

CAE Data Management and Quality Assessment of LS-DYNA Crash Models using V-CESS

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ABSTRACT

The meshing, modeling and evaluation of LS-DYNA crash models for vehicle crash simulations is constantly subjected to an increase in complexity, since the model sizes grow, several vehicle variants are instanced from one single CAE data set and since the number of load cases and the requirements on the evaluation quality are constantly increasing. Current models sometimes contain more than 1000 different components and 1 million elements. In recent years, the model complexity has also been increased since interior parts and dummy models are included. The increased complexity makes it difficult to handle the models since changes in parts in many cases influence many different vehicle variants and load cases.

V-CESS is a "Virtual Process Automation Framework" designed to simplify and standardize this type of CAE processes and is developed together with Daimler-Chrysler AG, department PBE/DAM [3]. The system was developed in a pilot project with the aim to manage the CAE data of the "Sprinter Successor" in order to create, manage and evaluate crash models in LS-DYNA.

In engineering projects together with DaimlerChrysler AG, department PBE/DAM, we have shown that the return on investment of V-CESS is reached at about 1.5 virtual prototypes. The meshing cost can be reduced by 15% and the engineering cost saving is approx. 30%.

INTRODUCTION

The numerical simulation process which supports the development of a new vehicle contains several steps which must be taken. Some of the most important steps are: collecting data from design departments, test departments and other sources, meshing of parts, assembling of models and modules, connecting models and modules, defining a load case, creating the final input deck with output and numerical options, performing the simulation, collecting and pre-processing of output data, processing of output data in order to reach a state at which conclusions from the simulations can be made and finally create presentation material for meetings where the performance of the design is discussed and changes are proposed.

As can be seen in the above listing of tasks, several tools and engineers are normally involved in order to run through the complete process. The robustness of the process and the quality of the results from the process does not only depend on each process step itself, but also on the transfer between process steps. This includes both transfer of knowledge and information between engineers performing different steps of the process and information and data which must be transferred between different pre-, postprocessors and solvers from one process step to the other.

The complexity of the vehicle simulation process of today is characterized by simultaneous processing of several load cases for several different simulation disciplines. A design change in a certain part of the vehicle must propagate through all final simulation models to assure consistent results for different load cases and different simulation disciplines.

It becomes clear that this task is hardly possible to handle without tools to support the flow of the process. These tools must also log the process steps such that each engineer involved can easily get an update of model changes made by others, of which data a certain model is based and of which results belong to a certain model and a certain load case. If the process supporting tool additionally contains automation of certain standard process steps, not only the process robustness is improved; this also leads to cost savings and removal of standard "boring" work for the engineers. The highly educated engineers can thus concentrate on tasks where engineering judgement not supplied by computers is necessary.

Certainly, there still exist departments and companies that still handle such processes without additional process controlling tools. However, as the complexity increases, the error probability increases which sometimes leads to significant time delays and extra costs.

Altair Engineering GmbH works for several years in the field of process automation and process control for numerically supported development processes. The above problem has been detected, and during the year 2002, a CAE Support System based on the Altair HyperWorks Suite of tools was developed to handle the simulation processes described above. In this paper, the system is described and examples are given how this system can help an engineering team working with modeling and simulation of complete car lines to improve the effectiveness of work and the organization of project data.

CAD/PDM and CAE

The overall performance of an automatized CAE process is mainly influenced by the quality of the CAD data. Improvements in the quality of geometry is related to the improvement of the CAE process. The better the quality of the geometry is, the more easy the meshing can be done. Even important is the quality of the spotweld information. Welding a crash model can take from 1 to 5 days depending on the quality of the spotweld data, which is the accuracy of spotweld location and the correctness of the reference about welded parts including the possibility of the FE realization.

