Session 2238

Introduction of Finite Element Methods in the Lower Division Mechanical Engineering Technology Curriculum

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Introduction

Many engineering technology students work in positions requiring familiarity with engineering analysis as well as design. They are asked to use commercially available software packages as a part of their job function. Some of the simple analysis is off loaded to the designer. One of main reason for this shift is integration of analysis as early in design process as possible. Another reason is availability of powerful software and hardware at reasonable costs to the companies. However, most engineering technology students are not exposed to Finite Element Methods as part of their educational process. This is especially true for our Associate Degree students.

In general, an Engineering Technology program has more hands-on orientation than an Engineering program. However, this does not extend to the use of Finite Element Analysis in most technology programs. It is true for Mechanical Engineering Technology Curriculum at University of Cincinnati. The Mechanical Engineering Technology Department offers a technical elective course in Finite Element Analysis for upper division students. At present, due to hardware limitations and student interest, about 15-20% of baccalaureate graduates take this course. Not a single student at associate degree level is exposed to computational analysis as a powerful problem solving tool.

Starting Winter quarter 1997, we are addressing this problem. All of our lower division students will be exposed to a modern tool for analysis and hands-on experience in using a commercially available Finite Element package. We are not teaching them a Finite Element Course nor it will be a software training module. We will integrate small modules of Finite Element Analysis in our existing Design Courses. We are hoping that, in the future, we might introduce them to some form of design optimization as well.

Current Format

Associate Degree students in Mechanical Engineering Technology are required to take the following courses as a part of their design sequence.

Course	**Credit hours**
Engineering Drawing I	3
Engineering Drawing II	4
Statics	4
Mechanics of Materials I	4
Mechanics of Materials II	4
Design of Machine Elements	5

All of the above courses are one quarter in duration and all of them have a laboratory associated with them except for Statics.

In Engineering Drawing students learn fundamentals of design and drawing, introduction to ANSI standards, dimensioning and tolerancing, fits, etc. In this sequence students are assigned an individual design project which they must complete from conceptual ideas to final working drawings. They also do assembly drawings and bill of materials as needed for their design project. Since students have not taken Statics or sophomore level Mechanics of Materials courses, they are not required to perform any strength computations.

The four credit hours Mechanics of Materials I and II courses are 3 hour lecture per week and a two hour laboratory session per week. The lecture component is traditional strength of materials, such as stress, strain, Mohr's Circle, normal and bending stresses, beams in combined loading and beam deflections, etc. Reinforcement of the principles discussed in the lecture is obtained by performing hands on laboratory experiments, i.e., obtaining experimental values of Young's Modulus, Poisson's ratio, continuous beam loading, stress concentration factor, constant stress beam, etc.

Design of Machine Elements is the first major design course and primarily involves design and selection of power transmission components, such as shafts, gears, bearings, chain and belt drive as well as couplings and keys. Each year professional societies, such as ASEE, ASME, etc., sponsor student design competitions. First project assigned in this course is a creative project to design, build and demonstrate a device. This assignment is sometimes based on one of the projects from the competitions. Their second project consists of designing, analyzing and selecting various components of a power transmission system. (Fig. 1).

