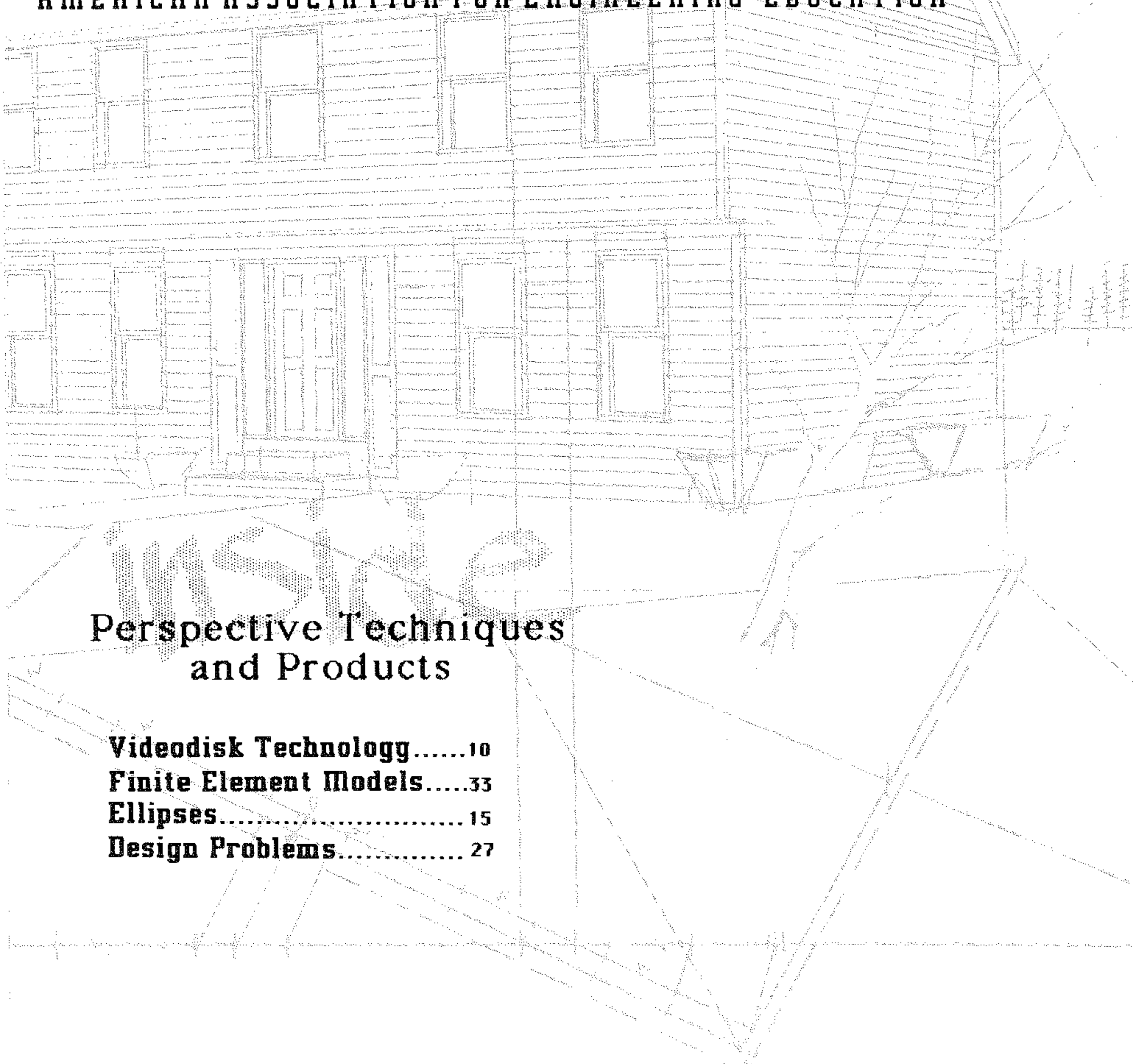
THE ENGINEERING DESIGN GRAPHICS JOURNAL

Journal

SPRING 1985 VOLUME 49 NUMBER 2

THE ENGINEERING DESIGN GRAPHICS DIVISION

AMERICAN ASSOCIATION FOR ENGINEERING EDUCATION



inside

Perspective Techniques and Products

CALENDAR OF EVENTS

ASEE ANNUAL CONFERENCES
1985 ATLANTA Host: Georgia Tech
1986 CINCINNATI Host: University of Cincinnati
1987 RENO Host: University of Nevada-Reno (tent)

EDGD MID-YEAR MEETINGS
1985 WEST LAFAYETTE Host: Purdue University
1986 AUSTIN Host: University of Texas-Austin
1987 TUSCALOOSA Host: University of Alabama

The Engineering Design Graphics Journal is published one volume per year, three numbers per volume, in Winter, Spring, and Fall by the Engineering Design Graphics Division of The American Association for Engineering Education for teachers and industrial practitioners of Engineering, Computer, Design, and Technical Graphics.

The views and opinions expressed by the individual authors do not necessarily reflect the editorial policy of the **Engineering Design Graphics Journal** or of the Engineering Design Graphics Division or of the American Association for Engineering Education. The editors make a reasonable effort to verify the technical content of the material published; however, the final responsibility for opinions and technical accuracy rests entirely upon the author.

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ENGINEERING DESIGN GRAPHICS JOURNAL OBJECTIVES:

The objectives of **The Journal** are:

1. To publish articles of interest to teachers and practitioners of Engineering Graphics, Computer Graphics, and subjects allied to fundamentals of engineering education and graphic technology.

2. To stimulate the preparation of articles and papers on topics of interest to its membership.

3. To encourage teachers of Graphics to innovate and experiment with, and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses.

4. To encourage research, development, and refinement of theory and application of engineering graphics for understanding and practice.

DEADLINES FOR AUTHORS AND ADVERTISERS

The following deadlines for submission of articles, announcements, or advertising for **The Journal** are:

Fall	September 15
Winter	December 1
Spring	February 1

STYLE GUIDE FOR JOURNAL AUTHORS

The Editor welcomes submissions for publication in **The Journal**. The following is an author style guide for the benefit of anyone wishing to contribute. In order to save time, expidite the mechanics of publication, and avoid confusion, please adhere to these guidelines:

1. All copy is to be typed, double spaced, on one side only using white paper and a black ribbon in standard English.

2. All pages of the manuscript are to be consecutively numbered.

3. Two copies of each manuscript are required.

4. Refer to all graphics, diagrams, photographs, or illustrations in your text as Figure 1, Table 1, etc. Be sure to identify all material . Illustrations cannot be redrawn. Accordingly, be sure that all lines are black and sharply drawn and that text is large enough to be legible when reduced to 4.25" in width. Good quality photocopies are acceptable of sharply drawn illustrations.

5. Submit a recent glossy black & white photograph (head to chest). Make sure that your name and address is on the back Photographs, illustrations, or other submitted materials cannot be returned unless postage is prepaid.

6. The editorial staff will edit manuscripts for publication, however galley proofs cannot be submitted for author approval. Authors are encouraged to seek editoral comment from their collegues before submission.

7. Enclose all material, unfolded, in a large envelope. Use heavy cardboard to prevent bending.

8. All articles shall be written using **Metric-SI** units. Common measurements will be accepted at the descretion of the editorial staff.

9. Send all material in one mailing to:

Jon M. Duff, Editor
The Engineering Design Graphics Journal
355 Knoy Hall of Technology
Purdue University
West Lafayette, IN 47907

REVIEW OF ARTICLES

All articles submitted will be reviewed by several authorities associated with the technical content of each paper before acceptance. Current newsworthy items, or comments, will be accepted at the discretion of the editors.

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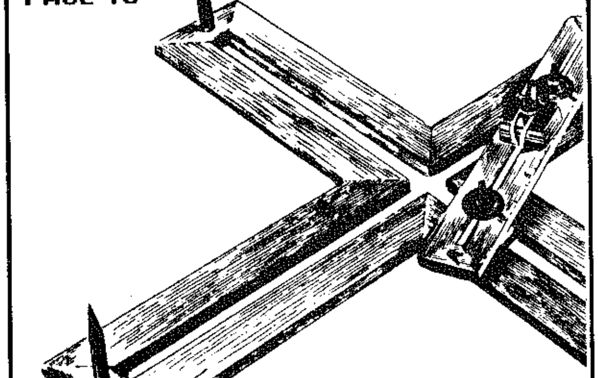

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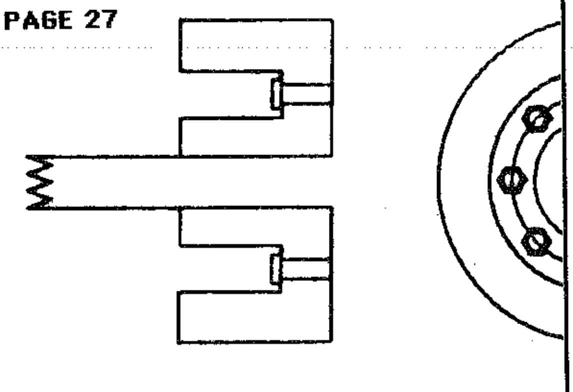

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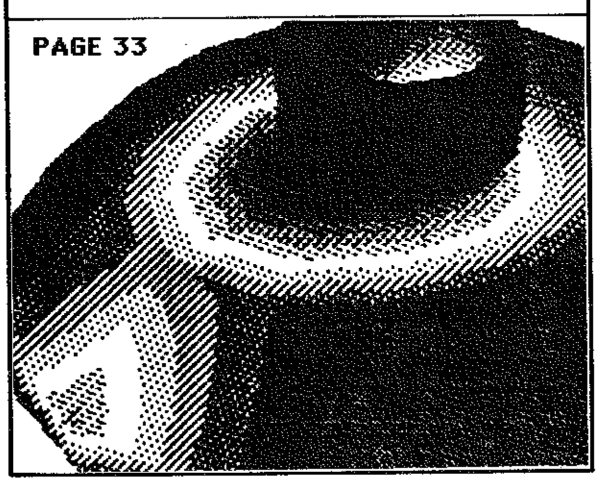
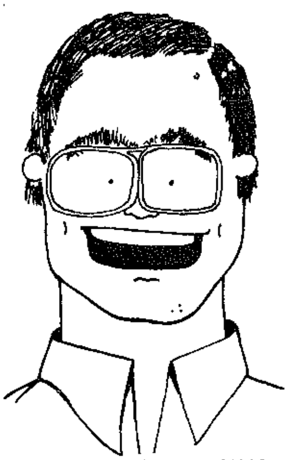


DEPARTMENTS

FEATURES

FROM THE DESK OF THE EDITOR



This issue has seemed to be heavier in the area of **perspective** than most. I want to share editorial opinion about the subject, encourage you to review the features and comment to me if you wish. Specifically, this issue contains book reviews, a product review, and a technical paper.

First, a little discussion of perspective philosophy. It is a drawing topic that has seemed tedious to many, yet it has been the most rewarding of all drawing techniques for others. Those of us who have taught the subject for a number of years to a variety of students, have developed our own techniques to efficiently and effectively teach perspective. We know from experience that there are students for whom perspective will allways be a mystery. I'm sure each of you has seen the **glazed look** in a student's eyes when he has no idea what you are drawing or talking about.

its the drivel that makes knots return to your stomach

David Yue's Perspective Drawings by Programmable Calculator is not the first effort to use new technology to draw perspectives, but I certainly hope that it is the last of its particular kind. It is touted to allow you to make perspective drawings quickly, cheaply, and at any size. In its attempt to make perspective drawing more efficient and understandable, it has made totally obscure a subject that if taught correctly, can be illuminating. The whole idea of plotting X-Y intercepts works, only if you don't have to plot the points manually. The same concepts Mr. Yue utilizes with a hand-held programmable calculator are very powerful when applied to a graphics device that can read the data, display the graphics, and translate , scale, or rotate the geometry without further effort on the part of the viewer. As it is, Mr. Yue's work has no place in the teaching of perspective drawing to students, or in the making of perspective drawings professionally. The examples are very simple, demonstrating the fallacy of producing perspectives this way.

There is a major fault in this work, and in many other works in perspective and technical drawing. The fault lies with teaching drawing as a two-dimensional exercise. Those who can really draw and understand geometry in perspective don't draw, don't plot points on the picture plane. Instead, they **build** or **model** the geometry in three-dimensional space. They don't draw lines on the sheet of paper. They construct form, intersect form, define space. Can you imagine **designing** in perspective by programmable calculator? It's ludicrous, and I am surprised thatMr. Yue, who is an architect, didn't see this.

There are two possible reasons for this impotent perspective method: the author never could draw in perspective, as many architects can't, or, he draws so well that the laborious calculation and plotting of points, and then the dot-to-dot connectivity, seems a natural extension of the laws of perspective. Ernest Burden has done much the same thing in Architectural Delineation, where perspectives are traced over photographs of carefully constructed scale models. Eee Gads! Another architect that can't draw!

On a brighter note, but still with some reservations, is the set of perspective charts and guides offered by Perspective Sciences called the **Perspectamat** . It is a more transportable version of the old perspective table. I was given a set to try out and I found the strong points to be the ease of selection of different perspective orientations, and quick approximations of measurements. On the short side, I felt the product would not stand up to daily use and felt limited with the generally small perspective grids.

Both the book and the perspective aid bring me to my major point.

> **Perspective short-cuts, aids, guides, and new and improved methods only make sense if you already know how to draw in perspective.**

I think many topics in graphics adhere to this statement. As educators, we must analyze the subject matter to find out just what the important aspects of graphics are, **independent** of computers, hand-held calculators, grids, guides, or tables. This is what we must teach.

