Advanced Results Databases Compression Techniques to Allow their Efficient Use in Results Data Management Systems

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Abstract

The usage of automated post processes is the rule nowadays. Simple scenarios include saving only specific LS-DYNA® results in post processing software native databases whereas in more sophisticated cases a series of report data are stored in data management systems. New challenges arose this way relevant to the need to download the report data from a data server as quickly as possible, display and compare them in the best way allowing in the same time as much access to the original results data as possible.

This paper presents a solution in this field. The compression capabilities of post processor META native database, specially designed for simulation results far exceed the conventional compression solutions reducing storage requirements and more importantly bringing database downloading times to affordable levels. The tool offers full control of the data accuracy stored and advanced parameterization per model/component/part and per result. Model simplification techniques produce 3d databases with a satisfactory draft display of the results field in sizes of one hundredth of the original ones.

This functionality allows the efficient usage of results databases inside the results data management system of the BETA suite. Curves, images and presentations are usually preferred to 3d databases in such systems because of the big downloading times stemming from the size of these databases. Using simplified model 3d databases brings noticeable benefits at negligible additional cost. LS-DYNA results or results derived from the LS-DYNA results, stored in such databases, can be selected for display in layouts predefined by the data management tool offering a much more efficient first check of the results in comparison to images, videos or presentations. Then the option is offered to interchange between the simplified and the original representation on component/part level on the fly and only where needed.

Introduction

Post processing of CAE simulations is a task where automation plays a dominant role in our days. In companies standard processes every LS-DYNA job submission is followed by a batch post scenario for the evaluation of the results calculated by the solver. In that case a series of report data may be generated including tables with values characteristic for the model's performance, images and videos displaying the results, curves graphs, reports in any format like html, pptx or xlsx. Another approach is the export to post processing software native databases to narrow down results stored to the ones necessary making the results file lighter and easier to access. In simple implementations these data are plainly stored in a file system in order for the analyst to review them. The link to the CAE model they refer to is implied by their file location, for example they are stored in a subfolder of the job submission folder. In more advanced implementation data management tools come into play to take over the storing of the reporting entities and their linkage to the simulation model they refer to. All these data need to be kept in locations reachable by all relevant persons – network file systems or servers - and need to be downloaded upon demand by the analyst.

This last fact makes the size of such report data of crucial significance, as storage size is always an issue if we take into account the massive volume of data needed to be kept. Furthermore, high sizes result to increased waiting times for the files to be transferred through the network or to be downloaded from the server. The need for fast access to the results data, having them in a displayed in way that the analyst can directly evaluate them, while keeping storage needs low, places pressure on the need to keep as much information as possible in the data leading the analysts to make compromises as to information stored. Choosing to use only generated report data like presentations, images, values and videos one loses a portion of the original information provided by the solver. Databases with the results in 3d might be stored complementarily but they are usually in a raw

format. One must process the data, manually or using library scripts, to display the results in a way that facilitate the extraction of engineering evaluations. Since this is a time consuming task it is not used for each simulation. Thus, problems detectable only in the 3d databases may be easily neglected if these problems are not detectable in an image or a video so the analyst does not choose to open the 3d database. On the other hand, relying mostly on databases with three dimensional results forces the analyst to lose time waiting while data are being loaded and processed. The paper starts first with a description of the functionality regarding the compression of data values and the compression through mesh simplification. Afterwards, an example case of using compressed metadbs as reports in a data management system is presented.

Data compression with META

META is the post processor tool of the BETA products suite. To store results it offers a native database of binary format, the metadb[1]. Two options are provided to compress the data stored in metadbs, the lossless compression and the lossy compression [2]. The lossless option is to compress the data as they are without losing any information, something very close to the commonly used compression techniques widely available. The difference is that the compression and decompression of data takes place concurrently with their loading and storing resulting to better performance.
However, this compression technique, as common compression solutions, does not take into account that, because of the nature of the data, not all information is actually needed to be kept. For example the positions of the grids of the model may be described with an accuracy of 10^{-6} mm when 0.01 or 0.1 mm accuracy would be enough for the correct display of the model. In case of stress results, original data may have an accuracy of 1 Pa whereas an accuracy of 0.1 MPa would be enough for most analyses. Of course the level of accuracy demanded may vary greatly depending on the results type and the analysis. The second compression option, lossy, addresses these issues effectively. Data are compressed by an advanced algorithm that keeps only needed accuracy of the values. The accuracy level can be totally transparent to the user through options to define the significant decimal digits up to which values should be stored intact or to define the discretization of the values range. This accuracy is not set globally but on data type level as there are usually different needs for different results. A user interface is provided for this purpose as depicted in figure 1.
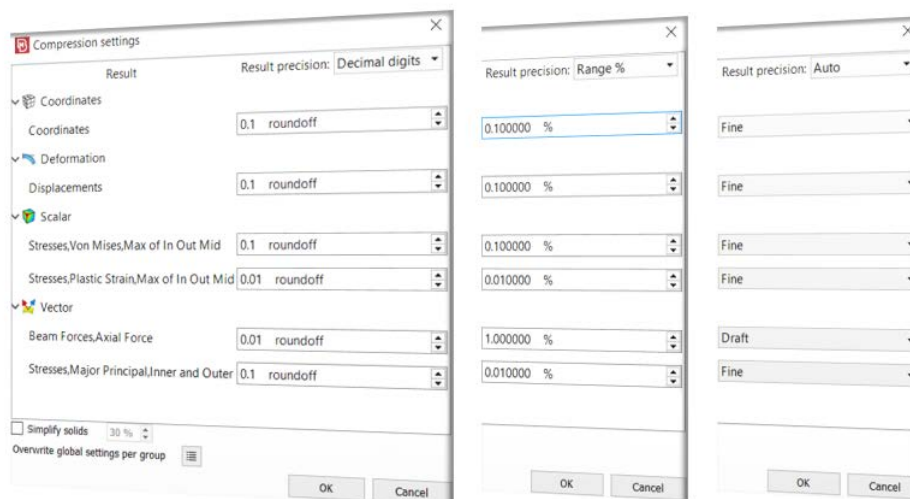