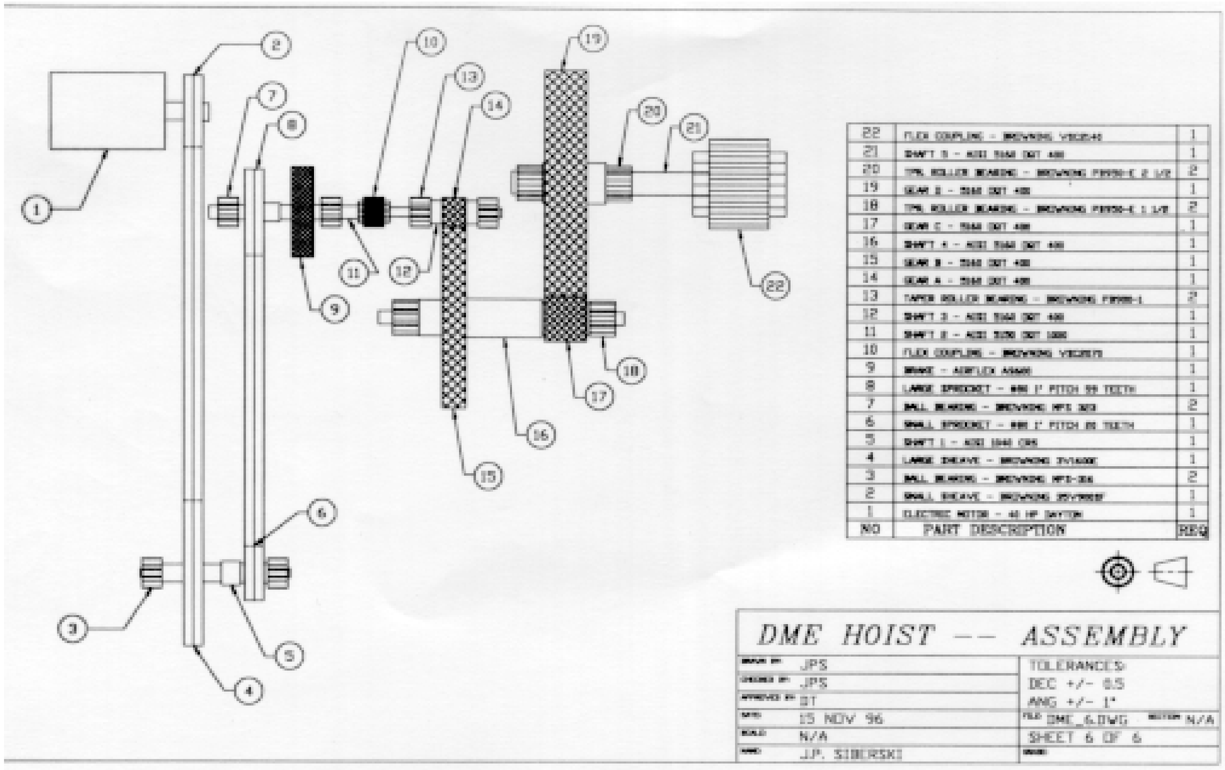


Fig. 1

Both projects are executed by teams of 2 to 4 students. For the creative project each team must demonstrate the functionality of their device. For the other project, a formal written report is required from each team. Oral presentations are required for both projects.

As stated earlier, our goal is to introduce finite element analysis to all lower division Mechanical Engineering Technology students. The following section describes our plans for integration of finite element modules in two of our courses.

New Format

Beginning Winter quarter 1997, finite element modules will be incorporated in following mandatory departmental courses for all Mechanical Engineering Technology students.

Mechanics of Materials II
Design of Machine Elements

Changes to the curriculum will be kept to a minimum and the finite element modules will be integrated in laboratory periods. All students will continue to perform basic experiments in the laboratory as they do now. Students will compare the results of finite element analysis with analytical and/or experimental results.

In the Mechanics of Materials II course, Finite Element Modules will be integrated with their experiments over a four week time frame. Topics covered will be as follows:

- Introduction to finite element analysis

- Demonstration of sample problem solutions by the instructor
- Hands on tutorial, pertaining to the beam experiments performed in the laboratory
- Interpretation of results

Vishay pregaged test beams and strain indicators are used in our laboratory experiments. The following three test beams are used for our finite element integration.

1. A rectangular beam with a hole, to determine stress concentration factor (Fig. 2). Three gages, are mounted on the beam at various distances from the edge of the hole along the width of the beam.

2. A constant stress beam with two tapered sections for constant stress (Fig. 3). Two segments are segment A and segment B in tables.

3. A rectangular beam with constant cross-section to compute bending stress at three gage locations along the length of beam.

Figures 4 and 5 show Vishay strain indicators and a different way of loading the beam than the one shown in figure 2. All students already perform these experiments and will now be using additional method to obtain results.