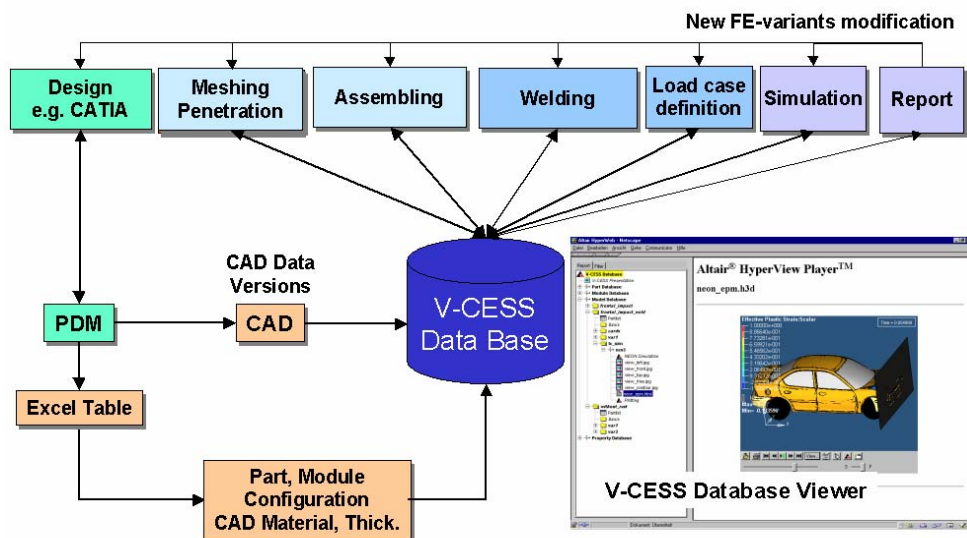


Figure 1 V-CESS PDM/CAD Coupling and CAE Process

Automized CAE solutions need a connection to existing CAD or PDM systems. The performance of the overall CAE process also depends on this interface. It provides the CAD data for parts, the CAD thickness and material, which is needed for the model, see *Figure 1*. These data are created during importing the geometry into the V-CESS database. A table matches between CAD material and LS-DYNA cards, to convert them automatically into LS-DYNA properties, LS-DYNA sections, and LS-DYNA materials. For each customer, this interface to the CAD or PDM system has to be implemented.

Based on the parts, PDM systems serve with different configurations as assembly lists for the different crash models and different load cases. An import module of these assembly lists into V-CESS must be implemented. This allows to have the geometry of the parts stored in a CAE database and assemble them for each configuration by applying this assembly list. Two different approaches are distinguished during this assembling process:

- The export of the CAD data is done instanciatedly. All transformations, which are applied to the parts in CAD are already resolved in the geometry which is meshed. Same parts in different locations have to be detected, to avoid redundant meshing work. In this case, the meshed parts are stored for each instance in the database, which makes it more difficult to manage.
- Non instanciated geometries only define a part in its part reference system, where the part does not know, how often and at which location it is used. In addition to the reference of the geometry, an assembly list also contains the transformation matrix to the vehicle system. The meshed part is only stored once in the database and modifications to this part are automatically applied to all references.

Objectives for an Optimized Automized CAE Process

Changes, as described in the previous chapter, lead to big change in the overall CAE process. The current CAE process can be analyzed and optimized for process time, cost, quality or other objectives. Major objectives for an automized meshing, assembling and documentation system, as shown in *Figure 1*, are as follows:

- Dramatical improvement in the productivity of CAE projects to save costs and time. Reduce process time for meshing, assembling, documentation and reporting and make a high percentage of automated processes. During process optimization projects the customers have realized that - depending on the current situation - between 20% and 50% of the time and costs can be saved.
- Manage all onerous daily work to motivate the project engineers. They should mainly do the real engineering work on products.
- High quality processes will be followed by implementing the required quality standards.
- Build up a CAE database with revision which administrates pre-processing data, post-processing data, process relevant data as a basis for process standardization and automation, see *Figure 2*.
- Reproducibility of processes and simulation results.
- Comparison of the contents in the database between different load cases and assembly lists. This allows to manage the history of parts and models.