Fig.1 : User interface with compression settings

So, 0.1 accuracy may be set for von mises stress result while a higher accuracy of 0.01 is used for plastic strains as the values there are lower. It should be noted here that no units are set in the tool. Accuracy is always set in the units of each result as this is output by LS-DYNA depending on the units the model is set up with. Another level of parameterization of the compression is the option to set different settings on various areas of the model. There are many analyses whereby only part of the model is of interest and the rest of the model is used complementary in order to capture the phenomenon correctly. An example case is the optimization analysis of the front bumper parts of a vehicle for a frontal crash analysis. While results need to be accurate for the bumper parts and possibly for the parts directly or indirectly related to the bumper parts, such a need does not exist for the remaining parts of the model that lie at the rear. Results for this area of secondary importance must still be included and reviewed during the evaluation of each optimization model version, as there might appear an unexpected impact of a design change on this rear area, an impact that needs further investigation. However, this purpose can be satisfied even with results of lower accuracy. The META compression functionality covers the above case by providing parameterization per area. Areas can be defined on part or on set level. The settings to be used and their impact on the resulting error inserted into the compressed results are depicted in figure 2.
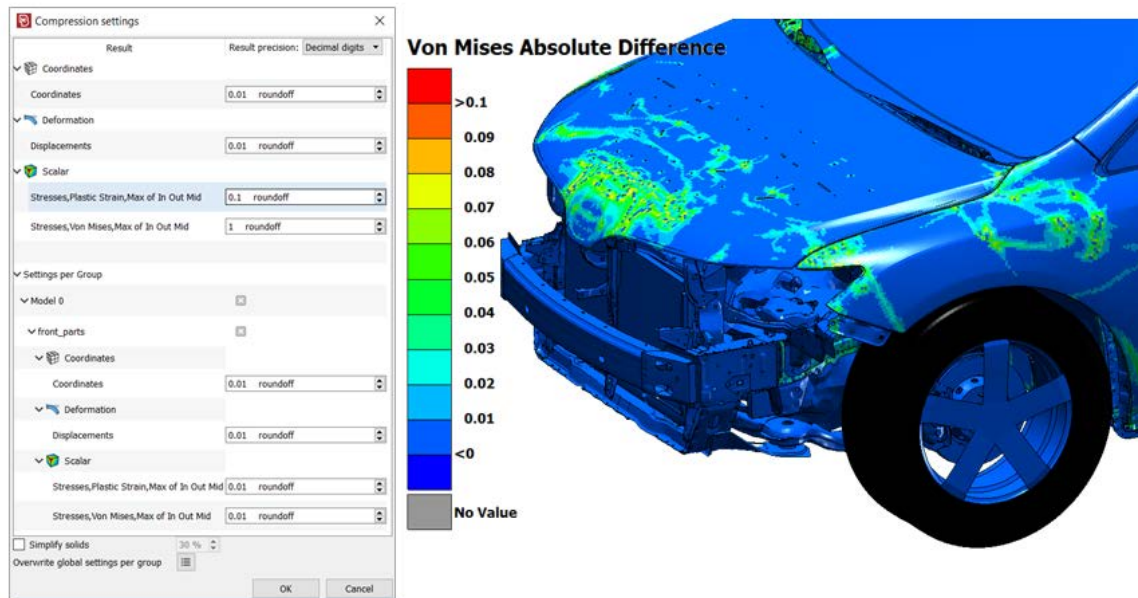

Fig.2 : Compression parameterization per model area

The compression ratios achieved are showcased with the finite element model of Toyota Venza. The model is publicly available at the official NHTSA site [3]. Its main characteristics are given in figure 3.

