Int. J. Engng Ed. Vol. 11, No. 2, pp. 98–102, 1995
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Using Advanced CAD Software in Teaching Design*

KARTHIK RAMANI
DAVID HENDERSON
School of Mechanical Engineering, Purdue University, West Lafayette, IN 47907, U.S.A.

The authors relate their experience in teaching a senior level Computer-Aided Design (CAD) course in Mechanical Engineering using advanced Computer-Aided Engineering software. The course balances the theory and the need for hands-on experience with commercial CAD software in solving practical design problems. Students are given assignments ranging from simple 3-D modeling exercises and 2-D finite element analyses to an optimization project requiring more advanced 3-D modeling and analysis. Where possible, analytical solutions are found and compared to the finite element results. The software allows the students to explore much more complex problems than would otherwise have been possible.

INTRODUCTION

ADVANCES in computers and computer-based software have created a growing need for trained engineers. Applications for computer-based software to solve complex engineering problems are well recognized by scientists, researchers and engineers in industry. However, with this power of computers comes a dangerous tendency to rely too much on canned computer solutions to technical problems. Hence we have to be careful in our approach in teaching CAD. Ferguson [1, 2] clearly points out that the lack of old-fashioned, direct hands-on experience can be disastrous. The history of engineering design failures clearly indicates that in several instances, bad design results from errors in engineering judgment which cannot be reduced to science or mathematics.

The notion of CAD varies greatly. In this article computer based software tools for design refer to solid geometric modelers such as Pro/ENGINEER† and finite element analysis (FEA) software such as ANSYS.‡ Drafting or engineering drawing is merely a subset of geometric modeling and drawings can be created automatically from solid models in several CAD packages. Hence the goal of CAD teaching is not to teach drafting, but to teach the intelligent use of computer tools to aid the design process in engineering problem solving. With the many advances in software available for Computer-Aided Engineering (CAE) has come the dilemma of deciding how much and what types of software should be taught or used in the curriculum. A balance must be struck between learning concepts versus skills, and the use of software versus problem solving.

The authors have been involved with teaching a senior level design course in Mechanical Engineering at Purdue University. The lectures are supplemented with laboratory assignments and demonstrations using Pro/ENGINEER for 3-D geometric modeling and finite element meshing, as well as ANSYS for doing finite element analysis. In addition, an interface package connecting Pro/ENGINEER and ANSYS called ANSYS/ProFEA‡ has been used to facilitate design optimization.

In this paper, we will discuss the assignments that the students are given and the problems encountered in teaching the course, as well as discussing the ways in which we prepare the students for using the software.

CONCEPTS VERSUS SKILLS

CAE tools are continually changing and becoming more powerful and comprehensive. These tools provide an important learning opportunity for students who use them to solve practical problems. However, learning to use CAE tools alone is not helpful to the students in the long range and create in them a tendency to rely too heavily upon 'black-box' computer solutions. **A balance must be found between teaching the fundamentals to provide an understanding of the theory involved and using the software to allow students to explore design alternatives and solidify concepts.** Haghighi [3] correctly remarks that study programs should be geared to train engineers instead of technicians.

Figure 1 illustrates the structure of the model CAD course in the School of Mechanical

* Paper accepted 30 August 1994.

† Pro/ENGINEER® is a registered trademark of Parametric Technology Corporation, Waltham, MA, U.S.A.

‡ ANSYS® is a registered trademark and ANSYS/ProFEA™ is a trademark of Swanson Analysis Systems, Inc., Houston, PA, U.S.A.

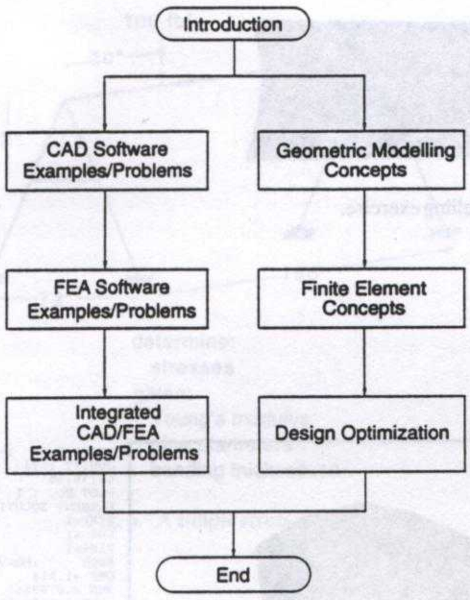

Fig. 1. Structure of the model ME CAD course.