A companion book by Van Nostrand Reinhold is Stephen Rich's Rendering Standards in Architecture and Design. This is a more traditional perspective text, very strong on rendering, but leaving the reader with the same nagging question: **Doesn't anyone really understand perspective any more?**

Standards contains incorrect terminology (SP on ground, for instance) as well as the unnecessary use of a second picture plane. This is unfortunate in an otherwise superb rendering book. And there, at the end of Standards in a section incorrectly titled "Computer Rendering" is more hand-held calculator drivel that returns the knots to my stomach.

At least Rich explains in one paragraph what Yue did not explain in his entire book: Just why would anyone ever want to use this method to draw perspectives?

> "The hand calculator generated perspective views have the advantage of ease of plotting without the need for drafting equipment other than triangle, a scale, pencil or lead holder with lead, and grid paper. One of the major advantages of this system is the ability to create a large perspective without having to plot vanishing points."

I hardly consider a calculator, a program, paper for recording data sets and the above mentioned supply list to be an improvement over traditional methods. And for anyone who has tried to trace over a perspective without refinding the vanishing points, you know that you run the risk of getting the perspective whacked out of shape. Visibility still has to be determined and I have yet to see a perspective with professional detail (like the one on the cover of this issue of The Journal) done this way.

And finally, the rationale concerning the size of the perspective drawing (distance of the VPs) shows how little is understood here about perspective. The fact is that a convenient arbitrary vanishing point can be used if the natural vanishing points are inaccessible. Far off vanishing points are hardly a reason for making perspective a non-drawing, key-punching, point plotting, connect-the-dot, 2-D travesty.

