USE OF NASTRAN AS A TEACHING AID

By Michael T. Wilkinson

Louisiana Tech University

SUMMARY

Recent experiences with incorporating NASTRAN as a teaching tool in undergraduate courses has been found pedagogically sound. Students with no previous computerized structures background are able to readily grasp the program's logic and begin solving realistic problems rapidly. The educational benefit is significantly enhanced by NASTRAN's plotting feature. However, the cost of operating the level 12 version presently makes the program difficult to justify.

SELECTION OF A FINITE ELEMENT PROGRAM

Undergraduate instruction in the area of structural analysis must begin by placing major emphasis on the fundamentals such as stress, strain, Mohr's circle, flexure formula, etc. However, all too often the undergraduate's progress does not extend far beyond problems in which a beam is either bent, sheared, twisted or buckled under a wide variety of end conditions.

It seems highly desirable that the undergraduate should also be exposed to more realistic structural problems such as are encountered in practice. These realistic problems generally present two major obstacles -- 1) they are usually too large for hand calculations and 2) they often cannot be analyzed using the simple formulas with which the student is familiar.

27

It is, of course, clear that the addition of large structural problems into the undergraduate curriculum should not precede a study of the fundamentals. However, realistic problems not only give the senior-level student a practical feel for the results but also provide a significant motivation factor. That is, students generally feel a greater sense of achievement when they successfully solve a significant engineering problem.

With this purpose in mind, the general finite element programs have significant potential as a teaching aid. In the selection of a finite element program, the instructor must consider the following characteristics of the programs:

1) Is it easy to use?

2) Will it handle a sufficiently broad class of problems?

3) Is it a program the student could be expected to encounter after graduation?

4) Is it expensive to use?

With regard to the first question, it is important that a minimum amount of classroom time is spent "checking out" the student on the program. Consequently, the program must be user oriented with easy input and extensive error checks. A corollary to this question is a requirement for a program which is dependable -- nothing dampens student enthusiasm like a program which fails to work!

The second question concerns the versatility of the program. This requirement arises for several reasons. If the program is used for senior level design work, the variety of problems will almost certainly require a general program. Furthermore, many students remain for graduate school and want to use the program as a research tool. Thus, while it is not mandatory, it certainly is desirable to acquaint the undergraduate student with a program which can also be used for graduate research.

The third question asks not only is the program presently widely used by structural engineers, but also is it one of lasting quality? This question is very difficult to answer and tends to be more of an opinion than anything else. All too frequently the answer is biased with how well the instructor can use the program in comparison to similar programs with which he is familiar. Fortunately, it is not imperative that the student be "trained" on a univeral program, provided the program used has the same major characteristics of the more commonly used ones.

The final question is more pragmatic and is one which cannot be ignored in view of the current financial pressure on institutions of higher learning. The cost of operating the program depends significantly on the type of computer installation and the method of charging for computer services. It is important that the instructor monitor the computer expenses to ensure they do not get out of hand.

While several excellent finite element programs are available (Ref. 1), the NASTRAN program was selected for the present study for the following reasons. First and foremost, the author felt NASTRAN struck a proper balance between easy usage and versatility (Ref. 2). It was also felt that the government's commitment (Ref. 3) to maintain and improve the program will assure an even wider acceptance of NASTRAN in the future. With regard to the question of cost, it is acknowledged that NASTRAN is an expensive system to operate (Ref. 2). However, with the significant time savings available between Levels 12 and 15, it appears the cost of operation can still be reduced.

PROGRAM UTILIZATION

The presentation of computer methods of structures primarily consists of three topics with which the student is unfamiliar:

1) Structural theory

2) Computer code

3) User experience

The instructor is faced with the problem of maintaining a proper balance between the three. If he devotes his time exclusively to presenting structural theory, he creates an "ivory tower" product who may make an excellent graduate student but a poor prospect for industry. On the other hand, total emphasis on user experience produces a "technician" who knows how to use a "black box" but who knows very little about how the "black box" works.

A balanced approach has been taken by the author in two separate senior-level courses -- one in aircraft structures and another in machine design in mechanical engineering. The two courses differ in that the aircraft structures course has an assigned problem of a small aircraft component whereas the machine design course allows the students to select individual projects. Typical projects which have been selected by students are:

1) Automobile brake drum

2) Concrete beam with spliced reinforcing steel

3) Automobile car roof

4) Railroad tank car

5) Motorcycle helmet

6) Outboard motor propeller

The diversity of subjects points out the wide variety of interests and backgrounds among engineering students.

In each course it has been found possible to start with a sequence of lectures on how to use NASTRAN for static analysis. By relying upon the physical concepts of the finite elements, it has been found that three periods are sufficient to check out students who have had no previous structural programming experience. This initial check out enables the students to spend the remainder of the course working on their particular structural problem. Following the first three periods, the remaining lectures are devoted to structural theory and computer coding.

The topic of computer coding is covered with a presentation of a simple finite element program written by the instructor to illustrate the major steps in program code development. Explanation of this simple program is intended to show the student the art of building a program. Thus, the student is spared the time consuming labors of writing his own computer code, debugging it, and finally trying to obtain some practical results before the course ends. The fact that the student can understand how to use NASTRAN before he has the structural theory and coding background significantly increases the amount of time he can spend developing first-hand experience. Thus, in a sense, he is able to see the "big picture" before becoming entangled in the details.

Based upon student accomplishments, understanding, and endorsement, this particular approach has apparently been successful. Its greatest shortcoming is that NASTRAN is expensive to operate. The program was run on an IBM 370/145 computer with 256K core. The charges for this machine are figured at $400 per CPU hour. The average student in the aerospace structures course used approximately one hour of CPU time, whereas the machine design students required an average of two CPU hours. Thus, the computer costs per student fell within the range of $400-$800. For comparison, a similar study on course instruction in basic FØRTRAN was found to cost less than $40 per student.

The author's experience has also shown that use of NASTRAN's plotting feature dramatically improves student acceptance of the results. The importance of the student seeing a scaled model of the structure, as opposed to simply scanning pages of numbers, cannot be over-emphasized. After gaining a feel for his problem, he is much more willing to study the tabulated results.

PROPOSED WORK

At first glance, students tend to be overwhelmed by the magnitude and bulk of the NASTRAN User's Manual. This initial shock could be eased with the availability of a "Mini-Manual" which describes the essential steps for writing a NASTRAN program. This manual should also contain simple example problems. After graduating from the "Mini-Manual," the student can then use the more extensive documentation contained in the present User's Manual.

REFERENCES

1. T. G. Butler, "On the Reduction of Proliferation of Finite Element Programs," paper contained in "NASTRAN: Users' Experiences," NASA X-2378, 1971.

2. J. L. Tocher and E. D. Herness, "A Critical View of NASTRAN," paper presented at the International Symposium on Numerical and Computer Methods in Structural Mechanics, Urbana-Champaign, Ill., Sept. 8-10, 1971.

3. J. P. Raney, D. J. Weidman, and H. M. Adelman, "NASTRAN: Status, Maintenance, and Future Development of New Capability," paper contained in "NASTRAN: Users' Experiences," NASA TM X-2378, 1971.