Advantages And Disadvantages Of FEM Analysis In An Early State Of The Design Process

Dipl.-Ing. Christoph W. Eckard

Creative Engineering Services
CES Eckard GmbH
Heßbrühlstraße 61
D – 70565 Stuttgart
Tel.: +49-711-781934-60
E-Mail: info@ces-eckard.de

Abstract:

In order to decrease development times, it is necessary to apply FEM analysis even in the very first steps of a design process. This first FEM analysis should be done by the designer himself. Without any doubt it serves the opportunity for a significant speed-up the design process. However, some problems have to be taken into account. This paper shows some consequences for the design staff and the design organisation.

1.) FEM – A short history

When FEM started in the early seventies highly qualified and trained specialists were needed to use this method . Neither grafical preprocessing nor matured FEM-tools were available. Too, the processing speed of the computers were low. From the viewpoint of today rather small problems required profound knowledge in mathematics, software development, and technical engineering. The efford needed for solving FEM problems was too high even to think about commercial application of FEM in industrial companies.

Increase of the processing speed of computers and development of first grafic oriented preprocessors opened the door of the FEM into industrial companies. However, the handling of the programs retained difficult and still required highly trained and educated personal. Thus, this method was restricted to only to larger companies which could afford their own calculation group.
Though CAD systems became convenient and widely spread tools in the same time, there was lack of integration between CAD- and FEM-systems. Data transfer was done via interfaces of very different quality. Not unsually, a complete scratch-up of the model was necessary prior calculation. The model had to be simplified in order to facilitate meshing and reduce computing time. Most often, weeks and months went by between the completion of the CAD model and the results of the calculation.
Several attempts to integrate the designer into the calculations process, were made. They failed because of great differences between the CAD- and FEM-systems and difficulties in handling of FEM systems. The acceptance of these non-integrated FEM tools was very low.

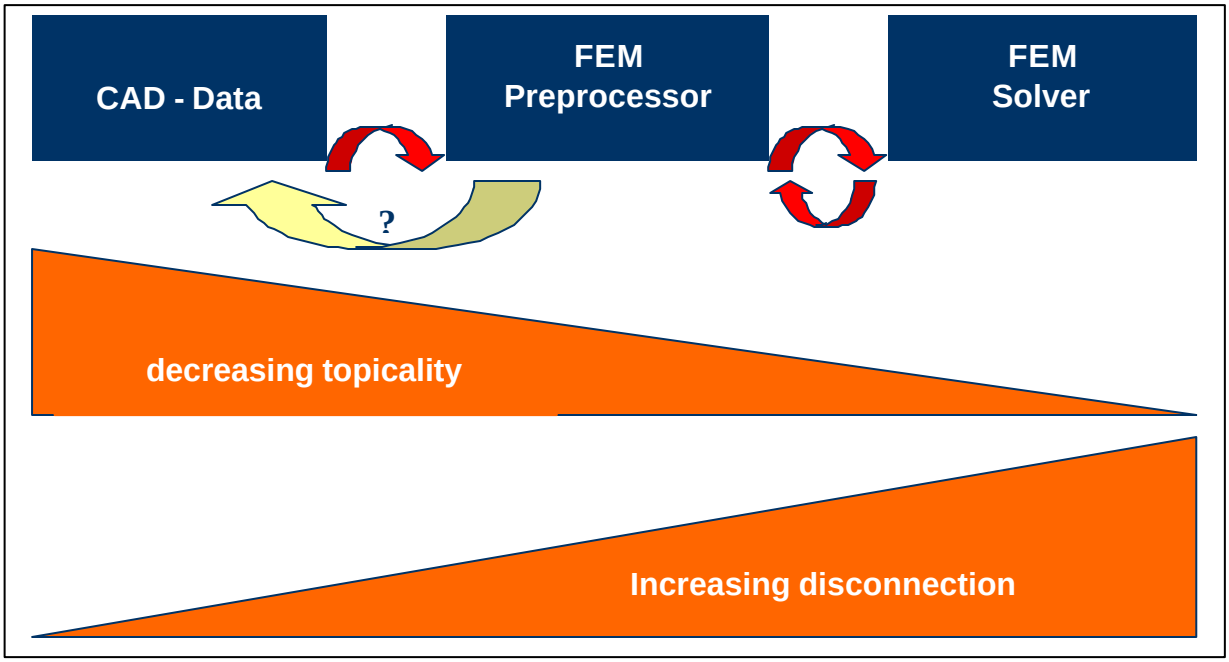

Fig. 1.1: Data-flow between CAD and FEM

The situation improved with the appearance of first integrated systems. Difficult geometry and data transfer into the preprocessor or rebuilding of the model was no longer necessary. However, the handling of the FEM tools retained complicated and required highly trained specialists.