Nodes	1.374.798
Shells	1.292.715
Solids	97.082
States	34

Fig.3 : Toyota Venza LS-DYNA model

The model is solved with LS-DYNA for the full frontal crash loadcase.
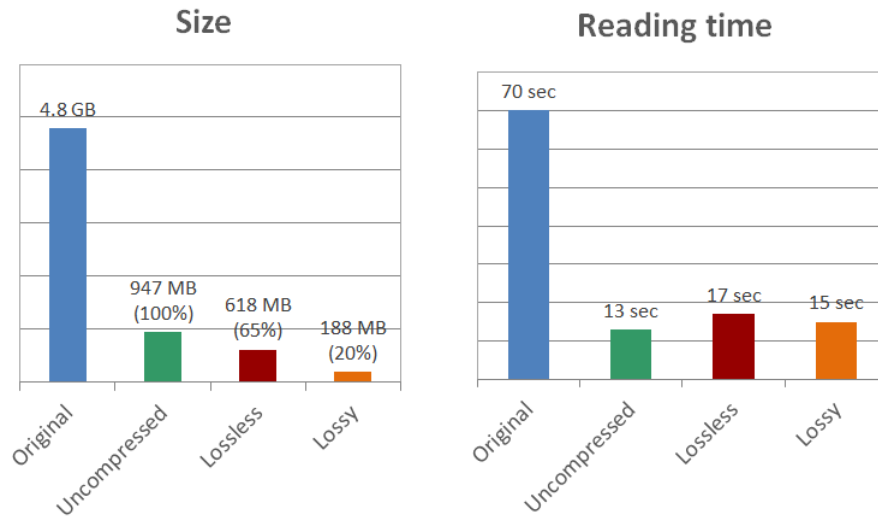
Fig.4 : Comparison of original / uncompressed / compressed results files

Figure 4 shows a comparison of the file sizes and the reading times needed for META to load the model geometry and all results. The original results files output by LS-DYNA reached a sized of 4.8 GB. It is assumed that the results of interest are the deformation of the model, the von mises stress and the plastic strains. For the von mises stress and the plastic strains the maximum value through the shell thickness in case of shells is kept. Storing the aforementioned results together with the initial geometry, as a META native database, leads to a metadb file of approximately 950 MB. This reduction is achieved solely by discarding unnecessary results. Compressing the metadb file with the lossless option, the file size is reduced approximately to two thirds of the original size. Using the lossy compression with an accuracy 0.1mm for original geometry coordinates and deformation, 0.01 for maximum plastic strains an and 0.1 for von mises stress, the compressed metadb file size is 188 MB. This corresponds to a 20% reduction of size from the uncompressed database. Reading time can also be a gain from data compression in cases where the network speed is the bottleneck defining the loading process. Since this is a factor that cannot be determined, the reading times depicted here do not take this into account and thus cannot show the gain in such cases.

Mesh simplification

To enhance further compression ratios a type of compression is applied not only on the values but also on the values distribution on the model's surface or in the model's volume. The goal is to have the same display of the model's shape and acceptably similar colored contour of the results on the model through a different simplified finite element mesh with a reduced number of elements. To achieve this, new mesh is actually created for the model. A different approach is followed for shell and solid models.
In case of shell surfaces a more draft triangular mesh is created keeping however a fraction of the original nodes. This simplified model can present the loaded status of the original model with a much smaller number of finite elements, thus with much fewer amount of data needed to be stored. An example of such simplified mesh is depicted in figure 5.
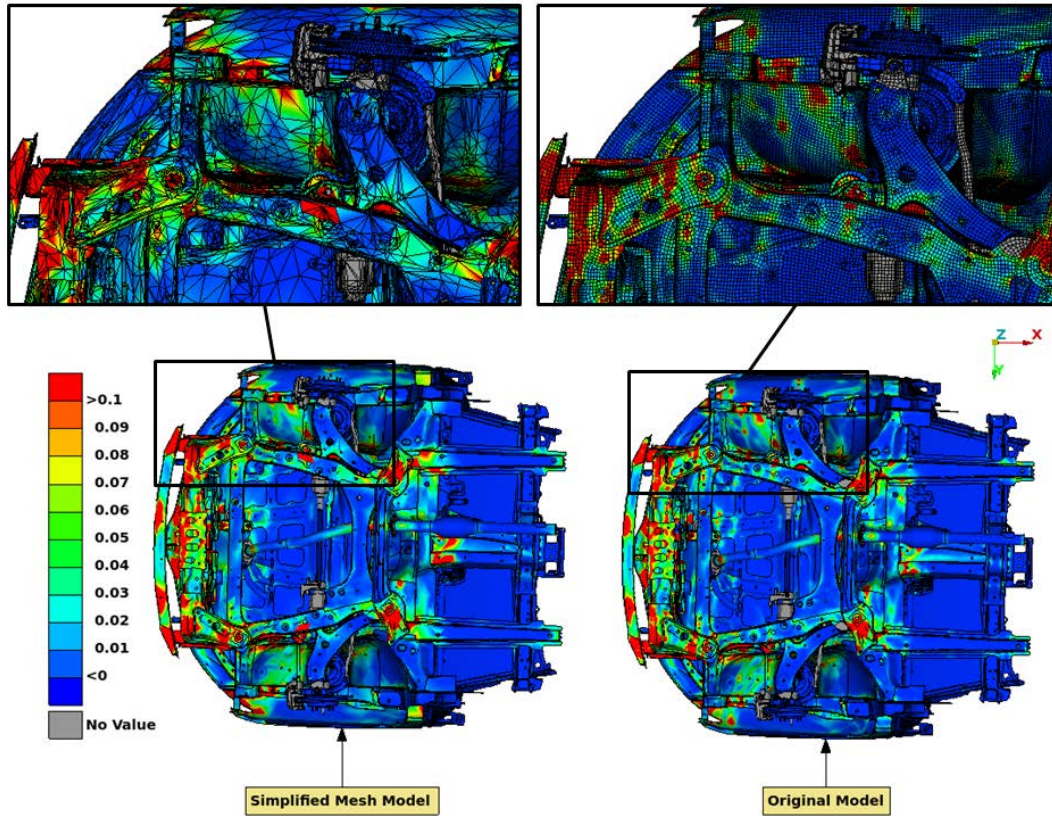
Fig.5 : Mesh simplification for shell surfaces