EDGJ

review

A REVIEW OF NEW PRODUCTS AND MATERIALS

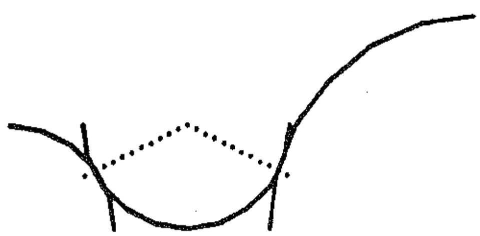


Fig. 3.10 Computer-generated display of an arc tangent to two given arcs

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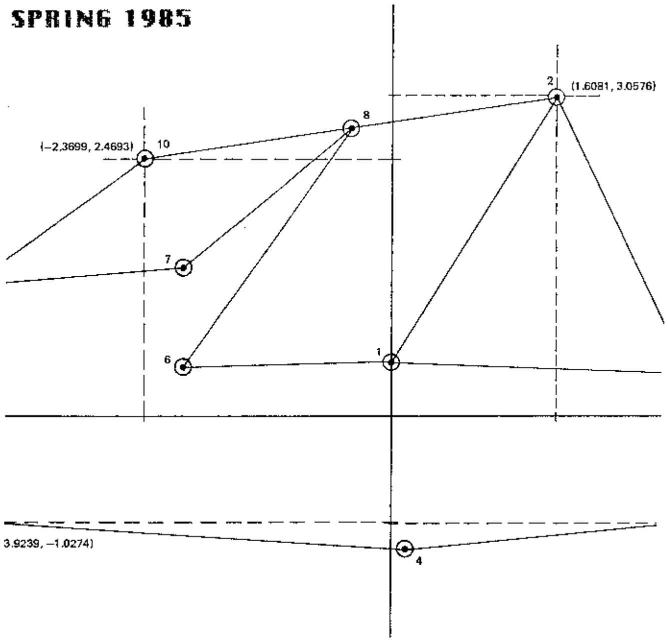
CALL GRSTRT(4010,1)
CALL NEWPAG
CALL MOVE(70.,10.)
CALL ARC(10.,0.,90.)
CALL MOVE(87.,20.)
CALL ARC(10.,0.,-180.)
CALL MOVE(115.,10.)
CALL ARC(20.,90.,180.)
CALL DASHPT(1)
CALL MOVE(87.,20.)
CALL DRAW(77.,15.)
CALL MOVE(87.,20.)
CALL DRAW(97.,15.)
CALL GRSTOP
STOP
END
```

Engineering Graphics and Design with Computer Applications

By David I. Cook and Robert N. McDougal

Holt, Reinhart and Winston 1985

A 385 page hard-bound engineering graphics text which doesn't treat computer graphics as a separate topic, rather it blends computer topics into each chapter. Traditional in its treatment of graphics topics including, equipment, geometry, projection, pictorials, sketching, sections, fasteners, dimensioning, auxiliaries, intersections, working drawings and engineering design. Up-to-date photographs but thinly illustrated and with fewer than the expected problems at the end of each chapter. The computer graphics is based on Tektronics Plot 10 graphic library calls.

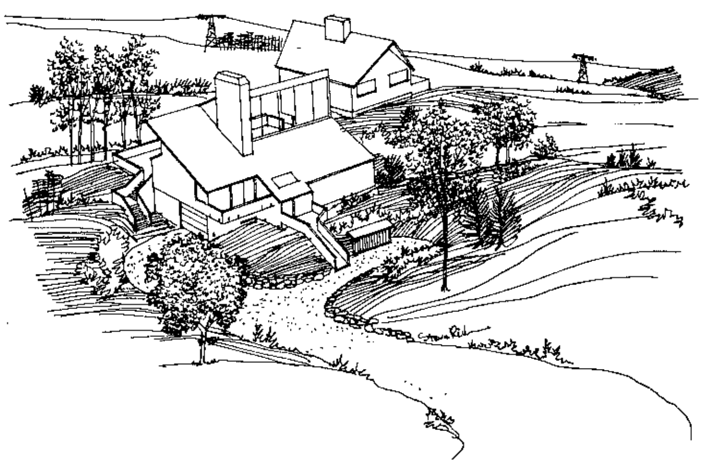


Perspective Drawings by Programmable Calculator

David Yue

Van Nostrand Reinhold 1984

A 230 page hard-bound text covering the use of programmable calculator generated perspective drawing. Perspective and calculators are reviewed historically and perspective programs for HP and TI calculators explained. After that, the author demonstrates the use of the technique in scaling, view determination, finding vanishing points, drawing grids and maps, unitary form, circles, and shadows. Program listings are presented in full in appendices.



Rendering Standards in Architecture and Design

Stephen W. Rich

Van Nostrand Reinhold 1984

A 400 page hard-bound text containing numerous examples of architectural rendering and step-by-step techniques. The author covers perspective systems, grids, interior and exterior perspective methods. The majority of the book covers rendering techniques (generally pencil or pen and ink). The variety of architectural rendering styles is impressive. Small chapter at the end on "computer rendering" that is actually wire frame display.

Perspectamat

Perspective Sciences

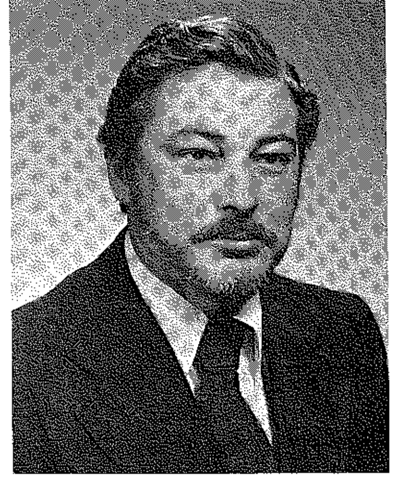
99 Green Lane, Camp Hill PA 17011

Perspectamat is a grid-based perspective aid for making perspective drawings from a variety vantage points. The system consists of an acetate work overlay to protect the grids, a large number of grids, self-adhesive guides to place on the overlay in alignment with the grid, and a special T-Square with pins to follow the guide. Much like a perspective table with adjustable sides. Self-adhesive vanishing points are also included. The set comes with a little book on perspective but the grids require no explanation for someone versed in perspective drawing.

EDGJ

Chairman

A MESSAGE FROM THE CHAIRMAN



Garland Hilliard, Chairman EDGD
North Carolina State University

By the time you receive this issue of the Journal, Spring and all its accompanying marvels hopefully will have brightened your life as we move forward into a new year of growth for the Division. Thanks to you, this year has been most enjoyable, enlightening and challenging. I have had the opportunity to work with so many of you and have become more appreciative of the many individual efforts that preserve our Division as one of the largest and strongest in ASEE. Yet, this has been but one of many years for the oldest Division in ASEE. Historically, the same individual qualities must have been evident in our Division's past members for us not only to have arrived at this point in time, but to have excelled in the process.

During the past two years I have spent considerable time reminiscing while reviewing past issues of the Journal. Upon reflecting back with a more objective perspective, I have come to more fully appreciate past events and their impact on us today. As one example, Klaus Kroner wrote a guest editorial, "A Look Beyond", in the 1969 Winter issue of the Journal. In that article he proposed an "international focus" on graphics and recalled the attempts of Steve Slaby a few years earlier to organize an International Conference. We have since seen that vision evolve into reality not once, but twice, and plans are for a third International Conference in Vienna, Austria in 1988.

Another historical example and one that received considerable attention and controversy at its first glimmer was the idea of teaching design in engineering graphics courses. A perusal of past issues of the Journal brings to focus the advocacy and resistance surrounding such a change. History reveals how we wrestled with the idea, incorporated design into graphics courses in various ways and to various degrees at our own schools, and struggled with a name change for the Division to reflect the new emphasis. History also reveals that the Creative Engineering Design Display - a direct product of the EDGD - was an immediate success. It has continued to improve and is now one of the major highlights of the ASEE annual conferences.

One of the most dramatic and far-reaching challenges that has affected engineering design graphics in the last two decades has been the computer. The Journal documents its seemingly insignificant emergence and traces its progression over the past twenty years. Do you remember, for example, how we once marveled at the computer's ability to produce even the simplest geometric shapes in their crudest form? And this was only after painstaking hours of programming and inputting data on punched cards! Recall, too, our early workshops, summer schools, and conferences as we all tried to keep abreast of the new technology that was invading our domain? I, for one, can recall my early contempt and disdain for the computer purporting to replace even the most menial graphics functions that I had been accustomed to performing. How difficult it must have been for those early authors and pioneers to enthusiastically continue their relentless pursuits in the midst of resistance like mine? Yet, through their persistent, systematic and dedicated efforts, the groundwork was laid for the realization of the current state of the art.

Yes, in reflecting back over past issues of the Journal where significant parts of Division history are recorded in print, I am forced also to recall other not so apparent moments - moments when we were a part of history in the making. Looking back we can indeed be proud of our accomplishments and our fervor for meeting challenges square in the face. Those seemingly insignificant events and episodes - and yes, even the arguments and dissent - have influenced where we are now.

The beauty of now and the future is that we will continue to face new challenges. This June, at our Annual Conference in Atlanta, the officers you elected this past winter will assume their duties. I wish to welcome them to the important roles they will play in our future challenge and continuing journey toward excellence in the Engineering Design Graphics Division. They, too, I am sure will enjoy the same support and cooperation that has been so inherent in our Division's history. I thank each of you for the opportunity to serve as your Chairman this year.

Garland

jobs

CURRENT JOB OPENINGS

PURDUE UNIVERSITY

The **Technical Graphics Department** in the School of Technology anticipates several faculty positions to be available in the areas of **Traditional Technical Graphics, Descriptive Geometry, Electronic Drafting**, and **Computer-Aided Drafting and Design.**

Positions are at the **Assistant Professor** level and generally require a **Master's Degree** in Engineering or Technology, **teaching experience** in graphics and computer graphics; **industrial experience** preferred. Individuals with a strong industrial background are encouraged to apply. Interested individuals should contact: **Professor Jerry V. Smith,** Chairman, Technical Graphics Department, 363 Knoy Hall, Purdue University, West Lafayette, IN 47907. Purdue University is an Affirmative Action/Equal Opportunity Employer.

RENSSELAER POLYTECHNIC INSTITUTE

Possible opening for full-time tenure-track position starting Fall, 1985. Rank and salary open but prefer assistant or associate professor. Must have MFA or PhD in hand. Must be able to develop **graphics track** for **MS** in **Technical Writing** program. Expertise in **computer graphics, print media,** and theories of **visual communication** desirable. Interest in cooperating with theorists in rhetoric, composition, and communication important. Apply to **Merrill D. Whitburn,** Chair, Department of Language, Literature, and Communication, Rensselaer Polytechnic Institute, Troy, NY 12180. AA/EOE

MICHIGAN TECHNOLOGICAL UNIVERSITY

The **Mechanical Engineering-Engineering Mechanics Departmant** has tenure-track faculty positions open in the area of **Mechanical Design** emphasizing **CAD/CAM, Computer Graphics, Kinematics and Mechanisms, Acoustics and Noise Control,** and **Robotics.**

Responsibilities include undergraduate and graduate instruction and the pursuit of funded research. Rank and salary will be commensurate with qualifications and experience. Preference will be given to U.S. citizens and permanent residents. Applications will be accepted until positions are filled. Applicants should send resumes with names of references to: **Dr. Harold W. Lord,** Chairman, ME-EM Department, Michigan Technological University, Houghton, MI 49931. Michigan Technological University is an Equal Opportunity Educational Institution/Equal Opportunity Employer.

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY

The **DEPARTMENT OF CIVIL ENGINEERING,** South Dakota School of Mines and Technology, invites applications for a faculty position in **Engineering Graphics** and **Computer-Aided Drawing and Graphics.** The successful candidate will also be expected to provide leadership in the development of courses using computer-aided design in an engineering discipline. The position is a tenure-track faculty line in the Civil Engineering Department and is available mid-August, 1985. Both junior and senior-level applicants are urged to apply. Experience is highly desirable. The appointee will be expected to pursue scholarly activities. Rank and salary will be commensurate with qualifications. A resume with three (3) references should be mailed to **Dr. Thomas Propson,** Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota 57701-3995. (605) 394-2440. SDSM&T is an Equal Opportunity/Affirmative Action Employer.

THE OHIO STATE UNIVERSITY

Two Positions at the Assistant or Associate Professor Rank

Engineering Graphics; PhD in engineering, engineering education or closely related field or an engineer with MS and significant industrial experience; ability to teach technical graphics and technical illustration; familiarity with solving engineering problems using numerical methods and **computer graphics is desired**; teaches and manages graphics courses; initiates and manages development projects; serves on departmental college, or university committees; offers services to the fields of engineering and technology. This is a nine-month position starting Fall Quarter, 1985. Salary: $28,000-$38,000 ●EDGJ

Mid-Year

ASEE/EDGD MID-YEAR MEETING

CALL FOR PAPERS

ASEE Engineering Design Graphics Division Midyear Meeting

Purdue University, November 24-26, 1985

The Engineering Design Graphics Division of ASEE invites papers for presentation at its midyear meeting to be held at Purdue University, West Lafayette, Indiana, on November 24-26, 1985. The theme of the meeting is "Educational Directions in Technical/Engineering Graphics."

Papers dealing with all levels of graphics instruction are solicited. Topics include: computer graphics, computer-aided design, automated drafting, hardware and software systems, technical graphics and illustration, engineering design projects, graphics teaching techniques, graphics programs in community colleges, descriptive geometry and theoretical graphics. Submit title and 500-word abstract by July 1, 1985, to:

Mike Khonsari
The Ohio State University
Engineering Graphics Department
2070 Neil Avenue
Columbus, Ohio 43210

note:

A workshop in computer-aided graphics is planned as part of the 1985-EDGD Mid-Year Meeting at Purdue.

Participants will experience the thrill of commanding a

COMPUTERVISION CADDS 4

workstation doing such exciting things as

- making drawings
- rotating geometry
- merging entities
- intersecting solid form
- plotting the whole shebang

If you might be interested contact

Peter W. Miller
Technical Graphics
357 Knoy Hall
Purdue University
West Lafayette, IN 47907

papers
REVIEWED TECHNICAL PAPERS

LASER DISCS AND MICROCOMPUTERS STATE-OF-THE-ART INSTRUCTIONAL TECHNOLOGY FOR ENGINEERING GRAPHICS INSTRUCTION

by

Dr. Leonard O. Nasman

Engineering Graphics Department
The Ohio State University
Columbus, Ohio 43210

ABSTRACT

Although laser videodisc technology has been available for a number of years, several factors have prevented widespread applications in engineering graphics education. Among these factors are: lack of information about the technology, the relatively high cost of hardware, difficulty of interfacing videodisc players to microcomputers, and the lack of availability of videodisc materials which have been specifically designed for engineering graphics instruction. This paper provides the reader with an overview of the current state-of-the-art of interactive videodisc technology, and outlines the author's plans to develop a videodisc specifically designed for use in engineering graphics instruction.

THE BEGINNING

Videodisc technology got its start in 1923 when James Baird began work on mechanical scanners and video display devices. (1) In spite of early and continuing experiments with videodisc technology over the last five decades, however, videodisc technology did not receive much notice by either the general public or the educational community until recently. The aborted attempt by RCA to enter the consumer market with a videodisc player using CED (capacitance electronic device) technology did little to demonstrate the credibility of videodiscs as an important instructional medium. The establishment of videodisc technology as a viable interactive instructional medium may be traced to the development of a standard laser-optical disc format by Phillips, and its acceptance by several major Japanese firms such as Sony and Pioneer.

THE ORIGIN OF TECHNICAL EDUCATION

Before dealing with the nature of interactive videodisc technology, and before deciding if it has potential as an effective instructional medium, let's briefly review the nature of instruction and instructional technology. Technical education and training had its beginnings in the apprentice system. Young men were assigned to a skilled craftsman, and were called upon to assist him in tasks of slowly increasing complexity as the apprentice observed the master and acquired skills and knowledge of his own. If we put aside for the moment consideration of the morality and ethics of assigning a young person to a sometimes indefinte period of servitude without consent, we might conclude that the apprentice training system had many instructional benefits. It was truly individualized. The learners all had the benefits of the personal attention of the master, and got a great deal of hands-on experience.

consider the technology in the context of learning theory and economics

As society, population, and technology underwent changes, education moved from the master's workshop with its small number of learners, to the large-scale public institutions we have today. Instructional technology became increasingly important as educators had to abandon the "show them, watch them, show them" approach of the apprentices' masters. Probably the first instructional delivery system used for simultaneously providing instruction to large numbers of students was the lecture. The lecture method, in spite of years of educational research demonstrating that it is one of the least effective instructional strategies, remains one of the most common methods of instruction. The primary reasons for this, I believe, are economics and laziness. Lecturing to a large group of students is relatively inexpensive. And, an average instructor can "wing" a socially acceptable lecture with no more preparation than thinking a little about the subject on the way to class.

Hi-Tech
APPLICATIONS FOR TEACHING

INSTRUCTIONAL TECHNOLOGIES

Regardless of the presence or absence of research on the effectiveness of various instructional technologies, application of these technologies by instructors seems to be directly related to ease of use. Instructors will use a chalkboard as long as it's fixed to the wall, and as long as they don't have to bring their own chalk. Overhead projectors are in common use, although more often than not the visuals used are typed, single-spaced pages full of information, unreadable to anyone sitting beyond the first two rows (which students, and audiences rarely seem to occupy). Many instructors are rightfully skeptical of new instructional technologies because they have observed so many fads and fancies presented by salespeople as the last word in delivering instruction faster, cheaper, and easier. Some instructional delivery systems have solid educational research supporting their use, but are impractical simply because they are too expensive to obtain or maintain. Such is the case of the PLATO system of computer assisted, computer managed instruction developed in the 1960's and 70's. PLATO was developed with large grants from the National Science Foundation. Quite a number of the more than 10,000 lessons developed for PLATO were proven effective by various educational researchers. However, at $1,200 per student work station per month, the system was too expensive for most institutions. In considering any new instructional technology, such as interactive videodiscs, we should consider it in the context of what we know about learning theory, and with attention to economic practicability.

LEARNING THEORY

Without getting into an academic discourse on research in learning theory, I would like to reflect on several, almost "common sense", principles of learning. One is that the more senses the learner is required to use, the more the learner retains. Research has shown that individuals retain about 10% of what they read, 20% of what they hear, 30% of what they see, and 50% of what they see and hear (2). Furthermore, when the learner is required to immediately complete an action that demonstrates what the learner has seen and heard, there is a dramatic increase in retention. It should be no surprise that research shows the lecture to be an ineffective (even though economical) means of delivering instruction.

Movies and television, although attacking more senses than lectures, do not require the active participation of the learner. Computer assisted instruction, when properly designed, does require the active participation of the learner. Computer assisted instruction, however, even on prohibitively expensive main-frame computers, cannot compete with color slides for visual impact, or movies or television for motion and sound. Color slides can be mixed with audio tape, or with a live presentation, to enhance instructional delivery. However, for an instructor to maintain and transport a library of several thousand, or even several hundred color slides, is a considerable undertaking that only a few dedicated souls would consider.

INTERACTIVE VIDEODISC TECHNOLOGY

The two major types of videodisc technologies used are the CED system and the optical laser discs. The CED system, now abandoned by RCA, uses a stylus (much like a very fine phonograph needle) which follows grooves on the surface of the disc. There are several problems associated with this approach. For one, it is not possible to randomly access individual frames on the disc, or to "freeze" on one frame for an indefinite amount of time. Although the CED discs are inexpensive to reproduce, they are largely restricted to a continuous play mode, much like a movie. Because the stylus and grooves are subject to wear, the expected life of both the stylus and the discs is fairly short (3).

The optical laser disc uses a narrowly focused beam of light reflected from a surface containing microscopic pits. Since nothing but light contacts the disc surface, wear on discs or disc players is not a factor. Laser discs are made in two formats, controlled linear velocity (CLV) and controlled angular velocity (CAV). CLV discs allow for up to 60 minutes of television, with stereophonic sound. CLV discs essentially compete with movies as an instructional medium. CAV discs allow for the storage of up to 30 minutes of television, with stereophonic sound. CAV discs, however, also allow the capability of complete random access to any of the possible 54,000 individual frames on the disc, and the capability of "freezing" indefinitely on any single frame (4). This means that it is possible to store the equivalent of 54,000 color slides in the space of an LP phonograph record, and to access any one of them in a worst-case search time of less than 5 seconds.

It is also possible to mix still frames and motion sequences. The motion sequences are displayed at 30 frames per second. Still and motion sequences may be stored on the same disk in any combination that adds up to a total of 54,000 frames. The CAV disk holds two channels of audio. These may be used to contain either stereophonic sound, or completely separate audio tracks. An application of the separate audio track feature would be to provide a choice of different languages, or different levels of explanation with the same video.

It should be noted that when the videodisc player is used to freeze on a single frame of video, the audio is not available. However, several manufacturers are marketing various devices to provide "compressed audio" for use with still frames. One of these devices allows over 100 hours of audio on one disc.

Laser videodisc players are classified into three levels (5). **Level one** players, such as the Pioneer VP-100, have a controller which allows the user to directly control functions such as: playback, search, freeze-frame, slow motion, forward, reverse, or fast scan. Some models can read chapter, stop, or scan codes if they are encoded on the disc. **Level two** players, such as the Sony LDP-1000, or the Pioneer 8210, have built-in microprocessors that allow some degree of programming. Controlling programs can be encoded directly on the disc, and are automatically loaded and executed when the player is turned on. This type of videodisc player is being used in training applications in the military and in private industry. Level-three systems consist of either level-one or level-two players coupled with a computer. **Level-three** systems, therefore, generally form the basis for what is commonly referred to as interactive videodisc technology. The most sophisticated level-three systems also provide for superimposing computer generated video directly over videodisc supplied video. Complete level-three systems are currently being marketed by a number of large companies such as Sony, Digital Equipment Corporation, and National Cash Register.

Videodiscs are significantly different from video tape in a number of ways. The advantage of disc over tape is in the area of fast random access, picture quality, durability, freeze frame and step frame capability, and ease of use. The disadvantage of disc compared to tape is in production. Videotape is both a playback and record medium, while videodiscs are playback only. It should be noted that videodisc recorders (sometimes referred to as "direct-read-after-write devices) are available, but are currently very expensive (starting at about $30,000). (6)

THE GOOD NEWS!

INTERACTIVE VIDEODISCS AS AN INSTRUCTIONAL DELIVERY SYSTEM

Let's review how interactive videodisc systems stack up against our analysis of learning theory. To be effective in increasing long-term retention, an instructional delivery system should allow us to attack as many of the learner's senses as possible. The system should allow for the learner to be **actively**, rather than passively **involved**. Interactive videodisc systems can provide text, audio, and visual materials in a manner previously unavailable. The systems can allow the merging of the best of the worlds of audio-visual aids and computer assisted instruction. Interactive videodisc systems have the potential of being the most effective delivery system short of the master craftsman individually training each apprentice.

But what about the cost? We should remember that even though computer assisted instruction on systems such as PLATO has been proven to be educationally effective, the cost of the required hardware can prohibit large scale application. Videodisc systems are not yet inexpensive (although a videodisc player was recently advertised, in a Columbus, Ohio newspaper, for less than $300). The trend is promising, however. In 1982, commercial-grade videodisc players cost about $3500 each. In 1984, players with more capability than the 1982 models are priced at less than $1000. Complete interactive systems are currently priced from $5500 to $12,000. Based on observed trends (and photos of Japanese systems not yet being imported into the U.S.), the author expects complete interactive systems, with video overlay capability, to be priced at less than $2000 per work station within two to four years. If this estimate is close to correct, we should have large numbers of interactive videodisc systems in schools and universities by 1990.

AND NOW THE BAD NEWS!

VIDEODISC AND SOFTWARE PRODUCTION

The biggest problem in using interactive videodisc systems in education is the lack of availability of both appropriate videodiscs and CAI software. Since videodiscs cannot be produced as simply as videotapes, the average educational institution is unable to develop original videodiscs. The process for developing videodiscs is to first generate a high quality one-inch video tape, and then send it to one of a limited number of disc production facilities for generating the master disc and multiple copies. The result is that in small quantities, the per copy cost is fairly high. If more than 100 copies of a disc are made, the cost per disc is less than the per copy cost of videotape. (7) Producing an original disc is no easy matter. If, for example, an instructor wanted to take advantage of the capacity of the disc and put 54,000 separate color slides on the disc, the slides would first have to be made or obtained. Then, they would have to be copied onto a master video tape. This might cost as much as one dollar per picture. You don't have to be much of a mathematician to see that it would cost more than the average instructor has in the petty cash fund. This only speaks to the cost of putting material on the disc. Before this can even be started, a great deal of planning must be done. This requires time, which is simply another way of saying **it costs money**. The cost to develop a typical educational videodisc ranges anywhere from $50,000 to $200,000. For a good description of the videodisc development process, you might want to review a chart prepared by WICAT Systems, and published in Byte magazine. (9) Even an institution with a large number of students would find it hard to justify the per student cost of developing a videodisc. Although the cost of videodisc hardware has been dropping, and is expected to continue to drop, the cost of videodisc development is unlikely to decrease.

So far we have only looked at disc production costs. Before the disc can be merged with a computer to complete the interactive system, computer assisted instruction software must be prepared. The literature asserts (and the author's experience has verified), that it takes anywhere from 200 to 500 hours to develop 1 hour of computer assisted instructed software. (10) For the equivalent of a forty-hour course, it costs an average of $200,000 to develop a complete computer assisted software package. One of the reasons for this high cost is that to develop good instructional software, it takes a team of people including: a content area specialist, a media expert, someone familiar with learning theory, a curriculum development specialist, and a programmer. The use of higher level authoring languages can reduce the need for programmers, but at the expense of using up computer memory and reducing flexibility in the software.

The only way likely to make the per student cost of videodisc and software development reasonable is to spread the development costs over significantly large numbers of students. This means developing materials that are used in large numbers of institutions. Before this will happen, instructors will have to be willing to accept curriculum and materials developed outside of their own institution, or materials that have been developed through the efforts of consortiums.

I have had a dream.......

AN ENGINEERING GRAPHICS INSTRUCTIONAL MEDIA DREAM

Ever since I saw a videodisc player in action, I have had a dream. My dream is to have a videodisc with every audio-visual aid that I can imagine for teaching engineering graphics, engineering drawing, and drafting. I would be able to access, within a few seconds, illustrations for every topic from the alphabet of lines to welding symbols. I imagine dozens of color pictures showing different fractional, decimal, or metric scale readings from which random individualized quizzes could be generated. I can see pictures illustrating shop processes. Not just a photo of each machine, but sequences of photos that show, step by step, how the machine works. Once you gain a feel for the potential capacity and applications of interactive videodisc technology, the head seems to spin and dance with exciting possibilities for enhancing instruction. The first problem in having this dream come true is the availability of an engineering graphics disc, and the second is the availability of the instructional software that uses the disc. Well, I've gotten impatient with waiting around until such a disc is developed. So, I have taken some small first steps to begin the development of a videodisc that will contain materials that can be used to teach engineering graphics, engineering drawing, and drafting at all levels from the university to junior high schools.

I have formed a company called Microcomputer Education Systems Inc., and I have started collecting and developing materials to be used on a generic graphics disc. The materials will primarily be color slides that, once they are on the disc, can be accessed in a variety of ways. They could be used as visual aids in normal classroom presentations, or they could form the basis for a number of different computer assisted instruction packages. To date, I have gathered about 2,000 slides. I hope to have enough materials collected so that about a year from now I will have a prototype videodisc to show. At the moment, I am proceeding with a beer-budget, one-man, skunk-works, operation. Even so, it is a start. With a little good fortune, it is possible that by the time low-cost interactive videodisc systems are available, I will have the basis for developing some respectable instructional materials. I am willing to put my time, energy, and resources into this project because I am convinced that interactive videodisc technology will provide significant improvements in the delivery of engineering graphics instruction. Your thoughts and comments regarding this undertaking would be most welcome.

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INTERACTIVE VIDEODISC SYSTEM HARDWARE MANUFACTURES

Digital Equipment Corporation
Educational Services Division

NCR Corporation
World Headquarters
Dayton, Ohio 45479

Sony Corporation of America
Sony Drive, Park Ridge, NJ 07645

●EDGJ

PUTTING THE ELLIPSE IN PERSPECTIVE

By Charles G. Moore
Northern Arizona University

When enrolled in a course in engineering drawing years ago, I was impressed with the ingenious techniques draughtsmen had devised for drawing curves to approximate the ellipse. For example, the four-point method resulted in a figure composed of four circular arcs and provided a fair approximation to an ellipse. An example of this curve is shown in figure 1.

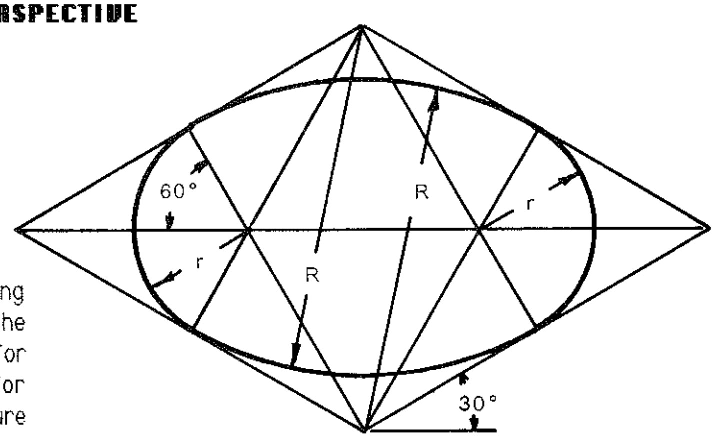


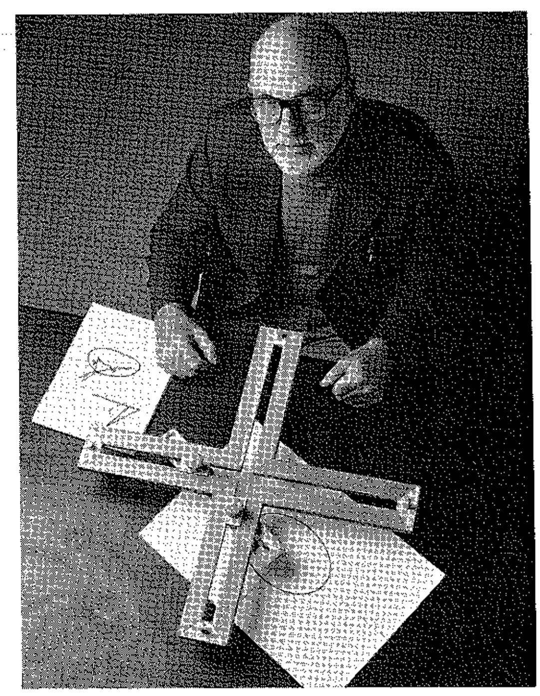
FIGURE 1

If a focus, directrix and the eccentricity are given, points may be constructed that lie exactly on the ellipse. After a sufficient number of discrete points have been located the judicious use of a french curve can produce a pleasing continuous curve which is still only an approximation to the ellipse containing those points.