- Automated batch reporting after the submission of jobs. Standardized reports help the engineers to compare and access simulation results in the web-browser.
- Using a web-based process documentation system for documenting and organizing all data.
- Data exchange between client and suppliers is required.

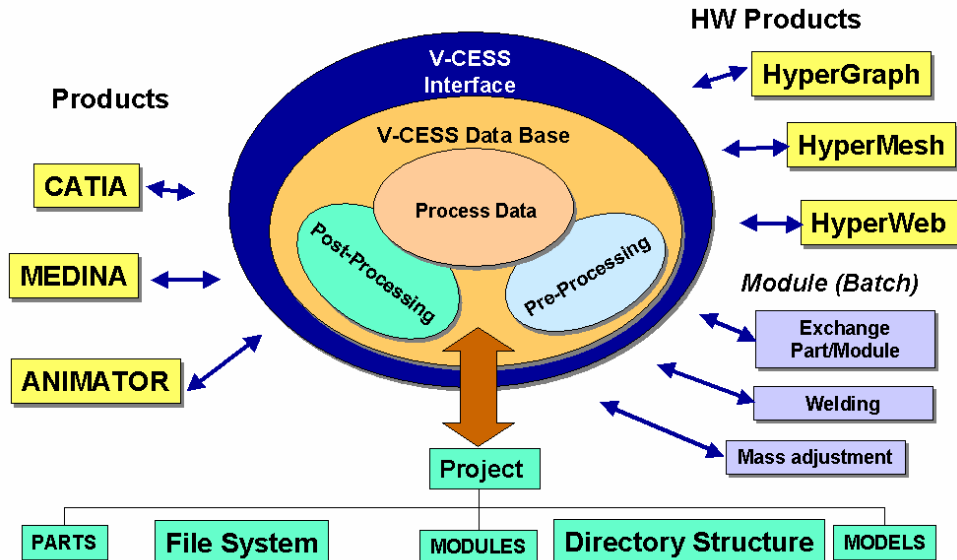


Figure 2 V-CESS CAE Data Management and Integration of Applications

V-CESS Quality Assessment

As described in previous chapters, the challenge is to manage this complex CAE process. A central data management consisting of parts and assembly lists is the first step to organize this process, and a big step forward towards the quality increase in the CAE process. Having decisions documented together with versioning of parts helps understanding the decision building up a knowledge database and improving the quality of the process and the product as well.

The second step is the implementation of tools around the data management, to support the engineers in improving the quality of the process by organizing and customizing the daily work to avoid or minimize the possibilities to make mistakes. These improvements can be done for the pre- and for the post-processing, by supporting the implemented process with quality and consistency checks. *Figure 3* for example shows a quality check report for the element quality.

Standardizing the post-processing also improves the quality of the reporting process. Reports and comparison of reports are the basis for the decision which are made during the project. This must be documented and be made available to all engineers in order to improve the quality of the CAE process.

V-CCESS Architecture

The architecture of V-CCESS is designed to be an open and extendable framework. The V-CCESS framework provides modules for the CAE data management with the database viewer, a module for the pre-processing and a module for the post-processing. This framework has to be adapted and implemented with the optimized process on customer site. The open architecture allows to adapt this framework to different CAD, PDM systems or pre- and post-processors, see *Figure 2*.

This paper describes the implementation into Altair HyperWorks® [1][2]. The pre-processing is integrated into Altair HyperMesh, the post-processing is integrated into Altair HyperView and HyperWeb (new product in HyperWorks 6.0 for web-based reporting and documentation). HyperWeb is used as a database browser for the V-CCESS database and allows to filter the database for parts, models, documentation, reports.

V-CCESS Data Management - Part - Module - Model - Results

The data management consists of parts, modules, models, documentation, simulation results and extracted reports. All this information is stored in the CAE database.

