INTEGRATION OF INNOVATIVE CAE METHODS IN CHASSIS ENGINEERING AT PORSCHE

Harald Bähr
Dr. Erich Schelkle
Dr. Ing. h. c. F. Porsche Aktiengesellschaft
Porschestraße
D-71287 Weissach
Tel.: +49 - 711 - 911 - 3105
Fax - 3104
e-mail : harald.baehr@porsche.de

ABSTRACT

The consistent application of CAE methods in Porsche's Chassis Engineering helps to clearly lower development times and costs while improving both quality and reliability.

This presentation describes the CAE-assisted development procedures used by Porsche in chassis engineering. It outlines the results obtained and the development activities planned for the future.

The CAE process chain is presented and software packages for various tasks such as linear and non-linear statics, dynamics, optimization, misuse and life are explained.

Further new subjects such as process simulation (casting, forming) are discussed.

Due to the rapid development in the field of CAD-integrated calculation tools, standard calculations are increasingly done in the design departments themselves. This trend will further intensify in future, since the scope and complexity of the calculation tasks to be accomplished by the calculation engineers keeps increasing.

Some examples of current chassis developments are given.

1. INTRODUCTION

The constantly increasing demands on the speed and quality of automotive engineering necessitate the use of computer-assisted methods.
This presentation describes the CAE-supported development activities in Porsche's Chassis Engineering, states the results obtained and gives an outlook on the future.
The paper first presents the departments involved in the development process followed by the explanation of the development process itself and the CAE-methods assigned to the respective development phases. Further, the CAE process chain is illustrated including a presentation of the programs used (examples are given).
In addition, the economic advantages of this approach are highlighted and an outlook is given on future trends.

2. DEVELOPMENT PROCESS

Figure 1 illustrates the cooperation between the various departments involved in the development process.
The designers receive specs from Styling and Packaging and, in addition, must take into account numerous production aspects.
The implementation of all these requirements is done in close cooperation with Calculation and Testing. There is an intensive exchange of data between all the departments involved. This presentation focusses mainly on the cooperation between Design (CAD) and Calculation (CAE).

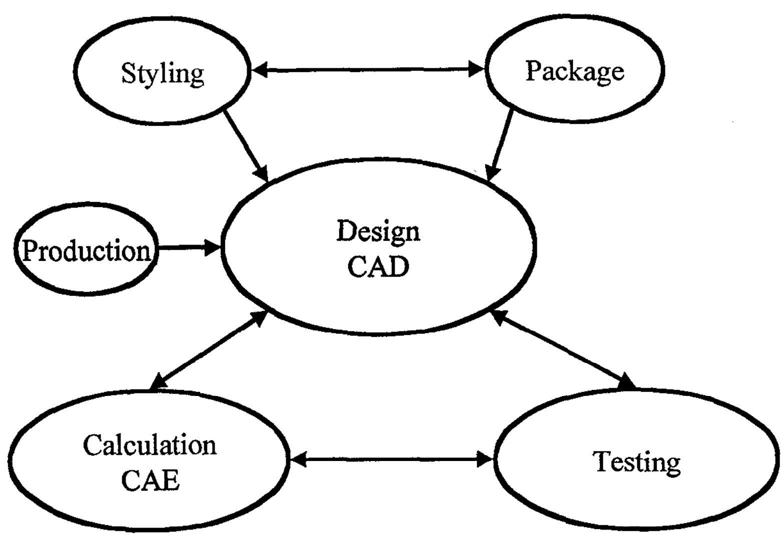

Figure 1 : Cooperation between various departements in the development process

Figure 2 illustrates the principles of a chassis development.

The development starts with the definition phase. As soon as all the requirements have been defined different chassis concepts are being examined in order to determine the optimum axle concept for the respective system. The definition and release of the axle concept is followed by the optimization of the chassis concept until it is ready for production.

The paper highlights the various CAE methods and indicates the phases in which they are employed.