Contour plots display plastic strains values. Contour plot of simplified mesh is able to capture all hot spots of high plastic strains values on the parts and approximate representatively the strain distribution. Figure 6 shows a comparison for the same VENZA model used in figure 4. The comparison is among the uncompressed metadb, the compressed metadbs using the original mesh and lossless / lossy options and the corresponding metadbs using the simplified model.
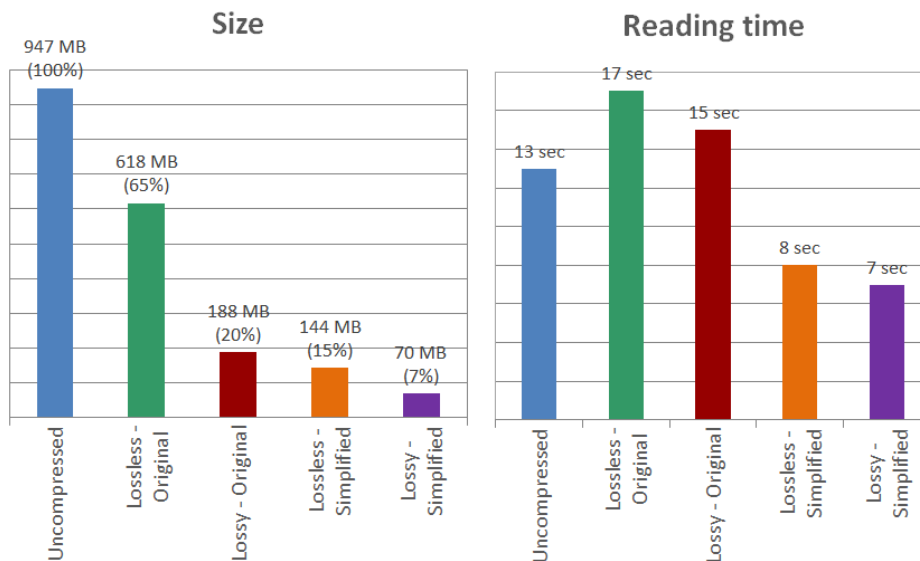

Fig.6 : Comparison of original / mesh simplified META databases

A great benefit provided by the functionality is the ability, while viewing results on the simplified mesh model, to replace selected parts of the model on the fly with their original representation. The link information between the original and the simplified mesh models is stored as metadata in the metadbs so that META is able to realize the interchange of the two representations on part level without loading a second model and with no additional effort by the user. So, the analyst can have a quick first impression of the results using the low cost – in terms of size and loading time – simplified mesh model, and then, only when a more thorough analysis is needed for some areas of the model, load the original mesh for just some few parts in question. The benefit is even greater for models containing some millions of elements because the model is never fully loaded with its original number of elements making it easier to handle in terms of memory and graphics performance.

