FE-Transfer : A computer and web based course for the application of finite element analysis in structure mechanics

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Abstract— **Today almost every workplace in the R&D departments of the machine industry is equipped with a tool for finite element analysis (FEA) or is at least prepared for the introduction of such a tool. Usually it is integrated in the CAD system and is easily applied. Only a few engineers, however, have sufficient knowledge of this powerful method from their basic education. This is due to the fact that in most undergraduate programs FEA is taught only as a sideline or only for a selection of the students. Its application to realistic problems is then covered incidentally. This situation has begun to change only in the last few years. The possibilities for acquiring the necessary know-how after basic education are limited. The training available from the software suppliers are understandably concerned mainly with their application and they do not cover the mathematical background of the method. Literature on applications is hardly available. In a co-operation between Universities of Applied Sciences, suppliers of FEA software tools, users in industry and a publisher, a course for the application of FE simulation has been developed in the environment of a Swiss Virtual Campus project. This combination of partners allowed an optimal concentration on the application of FEA on the one side and on the didactic needs of the students on the other. The course assumes the provision of independently accessible contents and makes use of computer- and web-based teaching technology. In particular, for the practice and application parts, the students work together and are guided and supported via Internet. The areas modeling, verification, presentation and interpretation of the results, as well as conclusions for the development of the product, are given precedence and implemented in the so-called "Interactive Process Model". Knowledge of the theoretical background of FEA and of the use a software tool is mostly assumed.**

Finite element analysis, web based training, e-learning

INTRODUCTION

The finite element method (FEM) was born about forty years ago. Right from the start, it went through many developments and it is only after becoming popular amongst engineers and physicians that mathematicians gave it an appropriate mathematical base. Since the invention of computers, this numerical method has highly improved and its use has not stopped growing.

Nevertheless, until recently, only a few specialists of aeronautic firms or research laboratories used the FEM. Nowadays, with the evolution of computers, many firms own three-dimensional software for computer-aided design (CAD), which gives them an easier access to specific application like the finite element method. On the other hand, the time available to put a product on the market has become so short, the functional and financial pressures so high, that it is essential to introduce simulation from the first stages of the product development. The fact that integrated calculation tools are available in CAD software allows development engineers to use new techniques for which they are not necessarily prepared. This FE-Transfer course is specially addressed to them. The course mainly based on practice, using concrete industrial cases, called study cases, will give them an opportunity to get used to the definition of digital models based on physical models, as well as the meshing techniques, the definition of boundary conditions, the numerical methods of resolution, the post processing and evaluation of the results. Good knowledge of mechanics of materials and a basic knowledge of a finite element program are required to follow this FET course.

This course was developed as part of a Swiss Virtual Campus project (FE-Transfer 200155) by three Universities of Applied Sciences (Berner FH, FH Nordwestschweiz, University of Applied Sciences of Western Switzerland, Fribourg), the Polytechnics of Zurich, and with the help of nine industrial partners (CAD-FEM AG, Sulzer Markets and Technology AG, VDF Hochschulverlag AG, Helbling Technik AG, MSC-Software GmbH, Paul Scherrer Institut, EMPA Dübendorf, Studer AG and Liebherr Machines Bulle SA).

1. Course Objectives

After having followed the first two modules of the course of about 120 hours each (20 % in classes and 80% individually), each participant will be able to solve, on his own, problems of linear static relating to his professional field. The course objectives are:

- to learn the basic theoretical knowledge of the finite element method;
- to ensure a know-how of the modeling process, which works with the virtual tool named "interactive process model (IPM)";
- to learn how to deal with quality aspects;
- to recognize their limits;
- to know where to find missing support or information.

To achieve these goals, a strategy is put into place:

- each learner works on real study cases with the IPM, has the right to auto-evaluate himself, is followed by a tutor with whom he is interacting, can compare his results to the ones defined by the industrial partners;
- each study case is perfectly documented;
- the course has been built up like an e-learning course;
- the entire content relies on appropriate didactic principals.

2. Interactive Process Model (IPM)

The interactive process model (IPM) is available on Internet and the course can be downloaded. It works on the same principle as e-Learning and allows to guide and/or to form an engineer to use the finite element method.