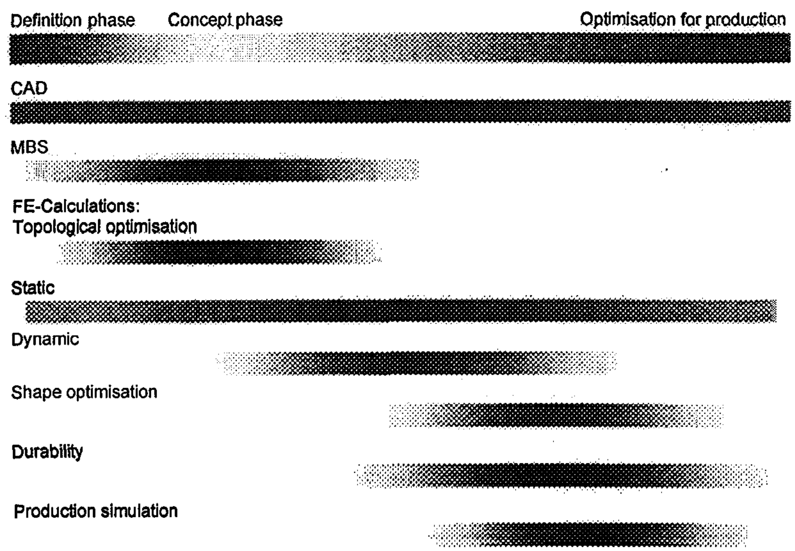

Figure 2 : CAE-Methods in chassis development

At Porsche, CAD is used throughout the entire development process.

During the initial phase multi-body simulations are used to compare various concepts with the aim of obtaining information on driving dynamics, vibrations and component loads.

In the phase that follows, various FE-based calculation methods are employed.

In the beginning of a chassis development, so-called topological optimizations are carried out for certain components.

Linear stiffness and strength calculations are performed from the beginning of the concept phase to production development. If required, dynamic investigations are carried out as well.
Durability calculation uses collective loads which are similar to those employed during Testing. The system allows complex multi-channel loads to be plotted and thus helps to determine really critical component areas - an approach which is not always possible with statical calculations.

As soon as the CAD data are available, shape optimizations are carried out as the development continues.

If required, production simulations are performed as well. These are generally done by the respective supplier.

Chassis development also must take into account the various crash requirements, reflected, for example, in the design of auxiliary frames or subframes for force transmission or energy absorption.

3. CAE PROCESS CHAIN AND RESPECTIVE SOFTWARE

Figure 3 shows the CAE process chain applied by Porsche.

Porsche's standard CAD system is CATIA [1] which, in particular cases, is complemented by other systems such as, for example, Pro/ENGINEER [2] or Unigraphics [3].

Frequently, the preliminary component layout is done by means of CAD-integrated calculation tools such as CATIA.GPS for instance.

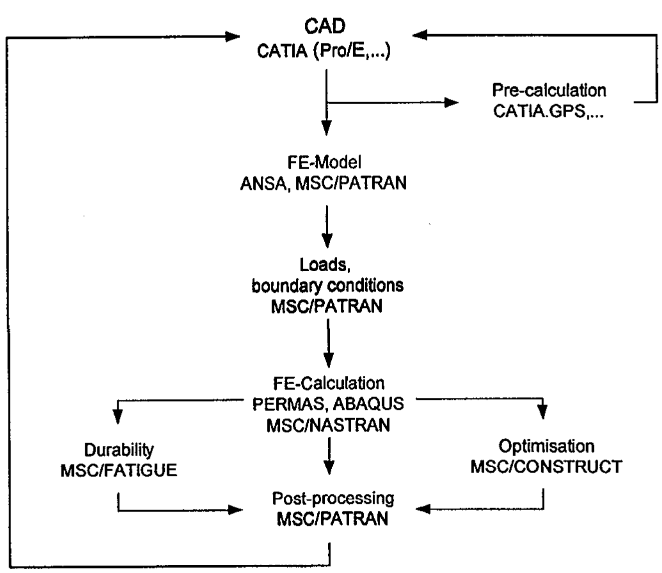

Figure 3 : Porsche CAE-Process chain

The calculation department uses ANSA [4] and MSC/PATRAN [5] to set up the FE models. Data are transmitted via the IGES or VDA interfaces.
For components to be calculated on the basis of shell elements the ANSA system is used.
For volume models, the surface mesh is mostly obtained via ANSA. The models are then completed by means of MSC/PATRAN using either hexahedron elements and sweep options or the automatic tetrahedron mesh function.

