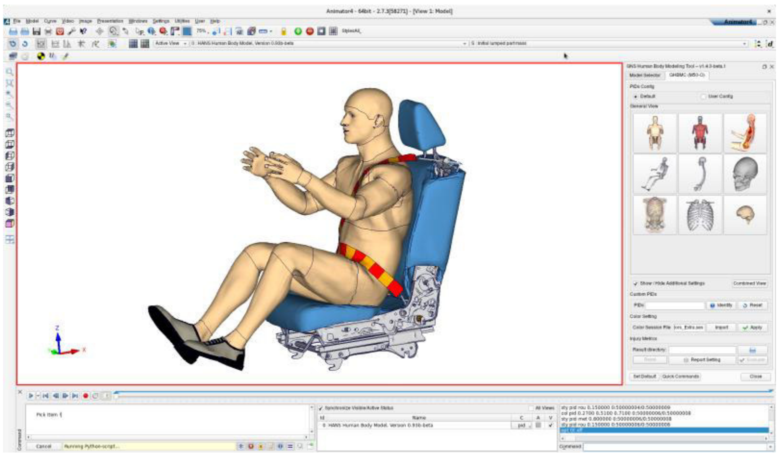

Fig.6: Animator4 main GUI

With the aim of facilitating the daily work of simulation engineers, the HBM Tool has been developed as part of Animator4.

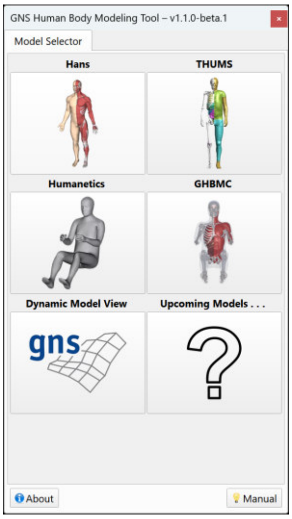

Fig.7: HBM model selector at the HBM-Tool in Animator4

This dialog box, dedicated exclusively to the management and evaluation of the various HBM models available on the market, offers assistance in two main areas: the management of model views and organ display, and the evaluation of results.

4.1 Visualization help

The level of detail in the human models, particularly the Hans model, makes it difficult to navigate through the different tissues, organs and fascias to obtain the desired view for evaluation purposes. This problem is solved by the “General” and “Combined” view panels on the tool.

On the one hand, the 'General view' area provides the most commonly used views for evaluating HBMs with a single click, making interactive evaluations more dynamic and convenient. Several buttons with easy-to-recognize icons offer a one-click solution to obtain the desired views.

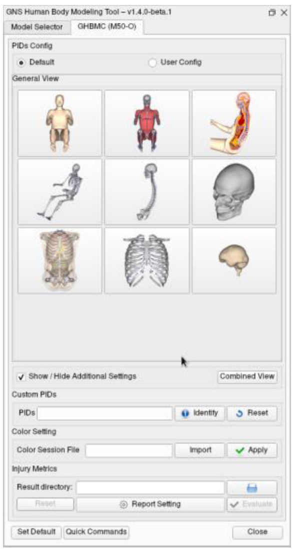

Fig.8: GUI of the HBM-Tool where the “General view” panel with predefined views can be seen.

On the other hand, the 'Combined view' area offers a list of the organs and systems present in the HBM that can be selected. This activates the visibility of the selected organs, making it possible to build the required views when specific views are needed and not available in the predefined views in the 'General view'.

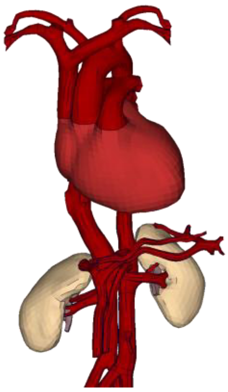

Fig.9: View created using the "Combined View" where the user selected the systems and organs of interest.

However, the user is not limited to the predefined views and organs of the tool. The Animator4 tool also offers flexible visualization assistance through the so called 'Dynamic Model View'.

When this option is selected from the main selector panel, a new tab appears where the user can scan the current model for groups defined in the input deck. Later, the groups found can be filtered according to the user's interests and saved as a configuration, providing easy access to them.