Each **part** can have different CAD versions, which are provided from the CAD system. During the import, CAD properties and materials are assigned in the database to the geometry. Each CAD version of the part can have any number of FE versions with FE properties and a FE material, derived from the CAD data. The FE model of a part only contains nodes and elements, no material or other cards are included. They are handled from V-CCESS during building up models. Even the IDs of nodes and elements are arbitrary. ID ranges can only be defined on modules.

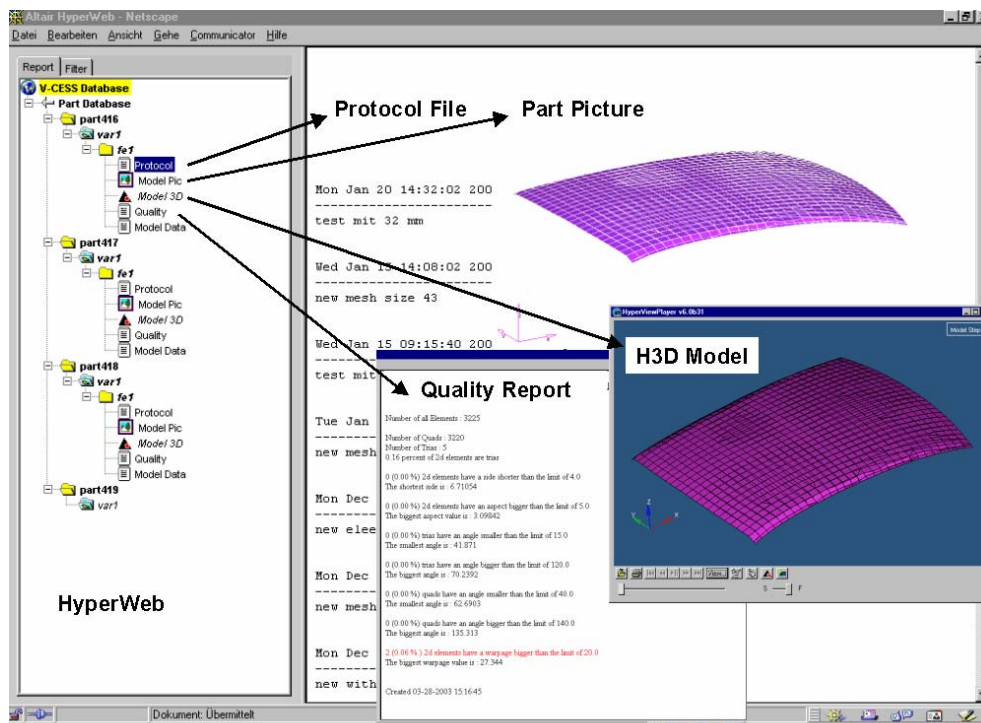


Figure 3 V-CCESS Database Browser for Parts with Documentation

Each entry in the database like the part can have a different status, free to overwrite this FE version of the part, locked if this FE version of the part is opened from another user, and finished, if this FE version of the part is protected against overwriting. If the engineers want to overwrite a finished part, this is not possible. Instead, the user has to create a new FE version from the same CAD version of the part. Both can be used in different configurations.

During saving FE versions of a part in the database, the pre-processor automatically creates the documentation of the parts, as shown in *Figure 3*. A protocol file documents all modifications, which have been made to the part, the screenshot gives an image of the mesh, the H3D file is an Altair file format, similar to the d3plot file, which allows the engineer to rotate the model in the Internet Explorer by using the Altair HyperView Player. In addition, the part statistics with quality check information is created, and the LS-DYNA input file for this part is stored in the database and can be viewed by the database viewer.