The assembly of the complete simulation model, the application of loads and boundary conditions as well as the definition of materials and properties is exclusively done by means of MSC/PATRAN.

Data are transferred from ANSA to PATRAN via the PATRAN Neutral-File format.

For actual FE calculations, various programs are available depending on the requirements to be fulfilled.

Post-processing is done by means of MSC/PATRAN.

3.1 Linear-static calculations

Linear-static and dynamic calculations are usually carried out by means of PERMAS [9]. For data transfer between PERMAS and MSC/PATRAN there is a direct interface.
The components are submitted to loads which represent extreme driving conditions and their response is evaluated using the calculated stresses as a basis. In addition, standard load cases are calculated in order to assess component stiffness.
Depending on the respective requirements, linear dynamic FE calculations are carried out as well with the aim of, among others, determining the natural frequencies and modes of individual components or subassemblies.

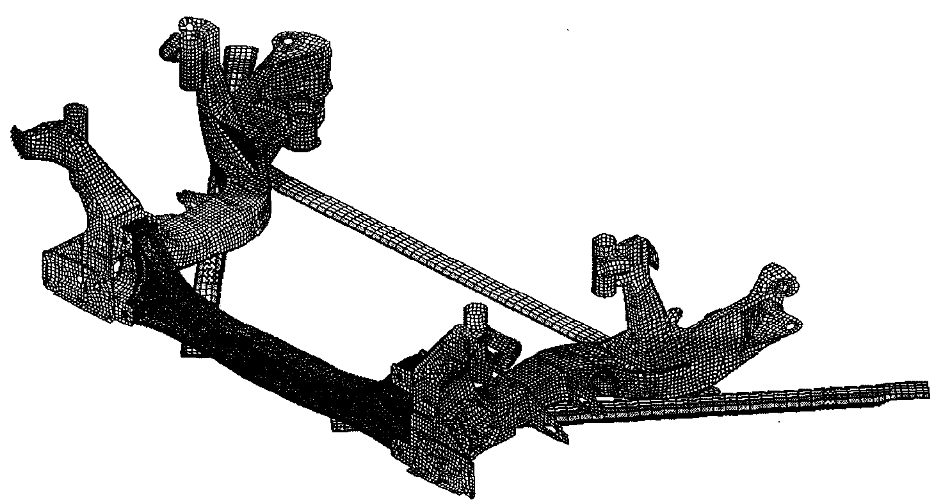

Figure 4 : rear axle subframe of the Porsche 911

3.2 Non-linear calculations

Tasks in which geometric or material non-linearities must be taken into consideration - such as, for example misuse loads under which the component is allowed to undergo a plastic deformation - are handled using ABAQUS [10].

One example of such a geometric non-linearity calculation is the aluminum spring plate of the new Porsche 911 Carrera 4 for which the contact between the spring and spring plate and the varying stress distributions under different compression conditions were calculated.

