The CAE-Bench Project – A Web-based System for Data, Documentation and Information to Improve Simulation Processes

Hägele[*], J., Hänle, U., Kropp, A., Streit, M.
BMW Group, Dept. EK-2, 80788 Muenchen, Germany

Kerner, C., Schlenkrich, M.,
Silicon Graphics GmbH, 85630 Grasbrunn, Germany

ABSTRACT

The simulation of components and full vehicle functions is state of the art in the automotive industry and is the basis of short development processes. However, the almost complete transition from the traditional, test-based approach requires a further change in the simulation process. While specialists in dedicated departments executed analyses in the past, the use of simulation for all vehicle functions in all projects is required in the future.

In order to enable a simulation based body in white development, an efficient IT-Structure has to be established which allows easy and transparent access to simulation data and results for everybody involved in the development process. Currently, reading and processing simulation data is restricted to the use of specialized applications and is in general not accessible by everybody. Therefore, an efficient and transparent structure is needed to enable a direct access with a flexible view to the prepared simulation data for all project members.
The web-based information system *CAE-Bench* addresses these needs. Installed on a server, *CAE-Bench* generates dynamic Web pages based on database transactions. Data is treated as so called ce-objects which have basic functionality and can be extended by data type. Hence, ce-objects can be stored in commercial databases or administrated in PDM systems as extensions of PDM objects. The primary focus of *CAE-Bench* is

- the creation of a consistent database with all data generated in the process,
- an automatic documentation and an efficient way to make them available via the Intranet,
- building up data exchange services for suppliers,
- the integration of automated pre- and postprocessing,
- the integration of resource- and job- management and
- the integration of datamining.

This focus enables, besides transparency and flexibility for the result access, a consistent archive concept. The relations between simulation results and the correspondent models are comprehensive at every time. Furthermore, this information system guarantees that simulation results are consistently generated with approved process standards by converting the CAE knowledge from the analysis departments into standard procedures and integrating them into the information system.

[*] Corresponding author. Tel: ++49 (0)89 382 43441, e-mail: jochen.haegele@bmw.de

INTRODUCTION

Simulations in the car design process represent a critical path in shortening this process. Simulations allow a reduction of traditional test based approaches and also enable the study of full-vehicle functions earlier in the design process. However, to integrate the simulation process tighter in the whole car design process, a new IT-infrastructure has to be built around the simulation based methods.

Currently, most of the data is still managed by moving flat files and organizing them in directory structures. In addition, most of the processes in pre- and post-processing are not standardized and the obtained simulation results are not very consistent between individual studies and, in a larger extend, between car projects. The results can thus not always be compared directly, since it has to be examined manually to which extend the data was generated consistently. Due to this current situation the simulation experts spend a considerable amount of time with administrative tasks of documenting simulations, preparing standard reports and communicating key results to process partners.

With the *CAE-Bench* project we focused on addressing these aspects and designed a web-based system for managing the simulation data, generating a standard reporting process and providing a consistent information system for the process partners. With this system in place some of the simulation processes will be accelerated, bringing us nearer to the goal of simulation based car design.

In addition to the pure data management of simulation results, there is an additional long-term focus, which we want to achieve with the *CAE-Bench* system: *Knowledge Management*

Knowledge Management

Each individual simulation performed in a car project represents a large number of information, however in the context of the individual study only specific functional characteristics are important and analyzed. Many additional insights are neglected. With *CAE-Bench* we want to build a datawarehouse, which holds all the simulation data from pre- and post-processing for all simulations performed in an organization. This datawarehouse holds in some encoded form a huge amount of knowledge obtained through simulations. With datamining approaches it will be possible to extract this knowledge, which should then lead to new insights and hereby, even further improves the car design process.

PROBLEM DEFINITION

Data explosion in High Performance Computing

Before going into the detailed problems of full-vehicle simulations, there is a general observation in the high performance-computing environment that the number of simulations is drastically increasing. While in the past, most simulations were performed sequentially one after the other, we see a trend towards simultaneous analysis of multiple parameters by methods such as stochastic simulations, optimization and multi-scenario analysis. While in the traditional approach, the number of simulations more or less increases linearly with time and number of experts, the introduction of these new methods results in a drastically increase of the number of simulations.