Engineering at Purdue. A parallel development of the software demonstrations in the computer laboratory and the concepts covered in the classroom lectures creates a balance between the concepts and skills imparted. The students use the skills developed in the laboratory and the concepts covered in the lecture to solve practical homework problems.

SOFTWARE TRAINING

Many commercial CAE software packages have very elaborate capabilities, and it can take a long time to become proficient in the nuances and subtleties of using them. In order to prepare the students for using the software, several laboratory demonstrations are held. The students are encouraged to follow along at individual workstations while simple modeling and analysis tasks are demonstrated. The use of an overhead projection system enables the students to see the computer demonstration while working at their own station. Tailor-made laboratory demonstrations help the students to reach a level of proficiency that is sufficent for solving the types of problems that are important in the course. Lab instruction is then available as the students work outside class in completing assignments.

MODELING AND ANALYSIS PROJECTS

In the early portions of the course, the students use the CAD system to create solid models of simple objects, while they are exposed to curves, surfaces and solids. Concepts such as cuts, slots, revolving, protrusion, sweeps and blends are illustrated with examples. The students are introduced to the CAD software by modeling a simple extruded object like that shown in Fig. 2. Parts such as a connecting rod are used to further the complexity of the models. In later exercises, the students create 3-D models such as the turbine blade and flywheel shown in Figs 3 and 4. In addition, the students learn to create conventional engineering drawings automatically from the solid models. they are later asked to redefine a model to take advantage of symmetry and to export the meshed geometry to the FEA software for analysis as shown in Fig. 4.

After an introduction to basic finite element concepts using a planar example, the students are introduced to concepts of structures and elements. Simple problems such as analysis of beams, that the students have already been exposed to in the core engineering courses, can be used to illustrate finite element concepts. The closed form solutions to these problems can be used as a comparison to the finite element results. Students are exposed to concepts of plane-stress, plane-strain, axisymmetric problems and associated elements. A typical problem that introduces the students to gap closure is shown in Fig. 5. Next, the students are introduced to 3-D analysis with problems such as that shown in Fig. 6 [4]. These types of problems can be easily entered into the FEA software without the need for advanced 3-D modeling.

In order to introduce the students to non-structural problems, they are given examples in thermal stress analysis and heat transfer. These are followed by an assignment to determine the thermal stresses in a bi-metallic joint. The students are introduced to shape optimization for weight reduction in a simple structural problem such as that shown in Fig. 7 [5]. For their final project, the students are given a more open-ended design and optimization project. In the most recent semester, students were asked to design and optimize an A-arm from an automobile suspension system. The objective was to minimize the weight of the arm given the overall dimensions and loading conditions. A picture of one of the submitted solutions is shown in Fig. 8.

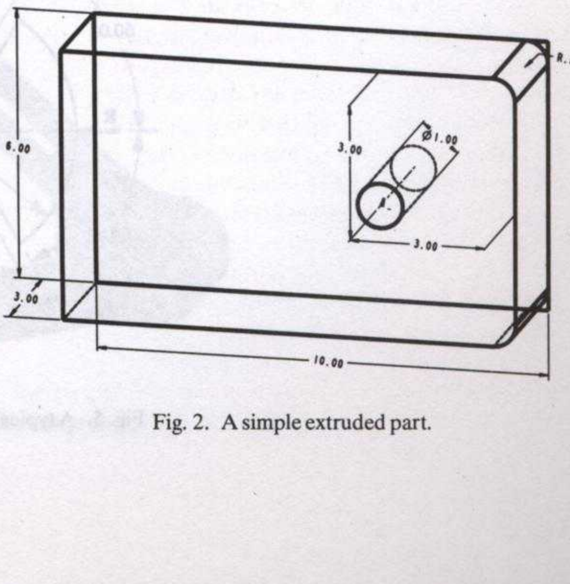

Fig. 2. A simple extruded part.

Fig. 3. A more advanced 3-D modelling exercise.