Actually, the situation has improved drastically. CAD system developers designed FEM menu structures especially tailored to be used designers. The main goal was easy handling to solve standard problems. Thus, any designer can apply simplified FEM tools today. Only little training is recommended for proper use. Handling of complicated problems is excluded. It still has to be done by specialists.

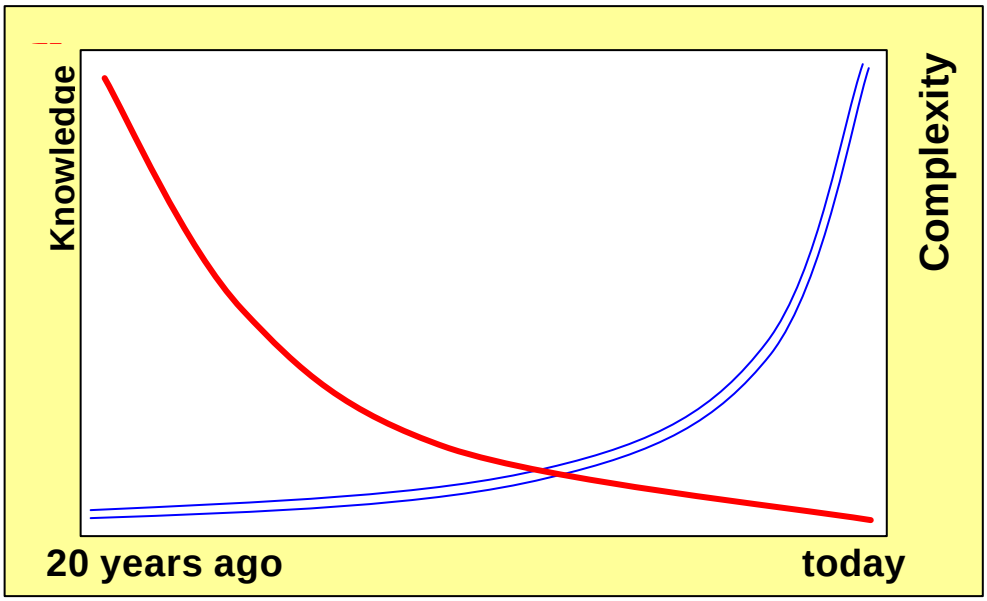

Fig. 1.2: Changes in complexity of solvable FEM-Problems and personal knowledge required therefor

2.) Consequences for the staff in design groups

FEM calculations in the design area require changes in the staff management.
Sound FEM-calculation requires appropriate training! You got only few commands on a very simple menue in the FEM tools for designers. Thus, trainings are short, but usually much too short. Knowledge about the functions of the commands only is insufficient as shown by the following data:

Reasons for incorrect FEM calculations of designers	estimated percentage
Wrong application of the loads	20 %
Wrong application of the restraints	30 %
Wrong free-cutting of the model	40 %
Wrong handling of the FEM-program	10 %

Obviously, about 90 % of all incorrect calculations rely on missing basic knowledge in technical mechanics!
In consequence only designers, familiar with the basics in technical mechanics should do FEM calculations. Without, you dare not expect reliable FEM results.

Regarding the results of FEM calculations, missing knowledge of FEM basics easily results in erroneous interpretation of these results, too. Even if designers never might look at junctions and elements face-to-face, they imparatively need well-founded knowledge of the background.

Therefor, a conception for a training, which has been successfully applied to about 400 designers takes this way:

1st day
Refresh: Basics and tasks / exercise in Technical Mechanics
Basics in FEM and FEM theory

2na day
Handling of the program
Tasks / exercise to any function with practical background

3ra day
Workshop with present problems and models of the designers

It has proved usefull to add an additional one-day workshop one week after the training. Here we deal with questions arising from the specific work of the company.

Often, companies already equiped with FEM calculation groups installate FEM calculations into the design process. Beside the objective of early recognition of weak points in the designed models the FEM calculation groups should be released from the daily routine work by this decision. However, it will not work without specific supporting the designers by the FEM calculation specialists.