It is possible now to purchase commercially prepared plastic templates from which ellipses can be drawn. Templates of various sizes based upon the projection of a circle at an angle of 15º, 30º, 45º, and 60º are common. Templates based upon projections at other angles are available at greater expense. Eventually storage becomes a problem and all one can do with the ellipse templates is use the one that comes the nearest to fitting a given situation. It is sometimes possible to **select a template to first draw an ellipse and then fit the rest of the technical drawing around it.** This process is unsatisfactory for the draughtsmen or technical writer because he feels that important properties of his drawing are dependent upon the template selected.

Would it not be better if it were possible to draw exactly the ellipse desired? It is the purpose of this paper to present both the mechanical and mathematical theory for a solution to this problem.

A device which will draw a continuous ellipse with any given semi-major and semi-minor axis may be built based upon the trammel concept. The author (see photograph) is shown with a working model of an "ellipsicom" of his own design. The semi-major and semi-minor axes A and B are set on the sliding arm.



The axes of the ellipsicom are then aligned with the axes of the desired ellipse and the continuous ellipse is then drawn by moving the sliding arm in its guide grooves. Details of the instrument are shown in figure 3.

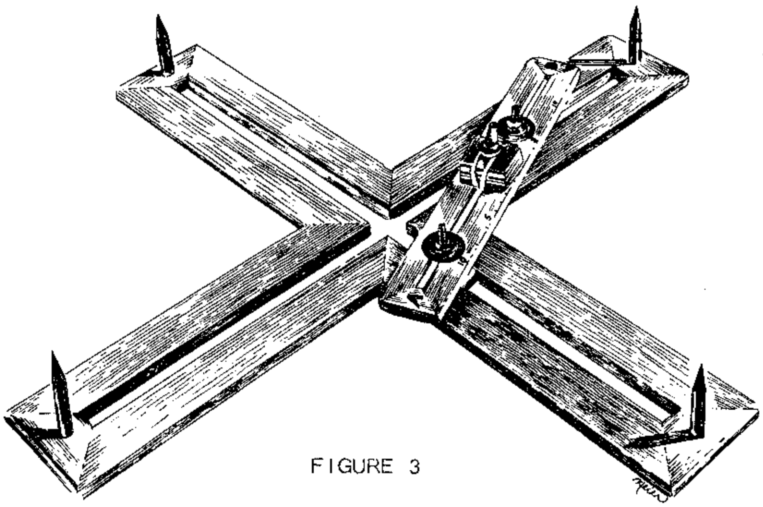


FIGURE 3

In order to state a problem the solution of which requires both the ellipsicom and some college mathematics, let us review the basic principles of two-point perspective drawing.

Principle 1) Parallel lines in perspective recede toward a single point on the horizon called a vanishing point.

Principle 2) The property of being an ellipse is invariant in perspective.

Principle 3) The property of tangency is invariant in perspective.

Problem: Draw in perspective an ellipse inscribed in a rectangle with major and minor axes parallel to the sides of the rectangle. Figure 4 shows a rectangle P1P2P3P4 drawn in perspective. Our problem is to construct the required ellipse. The center of the rectangle in perspective is the point of intersection of the diagonals. The intersection of the lines through the center parallel to the sides of the rectangle with the remaining two sides identifies the points of tangency T1,T2,T3, and T4 of the ellipse with the rectangle. Our problem is to construct the ellipse which is tangent to the rectangle at T1,T2,T3 and T4.

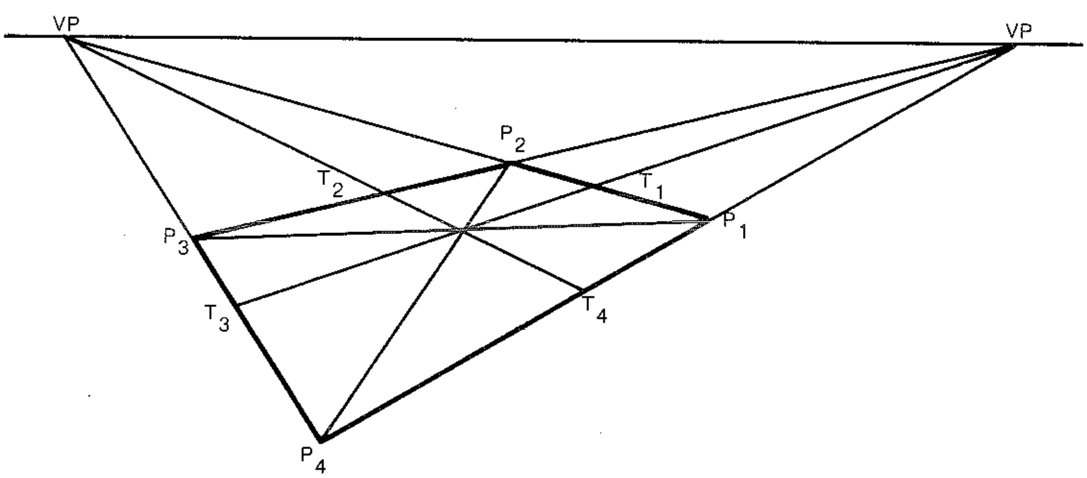


FIGURE 4

The work is simplified considerably by the fact that an easy construction exists for the location of the center of the required ellipse in perspective. The construction of the center will be based upon the theorem from the classical geometry of the ellipse that states that a line through the intersection of two tangents to an ellipse and passing through the midpoint of the chord joining the two points of tangency will also pass through the center of the ellipse. See figure 5.

The validity of the theorem may be verified by considering the construction on a circle and then projecting the construction at an angle onto a plane.

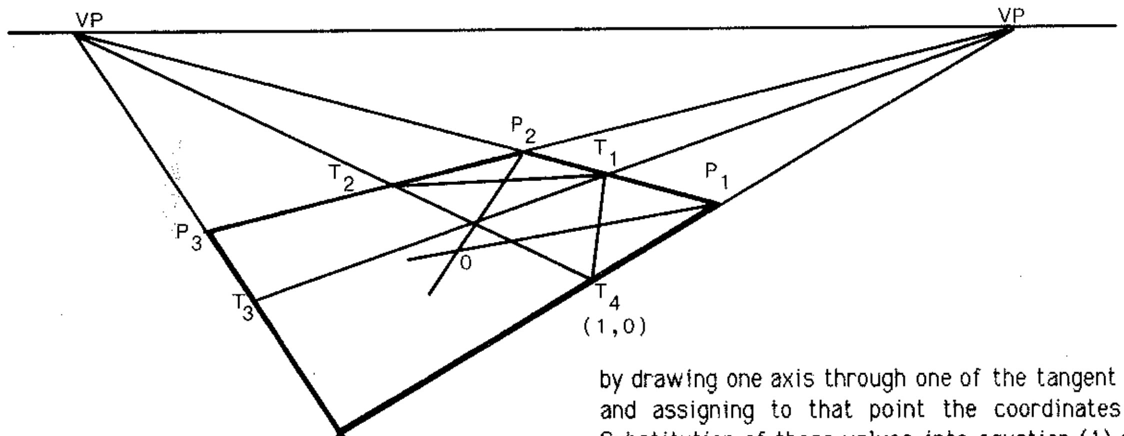


FIGURE 5

To locate the center, O, we may draw a line through P1 and the midpoint of chord T1T4 and a second line through P2 and the midpoint of chord T1T2. The center O is shown in figure 5.

By the utilization of Pascal's line and Brianchon's point [1], more points can be constructed on the ellipse but they do not enable us to identify the position and lengths of the major and minor axes of our inscribed ellipse. To identify these elements we shall turn to the standard analytic geometry for the rotation of axes.

If we take the center O to be the origin of a rectangular coordinate system we know that the ellipse we wish to construct is symmetric with respect to the origin and its equation is of the form

(1) $ax2+bxy+cy2 = 1$

We can substitute the coordinates of any three of the four points T1,T2,T3 and T4 that lie on the ellipse into equation (1) yielding three equations in three unknowns which may be solved by Cramer's rule. A considerable simplification can be achieved, however, by drawing one axis through one of the tangent points and assigning to that point the coordinates (1,0). Substitution of these values into equation (1) causes the coefficient a to have the value 1. Consequently, it will only be necessary to solve two equations in two unknowns to find the values of coefficients b and c. Assigning (1,0) to T4 in figure 5, (x1,y1) and (x2,y2) to points T1 and T2 respectively, and substituting these in turn in equation (1) we arrive at the equations

$$bx_1y_1+cy_1^2 = 1-x_1^2$$

$$bx_2y_2+cy_2^2 = 1-x_2^2$$

Solving by Cramer's rule yields

$$\Delta = 1(x_1y_1)y_2^2-(x_2y_2)y_1^2$$

$$b = \frac{(1-x_1^2)y_2^2-(1-x_2^2)y_1^2}{\Delta}$$

$$c = \frac{(1-x_2^2)x_1y_1-(1-x_1^2)x_2y_2}{\Delta}$$

We next let represent the angle through which the axes must be rotated to eliminate the xy term causing the axes of the required ellipse to be contained in the axes of a new x',y' system. From the theory for rotation of axis we know $= \frac{1}{2} \arctan \frac{b}{a-c}$

and with a = 1 $= \frac{1}{2} \arctan \frac{b}{1-c}$. Further, the substitutions x =cos x'-sin y' and y = sin= x'+cos y' result in the new equation

$$(2)\quad a' x'^2 + b'y'^2 = 1$$

and the longer of A and B yields the semi-major axis and the shorter the semi-minor axis of the required ellipse.

where

$a' = \cos^2 + b \cos \sin + c \sin^2$

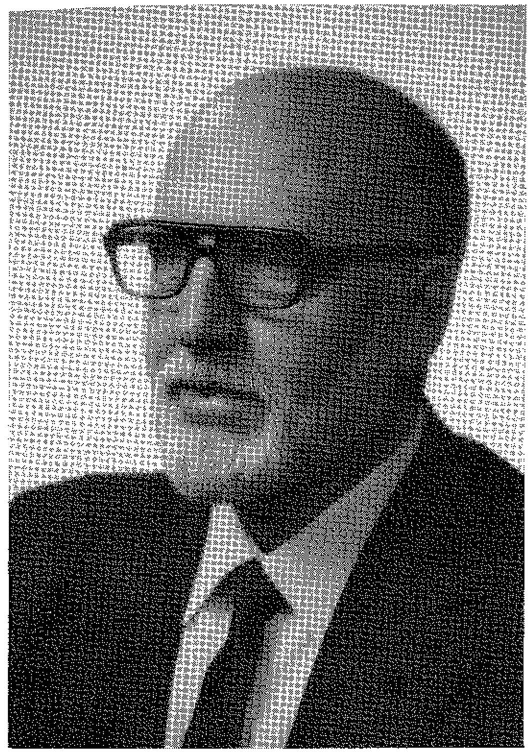
$b' = \sin^2 - b \sin \cos + c \cos^2$

we now let A=1 and B=1 and equation (1) takes the form

$$(3)\quad \frac{x'^2}{A^2} + \frac{y'^2}{B^2} = 1$$

and the longer A and B yields the semimajor axis and the shorter the semiminor axis of the required ellipse.

It is important to note that the computation for b,c,A and B involve only the four basic operations and the extraction of square roots and are, consequently, constructable with Euclidean tools. We may use the length of the segment from the center O to the point (1,0) as a natural unit for the problem. The constructions for products, quotients, square roots of line segments and the angle of rotation are reviewed in figure 6.



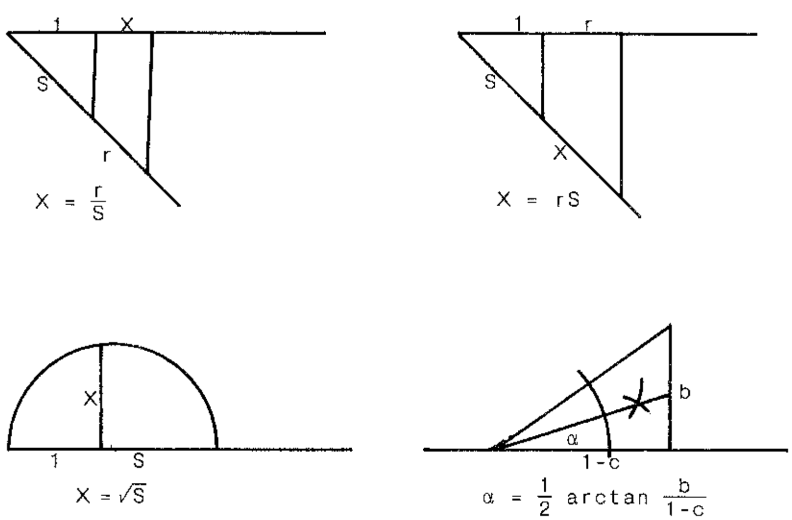


FIGURE 6

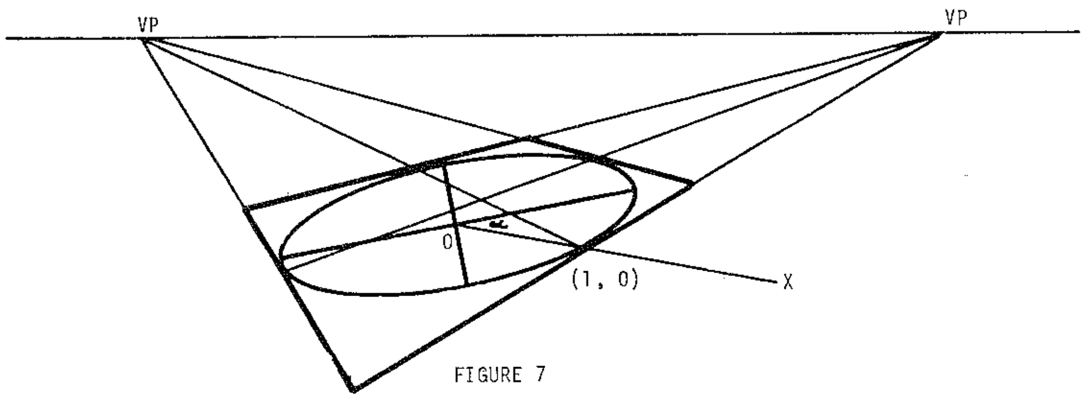


FIGURE 7

Once the rotated axes x' and y' have been drawn and A and B have been determined and set on the slider bar of the ellipsicom the continuous ellipse can be drawn and the required ellipse in perspective is shown to be constructable. In figure 7 the required ellipse is shown drawn in place.

If a situation arises where a true ellipse in perspective is needed, plastic templates, approximate methods of drawing or discrete points joined by a french curve will be unacceptable and an engineer with a knowledge of the foregoing principles will be required. The methods described also provide the calculus teacher with an application of the standard techniques of rotation of axes.

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EDGJ

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Editor's Note:

Professor Moore's paper presents a good treatment of a fundamental problem in graphics: how to make an ellipse formed by orthogonal projection fit the world of perspective projection. The method outlined here **approximates** a perspective ellipse by fitting an orthogonal ellipse within a correctly constructed enclosing form. Many graphics situations require that the perspective ellipse (which is not a symmetrical orthogonal ellipse) be plotted for accuracy. I'm sure those readers of the EDGJ who deal with perspective every day will recognize this limitation.

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Tolerance
MANUFACTURING CONTROL
EDUCATIONAL TOPICS

GEOMETRIC TOLERANCING IN DESIGN GRAPHICS EDUCATION FOR THE PRESENT AND FUTURE

BY
Richard S. Marrelli
Professor Emeritus of Industrial Education
Los Angeles Pierce College
Woodland Hills, California

ABSTRACT

This treatise advocates incorporating instruction in geometric tolerancing in the design graphics curriculum to accommodate present and future demand from industry.

Geometric tolerancing is defined, a brief history is given, and its value in design engineering is explained. A resume is present of the various geometric characteristics controlled by the system of geometric tolerancing and the advantages accrued from its use. Two examples are given to illustrate cost savings made possible. The importance of the subject in design and industrial engineering is stressed. Methods of qualifying prospective instructors are discussed; also the duration and format of possible courses are investigated and prerequisites are defined. All available texts are listed and briefly reviewed. Finally, information is given on visual aids and video training programs available at this time.

DEFINITION

Geometric tolerancing is used in the design and production of manufactured goods. It is the technique of assigning appropriate permissible error in the geometric characteristics of an object--the form of the object and the relationship of its features. In modern engineering drawing it is necessary to specify geometric tolerances as well as dimensional tolerances in order that each part will fit properly and perform the desired function.

THE NEED FOR GEOMETRIC TOLERANCING

Before mass production, when the same workman made both or all parts of an assembly, proper fits were attained by the individual worker so the assembly functioned according to the intent of the designer. With mating parts made in different plants and by sub-contractors, sometimes overseas, it is now necessary that the designer's intent be clearly delineated on the drawings.

In the more recent past, before the advent of geometric tolerancing, there was always a question about the geometric characteristics of an object. How **truly flat** did a surface need to be? How **truly concentric** were two cylinders shown on a common axis? These characteristics were seldom specified on the drawing, and when they were, usually by local notes, they were often misinterpreted by manufacturing and quality control. Sometimes a machinist spent too much time achieving precision that was not necessary and other times adequate precision was lacking and parts did not fit or function properly.

Geometric tolerancing has solved these problems by providing a standardized precise method of specifying all geometric characteristics.

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the units could be barleycorns or furlongs and the rules & practices would be the same

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A BRIEF HISTORY

Just before World War II at the Royal Torpedo Factory in Scotland, engineers began to develop a system of symbols to convey the design requirements more precisely to the manufacturing department. These symbols, with some additions and refinements, became the basis of our American standard on geometric tolerancing, which is now a part of a document of the American National Standards Institute (ANSI) entitled Dimensioning and Tolerancing of Engineering Drawings. The latest edition was formulated in December, 1982, and started circulation in 1983. It is designated ANSI Y14.5M-1982. The "M" stands for "metric". All the units used in this standard are millimeters, but this does not impede the use of the standard by organizations using English inches. In fact, the units could be barleycorns and furlongs, and the rules and practices would be the same.

Until 1966 the Federal Government had its own standard on dimensioning and tolerancing which was known as MIL-STD-8. In that year the then current ANSI standard was adopted for all design engineering and manufacturing on Government contracts. The acceptance of one standard in this area was a giant step forward in standardization.

THE VALUE OF GEOMETRIC TOLERANCING IN INDUSTRY

Geometric tolerancing is useful not only for precision machinery but for all engineered manufactured goods, even where there is no movement, products such as storage racks and cabinets--cabinets of large and small appliances and for electronic equipment. Simple one-piece items such as barn door handles and door-stop wedges are very successfully produced without geometric tolerances.

The manufacturing industry is turning to geometric tolerancing primarily because it increases productivity and reduces cost. The advantages may be summarized as follows:

1. It **increases productivity** by specifying maximum but workable tolerances, in many cases permitting manufacturing variation beyond the tolerance specified on the drawing. And that reduces cost.

2. It **ensures interchangeability** of mating parts.

3. It specifically **states design requirements** as they relate to function, making possible the use of functional gages and ensuring proper fits.

4. It **provides convenience** and uniformity in drawing delineation and interpretation.

5. It ensures effective documented communication between engineering and manufacturing and between engineering and quality control, not only throughout the United States, but, with minor variations, among all industrialized nations.

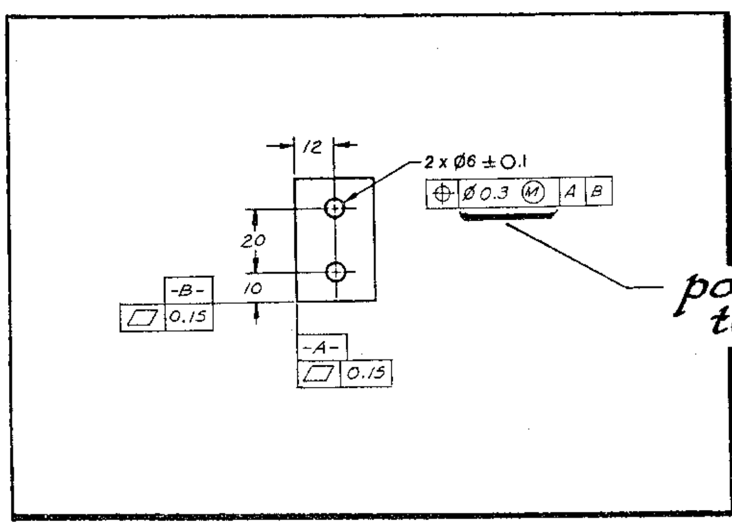


Figure 1. A Drilled Plate Dimensioned with Positional Tolerance

rejection rates have been lowered as much as 24%

A RESUME OF GEOMETRIC TOLERANCES

Geometric tolerances are grouped in five categories and thirteen characteristics as listed below. The symbol preceding each characteristic is used to specify that characteristic on drawings.

Form Tolerances

- ⏤ Straightness
- ⏥ Flatness
- ○ Circularity
- ⌭ Cylindricity

Profile Tolerances

- ⌒ Profile of a Line
- ⌓ Profile of a Surface

Orientation Tolerances

- ∥ Parallelism
- ⊥ Perpendicularity
- ∠ Angularity

Runout Tolerances

- ↗ Circular Runout
- ⌰ Total Runout

Location Tolerances

- ◎ Concentricity
- ⌖ Position

The most important and most commonly used of these geometric controls is position tolerance, which is the permissible variation of a feature from its intended location. A typical application is the location of a number of holes drilled in a plate and located by coordinates as in Figure 1.

The location tolerance is expressed not with the coordinate dimension but with the hole size callout, as a diametral area, called a <u>tolerance zone</u>, centered on the true axis of each hole. In Figure 1 the tolerance zone is 0.3 mm diameter. An enlarged view of the tolerance zone for one of the holes is shown in Figure 2. The actual axis may be anywhere within the tolerance zone.

A comparison between a positional tolerance zone (a circle) and a coordinate tolerance zone (a square) is shown in Figure 3. The positional tolerance provides 57% greater variation in the actual hole position with absolute assurance that the drilled plate will match the mating part.

Parts which formerly would have been rejected for being out of tolerance are now acceptable, dimensioned with geometric tolerances.

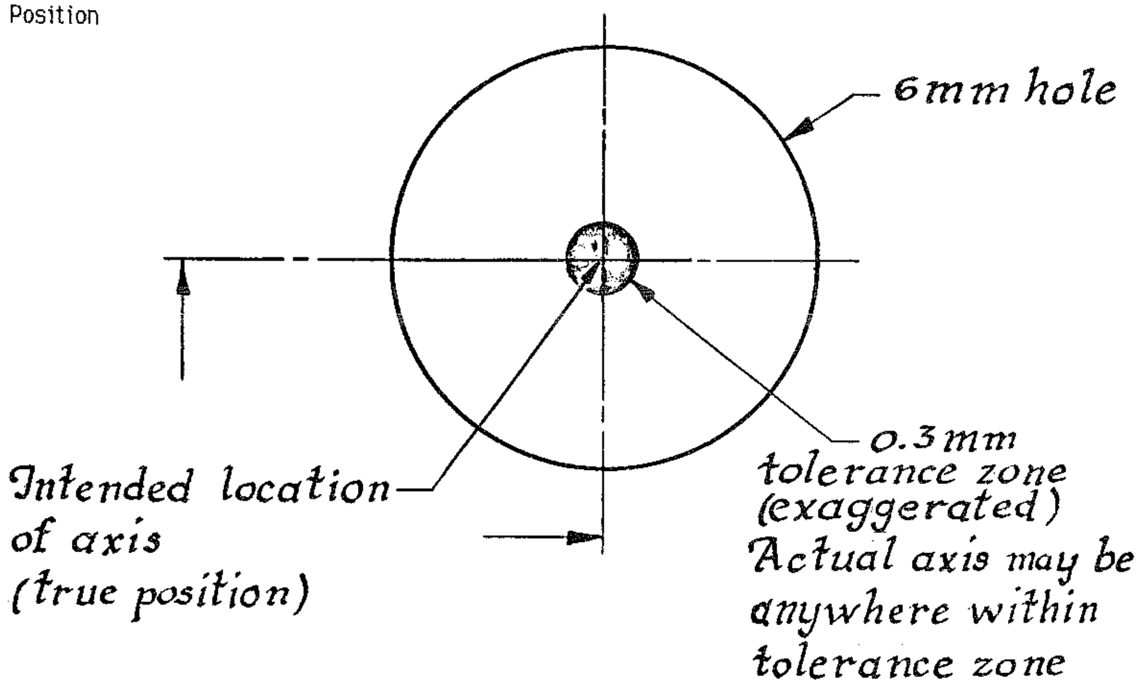


Figure 2. Enlarged View of Positional Tolerance Zone

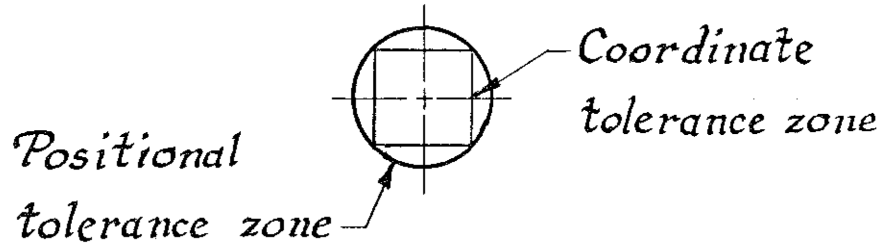


Figure 3. Comparison of Positional Tolerance Zone with Corresponding Coordinate Tolerance Zone

Another important cost-saving concept used in geometric tolerancing is the maximum material condition (MMC). The MMC of a feature is the condition of size within the prescribed limits where a feature contains the **most mass**--the largest permissible size for a solid feature such as a shaft, and the smallest permissible size for a hole or other hollow feature.

In all situations where parts need to assemble but a special close fit is not required, both parts are given positional tolerance limits which apply only at their MMC. When the parts as produced are not at MMC (not the largest shaft or smallest hole, for example) additional tolerance in a controlled amount is automatically allowed. The parts will assemble as easily as if they were at their nominal sizes. In Figure 1 the 0.3 tolerance applies only at the MMC of the holes (smallest diameter, 5.9). This is indicated by the circled "M" following the tolerance value. If the holes in an actual part should be their largest permissible diameter (6.1), then an additional position error of 0.2 is allowed, or a total error of 0.5.

Stated for the general case, if a feature as produced is not at its MMC, it can be more out of position and will still fit the mating part.

Using positional tolerance with the 57% larger tolerance zone and the MMC concept, rejection rates have been lowered as much as 24%.

INDUSTRY LOOKS TO COLLEGES FOR TRAINING

Geometric tolerancing is now so widely used that every student looking forward to a career in design engineering should be thoroughly familiar with it. If an engineer is to design machinery and other manufactured goods, he or she must be able to use geometric tolerancing techniques effectively.

Many engineering managers complain that incoming engineers are not adequately trained in geometric tolerancing. Many companies have instituted training programs conducted by an experienced member of their staff or by an outside consultant. They would prefer, however, that local colleges provide this training. They feel that education is the proper responsibility of the schools and they should be able to employ fully trained personnel.

In the Los Angeles area, four of about 20 community colleges are offering courses, mostly at night and mostly attended by working professionals who missed geometric tolerancing in their education.

What is needed is to incorporate this subject into the design graphics curriculum so that all engineering students who need the training will have it. This does not apply to engineering schools where the curriculum is strictly analytical--not design oriented. An engineer who devotes his career to analyzing and researching thermal or vibration problems or dealing with computer simulations, never involved with hardware design, has little need for geometric tolerancing. However, for schools which offer instruction in machine design or those offering a major in engineering technology or industrial engineering, geometric tolerancing is as important as descriptive geometry or strength of materials.

EDUCATING THE EDUCATORS

If we are to offer courses in a new subject, we need qualified instructors. Where do we find them? How do we train them? Many currently employed instructors already have the knowledge, especially those who were drawn from industry. For those who do not, an after-hours or summer course can be taken if another school in the vicinity offers it. Seminars are available throughout the year, conducted by experts who make this their business. There are at least two private companies offering seminars nationwide on geometric tolerancing. These are listed below. Also listed are four outstanding consultants, individuals who provide the same training. The companies and consultants present their seminars in large population centers around the country, and by special arrangement will conduct a seminar at any school or industrial firm. Many engineering schools have sponsored such seminars for their own people and for nearby colleges and the industrial community. A typical three-day program costs $300 to $400 per person.

<u>Sources for Seminars</u>

TAD Institute of Cambridge
Course Registration
PO Box 25
Beverly, MA 01915
(617) 927-3555

American Institute for Quality and Reliability
6583 Belbrook
San Jose, CA 95120
(408) 268-5700

Lowell W. Foster
3120 East 45th Street
Minneapolis, MN 55406
(612) 722-9115

H. Gary Whitmire
PO Box 18968
San Jose, CA 95158
(408) 283-9131

The cost of running a course in geometric tolerancing is low. No expensive equipment or special facilities are required. Prerequisites should be two semesters of engineering drawing and a course in manufacturing processes. Descriptive geometry may be taken concurrently.

TEXTS AVAILABLE

Not many teaching texts are commercially available. A summary of those now in print is given below. They are all softcover, 81/2 x 11 pages size, and profusely illustrated with line drawings. The prices given at list bookstore prices are 20% less.

GEO-METRICS II--THE APPLICATION OF GEOMETRIC TOLERANCING TECHNIQUES (USING CUSTOMARY INCH SYSTEM), 310 pp, $18.95

Lowell W. Foster
Addison-Wesley Publishing Co. (617) 944-3700
Reading, MA 01867

Revised 1983 edition contains an addendum based upon latest ANSI (1982) practices. Mr. Foster is the leader in this field. Excellent handbook for professional use but not easy to teach from. Does not contain problems.

GEO-METRICS

Identical to GEO-METRICS II except that it is metric.

MODERN GEOMETRIC DIMENSIONING AND TOLERANCING, 216 pp, $9.95

Lowell Foster
National Tooling and Machining Association
9300 Livingston Road 248-6200
Washington, DC 20022

Condensation of the author's GEO-METRICS II. Good teaching text. Includes a 55-pages bound-in workbook. Difficult to remove sheets. Lacks an index. Answer book available.

APPLIED GEOMETRIC TOLERANCING, 690 pp, $27.50

Samuel J. Levy
TAD Products Corp. (617) 927-3555
PO Box 25
Beverly, MA 01915

Includes a supplement based upon latest ANSI (1982) practices. Most comprehensive of all. Contains a quiz after each chapter. Includes seven appendixes on related topics such as gaging and statistical tolerancing. Lacks an index. Too complicated.

GEOMETRIC AND POSITIONAL TOLERANCING--A REFERENCE BOOK, 96pp, $11.50

Aubrey N. Yuen
TAD Products Corp. (See address above)

A how-to approach, designed as a self-teaching text. Contains a bound-in workbook with answers. Does not treat all topics of the subject. Based on the 1973 standard. Overpriced.

GEOMETRIC DIMENSIONING AND TOLERANCING SIMPLIFIED, 305 pp, $24.75

H. Gary Whitmire and James Swarthout, 305 pp. $24.75
TAD Products Corp. (See address above.)

Designed as a teaching text and reference. Includes three sections of "workshop" problems with analysis of the correct answers. Overpriced.

GEOMETRIC TOLERANCING--A TEXT-WORKBOOK, 244 PP, $8.00

Richard S. Marrelli
Glencoe Publishing Co. (818) 990-3080
17337 Ventura Blvd.
Encino, CA 91316

Designed as a teaching text. Includes a bound-in workbook with perforated pages. Instructor's manual available giving course outlines, teaching strategies, tests, and a final examination.

AMERICAN NATIONAL STANDARD, ENGINEERING DRAWINGS AND RELATED DOCUMENTATION--DIMENSIONING AND TOLERANCING, 150 pp, $20.00

Authored by:

American Society of Mechanical Engineers
Society of Automotive Engineers
American National Standards Institute

Published by:

American Society of Mechanical Engineers

Distributed by:

American National Standards Institute
1430 Broadway
New York, NY 10018

The New Testament according to ANSI. A necessary reference for instructors; optional for students.

TEACHING AIDS

Complete training programs on color video cassettes are available from two sources listed below.

National Tooling and Machining Association
(See address above.)

The author and lecturer is Lowell W. Foster. Two programs are offered, both accompanied by printed study guides, review problems, and a final examination.

Program D10: 14 cassettes, about an hour each, $4900 purchase price, $2100 to rent for 12 weeks.

Program TD10: Eight cassettes of about half-hour each, purchase price $2800 (not rented).

TAT Products Corp. (See address above.)

The authors and lecturers are H. Gary Whitmire and James Swarthout. Contains 12 cassettes which vary from a half-hour to an hour, purchase price $3475, 30-day rental $900.

A training program on 35 mm slides is available from:

Lowell W. Foster Associates, Inc.
(612) 722-9115
3120 East 45th Street
Minneapolis, MN 55406

Covers the subject thoroughly, containing enough material for a 50-hour course. Available in either inch or millimeter units at $800.

Full-size models of machine parts illustrating geometric characteristics are available from two sources.

TAD Products Corp. (See address above.)

Catalog No. 91-5014 Two models $25.00

This company also supplies a number of other aids, such as 8 1/2 x 11 quick-reference quides, a wall chart, and several slide-rule-type calculators.

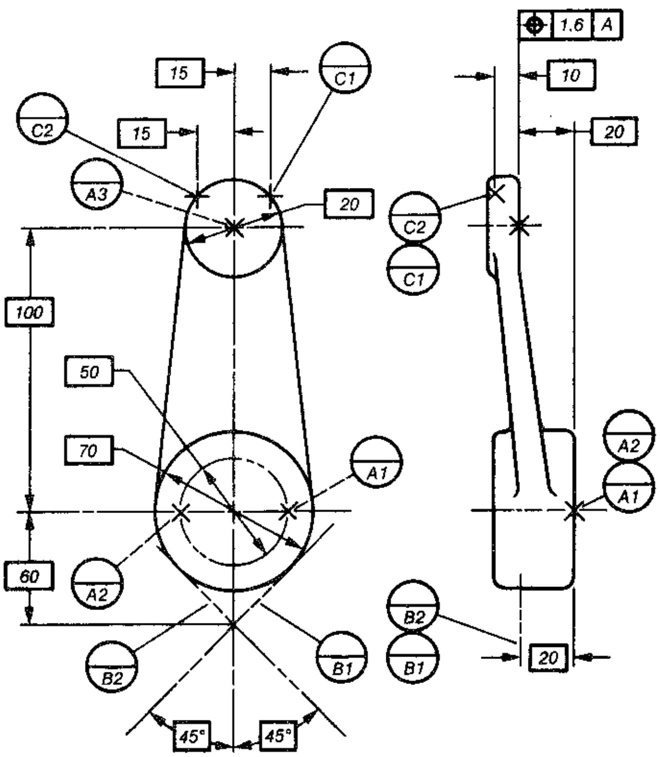
South-Western Publishing Co.
5101 Madison Road
Cincinnati, OH 45227

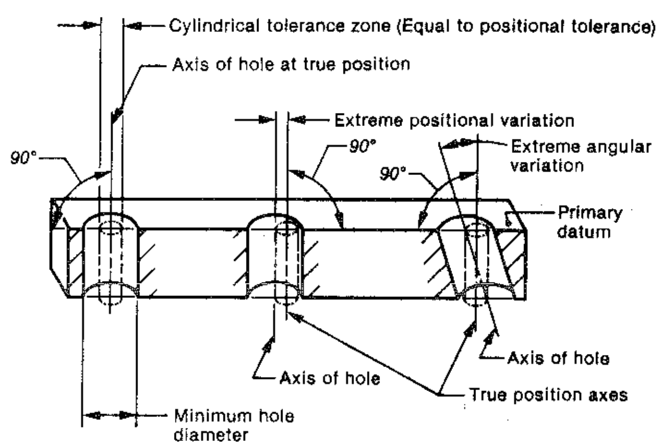
PHOTO-DRAFT MODULES Set of six $63.60, including shipping. Manufactured by Omar Products, Inc., Barrington, IL

SUMMARY

Geometric tolerancing is a valuable tool which is increasing productivity and reducing costs in design and manufacturing. Its use is growing at a rapid rate, and there is an increasing demand for design engineers and technologists who have this knowledge. It is incumbent upon our higher technical education system to provide this training--for the present and for the future.

●EDGJ





Axis of hole is coincident with true position axis

(a)

Axis of hole is located at extreme position to the left of true position axis (but within tolerance zone)

(b)

Axis of hole is inclined to extreme position within tolerance zone

(c)

Note that the length of the tolerance zone is equal to the length of the feature, unless otherwise specified on the drawing.

COMPUTER AIDED DESIGN AND DRAWING OF SAFETY FLANGE COUPLING

By

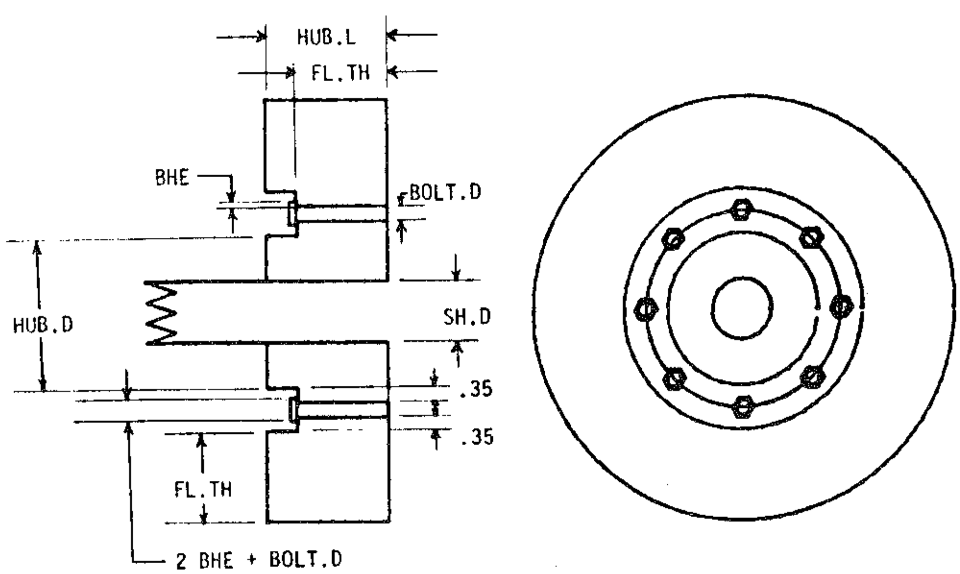
J. S. Duggal and M. L. Bourque
Texas A&M University

INTRODUCTION

Safety flange couplings are designed to connect the ends of two shafts in order that they can act as one continuous member. In most applications a standard flange coupling available commercially could be used if there are no restrictions on the requirements of space. The conventional method of designing the coupling is to make design calculations to find the sizes of various parts and then ask a draftsperson to draw it out. The design engineer then checks the final design in relation to other moving and stationary members of the machine for any possible interference. Location of a flange coupling may impose certain conditions with respect to size of the coupling itself. At times one might need a relatively wider coupling because of less vertical space. Also, there may be another situation where vertical space is plentiful and width is restricted; in that case a relatively higher coupling may be required.

design and draw machine members using existing subroutines

The designer may also want a lighter and bulkier coupling as opposed to one that is heavier and compact. This would mean that the designer needs to look into various feasible designs of flange couplings using different materials for a given load and shaft size. **This can be accomplished faster using a computer** In the following pages a generalized flange coupling design and drawing computer program is introduced. The computer program will assist the designer to expeditiously look into many possibilities of connecting the two shafts. The designer can then select the design which would meet the space, weight, and volume requirements.



FL.TH - Flange Thickness

HUB.L - Hub Length

BHE - Bolt Head Extension

HUB.D - Hub Diameter

SH.D - Shaft Diameter

BOLT.D - Bolt Diameter

Figure 1

The program described here is written to design and draw flange couplings, as shown in Figure 1, for connecting colinear shafts ranging from one-half inch to twelve and one-half inches in diameter. The inputs to the program are ultimate tensile strength of bolt and flange materials, the maximum torque to which the shafts are subjected, and the diameter of the shaft. The outputs are the number of bolts and their diameter, the hub and bolt circle diameters, thickness of the flange, length of the hub, and the length and thickness of the key. In addition to design calculations, a subroutine also provides a scale drawing of the coupling.

DESIGN CONSIDERATIONS

The following configurations and assumptions are made in design of flange coupling as discussed in this paper:

1. Bolt diameter and hole diameter should normally have a running and sliding fit. This will allow for variations in matching the holes with the bolts. This would also cause the flange of the flange coupling, when in use, to bear on some of the bolts only, resulting in these bolts resisting the shear force while others do not. Hence it is assumed that the number of bolts acting to be one-half of the total number of bolts in the coupling.

2. The hub diameter by rule of thumb is taken as two times the diameter of the shaft.

3. There must be sufficient clearance between the lip and the hub to allow for the use of a socket wrench in tightening the bolts. This clearance and the design dimensions are also shown in Figure 1.

4. Length of the hub will determine the size of the key to be used.

5. Factor of safety can be inputed by the user. A factor of safety of three is recommended .

IMPORTANT DESIGN FORMULAE

Following are major formulae which have been used in the computer program. Corresponding line numbers for these formulae, in the program, are also specified.

(a) Line 255 - Number of bolts required

$$N = \frac{8 * SFBC}{PI * ((BOLT.D) \wedge 2) * BSS} \quad \text{-----(1)}$$

Where:

N = Number of bolts
SFBC - Force exerted at the bolt circle
PI - The constant
BOLT.D - Bolt diameter
BSS = Design shear stress for bolt.

(b) Line 275 - Flange thickness for bearing failure

$$FLT = \frac{2 * SFBC}{NBOLT\% * BOLT.D * FBS} \quad \text{---------- (2)}$$

Where:

FLT = Flange thickness
SFBC = Force exerted at the bolt circle
NBOLT% = Number of bolts
BOLT.D = Bolt diameter
FBS = Design bearing stress for flanges.

(c) Line 285 - Flange thickness for shear failure

$$FLT = \frac{FNSHEAR}{PI * BOLT.D * FSS} \quad \text{--------- (3)}$$

Where:

FLT = Flange thickness
FNSHEAR = Force exerted at the outer surface of the hub
PI = The constant
BOLT.D = Bolt diameter
FSS = Design shear stress value for flange.

(d) Line 355 - Hub length for bearing flange.

$$HUB.L = \frac{2 * FNSHEAR}{FL.TH * FBS} \quad ---------- (4)$$

Where:

HUB.L = Hub length
FNSHEAR = Force at the circumference of the shaft
FL.TH = Flange thickness
FBS = Design bearing stress for flange.

THE COMPUTER PROGRAM

The program described in Appendix 1(a), 1(b), 1(c), and 1(d) is written in Microsoft Basic (MBASIC) in conjunction with Controlled Program for Microprocessors (CP/M)) operating system. The algorithm used to design and draw the flange coupling have the following features:

1. Prints instructions and limitations.
2. Prints commonly used materials for flange coupling design and their tensile strengths.
3. Designer inputs ultimate stress values for flange and bolt material.
4. Computes design stress values in shear and in bearing by dividing the ultimate stress value by factor of safety.
5. Designer inputs the shaft diameter and torque value.
6. Designer inputs the diameter of the bolt.
7. Computers number of bolts using equation (1).
8. Computes minimum flange thickness considering bearing and shearing in flange using equations (2) and (3).
9. Designer inputs key thickness for the given shaft size.
10. Computes hub length using equation (4).
11. Prints the design dimensions.
12. Sets scale for ten inches by seven inches screen.
13. Read coefficients from files for plotting function.
14. Plots the designed flange coupling.

To save memory space it was necessary to use sequential and random access files to print out instructions, stress value tables, and to read in bolt specifications and graphic point coefficients. The use of files reduced the complexity of subroutines and turn-over time.

THE PLOTTING ROUTINE

In plotting the designed flange coupling two generic equations were used. One set of x and y plot values are read on each iteration from PNT.DAT file.

The PNT.DAT file is organized in the following manner:

1. Number of Data Sets
2. Data Set #1
   A,B,C,D,E,F,G, - Coefficients for X-Plot
   H,I,J,K,L,M,N,Z, - Coefficients for Y-Plot
3. Data Set #2----Data Set #3---etc.

The user defined functions incorporated in lines 6005 and 6010 are used in plotting the front half sectional view of flange coupling. The side view is drawn using standard circle, polygon and bolt circle subroutines.

CONCLUSIONS AND RECOMMENDATIONS

With the development of basic subroutines such as rectangle, circle, polygon etc., for most computer systems, it is now possible to use these routines in a CAD system. In this paper a flange coupling design is taken as an example. Many more machine members could be designed and drawn simultaneously using the existing subroutines. A plot of a typical flange coupling design is shown in Figure 2.

The plot has not incorporated section lines for the sectional front view. Also it must be noted that the drawing is not dimensioned. Those extra features to the plot could be added with additional programming.

REFERENCES

1. Rosenthal, Emanuel and G.P. Bischof, 1955, Elements of Machine Design, McGraw-Hill Book Company, New York.

2. Creamer, Robert H., 1979, Machine Design, Addison-Wesley Publishing Company, California.