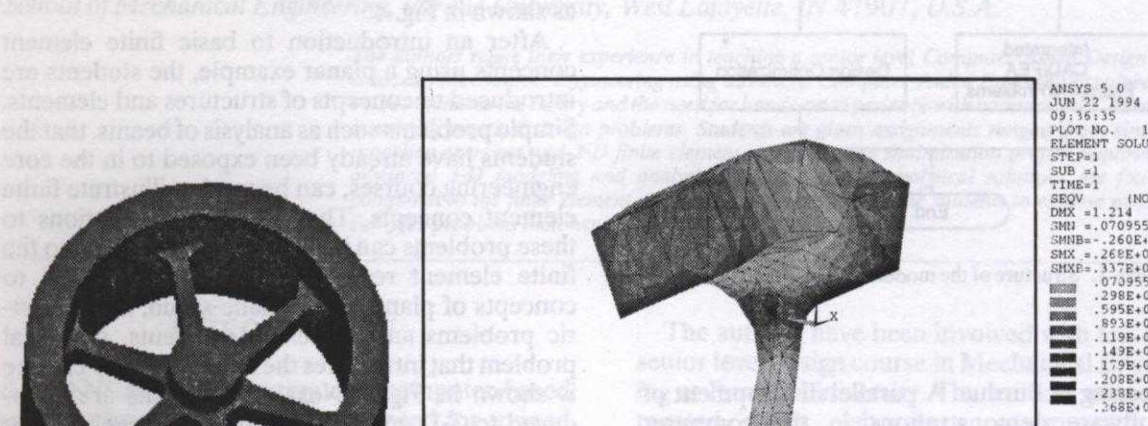

Fig. 4. A 3-D model of a flywheel and corresponding finite element analysis.

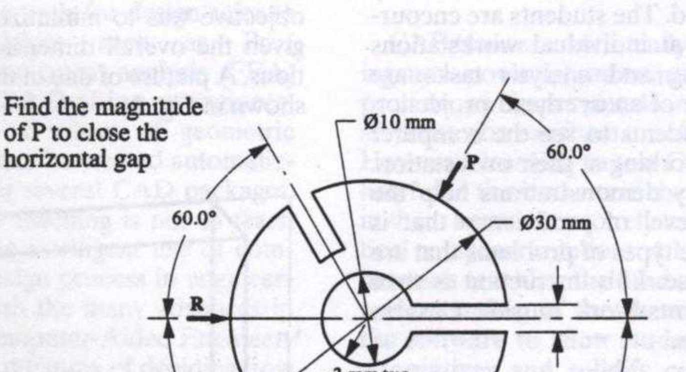

Fig. 5. A typical 2-D FEA exercise.

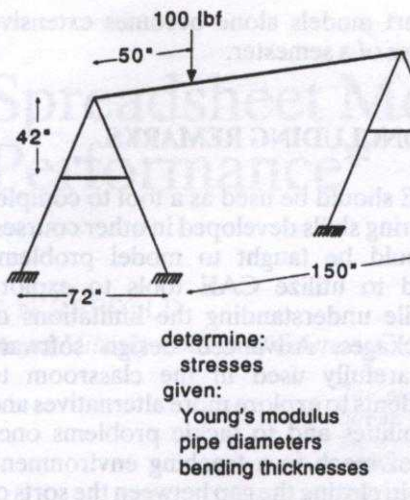

Fig. 6. A simple stress problem.

OBSTACLES

One of the major problems associated with using advanced software in coursework is the additional time involved with software training. Companies typically spend large amounts of time and money for such training, and it is difficult to squeeze enough instruction into the curriculum to enable students effectively to make use of the software.

A related problem is that of making software documentation available to the students. The user manuals for commercial CAE programs are typically quite extensive, and it is difficult to assemble the critical information and make it readily available to the students. This problem can be alleviated somewhat by the availability of abbreviated manuals, which are now provided by some software vendors. It is useful and important

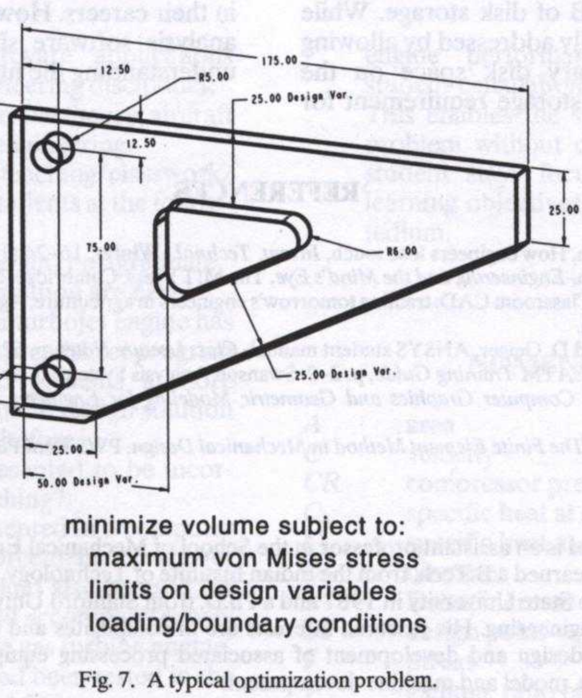

Fig. 7. A typical optimization problem.