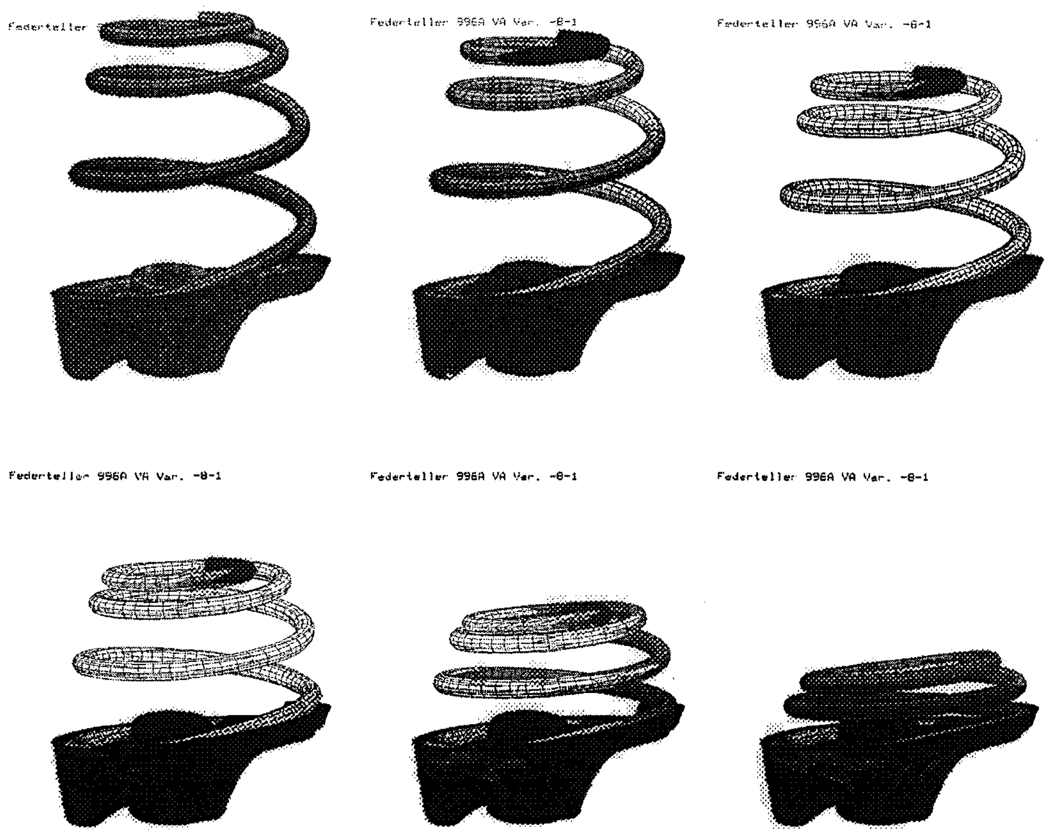

Figure 5 : Non-linear calculation of a spring with spring plate

3.3 Optimization of topology and shape by means of MSC/CONSTRUCT [7]

The use of optimization procedures in chassis development is constantly increasing at Porsche not only for topology but also for shape improvement.

When it comes to the development of a new component, the first step is to determine its rough configuration by means of a topology optimization approach. Then - using the given loads, boundary conditions and packaging space as a basis - a design concept is defined which must be as light-weight as possible while meeting all the demands in terms of stiffness and strength. The results of these calculations are then employed by the design engineers to create a draft of the component concerned.

Components for which CAD data are available, can be further optimized in terms of stresses and weight.

For component-structure optimization, the parameterless optimization program MSC/Construct is used. Pre- and post-processing is done by means of MSC/PATRAN whereas the required FE calculations are conducted with MSC/NASTRAN [6]. In Figure 6, the topological optimization of a wishbone is shown: the proposed partly hollow configuration would have optimally coped with the loads to which the part is submitted. For feasibility reasons, however, this configuration had to be rejected.

The shape-optimized wishbone finally adopted is illustrated in the following figure: In this particular case, the optimization approach helped to lower the mass by 11 % without prejudicing the stress level.