```
10  REM                   -FLANGE COUPLING DESIGN-
12  REM
15  REM                                  M.L. Bourcue & J.S. Duggal
20  REM                                  July 1984
40  REM
45  REM                   Control varibles & functions
50  REM                                                          REM ----------
60      DEF FNSHEAR(TORQUE,RADIUS)=TORQUE/RADIUS:                REM| Shear fun|
65      SMOON$=CHR$(20):SMOOFF$=CHR$(21):                        REM| Scroll   |
70      REVON$=CHR$(1):REVOFF$=CHR$(2):                          REM| Vidio rev|
75      HYON$=CHR$(18):HYOFF$=CHR$(19):                          REM| Hybrid   |
80      CURSON$=CHR$(24):CURSOFF$=CHR$(25):                      REM| Cursor   |
85      SCON$=CHR$(28):SCOFF$=CHR$(29):                          REM| Screen   |
90      CLEAN$=CHR$(4):BELL$=CHR$(7):                            REM| Misc.    |
92      PI=4*ATN(1):                                             REM ----------
95      DEF FNCURSOR$(YLINE%,XLINE%)=(CHR$(27)+CHR$(61)+CHR$(XLINE%+31)+
        CHR$(YLINE%+32))
100 REM
105     PRINT HYON$:GOSUB 5000:PRINT SCOFF$
110     OPEN"R",1,"WARNING"
115     FIELD 1,64 AS WARN$:PRINT TAB(9):                        REM ----------
120     FOR FL1%=1 TO LOF(1):                                    REM| Structre |
125             GET 1,FL1%:C$=WARN$:                             REM| to print |
130             PRINT C$:PRINT TAB(9);:                          REM| warning  |
135     NEXT FL1%:                                               REM ----------
140     CLOSE:PRINT SCON$;CURSOFF$;FNCURSOR$(27,20);"HIT (CR) TO CONTINUE"
145     FOR FL2%=1 TO 3:PRINT BELL$:NEXT FL2%:                   REM  Ring bell
150     INPUT "",DUMMY:
155     OPEN "R",2,"STRESS":FIELD 2,30 AS STRESS$
160     PRINT SCOFF$:GOSUB 5000:PRINT REVON$:PRINT
165     FOR FL4%=1 TO LOF(2):                                    REM ----------
170             GET 2,FL4%:                                      REM| Structre |
175             IF FL4%)8 THEN PRINT FNCURSOR$(40,FL4%-4);:      REM| to print |
180             C$=STRESS$:PRINT C$:                             REM| stress   |
185     NEXT FL4%:                                               REM|  values  |
190     CLOSE:PRINT REVOFF$;SCON$;FNCURSOR$(15,15);:             REM ----------