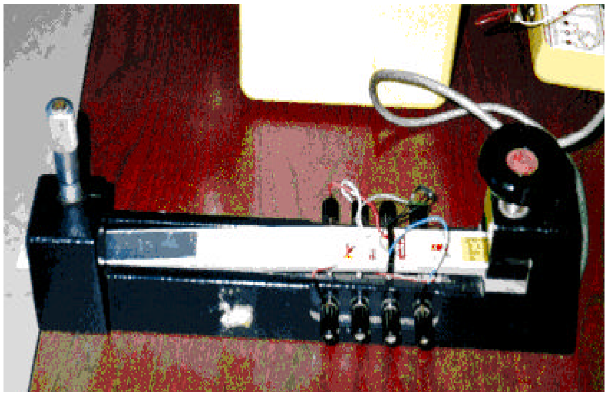


Fig. 2

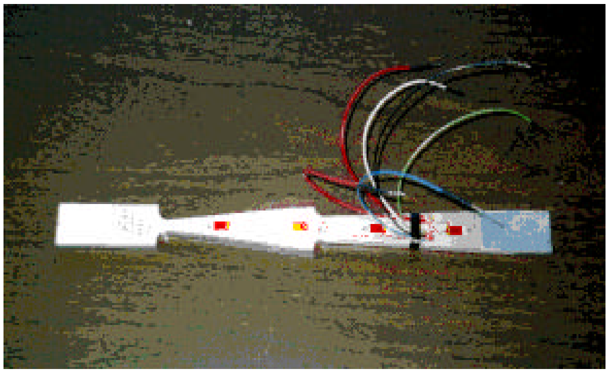


Fig. 3

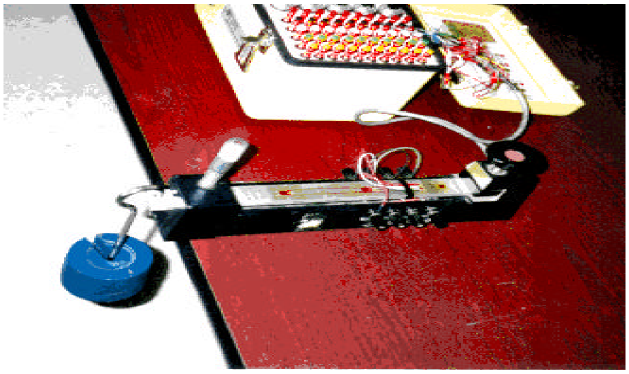


Fig. 4

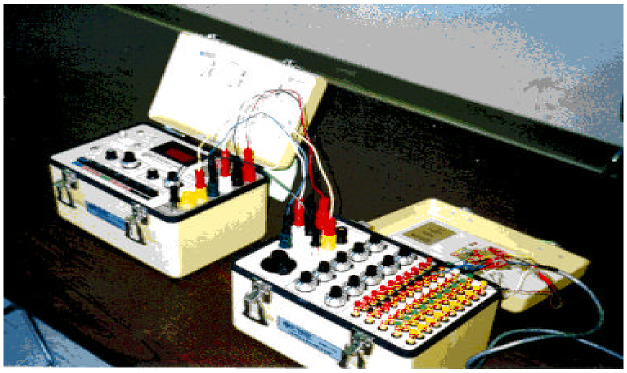


Fig. 5

Finite element mesh and stress analysis results for all three of the above beams are shown in figures 6, 7 and 8. Summary of results in a tabular form is shown below.

Results

Table I

Stress computations for a **beam with hole** in it.
All values for stress are in psi.
Theoretical K_t value of 1.788 was used to obtain maximum stress.

Location	Analytical Stress	Experimental stress	FEA stress
1	20352	25220	26260
2	20352	21320	23307
3	20352	19375	19708
Maximum stress at the edge of hole	36385	30375	28900