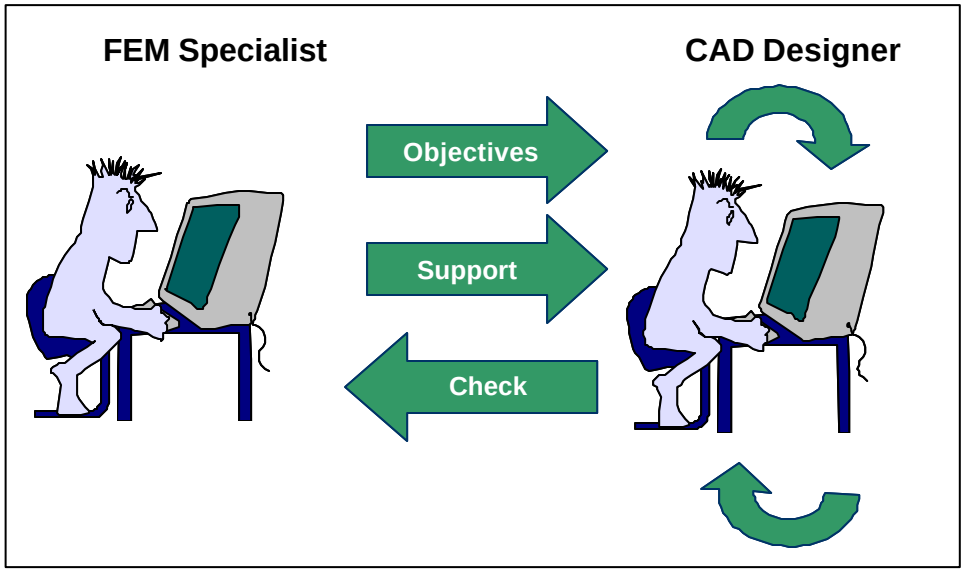

Fig. 1.3: Distribution of tasks and responsibilities between designer and FEM specialist

A designer should never calculate with the highest possible accuracy, but – hopefully – only with sufficient accuracy. He needs objectives for values of loads, stiffness and other goals for his optimized design. At this point, the FEM specialist must e. g. convert complicated load cases to quasi static loads applicable by the designer.

3.) Consequences for the organizaton of FEM calculations in the design process

Installation of FEM into the design process will not only affect the training of personal as shown above. It will also affect the process of design. To achieve the goal of intense time-saving, priorities and time schedules have to be set new. But while arguing about “invest in hard- and software” or “invest in qualification of personal” might be an easy game, arguing about “rearrangement of processes” is a very hard job in gereral.

But if this important last section is ignored or neglected, you can be sure that any invest in computers and personal qualification is in vain. The resulting will be only disappointed co-workers and disappointed superiors.