In case of solid mesh the functionality creates hexa elements fewer in number than the elements of the original mesh. The functionality targets CFD applications in this case and has thus as a goal to be able to extract isosurfaces, streamlines and contour plots at volume cutting planes with the simplified model that can give a satisfactory representation of the results.
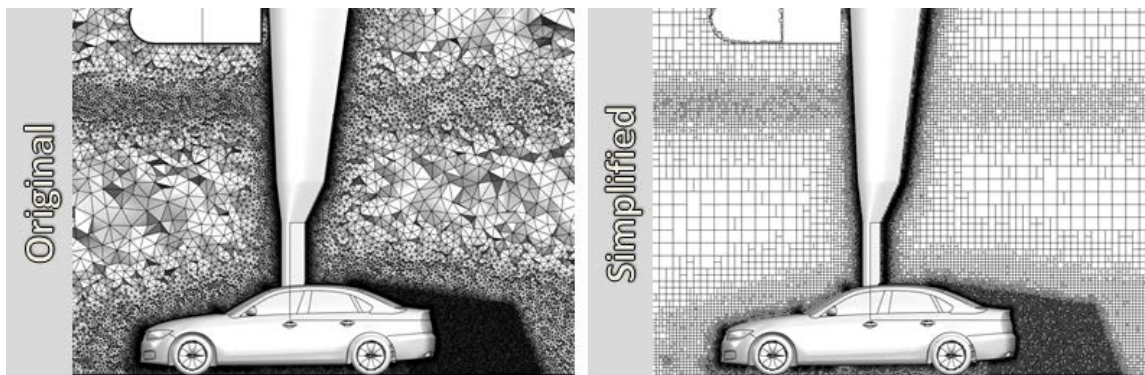

Fig.7 : Mesh simplification for volumes

Figure 7 shows such a simplified volume model compared to the original one. The element size of the newly created hexa follows the local density set in each area. This way, areas set up with fine element size so that results there are evaluated with higher accuracy keep this feat also in the compressed model.

Use of compressed metadbs in a data management system

The combination of lossy compression for data values with the simplified mesh representation brings the 3d results databases to sizes almost comparable to the ones of images and videos. Moreover, the functionality that allows saving multiple snapshots of the loaded status of the model in the same metadb without any unnecessary duplications in terms of data storage, each one with separate and independent presentation settings - the visibility of the model, the depicted result, the contour or vector fringe and its range - renders the metadb a very efficient option for storing results reports in a data management system. The time to load the metadb should not be compared to the time needed to load one image or one video in this case, but to the time needed to load all relevant images or videos that this metadb can substitute.

A use case of implementing the results data management tool of the BETA suite for the analysis of the car model VENZA in full frontal crash is described below. The benefits of the compressed metadb option are better comprehended with this use case. The results evaluated for this analysis are the intrusions at specific positions, the general behavior of the firewall and the parts in front of it during the crash, the plastic strains, the spotwelds failure, the accelerations and section forces on selected positions.

The process described begins right after the submission of the calculation runs and the export of the results by LS-DYNA. Although components modelling, model assembly and loadcase set up can also be part of the data management system the latter are not subject of the current paper and therefore left out. More information about

them can be found in [4] and [5]. Each model calculated, referred to as simulation run from now on, is saved in the data system with its metadata like project, variant, versioning information and loadcase information. The LS-DYNA field results calculated are the displacements of the model and the plastic stains whereas there are some time history results calculated like the beam forces for the spotwelds, forces on predefined sections of the model and accelerations on specific positions [6]. The results are post processed with META using an automated process driven by a script that extracts all reports items needed. It loads all field results – deformations, plastic strains - and calculates intrusions values. It loads the history results of the spotwelds (beams) forces and combining them with model data like the thickness and the material characteristics of the connected parts it calculates the risk of failure for each spotweld and sets this value as a new field result for the spotwelds. The section forces and accelerations results are plotted using some predefined settings, like filtering, and are placed in a preset layout. Now the common path would be to store values, images and videos of the model results as separate entities in the data management system. Instead, in this case, some values and curves may be saved separately in order to make it possible to have an instant comparison for some specific results; however the field results are saved as a compressed metadb. Each results display needed is saved in a separate independent unit of the database, called pages hereafter. In more detail, one page is created showing the deformations of the whole model, one page shows the plastic strains contour, one page is created for the contour with the intrusions on the firewall and one page displays the spotwelds failure risk result. The metadb is saved compressed once with the original mesh and once with the simplified mesh. There is one separate metadb saved with only graphs of time history results – the energies, the accelerations and the section forces. All above metadbs and other reports entities are stored in DM under the simulation run to which they belong through simple session commands.