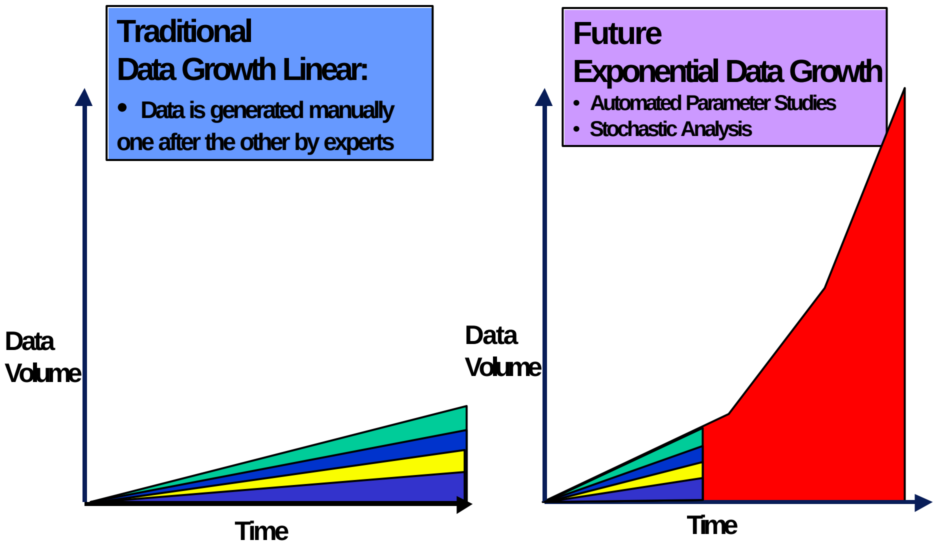

Figure 1: Data growth in technical scientific computing today and in the future.

In some industries, the data generated with simulation methods increases at a higher rate than the density of magnetic disk drives increases. This represents a huge challenge for the IT-infrastructure, since today most data is managed on a file basis using directory structures in a distributed environment of workstations and servers.

The management of this increasing amount of data is not only a pure indexing and structuring problem. In contrast to most commercial data management systems, we are faced in the technical / scientific world with additional requirements:

- The number of simulation results/data is drastically increasing, confronting us with major performance challenges. We cannot rely on computer technology advances to solve this performance issue.
- The data has to become more consistent, which requires the processes of how simulations are performed to be more standardized.

- New methods to analyze data. With this increase in the number of simulations, the post-processing will shift from looking on one individual simulation to the interpretation of multiple simulations. This requires new analysis tools such as datamining, but also puts large stress on the data management, since the access patterns to data will chance from the access to individual objects to the access of 10's to 1000's of objects at the same time.

The Simulation Process

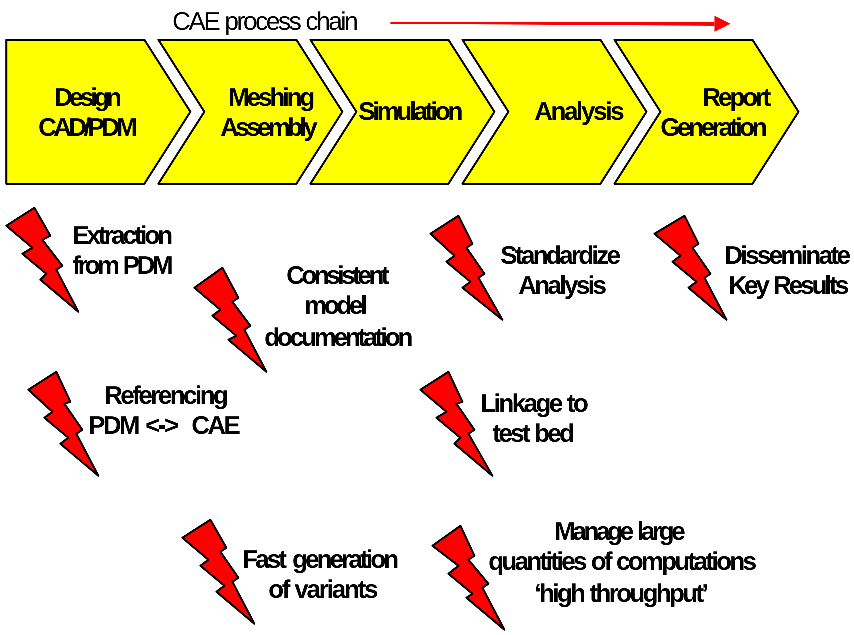

Figure 2: Idealized CAE process with current challenges

The individual simulation process can be idealized into 5 phases:

1. Design: This process is independent of the simulation process, but represents the starting point for most simulations.
2. Pre-processing: Meshing and assembly
3. Simulation: Running the solver with the appropriate loadcase
4. Post-Processing: Analysis of an individual simulation
5. Report Generation: Extracting the key results. This process normally consists of the comparison of multiple simulations, from which the key results can be derived.

In this idealized process multiple challenges can be identified:

- Extraction processes from the PDM system into the CAE process and particularly the referencing between meshes and the corresponding PDM equivalent. Since there is no 100% identity between a 3D CAD model and the meshed part, the referencing must include all information of how the meshes where derived, and what kind of specific modifications where performed on the meshed part.
- Consistent model documentation. Assembled car models consist of 100's of individual parts, spot weld definitions, mass trims, material definitions, contact definitions and other simulation relevant information, which need to be documented in a consistent way so that comparisons between different simulations can be performed.

- Standardized Analysis. For individual load cases, there is normally a standard set of analysis, which needs to be performed in addition to the individual project-specific investigations. This standard part of the analysis still occupies a considerable amount of time for the simulation expert and should be automated.
- Dissemination of Key Results. Simulations have to be compared and key trends derived which represent the key results fed back into the car design process. This step is very time consuming and involves all process partners, for instance the design department.
- Linkage to the test bed. In addition to the referencing between simulation model and PDM-state, there needs to be a corresponding referencing between traditional tests and their corresponding simulations.
- Fast generation of variants. The variation of simulation models, such as modifying metal sheet thickness or varying the loadcases, should be fully automated to reduce the necessary pre-processing time of the expert.
- Management of large quantities of computations. As already mentioned, there is a considerable administrative challenge to manage the simulation data generated from stochastic simulations for instance.

In an attempt to accelerate the CAE process, these challenges have to be addressed, which means not only centralizing the management of data, but also including automation and efficient dissemination mechanisms.

Synchronization between PDM – CAE

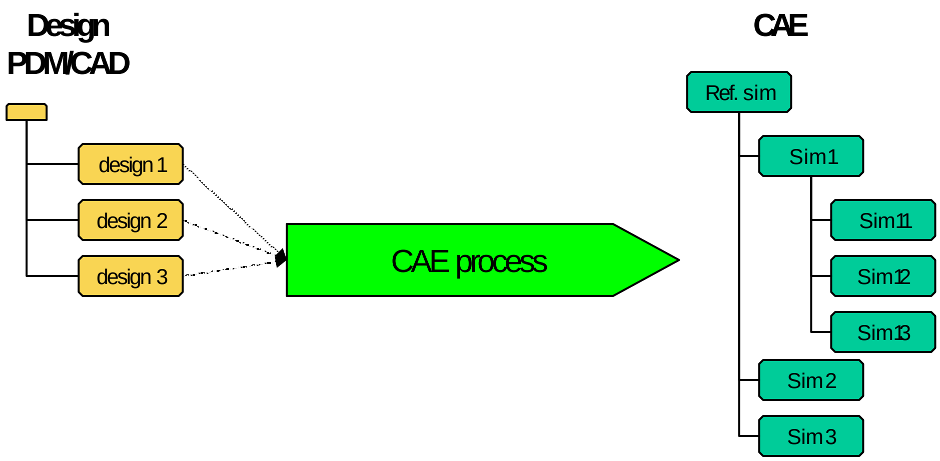

Figure 3: Process of how CAE data is generated and structured relative to PDM data

The initial idea in many approaches in creating a data management environment for simulation based data was to expand the PDM system to manage also the additional simulation based data formats. However, this approach is in our view very misleading, since there are essential differences between the focus and structure of a PDM system relative to a corresponding CAE data management system.