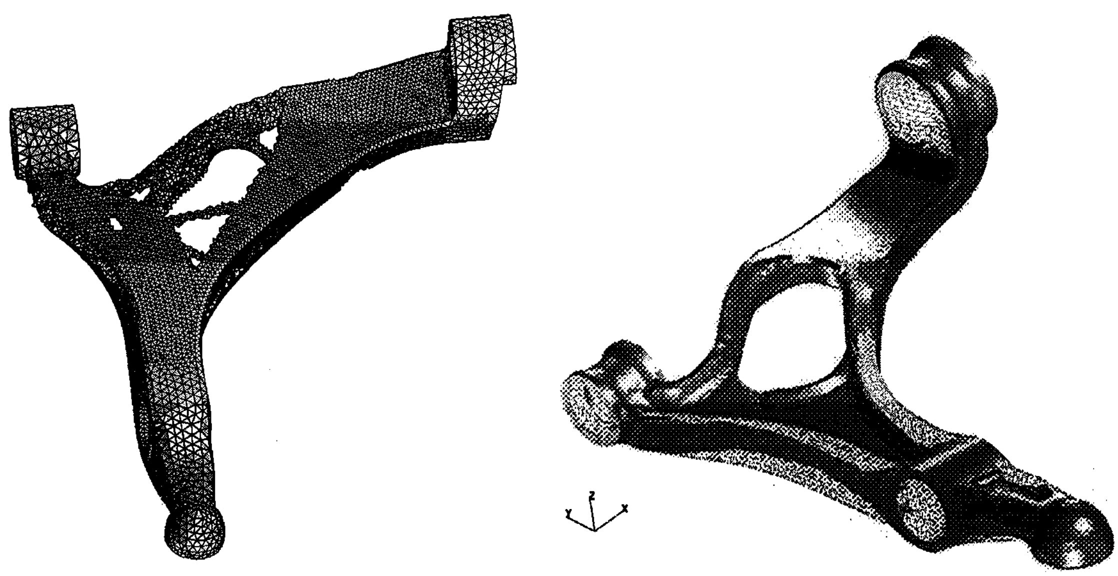

Figure 6 : LH : topologically optimized wishbone, RH : shape-optimized wishbone

3.4 Durability calculations using MSC/FATIGUE [8]

At Porsche, durability calculation on the basis of FE results has become a standard approach mainly in the field of chassis development. The system used by Porsche is MSC/FATIGUE which, in combination with MSC/PATRAN allows to handle results from different FE programs.

For bench testing, Porsche employs uniform collective loads which easily adapt to the masses, dimensions, spring rates, drive concept etc. of the respective car.

The same collective load is also used for durability calculations. Since there are 4 channels per wheel [vertical load Fz, lateral load Fy as well as longitudinal loads Fx and Fxbr (with brakes applied)] to apply the collective load, critical points can be detected which would remain unnoticed in mere linear-static calculations. In addition, areas recognized to be critical are weighted and thus can be specifically optimized. Thus, calculation serves to simulate bench tests and allows incipient cracks to be predicted.

Another option is to enter loads obtained from vehicle measurements on the test track and to use them as a calculation basis.

The results are presented in the form of collective-load cycles which a component is able to endure before it cracks.

The real running time usually deviates more or less from the calculated values since there are several uncertainties which affect the calculations, such as, for example, insufficiently correct FE results, material data which are unknown and have to be guessed, influence of surface conditions and so on.

Despite these restrictions, the results obtained are encouraging enough to have durability calculations performed for each new design.