The Data Management tool [7], a tool available in both pre-processor ANSA and post-processor META of the BETA suite is used to filter and view the stored results for each model version and compare them. Simulation runs are filtered so that the analyst views a series of versions which are part of a suggestion improvement. Another case would be to simply check the simulation runs calculated last night by LS-DYNA. As a first step the energies curves are selected to be viewed so that there is a first quick check that there is not something wrong with one of the simulations.
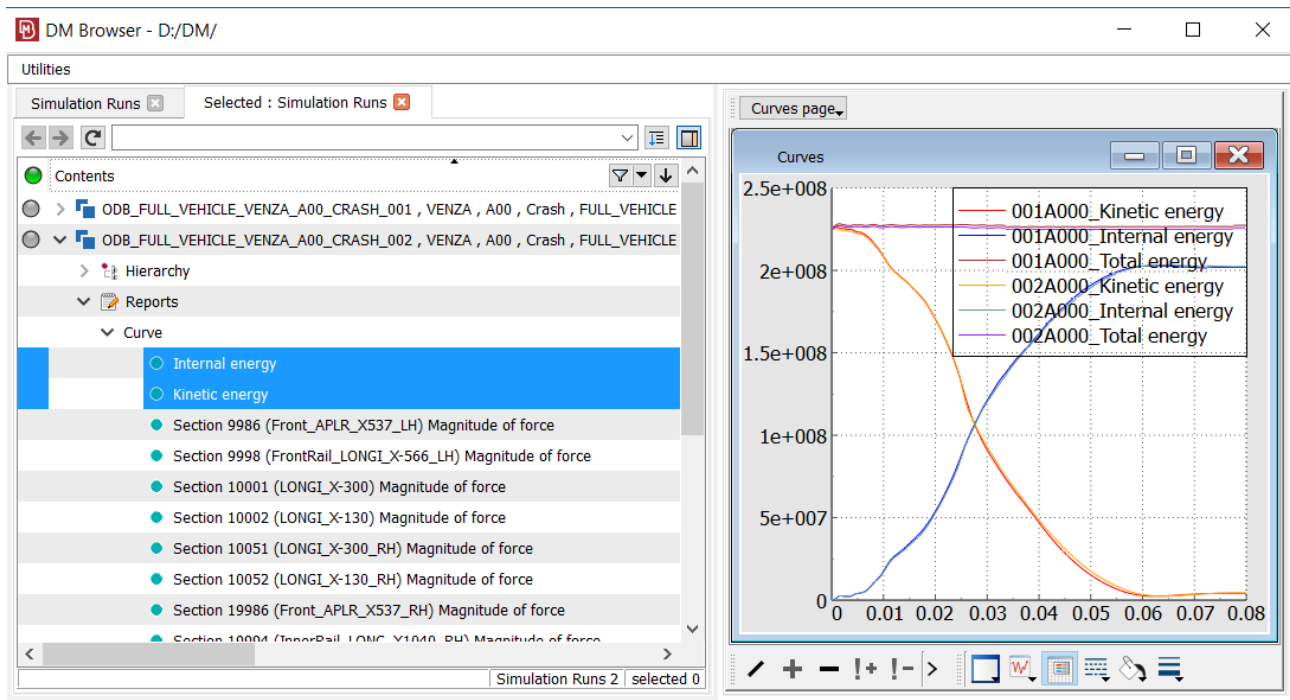

Fig.8 : Viewing energy curves in Data Management tool

In a second step the intrusions values are checked for all versions inside the Data Management tool as below.
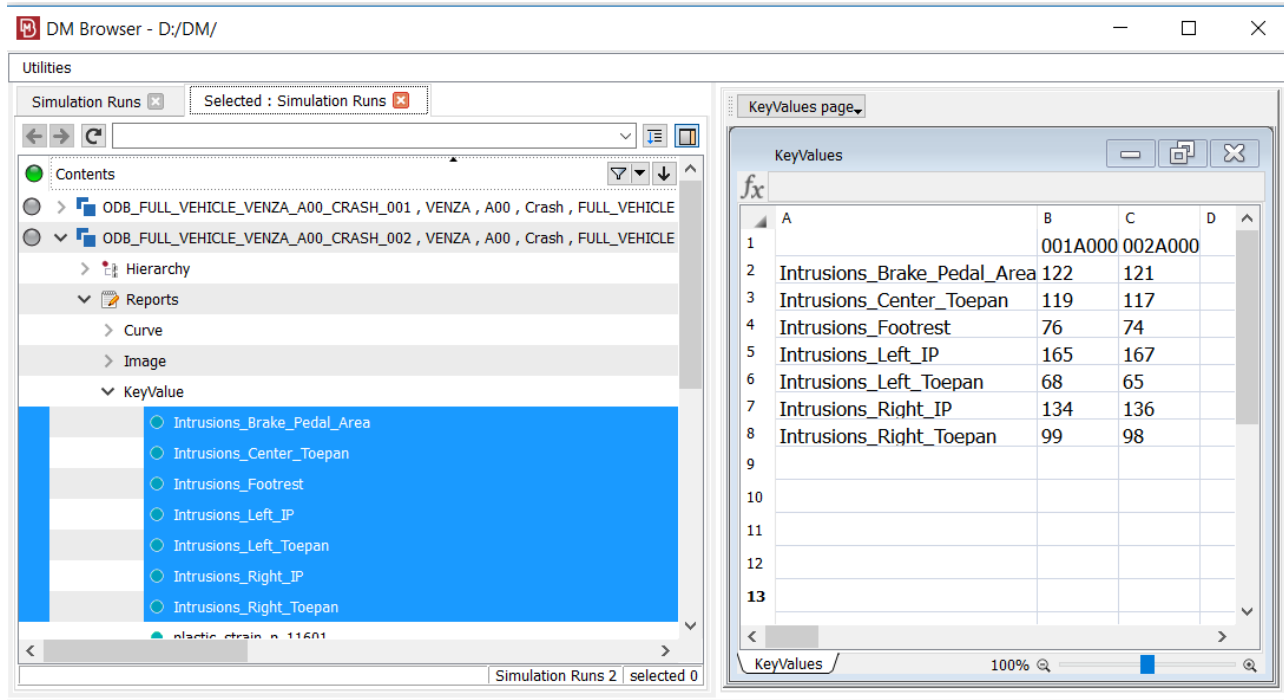

