DEVELOPMENT OF A COURSE IN FINITE ELEMENT ANALYSIS FOR MECHANICAL ENGINEERING TECHNOLOGIST

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Abstract

An elective, senior level course in finite element analysis is developed for incorporation into a mechanical engineering technology program. The curriculum for the course is developed with the varied roles of the mechanical engineering technologist in industry today in mind. These roles are examined in detail in order to formulate appropriate course objectives. The course is taught in a computer lab setting. Students will gain hands on experience with a commercially available finite element analysis software package. The primary evaluation tool to assess if students are meeting the objectives of the course are reports submitted detailing the analysis undertaken in sample projects assigned in class. The reports are written in a format used successfully in industry.

Introduction

In its report recommending six-year accreditation for the mechanical engineering technology program at Buffalo State College in 1998, TAC-ABET cited as a weakness the lack of technical electives offered within the program. In order to address this weakness by our mid-term letter of 2001, it was decided by the faculty in the program to offer an elective in finite element analysis. As the faculty member with the most industrial and academic experience with finite element analysis, it fell upon the author to design the curriculum for the course and prepare a course outline for routing through the various curriculum committees at the college.

At first, the prospect of performing this task was met with great excitement, as it would allow the author an opportunity to formulate and teach a course in his specialty area; however, this excitement soon gave way to skepticism. The author had taught the course on a graduate level; here, it must be taught on an undergraduate level. The course had been taught from a theoretical point of view that even university prepared students had difficulty with; here, the theoretical preparation would be lacking even more. Surely, a "traditional" course in finite element analysis would not be appropriate for an undergraduate mechanical engineering technology program.

Rather than abandoning the task, the author decided to take a different approach. Could one design a finite element analysis course for mechanical engineering technologists? What would be the benefits of such a course to the students, to the employers of our graduates, to the author himself?

This paper describes the research steps taken by the author in order to formulate appropriate objectives for a finite element course for mechanical engineering technologists, the devising of a curriculum to meet those course specific objectives (as well as general ABET objectives), and the choosing the appropriate evaluation methods to assess the students' achievements in the course.

The Role of the Engineering Technologist

It is believed that the most important aspect in formulating the objectives for the finite element analysis course for mechanical engineering technologists was to understand the role of the mechanical engineering technologist in various industrial settings and the possible function finite element analysis may play in that role. The information needed for this understanding would come from three sources:

- A panel discussion regarding the general role of engineering technologists presented at a recent conference [1].
- In-depth discussion with members of our program's advisory board concerning finite element analysis and engineering technology at their companies.
- The author's own industrial experience as a finite element analyst and his interaction with engineering technologists at large, mid-size and small companies.

Three primary mechanical engineering technologist roles were identified as either requiring or benefiting directly from a reasonable amount of finite element training. These roles are by no means exhaustive or all-inclusive, but are believed to be most prevalent. They are described below:

- **Role in a Small Manufacturing Facility.** Small manufacturing companies many times act as suppliers to large companies operating under formal specifications for their products. As a result, there is increased demand for analytical validation of the suppliers' products. The responsibility for this validation is filtering down to the supplier level. The accepted method of analytical validation is generally some form of finite element analysis on the product. These small companies cannot afford to have specialized finite element analysis capability on staff full-time. Many times, they cannot afford part-time consultants. They certainly would be unwilling to purchase the more sophisticated finite element codes and pay their associated costly maintenance fees. At these companies, a mechanical engineering technologist generally acts as a jack-of-all-engineering-trades. This technologist, if trained, can perform simple analyses using relatively inexpensive finite element programs.

- **Role in a Design Company.** As with the small manufacturing facility, the mechanical engineering technologist will be acting in a variety of engineering related roles. Mechanical engineering technologists generally have had CAD training. Today, many CAD packages contain simple finite element meshers and solvers. A trained mechanical engineering technologist can perform simple analyses using these embedded solvers.

- **Role as a Project Engineer.** In a larger organization, the mechanical engineering technologist could act as a project engineer. The project engineer shepherds a product through design, analysis, manufacturing, test and deployment by interfacing with designers, engineers, technicians, management and the customer. The need for finite element analysis background will be essential for project engineers interfacing with analytical engineers on staff. The project engineer must understand what this engineer is doing so that he can ask intelligent questions about the methodology used; he can understand and check the results given to him; he can provide the analytical engineer with the information that that engineer may request; and he can effectively communicate the results to management and the customer.