The **module** information is also created automatically during importing the information from CAD or PDM. A module refers to parts or modules, positioned with a transformation matrix on each part or module. For that reason, modules only have FE versions and no CAD version, because parts from different CAD versions can be assembled together. A body in white module normally does not contain any material information, because they are directly stored in the part and they are assembled out of such parts.

A second version of module is a completed include file, where V-CESS does not know about the contents of this file. This type of module is used for interior part, for dummies, barriers or any file, which is not touched by V-CESS. Because the contents are not known, they do not need an assembling list, V-CESS does not know about the ID in this module, and they can contain any LS-DYNA card the user wants to use. V-CESS can help managing the ID ranges of the modules by implementing an ID range concept for assembled modules.

A **model** also refers to an assembly list. Additionally, it contains the load case definition, the input file for the simulation and the raw **results** and the report of the simulation. Raw results are the files created from solver runs. The report is an evaluation of the raw results with a report template.

V-CESS Pre-Processing - Meshing - Penetrations - Assembling - Load Case

This chapter describes a typical process for creating a LS-DYNA crash model starting with getting the CAD data from the client to the engineering supplier. V-CESS can be the basic database for the exchange of this data. In this case the V-CESS database is built by the client and sent to the supplier. Another possibility is that the client has its own import script to import the geometry with all models and module definitions into the V-CESS database.

Meshers can start working now, without the need to know, where the parts are stored. They organize their work through V-CESS, check which parts or modules are already meshed, and can directly load the geometry of parts or modules from the database. If they choose a module, V-CESS knows which parts to assemble for this module. *Figure 4* shows the unmeshed geometry, the meshed geometry and the dialog to save this in the V-CESS database.

To lock this module for other meshers, the status is set to locked. After the meshing of this module is done and the penetrations of this module are removed, materials, properties and sections are defined with the Part Property GUI, see *Figure 4*. These information is stored in the V-CESS database independent from the FE part. The meshers can save the meshed parts with a given FE version and a description text in the database. They have the choice to set the status of the part or module to be free again or to finish it. Parts are automatically disassembled and stored as parts together with all the documents from *Figure 3* in the database. In this step, users do not have to care about IDs, filenames, or other things at all.