--------------------------------
192 REM         Begin varible manipulations and calculations              |
193 REM ----------------------------------------------------------------------
195     INPUT"Please give the ultimate stress for flange material ",FL.STR
200     FBS=FL.STR/3:FSS=FL.STR/6:PRINT TAB(16);:'factor of safety = 3
205     INPUT"What is the ultimate stress value for bolt material ",BLT.STR
210     BBS=BLT.STR/3:BSS=BLT.STR/6:PRINT TAB(16);:' shear = ultimate/6
215     INPUT"Please give diameter of shaft (in.) ",SH.D:PRINT TAB(16);
220     INPUT"What is the maximum torcue exerted on shaft ? ",TORQUE
225     OPEN "I",#3,"BOLT":                                      REM ----------
230     WHILE NBOLT%)8 OR NBOLT%=0:                              REM| Loop to  |
235             INPUT #3,BOLT.D,BHE:' Bolt Head Extension        REM| get bolt |
240             HUB.D=SH.D*2.5:HUB.R=HUB.D/2:                    REM| & lip sze|
245             BOLTC.R=BHE+HUB.R+.35+BOLT.D/2:                  REM| find dep.|
250             SFBC=FNSHEAR(TORQUE,BOLTC.R):                    REM| varible  |
255             N=(8*SFBC)/(PI*(BOLT.D^2)*BSS):                  REM| values . |
260             IF N(=8 THEN NBOLT%=8:                           REM ----------
262             IF N(=6 THEN NBOLT%=6
265             IF N(=4 THEN NBOLT%=4
267             IF N)8 THEN NBOLT%=N
270     WEND:CLOSE #3:                                           REM ----------
275     FLT=2*SFBC/NBOLT%*BOLT.D*FBS:' For bearing in flange     REM| Calculate|
280     TMAX=FLT:                                                REM| maximum  |
285     FLT=FNSHEAR(TORQUE,HUB.R)/(PI*BOLT.D*FSS):' Shearing     REM| flange   |
290     IF FLT)1 THEN FL.TH=FIX(FLT):                            REM| thickness|
295     IF FLT(=(5/8) THEN FL.TH=(5/8):                          REM| required |
300     IF FLT(=(1/2) THEN FL.TH=(1/2):                          REM ----------
305     IF FL.TH((2*BOLT.D) THEN FL.TH=(2*BOLT.D):' See guidelines
310     LET SD=SH.D:
315     IF SD(=12.5 THEN KT=2:IF SD(=9+(7/8) THEN KT=1.75:       REM ----------
320     IF SD(=7+(3/8) THEN KT=1.5:IF SD(=5.5 THEN KT=1.25:      REM| Get A.S.A|
325     IF SD(=4.5 THEN KT=1:IF SD(= 3.75 THEN KT=(7/8):         REM| key thick|
330     IF SD(=3.25 THEN KT=(3/4):IF SD(=2.75 THEN KT=(5/8):     REM| ness rel-|
335     IF SD(=1.75 THEN KT=.5:IF SD(=1+3/8 THEN KT=(5/16):      REM| ative to |
340     IF SD(=1.25 THEN KT=.25:IF SD(=(7/8)THEN KT=(3/16):      REM| diamtr of|
345     IF SD)12.5 OR SD(.5 THEN PRINT CLEAN$;:GOSUB 5015:END:   REM| shaft .  |
350     KEY.T=0:SWAP KT,KEY.T:                                   REM ----------
355     HUB.L=(2*FNSHEAR(TORQUE,SH.D/2))/(FL.TH*FBS):            REM ----------
360     GOSUB 5000:PRINT :PRINT TAB(22);:                        REM| Print out|
365     PRINT REVON$;"   DESCRIPTION FOR FLANGE COUPLING   ";:   REM| coupling |
370     PRINT REVOFF$:PRINT:PRINT TAB(28);:                      REM| descriotn|
375     PRINT"NUMBER OF BOLTS---";NBOLT%:PRINT TAB(28);:         REM| NBOLT%   |
380     PRINT"BOLT DIAMETER ----";BOLT.D:PRINT TAB(28);:         REM| BOLT.D   |
385     PRINT"HUB DIAMETER------";HUB.D:PRINT TAB(28);:          REM| HUB.D    |
390     PRINT"BOLT CICLE DIA----";BOLTC.R*2:PRINT TAB(28);:      REM| BOLTC.R  |
395     PRINT"FLANGE THICKNESS--";FL.TH:PRINT TAB(28);:          REM| FL.TH    |
400     PRINT"HUB LENGTH--------";HUB.L:PRINT TAB(28);:          REM| HUB.L    |
405     PRINT"KEY THICKNESS-----";KEY.T:PRINT TAB(28);:          REM| KEY.T    |
410     PRINT"KEY LENGTH--------";HUB.L:PRINT TAB(28);:          REM| HUB.L    |
414     PRINT FNCURSOR$(27,19);"TYPE '001' TO PLOT"
415     PRINT FNCURSOR$(27,20);CURSOFF$;"HIT (CR) TO CONTINUE": REM ----------
420     PRINT SCON$:INPUT"",DUMMY:IF DUMMY()0 THEN P.OUT%=1:GOSUB 9000
421     HUB.R=HUB.D/2:SWAP HUB.D,HUB.R:GOSUB 6000:SWAP HUB.D,HUB.R
425     GOSUB 7000:GOSUB 6495
430     PRINT SCON$
435     END
```