Fig.9 : Viewing intrusions values in Data Management tool

In case the intrusions need to be checked in detail, the metadb of the simplified mesh is loaded in the embedded viewer of the data management tool and set to the page with the intrusions contour. The metadb file has a size of only some MB, so the loading time is negligible. It is capable, however, of showing the intrusions results satisfactorily as shown in figure 10, where the results are compared to the original ones and offers the capability to have a better understanding of the model's behavior compared to a video or a series of images.
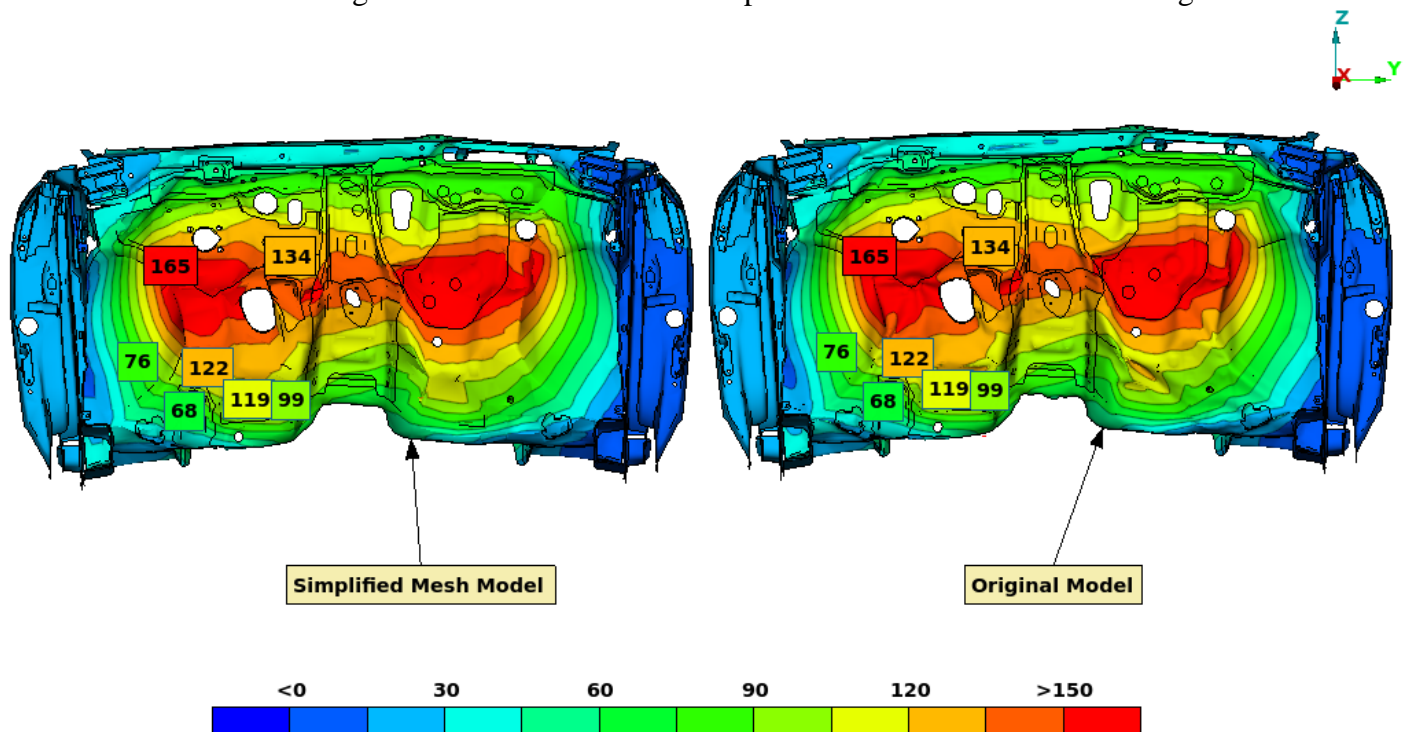

Fig.10 : Viewing intrusions contour plot in Data Management tool

The model can be rotated inside the viewer while simulation can be animated. The viewer offers some basic post processing functionality like basic query on model entities and results and change of visibility. The predefined set up of the settings fitted to show the intrusions help the user get the simulation run in a ready-to-evaluate state. The firewall part is selected in a second step and is replaced by the original mesh, as this part needs to be analyzed more accurately. The replacement is done inside the viewer without leaving the tool to go back to the simulation results data structure. The page with the deformation of the whole model is selected to check the behavior of the whole model during the simulation and to see how this affects the intrusions measured. Similarly, the pages with the plastic strains and the stresses are evaluated with the option to bring any part with the original mesh in areas that this is needed.