While it is recognized that a mechanical engineering technologist could become proficient enough in finite element analysis to possibly make a career move in that direction, the roles described above assume that finite element analysis knowledge is another tool in the toolbox of a career engineering technologist.

Course Objectives

In recognition of the above roles of the mechanical engineering technologist, the following course objectives were established:

- To understand the purposes and uses of the finite element analysis process in industry and the possible roles of the mechanical engineering technologist in that process.

- To learn the basic terminology and concepts associated with finite element analysis.

- To gain hands-on experience with a commercially available finite element analysis program.

- To interpret one's results, check one's work and report one's findings.

Curriculum

The class will be held in a computer laboratory environment. A commercially available finite element analysis program will be installed or accessible from every PC in the lab, including the instructor's. The instructor's screen will be projected onto white screen installed in the lab.

The class is envisioned as meeting twice a week for 1.5 academic hours per meeting. Approximately one day per week would be devoted to lecture, while the other day would be devoted to laboratory, during which students would work on their projects while the instructor would act as a mentor.

The lecture material would include, but not necessarily be limited to, an introduction explaining what finite element analysis is, what is its place in the industrial setting, and what is the role of the engineering technologist; enough theory so that a student could, *in words*, explain the justification for the use of the method; terminology; elements of model building; post-processing and checking; and reporting. A detailed list of topics is attached in the Appendix.

These lectures would be juxtaposed with the assignment of projects, with specific applications relating to these projects. The projects would give the students the hands-on use of the installed finite element analysis program. The projects would increase in structural complexity, for example, truss to frame to 2D structure to 2D heat transfer analysis, during the course of the semester. The projects would create a design scenario so that students would understand that the objective of the analysis was to verify a design against specific criteria. A reporting format, used by the author successfully in industry, would serve as a basis for reports generated by the students for each of their projects. The quality of the finite element modeling, analysis results and reporting would serve as the evaluative tools to determine the students' grades.

While it is believed that a textbook specifically geared to the philosophy of the course as presented herein does not exist presently, it is has been generally noted that students feel more comfortable with one. A textbook was found that was written around the installed finite element program [2], and will be used for at least the first year that the course will be offered.

Summary

A curriculum for a finite element analysis course particularly suited to senior level mechanical engineering technology students has been formulated. The course concentrates on skills required by the engineering technologist to perform, monitor and report on a finite element analysis.

Appendix: List of Topics

A. Introduction (2 weeks)
1. What is the Finite Element Method?
2. Role of the Engineering Technologist

B. Basic Notions (3 weeks)
1. Nodes
2. Elements
3. Basic Variables
4. Continuity/Compatibility
5. Equilibrium/Conservation Laws
6. Assembly
7. Loads
8. Boundary Conditions
9. Solution
10. Post-Processing

C. Modeling Techniques (3 weeks)
1. Choosing the Right Elements
2. Appropriate Material Properties

3. Variable Mesh Sizing
4. Taking Advantage of Symmetry
5. Other Considerations

D. Interpretation of Results (3 weeks)
1. Reactions
2. Concentrations
3. Other Considerations

E. Reporting (3 weeks)
1. Objective of the analysis
2. Design criteria to be satisfied
3. Assumptions made
4. Material properties used
5. Loads and boundary conditions
6. Results and conclusions

F. Computer Laboratory Experiments (samples; interspersed throughout):
1. Truss Analysis
2. Plate with a Hole in Plane Stress
3. Heat Transfer For Electronics
4. Thermal Stress Analysis

Bibliography:

1. Waintraub, J., "Panel Discussion on Multidisciplinary Programs in Engineering Technology," presented at the Fall 2001 NYSETA Conference, October 25-26, 2001, Buffalo State College, Buffalo, NY.

2. Logan, Daryl, "A First Course in the Finite Element Method Using Algor," 2nd ed., ISBN 0-534-38068-9, Brooks/Cole (2000).

Biography:

SLADE GELLIN received in Ph.D. in Applied Mechanics from Harvard University in 1977. He has been involved in finite element research in both industrial and academic settings, publishing several papers and numerous reports in the field. Since arriving at Buffalo State College in 1993, he has pursued interests in the analytical training of engineering technology students.