```
4995 REM                   Heading sub
5000     PRINT FNCURSOR$(1,1);SCOFF$;CLEAN$;STRING$(79,ASC("-"));SCOFF$
5005     PRINT TAB(29);REVON$;"FLANGE COUPLING DESIGN";REVOFF$;:RETURN
5010 REM                   Error sub
5015     PRINT FNCURSOR$(17,5);REVON$;CURSOFF$;"Shaft diameter exceeds the lim";
5020     PRINT "its of this program";REVOFF$;CURSOFF$:RETURN
5025 REM                   Char position sub
5030     CHAR.Y=CHAR.Y-.2:CHAR.X=.5:CHAR.H=.1:RETURN
5990 REM -----------------------------------------------------------------------
5995 REM                   Section sub                                          |
5999 REM -----------------------------------------------------------------------
6000     OPEN "I",#1,"PNT.DAT":INPUT #1,SIG%
6005     DEF FNPNT(A,B,C,D,E,F,G,SF)=A*XP+(B*FL.TH+C*HUB.L+D*BHE+E*BOLT.D+F*HUB.D
         +G*SH.D)*SF
6010     DEF FNPNTY(H,I,J,K,L,M,N,Z,SF)=H*YP+(I*FL.TH+J*HUB.L+K*BHE+L*BOLT.D+
         M*HUB.D+N*SH.D+Z*.35)*SF
6015     FOR FL5%=100 TO 1 STEP -1:                             REM ----------
6020             SF=FL5%*.01:                                   REM|          |
6025             FLD=SF*4*(.7+BOLT.D+2*BHE+FL.TH+(HUB.D/2)):    REM|  Scale   |
6030             FLW=SF*HUB.L:                                  REM|  factor  |
6035             IF FLD<=5 AND FLW<=8 THEN GOTO 6045:           REM|          |
6040     NEXT FL5%:                                             REM ----------
6045     PRINT HYDN$
6050     XP=3:YP=1:IP%=3:GOSUB 9000
6055     FOR FL6%=1 TO SIG%:                                    REM ----------
6060             INPUT#1,A,B,C,D,E,F,G:                         REM| Read in  |
6065             XP=FNPNT(A,B,C,D,E,F,G,SF):                    REM| generic  |
6070             INPUT#1,H,I,J,K,L,M,N,Z:                       REM| coeffi-  |
6075             YP=FNPNTY(H,I,J,K,L,M,N,Z,SF):                 REM| cients & |
6080             INPUT#1,P:IF P<>3 THEN IP%=2 ELSE IP%=P:       REM| plot out.|
6085             IF FL6%=19 THEN YP=YP+HUB.D*SF:                REM ---------
6090             IF FL6%=6 OR FL6%=25 THEN XP=XP+BHE*SF
6095             GOSUB 9000
6100     NEXT FL6%:CLOSE #1
6105     XP=3-HUB.L*SF:YP=1+(.7+2*BHE+BOLT.D+FL.TH+HUB.D+SH.D/2)*SF:IP%=3:
         GOSUB 9000
6110     FOR FL7%=2 TO 7:XX=XP:
                 XP=XX+(SF*((-1)^FL7%)):YP=YP-(SH.D/6)*SF:IP%=2:GOSUB 9000
6120     NEXT FL7%:XP=0:YP=0:IP%=3:GOSUB 9000
6125     XP=0:YP=7:IP%=2:GOSUB 9000:XP=10:IP%=2:GOSUB 9000:YP=0
6130     IP%=2:GOSUB 9000:XP=0:IP%=2:GOSUB 9000:IP%=3:GOSUB 9000
6135     RETURN
6139 REM -----------------------------------------------------------------------
6140 REM                   Labeling sub                                         |
6141 REM -----------------------------------------------------------------------
6495     CHAR.X=.5:CHAR.Y=6:CHAR.H=.1:                          REM ----------
6500     CHAR$="USING"+STR$(NBOLT%)+" BOLTS":GOSUB 9301:GOSUB 5030:'| Plot out |
6505     CHAR$="BOLT DIA="+STR$(BOLT.D):GOSUB 9301:GOSUB 5030:  REM| descrip- |
6510     CHAR$="HUB DIA="+STR$(HUB.D):GOSUB 9301:GOSUB 5030:    REM|   tion   |
6515     CHAR$="BOLT CIRCLE"+STR$(BOLTC.R*2):GOSUB 9301:GOSUB 5030:' ----------
6520     CHAR$="FLANGE THICKNESS="+STR$(FL.TH):GOSUB 9301:GOSUB 5030:
6525     CHAR$="KEY THICKNESS="+STR$(KEY.T):GOSUB 9301:GOSUB 5030:
6530     CHAR$="HUB & KEY LENGTHS="+STR$(HUB.L):GOSUB 9301:GOSUB 5030
6535     IP%=3:XP=0:YP=0:GOSUB 9000:CHAR.X=8.5:CHAR.Y=.35:CHAR$="SCALE:"+STR$(SF)
         :GOSUB 9301:CHAR.Y=6.5:CHAR$="FLANGE COUPLIN
G DESIGN":CHAR.H=.15
6540     CHAR.X=3.35:GOSUB 9301
6545     RETURN