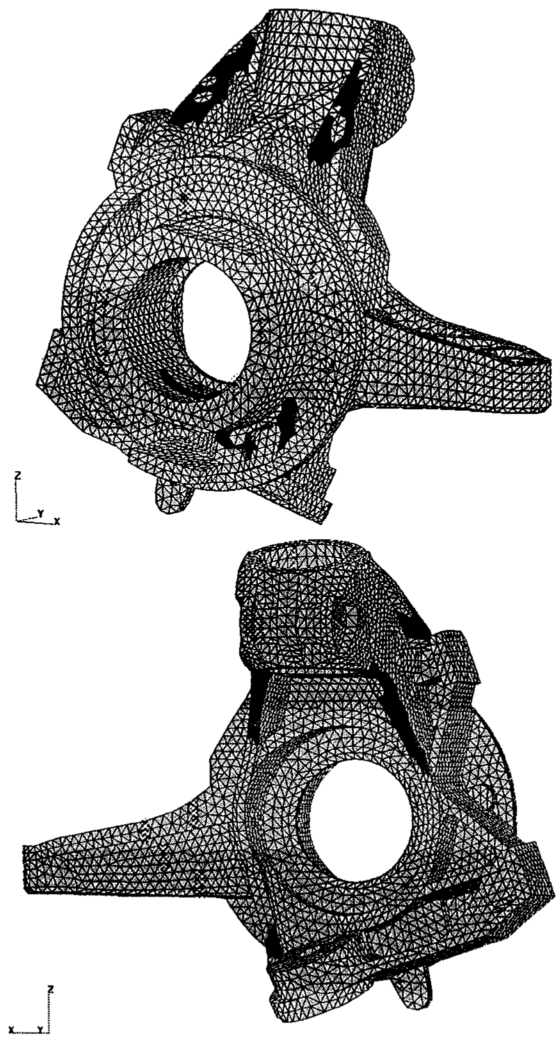

Figure 7 : Durability calculation of a wheel carrier

3.5 Production simulation

Porsche is currently doing forming simulations using the Autoform One-Step [11] program. Complex forming simulations as well as casting and forging simulations are generally carried out by the respective supplier.
If required, the services of external specialists are engaged.

4. ECONOMIC EFFICIENCY

Despite such new methods as Rapid Prototyping – which are useful for various other reasons - it has been a generally acknowledged fact, that a component should first be numerically optimized before corresponding tests are carried out.

Porsche's Simulation & Calculation is a centralized service department.

For a comparatively small automotive manufacturer such as Porsche decentralized calculation services handling many activities in parallel would result in a considerable increase of expenditure and require corresponding specialists in all design departments. Moreover, further extending the tasks of the designers would mean to overtax their capacities. FE calculations for sophisticated projects require an ample specific know-how and cannot be accomplished as a sideline job. However, designers are more and more expected to also carry out simpler calculations which can easily be done with CAD-integrated tools.

Porsche is constantly looking for software systems optimally suited for the respective application. Such comprehensive packages as MSC/PATRAN provide a sound data basis for the various tasks to be accomplished in Chassis Engineering. Other automotive areas such as Body Calculation, for example, use other specifically optimized software packages.

ANSA and MSC/PATRAN allow high-quality complex FE models to be quickly generated.

Post-processing with MSC/PATRAN provides ample possibilities to cope with practically any application - an advantage which current CAD-integrated systems are not able to offer.

5. OUTLOOK

Despite the afore-mentioned advantages of a centralized calculation department, the integration process in the CAD environment must go on. In view of the enormous scope and complexity of the calculation tasks there will certainly not be any lack of occupation for the calculation specialists in the foreseeable future.

Model preparation will become easier and easier as the meshing programs continue to be optimized. The same is true for data exchange. However, it is questionable whether, in the years to come, CAE and CAD will operate in the same environment.

In addition, new calculation methods are being developed which do entirely without finite elements (meshless method) and it remains to be seen whether these new approaches will be able to prevail.

6. REFERENCES

[1] CATIA, Version 4.2.1, Dassault Systems

[2] Pro/Engineer, Parametric Technology Corporation, Waltham, U.S.A.

[3] Unigraphics, Unigraphics Solutions, Inc.

[4] ANSA, Version 8.5, BETA CAE-Systems, München, Germany

[5] MSC/PATRAN Version 7.5/8.0
[6] MSC/NASTRAN Version 70.5
[7] MSC/CONSTRUCT Version 2.5
[8] MSC/FATIGUE Version 6.0 MacNeal-Schwendler Corporation, Los Angeles,
U.S.A.

[9] PERMAS, Version 6.1, Intes GmbH, Stuttgart, Germany

[10] ABAQUS, Version 5.8, Hibbitt, Karlsson & Sorensen, Inc. , Pawtucket, U.S.A.

[11] AUTOFORM, AutoForm Engineering GmbH, Zürich, Switzerland