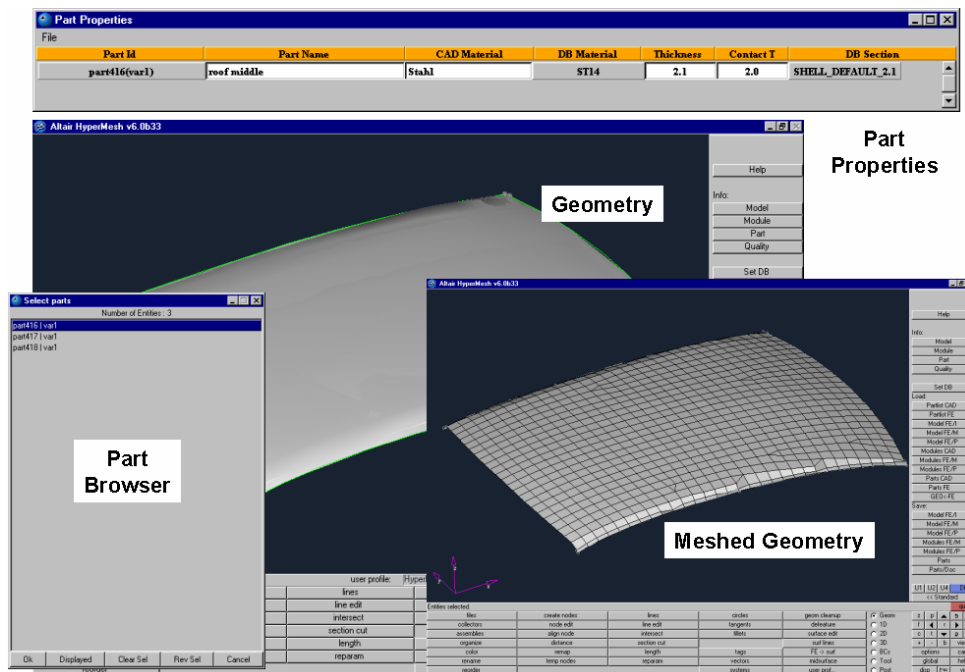


Figure 4 V-CESS Loading Geometry, Part Property, Meshing and Saving Meshes

After all modules are being meshed, the model is loaded based on the assembly list. This model can have penetration between different modules or other changes must be made to the entire model. After the modifications are made, the disassembled parts can be stored again in the database. This step is also independent from ID handling, because V-CESS organizes the IDs of nodes, elements and parts.

After assembling, the connections of the model are applied. Spotwelds are created from V-CESS either with a search radius or with given part IDs to weld the model by retrieving the spotweld information from the database. Tools for consolidating the spotwelds are provided by V-CESS.

The node independent connectivity, which is created from a connectivity template, is located in the V-CESS database; *Figure 5* shows the revolute joint of this door. This connectivity can have any numbers of connection elements.

Time history nodes are defined by coordinates and attached components; it will find the closest node of this component and creates a time history node at this place. This ID independent information is stored in the database and a list of time history nodes can automatically be applied. Cross sections are defined by coordinates, a vector, and the parts included in this cross section which can also be automatically applied by using definitions from the database. In the end, a completed runnable LS-DYNA model is created, including all cards needed to run the model, and stored in the V-CESS database.

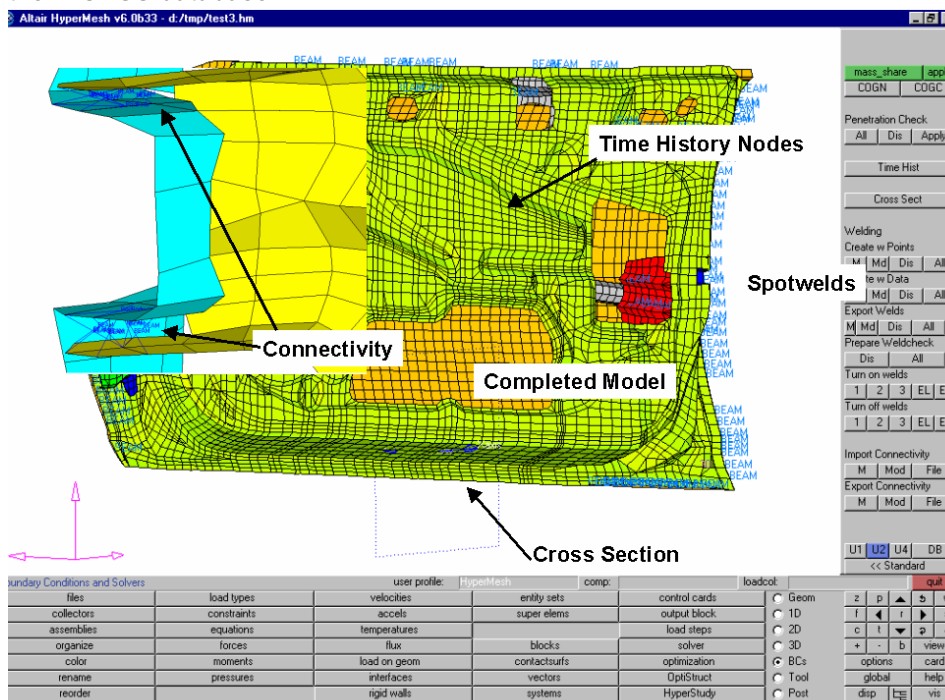


Figure 5 V-CESS Building a Complete Crash Model with different Connection Types

V-CESS Post-Processing

For a current project, 10 simulations a week is a reasonable number of submitted jobs, which is about 500 simulations a year. The post-processing of them takes a long time, if it is done manually or partly manually. In such a case, the post-processing can take up to 30% of the total project time, depending on the phase of the project.