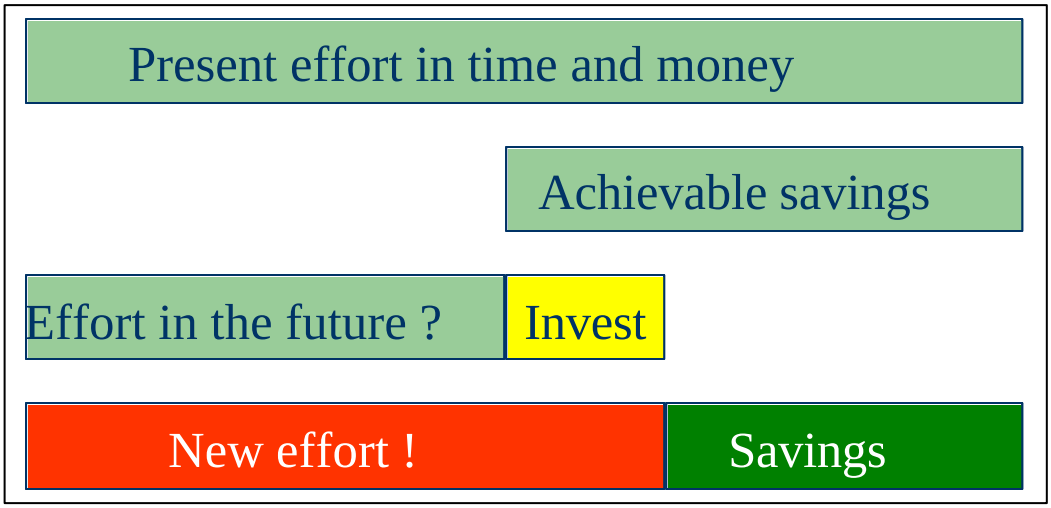

Fig. 3.1: Relation of savings to re-invest

It is often missed, that installation of FEM into the design process results in increasing work to be done by designers. In principle, this should be no problem for week points in models will be recognized and removed in an early stage. This invest in time and money will obviously be saved in multiple in latter stages of the project. However, the larger a company and the more pronounced its devision, the harder the realization of this change in time-management. It came to pass, that the time schedule for designers was shortened, for installation of FEM into the design process should save time…

As a rule of the thumb, a re-invest of about 1/3 of the savings in time and money is necessary. If 100 days of experiment should be saved, an invest ofabout 30 days in simulation is needed. In fact, you will save “only” 70 days in this case.

The same relation of savings to re-invest is effective if FEM-calculation groups should be be reliefed. About 1/3 of the time saved has to be invested in support of the designers to enable them to achieve this relief in fact.

The importance to verify important decision in an early stage of a project has been verified by another study, too. The run of the ratio of actual accumulated costs to the costs generated at this time for the future was investigated for the run-time of a typical project.

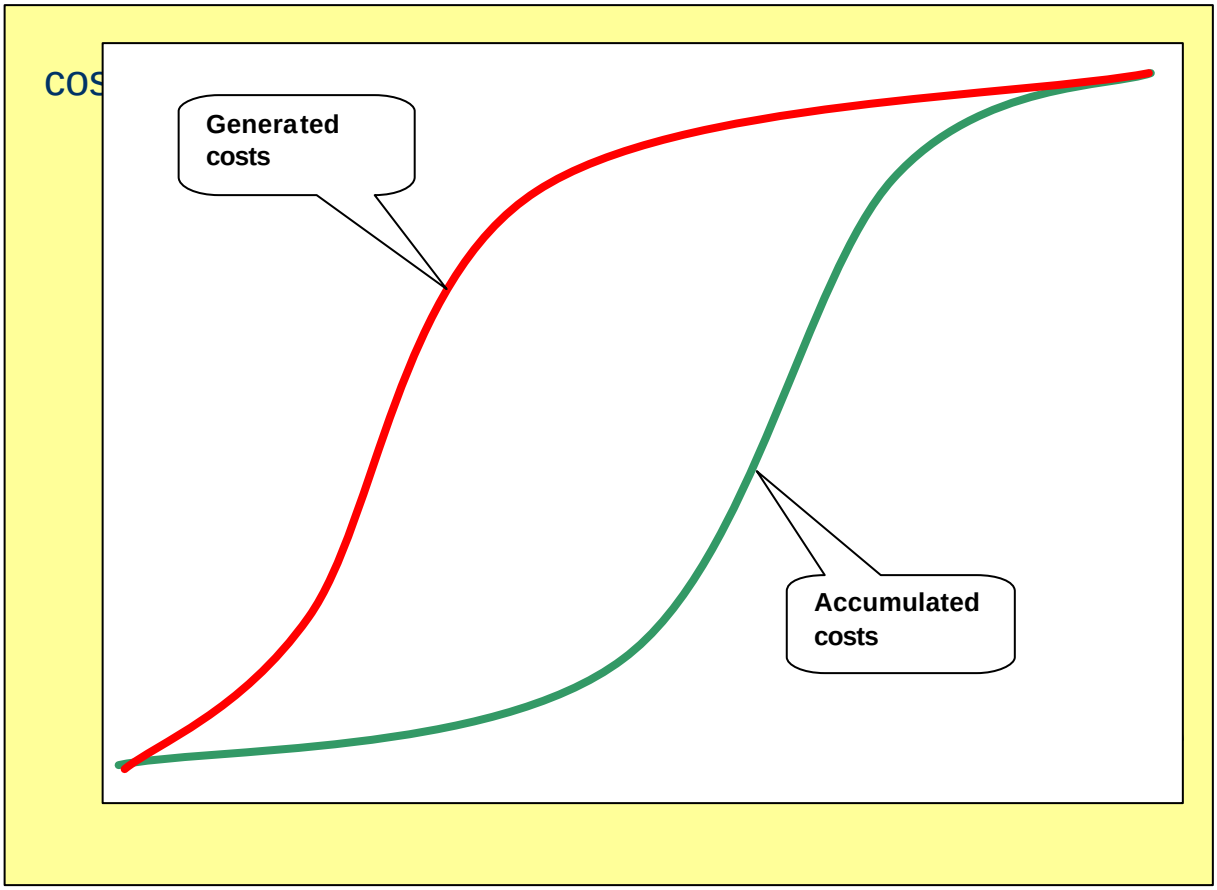

Fig. 3.2: Ratio of presently accumulated costs to costs generated at this moment for the run of a project