The user can also define their own configuration for any model in a simple XML format. This provides a straightforward option for quickly creating a panel view.

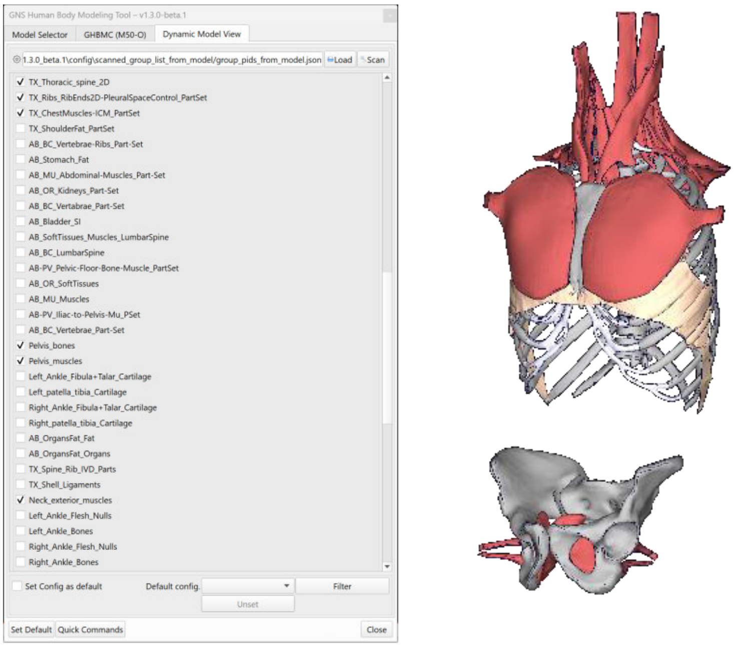

Fig.10: Selection of model groups of interest after model scan

4.2 Automatic report with injury metrics evaluation

The tool also provides an automatic evaluation of the model, presented in a report with all the values and parameters obtained from the simulation.
This automation is an invaluable aid to the simulation engineer, as it evaluates the results in order to provide easily interpretable conclusions.

The evaluation of the simulation results is based on scientific publications in the field of simulation and medicine.

Some of the offered injury evaluations are described below and can be selected from the evaluation configuration

Fig.11: Injury evaluations selector for report generation

4.2.1 Brain damage evaluation

The cumulative brain damage evaluation is calculated based on the maximum plastic strain, which is determined by evaluating the relative volume of the brain area experiencing a maximum plastic strain above a certain threshold limit.
Apart from the CSDM value itself, curves reflecting cumulative strain damage versus time and plots of maximum plastic strain are provided.

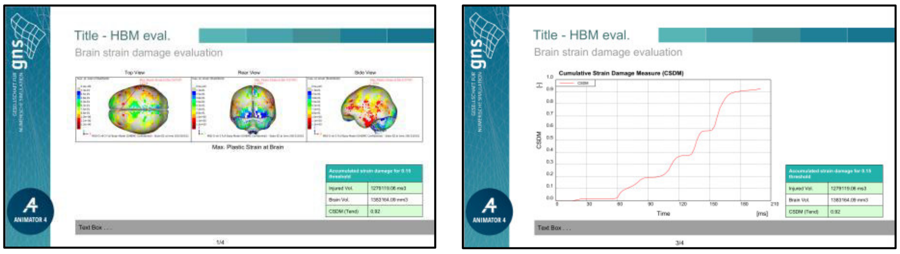

Fig.12: CSDM report offered by the HBM-Tool

$$CSDM_{15} = 100\left[\frac{Vol_{d15}}{Vol_{total}}\right]$$

CSDM = Cumulative Strain Damage Measure.
Vol_{total} = Total brainvolume.
Vol_{d15}= Brain *volume* above 15% of max. plastic strain

Fig.13: Formulas used to calculate the $CSDM_{15}$

4.2.2 Brain injury criteria (BrIC)

The brain injury criteria (BrIC) focuses and evaluates the angular velocities suffered by the brain during the simulation.