This is a big opportunity to reduce time and costs needed for the post-processing of the results by implementing standardized reports. Standardized reports have a common look and are helpful to compare reports of different simulation runs. Reports together with annotations build a knowledge database for the behavior of the model. Making them available for all project partners, designers or the test engineers allows a much better communication on the current project, which is a step forward towards

the assessment of the quality of the process, because decisions depend on the evaluation and comparison of reports.

A linkage between pre- and post-processing data, also between the parts, modules, models, load cases and eventually test data, and the simulation results, give a certified basis for making design decisions on the products. The simulation results and the report is stored in the V-CCESS database together with the input deck of the simulation run.

Publishing these reports in HTML format allows all project partners and engineers to simultaneously look at these reports, because they can be published through the Internet and Intranet. HyperWeb enables the engineers to publish results in HTML format and supports them to analyze the results by comparing them. This comparison is done in HyperGraph or HyperView. Tools are available to publish the comparison of reports to HyperWeb and insert this at the current HyperWeb report document.

Each link in HyperWeb has a document to show, a working directory of the registered application and an additional application file. Both, the HTML document and the application input file, are associated and managed from HyperWeb. *Figure 6* shows HyperWeb starting different applications on different links in the project.

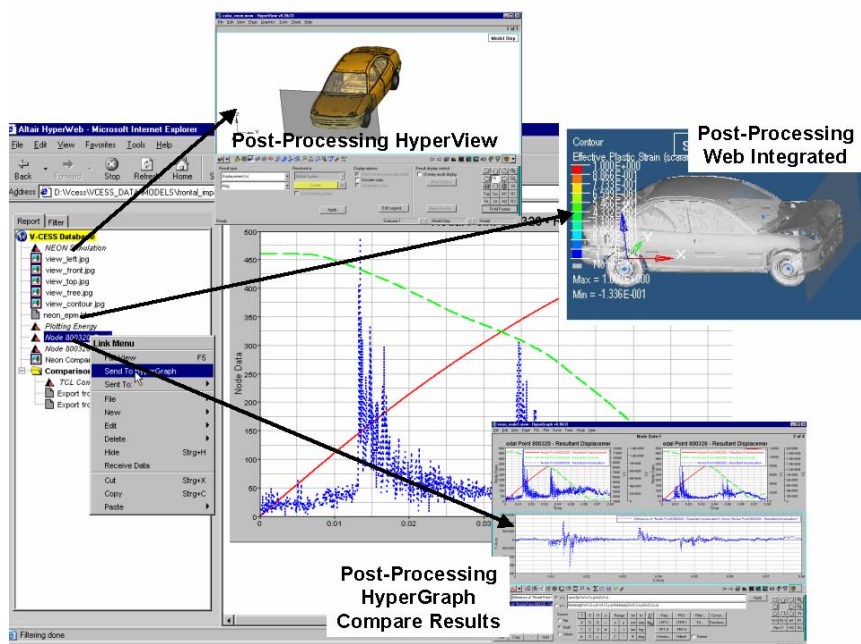


Figure 6 HyperWeb Report with Links to the Applications

Summary and Conclusions

As outlined and described in this paper, software systems like V-CESS, give a big opportunity to reduce costs and process time. At the same time, the quality of the process and the product is constantly increased by establishing CAE quality standards. The management of variants of models and load cases need to be supported by tools like V-CESS. It is the only way to handle the increasing number of simulations, the huge amount of data and the sharing of the data and project resources by a team.

V-CESS combines the main tasks of the project work, data management, preprocessing, postprocessing, documentation to a continuous reproduceable process. The implementation of systems like V-CESS is highly dependent on the environment in the simulation and design department. V-CESS is a framework to build process solutions in these local environments but each solution has to be customized. But the return of this investment will be done fast.

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