The study shows, that more than 80 % of costs are generated in the first stages of a project were only little costs accumulate. These important results are well known since about 20 years. However it took until the recent years to start a process of vast implementation of effective tools for simulations into the groups responsible for development and design.

But without changes in the project- and time-management, the success, wanted and needed is in danger.

4.) Possible versus sufficient accuracy of FEM simulation in the design process

One argument, sometimes uttered – especially be FEM specialists – against implementation of FEM into the design, is the lack of accuracy of these calculations.
Sure, a designer generally will conduct calculations with larger errors for he works with simplfied problems. But is this really an argument against FEM in design?
Accuracy is no end in itself! Not seldom, meaningful words like “island” or “ivory tower” are uttered in companies while talking about FEM simulation and calculation groups.

In order to objectify this discussion, which became rather emotional, the results of investigations of an economist, Vilfredo Pareto, 1848-1923, might help. His studies, which elucidate the ratio between effort and result are still valid today:

His result: About 80 % of a goal are reached with 20 % of the efford needed to reach 100 % of the goal.

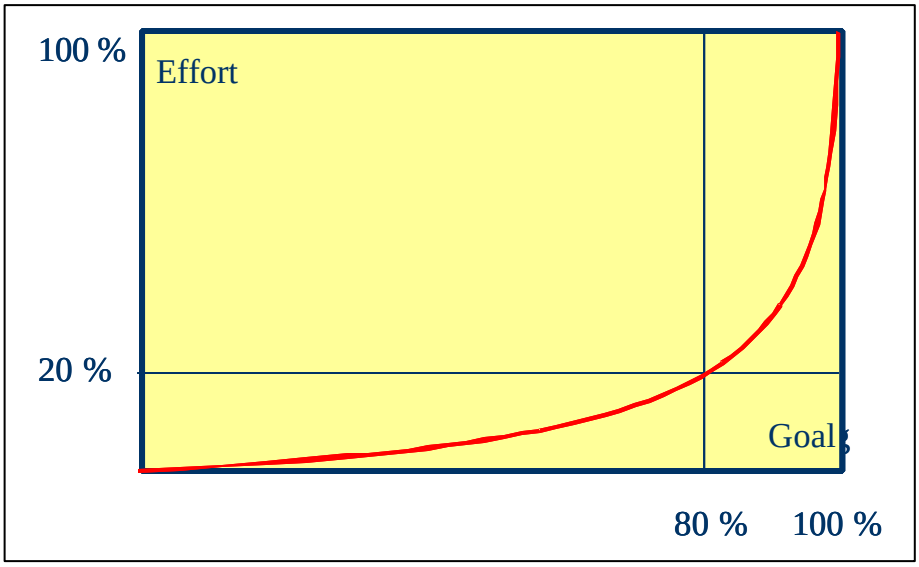

Fig. 4.1: The PARETO-principle (the 20 : 80 principle)

Application of the PARETO principle to the accuracy of FEM calculations in the design means: Calculations speed up by a factor of about 5 if an accuracy of 80 % is sufficient. Even in the very first steps of design processes accuracy is not needed. Just the feasibility of ideas has to be checked. An approach of any goal with a buffer of 20 % should be sufficient and effective.

Self-evident, not every calculation must be carried out by designers. If high requirements are met, no buffer can be defined and high accuracy is needed, these calculations belong to well trained specialists.

Inquiries at several companies showed, that a buffer of about 20 % is sufficient for the practical work. Most Experiments showed much higher variations.

The era, where any calculation was computed as exactly as even possible comes to an end. Today, designers and calculators must answer the question of the ratio between economic viability and accuracy of calculations.

5.) Sumary

A) Simple FEM calculations in the design process are imparative for further decrease in times of development.

B) Designers which should carry out FEM calculations need a usable theoretical background.

C) A reorganization of the design process is necessary to get the results wanted.