Table II

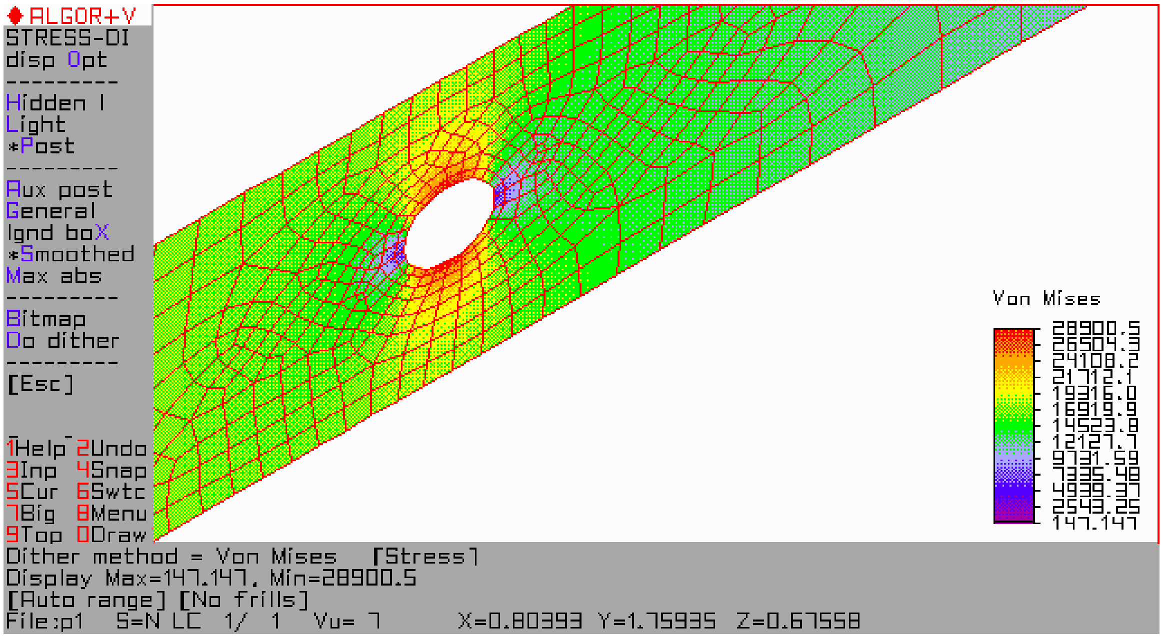
Stress computations for a **Constant Stress beam.**
All values for stress are in psi.

Location	Analytical results	Experimental results	Finite Element results
Segment A, gage 1	20500	20488	20526
Segment A, gage 2	20500	20332	20670
Segment B, gage 3	10600	10690	11300
Segment B, gage 4	10600	10400	11397

Table III

Stress computation for a **Straight beam** for bending stresses.
All values for stress are in psi.

Location	Analytical Stress	Experimental stress	FEA stress
1	6150	6156	5960
2	4350	4316	4210
3	2550	2496	2225
Maximum at the wall	6700	----	6731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Hidden l
Light
*Post
Aux post
General
lgnd boX
*Smoothed
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Bitmap
Do dither
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1Help 2Undo
3Inp 4Snap
5Cur 6Swtc
7Big 8Menu
9Top 0Draw
Von Mises
28900.5
26504.3
24108.2
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16919.9
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Fig. 6

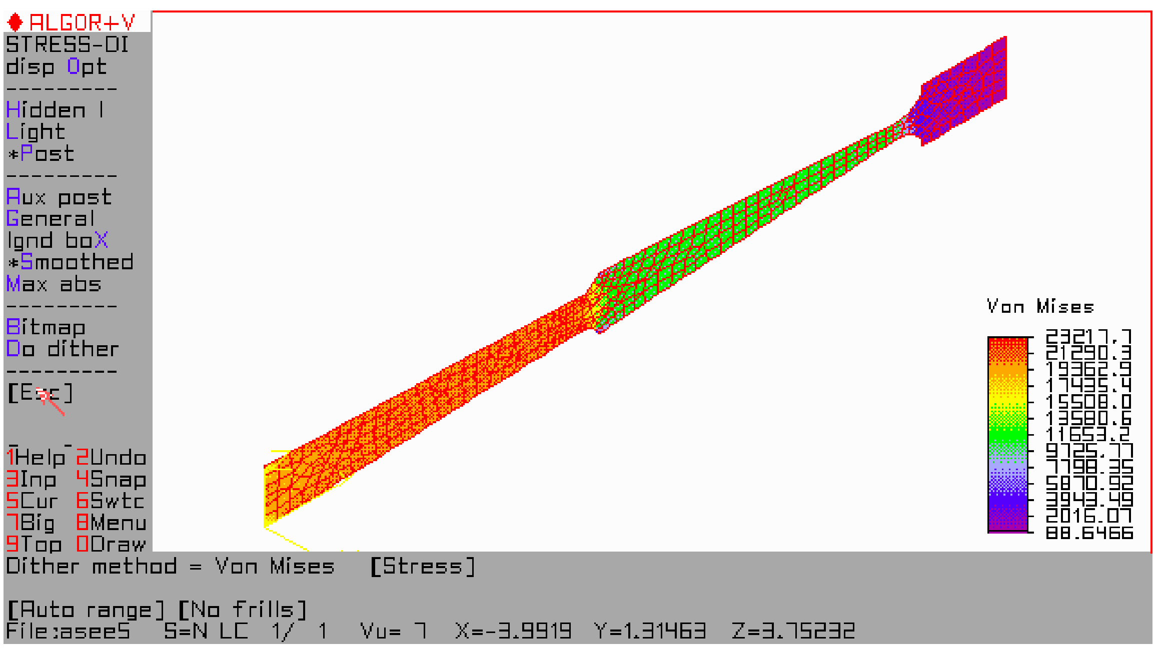
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Fig. 7