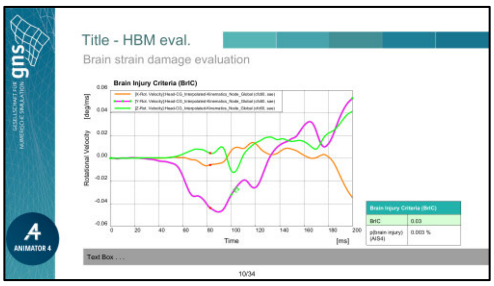

Fig.14: BrIC report offered by the HBM-Tool

$$BrIC = \sqrt{\left(\frac{\omega_x}{\omega_{xC}}\right)^2 + \left(\frac{\omega_y}{\omega_{yC}}\right)^2 + \left(\frac{\omega_z}{\omega_{zC}}\right)^2}$$

ω_x = Angular velocity X.
ω_y = Angular velocity Y.
ω_z = Angular velocity Z.
ω_{xc} = Critical angular velocity X.
ω_{yc} = Critical angular velocity Y.
ω_{zc} = Critical angular velocity Z.

Fig.15: Formulas used to calculate the BrIC

4.2.3 Head Injury Criteria (HIC)

The HIC is another measure of the likelihood of a head injury resulting from an impact. Although it is widely used for evaluating traditional dummies, it still provides valuable information when evaluating HBMs.
This value is derived from the accelerations at the center of gravity of the brain when it is exposed to crash forces.

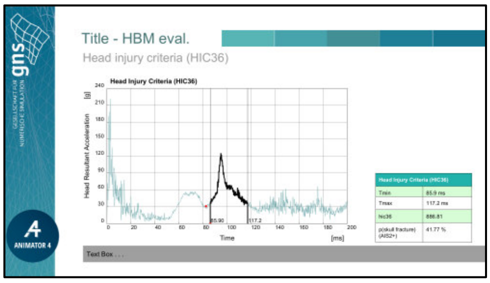

Fig.16: HIC_{36} report offered by the HBM-Tool

$$HIC = \max_{(t_1,t_2)}\left\{(t_2 - t_1)\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)\,dt\right]^{2.5}\right\}$$

$a(t)$ = Resultant linear acceleration in g.
$t_2 - t_1$ = Critical time step, 36ms or 15ms.

Fig.17: Formulas used to calculate the HIC36

4.2.4 Rib fracture evaluation

Fig.18: Rib fracture evaluation extensive report offered by the HBM-Tool

Thoracic area evaluation is an important part of HBM evaluation and the resulting report. The animator4 tool produces tables, plots, curves and fracture risk probability values to help the simulation engineer to evaluate the system and make design decisions based on those results.

In order to calculate the risks for each rib, the strains suffered and the age of the model used are taken into account as described at the publications from Larsson et al.[3]

$$\boldsymbol{Risk} = \frac{1}{2} + \frac{1}{2}\boldsymbol{erf}\left[\frac{\boldsymbol{ln(strain)} - (\boldsymbol{\beta_0} + \boldsymbol{\beta_1.Age})}{\sqrt{2}.\boldsymbol{\alpha}}\right]$$

erf = Gauss error function.
α, β_0, β_1= Constants.
Strain = max. plastic Strain
Age= 30 – 40 (Range)

Fig.19: Formula used to calculate the fracture risk

4.2.5 Risk of AIS3+

Based on the papers and investigations of Forman et al. [4], the risk of sustaining serious injuries to the rib cage is calculated. Therefore, the user obtains a probability of serious injury to the thoracic area, calculated from the maximum plastic strain values at the ribs.

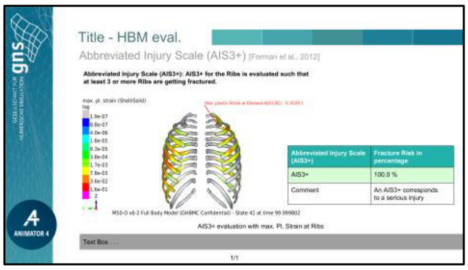

Fig.20: Risk at the rib-cage of AIS3$^+$ report offered by the HBM-Tool

4.2.6 Simulation quality criteria

To verify the quality of the numerical calculation evaluated and in response to the requirements presented in the NCAP technical bulletin[5], various evaluations of the total energy balance are also presented.