Next, the database page with the spotwelds failure risk is checked. Figure 11 shows how the model is displayed in this page. The risk failure result is visualized using a circular annotation for each spotweld, annotations colored according to the failure risk. The calculation defines a low and a high limit so all spotwelds are colored green, yellow, orange or red according to where they lie compared to these limits.
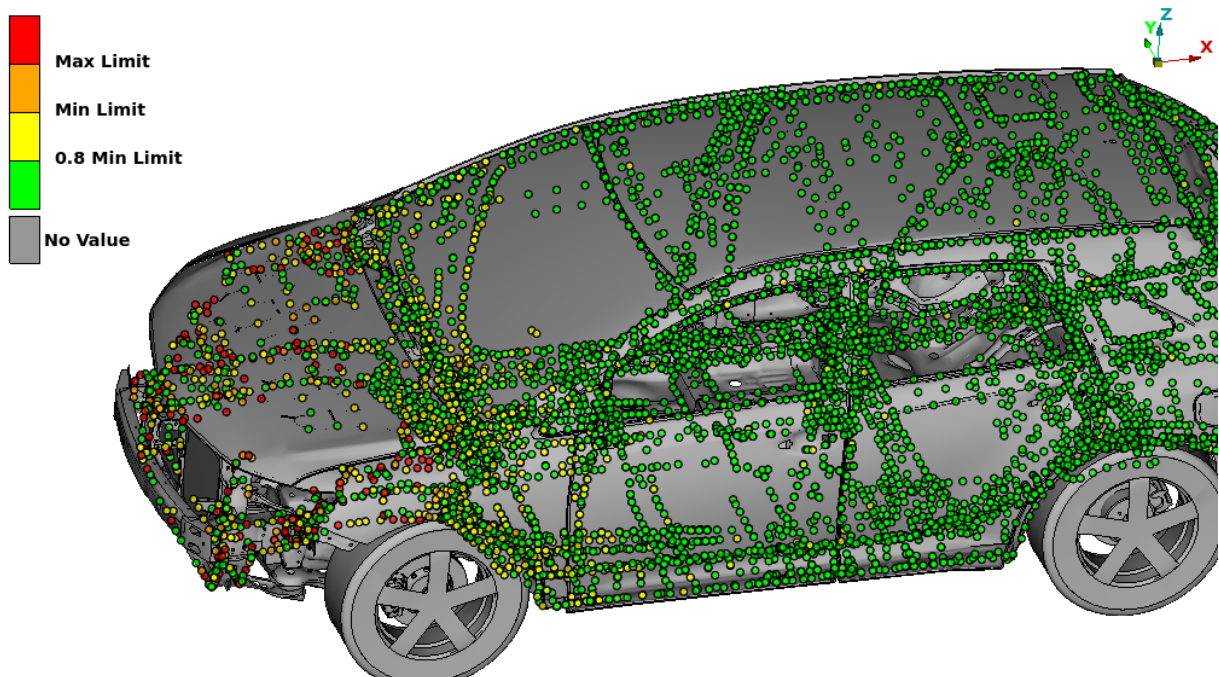

Fig.11 : Spotwelds failure plot on the simplified model

This is one of the best examples of the compressed metadb advantage. The simplified mesh is more than enough, as the purpose is to have the model shape without full detail in order to recognize each spotweld by its location while the total number of spotwelds on such models makes the use of images or videos in certain library views unsuitable. One must be able to zoom in and manipulate the model in three dimensions to be able to examine the spotwelds clearly.

In a last step the databases with the accelerations and section forces graphs are loaded. In this case all curves from the selected variants are overlaid inside the same window. The plot settings like the plots layout, the range and the axis titles have been already set at the batch post processing step, when these metadbs are created, making the review process as efficient as possible.

Conclusions

The two-level compression of results databases that post-processor META offers - one at the values level and one at the mesh level – is able to reach significant compression ratios and deliver database sizes that can be downloaded by data management systems in affordable times. Considering the advantages which 3d databases bare compared to the traditional options of images and videos in terms of comfort and efficiency to inspect results, their usage as means to store LS-DYNA results, allowed by their small compressed size, is greatly beneficial. An example case of a data management system with the respective tool of the BETA suite using such compressed META databases was provided to showcase the benefits. One specific analysis, the full frontal crash, was analyzed. Of course, each analysis may have its own individualities and needs. However, the high level of parameterization offered firstly by the compression functionality, secondly by the general META automation capabilities to post process and present results and thirdly by the data management tool can address each case uniquely offering the best solution.

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