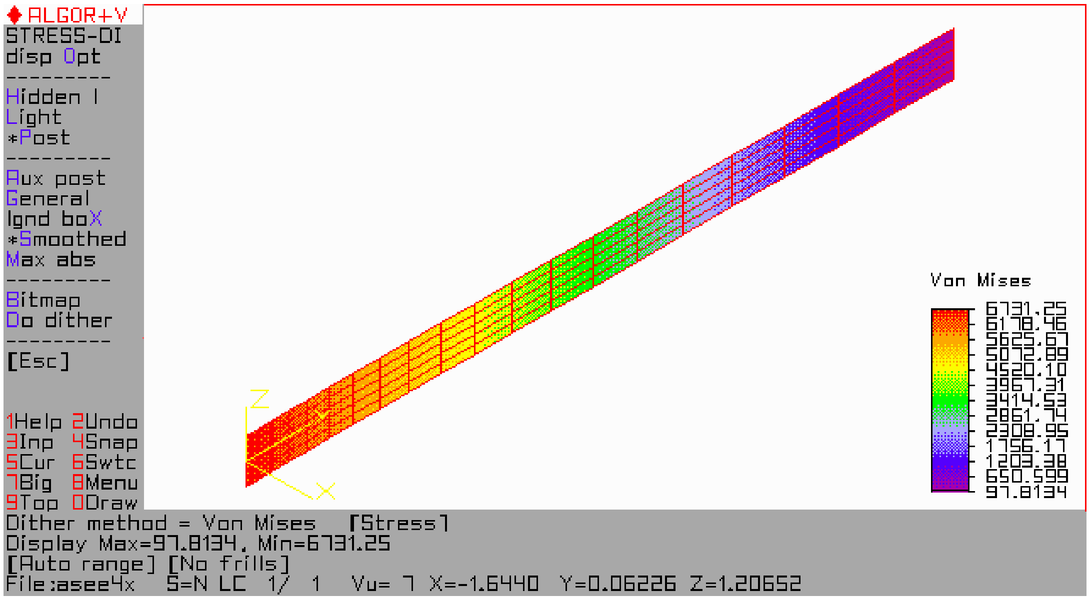

Fig. 8

As can be seen from the tables in all but one case stress values obtained by analytical, experimental and finite element methods are in good agreement. For the maximum stress in beam with a hole, there is a discrepancy in results between the analytical method and the other two. As per Peterson, for transverse bending, rounding of hole edge may result in reducing the stress concentration factor at the edge of hole.

By performing the above analysis as per detailed tutorials, students will obtain the results of simple beam problems using three different methods. They will also become familiar in use of a finite element software. This should give them additional help in understanding the processes used and better confidence in computational methods when applied to more complex problems. Students will have some appreciation for various choices available to them to solve a given problem. Students will not be expected to formulate the finite element problem due to lack of class time.

Similarly, in the Design of Machine Elements course, two assignments involving finite element methods will be given. One of the assignments, figure 9, will be a tutorial for shaft design. The other one, will use the finite element method to design the shafts for the other project, shown in figure 1. Instructional handout will provide only the major steps involved.