- To guide: the user is guided in his modeling process. By having to answer a certain amount of questions, he will be brought to solve and document his problem. In this case, the IPM is used as a reminder permitting to solve all sorts of problems, independently of the study cases provided with the course.
- To form: by realizing real study cases, the learner is guided through the modeling process and must also answer a series of questions. Each question is justified, the prerequisite defined and an example of answer is presented. The related theory is available as well as links towards external sources of documentation.
- To interact: the process is interactive because the learner, to be able to solve the proposed study case, has to establish a connection with a server which will send him back automatically the "official" answer in reply to his own answer. If the learner's answer is too far away from the one suggested by the system, he has the opportunity to send back an auto-evaluation in which he will describe his incomprehension of the question or a different way to treat the problem.
- To correct: for each learner a tutor corrects the answer and auto-evaluation. Tutor and learner can communicate on line using the IPM. The learner can answer the questions only once, but he is allowed to modify his auto-evaluation and to communicate with the tutor as much as he wants, which gives him the chance to overcome the difficulties he might have had.
- To edit: the learner's answers, the "official" answers, the last auto-evaluation and the tutor's comments are saved in an IPM protocol, which will be used as the analysis report.

3. IPM'S CONTENT

The interactive process model, as in Fig. 1, is described through six chapters corresponding exactly to the six steps of the analysis process.

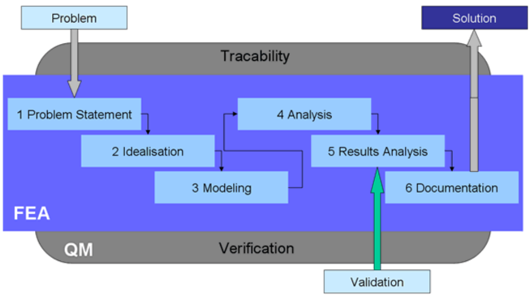

Figure 1. Analysis process

Each chapter contains a series of questions, of which the answers are the key elements to solve the finite element problem. Steps 2, 3, and 5 are the essential points of the simulation technique.

- Problem statement

  The first chapter sets out the elements required at the start of a project, which means: to write down specifications, a list of demands and to make a risk analysis. The goal to achieve must be described in the clearest and most concrete way. To be delivered: specifications, list of demands, risk analysis.
- Idealization

  The idealization is the first step to go from a real or physical model to a digital model. At this stage, it is very important to define which physical effects or influences act on the model. It is also at this stage that the learner expresses the first simplifying assumptions and tries to answer the question: “What can be neglected?” An analytical approach of the problem is made to estimate the orders of magnitude. These results will enable a first validation of the simulation’s results. This second chapter contains general notions of mechanics, such as the linear or non-linear behavior of materials, the various rupture criteria, the Smith diagram and the S-N Diagram. To be delivered: definition of the physical laws applying to the model, list of the simplifying assumptions.

- Modeling
  Modeling is the second step going from a real case to a digital model. It involves expressing idealized physics laws with the help of a finite element model. This third chapter deals in particular with the creation of the finite element model and allows the learner to define the type of analysis which need to be done (linear, non linear, static, thermal, dynamic, …), to choose the elements allowing to represent correctly the structure, to define the meshing density, to control the elements quality, to define the boundary conditions. To be delivered: finite element model, definition of the physical properties of the model.
- Analysis
  To achieve a static linear analysis, this step is quite simple. The results are directly calculated on the base of the finite element model provided and the analysis options. The analyst has only very little influence on the solution. To be delivered: analysis results.
- Evaluation and interpretation of the results
  Once the results have been obtained, it is necessary to check if the digital model’s behavior corresponds to the behavior of a real case. Therefore it is recommended to compare the results to the ones obtained with an analytic approach and even more important to the results of an experimental analysis. It is only in that case that the model can be validated. This fifth stage will end with a discussion about the obtained results. Finally, the last point to check is to verify that the analysis objectives have been reached. To be delivered: discussion and validation of the results depending on the analysis objectives.
- Documentation
  The sixth chapter relates to the way of documenting a finite element analysis and the methods used to archive data.

4. User Interface and Work Process

The user interface is the same for each study case and each chapter. The repeated treatment of these stages through the various study cases has for effect to “print” in the student memory a clear and well-ordered way of thinking and work methodology.