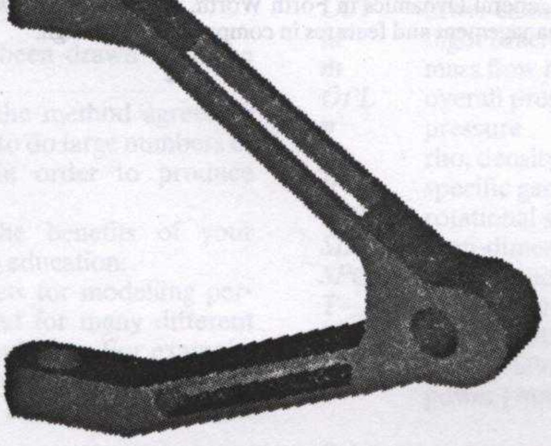

Fig. 8. A-frame optimization project.

to have a complete set of documentation available for student reference, but the more immediate access to smaller manuals is critical in a laboratory and teaching environment. Although separate books can be found that cover concepts in computer graphics [6] and finite element method [7], no single book covers the concepts that are required to comprehend the concepts and practice them at the undergraduate level.

Perhaps the most critical obstacle in teaching with design software is the large amount of computer equipment necessary to support its use. Not only are powerful workstations required to run the software, but the amount of disk storage required to allow 40 or so students to build, analyze and possibly optimize a part or assembly is quite daunting. For example, to run a design optimization using the CAD/FEA interface module for the example problem shown in Fig. 7 required well over 20 MB of disk storage. While ths problem can be partially addressed by allowing students to use temporary disk space on the individual machines, the storage requirement for saving the part models alone becomes extensive over the course of a semester.

CONCLUDING REMARKS

CAD/CAE should be used as a tool to complement engineering skills developed in other courses. Students should be taught to model problems correctly and to utilize CAE tools to explore solutions while understanding the limitations of software packages. Advanced design software should be carefully used in the classroom to empower students to explore more alternatives and design possibilities and to tackle problems once thought out of reach in a teaching environment. This can help in closing the gap between the sorts of problems that students encounter during their formal education and those that they are faced with in their careers. However, the use of modeling and analysis software should not take the place of understanding the fundamentals of engineering.

REFERENCES

1. E. S. Ferguson, How engineers lose touch, *Invent. Technol.*, **Winter**, 16–24 (1993).
2. E. S. Ferguson, *Engineering and the Mind's Eye*. The MIT Press, Cambridge, MA (1992).
3. K. Haghighi, Classroom CAD: training tomorrow's engineers in agriculture, *Agric. Engng*, **May/June**, 18–21 (1987).
4. K. Ramani and D. Geiger, ANSYS student manual, *Class Lecture Notes*, p. 62 (1993).
5. *ANSYS/ProFEA*TM *Training Guide*, p. 2–2. Swanson Analysis Systems (1993).
6. V. B. Anand, *Computer Graphics and Geometric Modeling for Engineers*. John Wiley and Sons (1993).
7. C. E. Knight, *The Finite Element Method in Mechanical Design*. PWS Kent Publishing Co. (1993).

Karthik Ramani is an assistant professor in the School of Mechanical Engineering at Purdue University. He earned a B.Tech. from the Indian Institute of Technology, Madras, in 1985, an M.S. from Ohio State University in 1987 and a Ph.D. from Stanford University in 1991, all in Mechanical Engineering. His research interests are in composites and polymer processing, novel process design and development of associated processing equipment through concurrent process, model and machine development.

David Henderson is currently working on his Ph.D. in Mechanical Engineering at Purdue University. He received his B.S.M.E. degree from Brigham Young University in 1990 and his M.S.M.E. from Purdue in 1992. While an undergraduate, David alternated school semesters with internships at General Dynamics in Forth Worth, Texas, U.S.A. His research interests include constraint management and features in computer aided design.