The essential focus of a PDM system is to synchronize all the design partners and provide them with the most up-to-date information about the current design state. The PDM system holds all data relevant to a car design in a product oriented structure and versions and up-dates all the components and parts, so that the involved people have the most actual view on the current car design.

From this PDM system the 3D structural data is extracted into the CAE-process described previously. This process consist of considerable modeling phases, since the 3D structures have to be meshes, assembled and combined with the load case. In this process multiple new information is added to the model, particularly as simulations are performed in the early phases of a car design process when not all data is present in the PDM system. At the end there is a reference CAE model that is used in the different loadcase simulations.

It is important to note that one simulation does not carry very much information, but always has to be put in context to other simulations. Against this background, a simulation project consists of multiple simulations in which the model itself and the loadcase are varied. By comparison of these variations, trends and insights can be derived which represent the key results communicated back into the car design process.

As a result, the data management system for simulation data is more oriented around structuring all the different variants. There is no equivalent variant structure in a PDM system. Therefore, one design choice taken with *CAE-Bench* was to build an independent data management system with references to the PDM system.

The *CAE-Bench* system

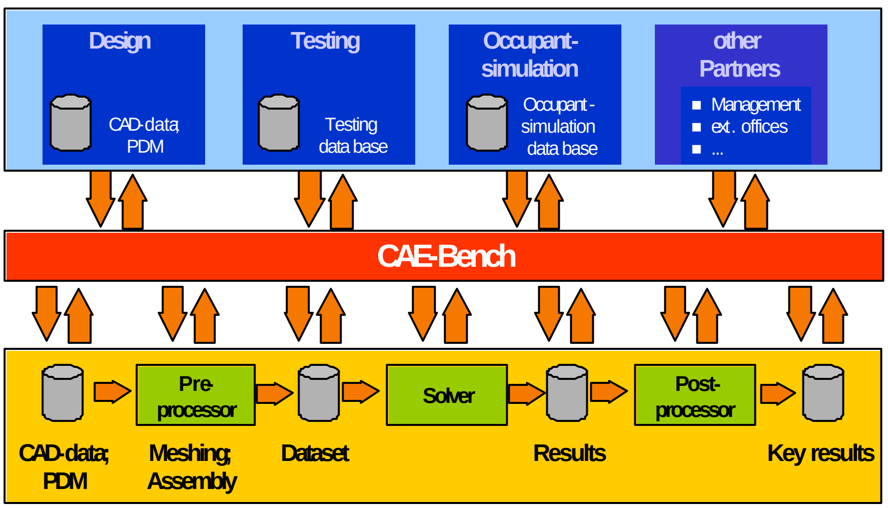

Figure 4: *CAE-Bench* represents a communication platform for the information created in the CAE-process and by the process partners.

The *CAE-Bench* system is web-based which allows all process partners to transparently and easily access all the simulation information. It manages and disseminates all the data generated along the CAE process in a consistent way.

Data feed into *CAE-Bench*

A critical issue in any data management system is the data feed, since the success of such a system is not determined by the functional richness but by the acceptance of the users in importing their data. Special attention was paid in the design of *CAE-Bench* to off-load the CAE expert with routine tasks and not to increase his efforts by importing the data into *CAE-Bench*.