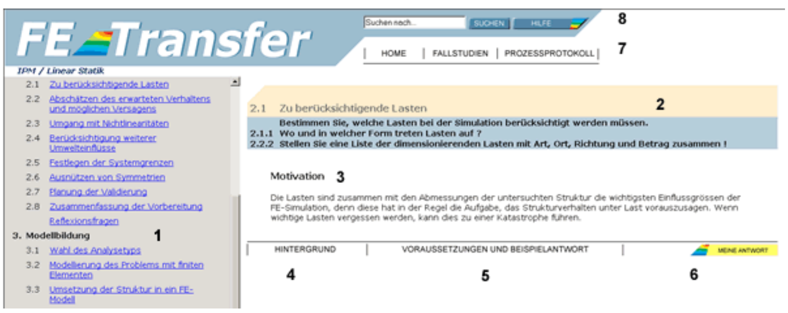

Figure 2. User Interface

The functions available are:

1. Access window to chapters and under-chapters. This window can be closed to facilitate the reading of the main window.
2. Questions relating to the under-chapter. The interactive IPM will bring an answer to all the questions.
3. Question motivation.
4. Access to pages and links presenting the theory and practical advices.
5. Access to the description of the prerequisite and an example of an answer to questions.
6. Access to the answering form.
7. Access to the IPM protocol, which is also used as an analysis report.
8. Search function by keywords.

The theory pages are illustrated with many figures, tables and flash animations. They also give access to VRML files allowing manipulating the presented models. The majority of the under-chapters end with a checklist and a list of links to be looked at. The interactive modeling process can be downloaded; the learner can therefore work locally and then, once his answers are ready, connect himself to the server to send his answers as well as the attached figures and multimedia files.

After having answered one or many questions, or at the end of the study case treatment, the learner can consult the modeling process protocol.

The available functions are the following: choice of the question to be referred to, reading of the official answer, possibility of an auto-evaluation when the learner's answer varies from the official answer, reading the comments field of the tutor.

The complete protocol of a case study is considered as the analysis report, which can finally be archived.

5. TECHNOLOGIES USED TO CREATE THE COURSE

This course has been developed with the help of the dotNet platform. This choice is justified by the increased interest given to this platform by the industries, but also by the benefits it offers in matter of standards supports, XML, SOAP and web services.

A WebCT server must be able to manage the clients' accounts (learner and tutor) and give access to the project database. WebCT makes the courses management easier and offers an extra exchange platform between learners and tutors. The University of Applied Sciences of Fribourg (UASF) Windows IIS server hosts a web dotNet service. The course content has been compressed, packaged and made ready for downloading on the UASF server. The official answers, the input generated by the learners, the auto-evaluations and the tutors comments are saved in a relational database (Windows SQL server 2000) on the UASF server. The pages of the FE-Transfer course have been conceived with multimedia tools Macromedia, Dreamweaver X, Fireworks, Freehand and Flash.

6. FIRST TESTS

During these last twelve months, the course has been tested with the students of the university partners of the project and with industrial engineers. This has permitted to bring many corrections to the IPM. Generally, the course has brought positive feedbacks from the people who reported that they had reached the course objectives easily, thanks to the IPM. The interaction between the learner and the tutor, made possible by the IPM, really helps the student to improve in his study of the finite element method. This approach also opens new educational ways for the tutor.

CONCLUSION

The realization of this course, which has not been brought to fruition yet, has meant meeting many challenges.

First, there were human challenges to the extent that a close collaboration was called for between many universities and industrial partners, who were not used to working together. After numerous meetings, a consensus was reached and the interactive modeling process was established.

Second, there were technological challenges, because the majority of the course authors had only a limited experience in the e-learning field and its tools.

Third, there were scientific challenges, because many theoretical courses on the finite element method are available, but there are very few publications on the practice of finite element methods.

Fourth, there was the educational challenge, because the teaching of the finite element method relates to various competence domains, like the analysis processes, the FEM tools and the simulation techniques. This course presents a much higher level of complexity than what can be found in other traditional e-learning type courses.

Fifth there were the linguistic challenges, because of the diversity of the project participants' mother tongue.

Sixth, there were the economic challenges, because once realized, this course will need to generate incomes permitting its auto financing.

In spite of all these challenges, we think that we have achieved our objectives. This has been confirmed to us by the twenty people who tested the course and by the experts of the Swiss Virtual Campus.

REFERENCES

[1] D. Euler, "E-Learning als Katalysator einer Qualitätsverbesserung in der Lehre – Konzepte und Erfahrung an der Universität St.Gallen." In : Franzen, M. (Hrsg.): Mensch und E-Learning. Bildung Sauerländer, Aarau, 2003

[2] F. Flückiger et al., "New Techological and Organizational Concepts for Continuing Education in the Knowledge Society." In : Proceedings of the 4th European Forum for Continuing Engineering Education, Trondheim, 1999

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