1. Evaluation of the Max. hourglass energy of full setup with regard to the max. internal energy.
2. Evaluation of the added mass added due to mass scaling for both the complete model and the HBM.
3. Evaluation of the Y-displacement for the acetabulum center.

4.2.7 Automatic report presentation

Once the desired injury criteria have been evaluated, the user is provided with a comprehensive report containing graphics, pictures, videos and result values.
The presentation is interactive, meaning the user can add extra information or evaluations of interest to the document. Later on, Animator4 offers the option of exporting and saving the data in various formats for future use, such as native A4 databases, PowerPoint or PDF.

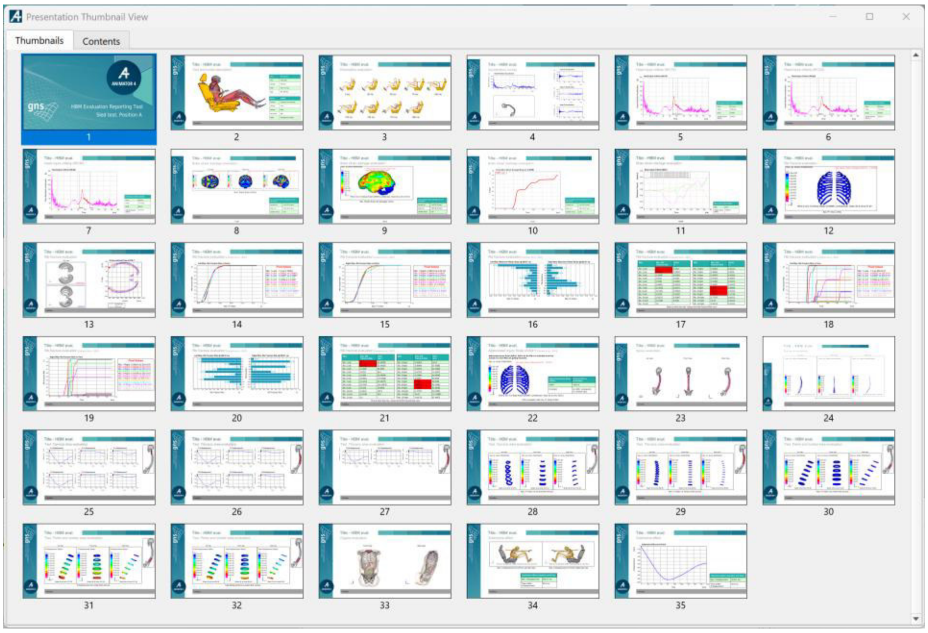

Fig.21: Created report after HBM evaluation in Animator4

5 Summary

During the presentation, the new Animator4 tool for HBM evaluation will be introduced, along with the various injury criteria based on biofidelic assessments.

To obtain the required simulation results, the processes to be followed in Generator4 and Animator4 when working with human body models will be demonstrated.

Generator4 provides a flexible and dynamic pre-processor that helps to pose any mannequin or human body model in an effortless way. Animator4 is a powerful post-processor capable of managing the complex HBM models with ease. Toguether with the newly developed evaluation tool, it is the perfect combination for overcoming all the difficulties involved in evaluating complex human models.

6 Literature

[1] DYNAmore website. https://www.dynamore.de
[2] Benito cia,L:“Hans meets the GNS software. Working with HBMs in Generator4 and Animator4“, International LS-DYNA conference, Metro Detroit, Michigan USA, 2024
[3] Larsson et al. “Rib Cortical Bone Fracture Risk as a Function of age and Rib Strain: Updated Injury Prediction Using Finite Element Human Body Models”, Front. Bioeng. Biotechnol., 2021
[4] Forman et al. “A Method for Thoracic Injury Risk Function Development for Human Body Models”. IRCOBI conference proceedings, 2022
[5] Euro NCAP Technical Bulletin TB 551, Human Body Model Simulation for Frontal Impacts,. Version 1.0, May 2025.