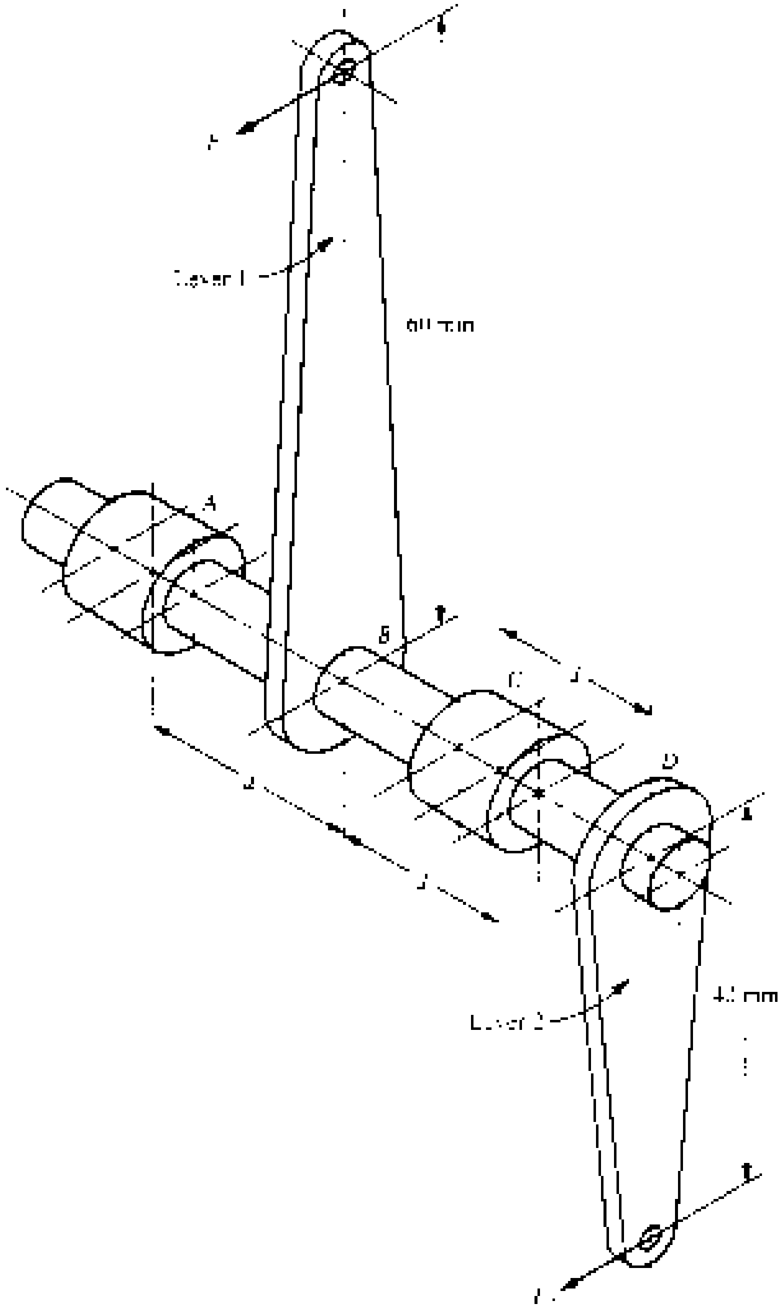

Fig. 9

Conclusion

Today designers perform the jobs analysts were doing few years ago. These courses will be offered beginning Winter 1997 for the first time. As such, we can not report on the effectiveness and student feedback of this approach. However, we will have the results of our approach and its effect on lower division technology students by the time of ASEE conference in June 1997. We are confident that this approach will be beneficial to the lower division students. It is anticipated that students will appreciate different ways of solving problems. They will be better prepared for today's workplace and further education.

This paper was initiated at an Undergraduate Faculty Enhancement (UFE) workshop supported by the National Science Foundation(NSF), Grant No. DUE-9455076, through the Division of Undergraduate Education(DUE), Directorate for Education and Human Resources(EHR).

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6. Concurrent Engineering Design workshop at Austin, Texas sponsored by NSF. (August 1996)

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