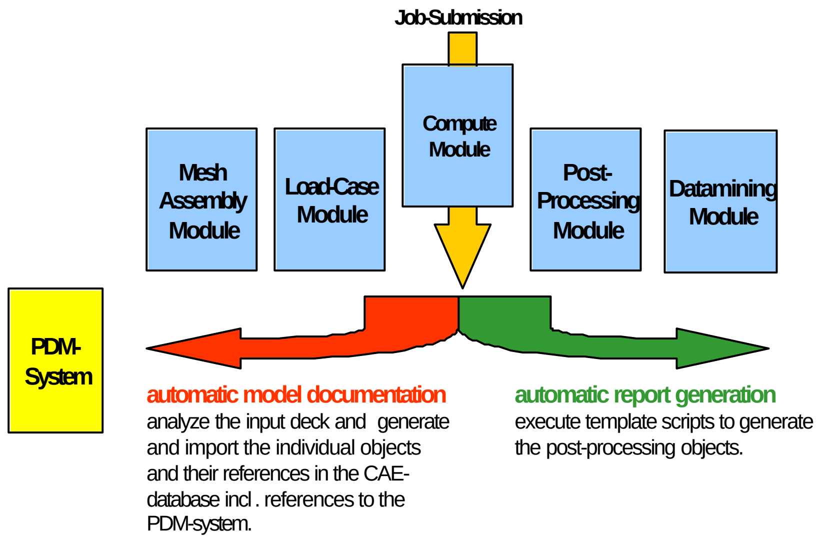

Figure 4: Schematic representation of how data is imported into *CAE-Bench*

If we consider the number of individual objects, which are managed per simulation, this adds up to a large number:

- There are roughly 500 individual parts in a car model
- The loadcases
- The simulation output
- The standard and individual analysis results (e.g. curves), which can account for over 100 individual objects.

It is not feasible for the simulation expert to import all those different objects individually. The import process needs to be automated as much as possible.

There is a helpful circumstance to achieve a highly automated procedure for the import of all the different objects with one process: For a simulation, all the relevant information is in the input deck for the solver, which in any case has to be submitted to the compute server. Therefore, the submission of a simulation job represents an ideal instance, where the import of the data in the *CAE-Bench* system can be achieved.

Once a job is submitted to the batch queuing system, two individual import processes will be initiated:

1. Automatic Model Documentation

In this process, the input deck is imported into the *CAE-Bench* system. After this import, the input deck is decomposed into the loadcases and the assembled model. The assembled model is then decomposed into the individual components and based on some comment card conventions we can even establish a reference to the PDM part they refer to. All those objects created in the decomposition step of the input deck are imported into *CAE-Bench*, where they are compared to the already existing objects. If the object exists, references ('audit trails') are created, if there is no equivalent, a new object is automatically created. A model documentation web-page is created which reports the results of the decomposition and import processes and allows the user to add comments and further information.

2. Automatic Report Generation

After the execution of the solver, the resulting output files are automatically imported into *CAE-Bench*. Based on the project and load case specifications, specific standard post-processing scripts are started, which create multiple different analysis. These range from the calculation of individual values over the creation of curves/plots to the 3D visualization of parts or full car behaviors (created in batch). All those different post-processing objects are imported into the system and a standard report is generated to which the user can add comments and trigger more specific analysis.

These two automatic processes dramatically reduce the workload of the experts in terms of entering the different objects into the system and performing automatically most of the currently time-consuming model documentation and standard analysis. The required interactions are minimal and the traditional working steps, particularly in the pre-processing, are unaffected. The *CAE-Bench* system should not be seen as a guiding framework, which enforces specific work patterns (e.g. how the expert creates models and input decks). *CAE-Bench* is an intelligent information management system, which independently analyses the models and structures the data in an appropriate form.

Current State

CAE-Bench is currently in an early production phase at BMW, at which data from selected projects are imported. This represents the critical phase at which all the user acceptance issues and feasibility are evaluated and the plans for a deployment to all simulation projects are developed.

If in the near future enough simulation results are within the system, we are looking forward to add datamining capabilities for starting to derive new promising insights from simulation results made in the past.

CONCLUSIONS

The introduction of *CAE-Bench* at BMW is an ambitious project, which is of major importance in the process of reaching the goal of simulation based car design. The focus of *CAE-Bench* is

- to develop an efficient and transparent information platform for our process partners,
- to structure our simulation data in a consistent form,
- to layout the data management structure for further datamining and
- to integrate as much as possible automated procedures.

While *CAE-Bench* is a necessary development to enable a more efficient deployment of simulation, it will deploy it's full impact together with improvements in the application domain, which should enable more automated meshing and assembly processes like the new capabilities of MSC.AMS. Both developments together will drastically accelerate the simulation process and hereby also accelerate the car design process.