6994 REM -----------------------------------------------------------------------
6995 REM                   Boltcircle sub                                       |
6996 REM -----------------------------------------------------------------------
7000     R=(2*BHE+HUB.D/2+.7+BOLT.D+FL.TH)*SF:XCTR=SF*HUB.L+4+R:YCTR=R+1:GOSUB 70
55
7005     XC=SF*HUB.L+4+R:YC=1+R
7010     FOR FL8%=1 TO NBOLT%:                                  REM ----------
7015             XCTR=XC+(BOLTC.R*COS(2*PI*FL8%/NBOLT%))*SF:    REM| This sub |
7020             YCTR=YC+(BOLTC.R*SIN(2*PI*FL8%/NBOLT%))*SF:    REM| controls |
7025             NOSIDES=6:R=(BOLT.D/2+BHE)*SF:GOSUB 7105:      REM| varibles |
7030             R=(BOLT.D/2)*SF:GOSUB 7055:' Cirsub for bolt   REM| for boltc|
7035     NEXT FL8%:                                             REM ----------
7040     R=SH.D*SF/2:XCTR=XC:YCTR=YC:GOSUB 7055:' For shaft
7041     R=(BOLTC.R)*SF:GOSUB 7055
7042     R=(HUB.D/2)*SF:GOSUB 7055:R=(HUB.D/2+.7+2*BHE+BOLT.D)*SF:GOSUB 7055
7045     RETURN
7050 REM                   Circle sub
7055     N=FIX(2*PI*R/.1):IF ABS(R)<.5 THEN N=20:               REM ----------
7060     DUMMY=360/N:                                           REM| This sub-|
7065     FOR FL9%=0 TO 361 STEP DUMMY:                          REM| routine  |
7070             XP=XCTR+R*(COS(FL9%*.01745)):                  REM| draws cir|
7075             YP=YCTR+R*(SIN(FL9%*.01745)):                  REM| cles. The|
7080             IF FL9%=0 THEN IP%=3 ELSE IP%=2:               REM| .01745 = |
7085             GOSUB 9000:                                    REM| pi/180 . |
7090     NEXT FL9%:IP%=3:GOSUB 9000:                            REM ----------
7095     RETURN
7100 REM                   Polygon sub
7105     DUMMY=360\FIX(NOSIDES):IF ABS(R)<.5 THEN N=20:         REM ----------
7110     FOR FL10%=0 TO 361 STEP DUMMY:                         REM| Subroutne|
7115             XP=XCTR+(R*(COS(FL10%*.01745))):               REM| to draw  |
7120             YP=YCTR+(R*(SIN(FL10%*.01745))):               REM| general  |
7125             IF FL10%=0 THEN IP%=3 ELSE IP%=2:              REM| polygons.|
7130             GOSUB 9000:                                    REM ----------
7135     NEXT FL10%:IP%=3:GOSUB 9000
7140     RETURN
9000 'NorthStar ADVANTAGE LINE PLOTTING SUBROUTINE * SYSPLOT.BAS ***REV-3/P0/A4
```

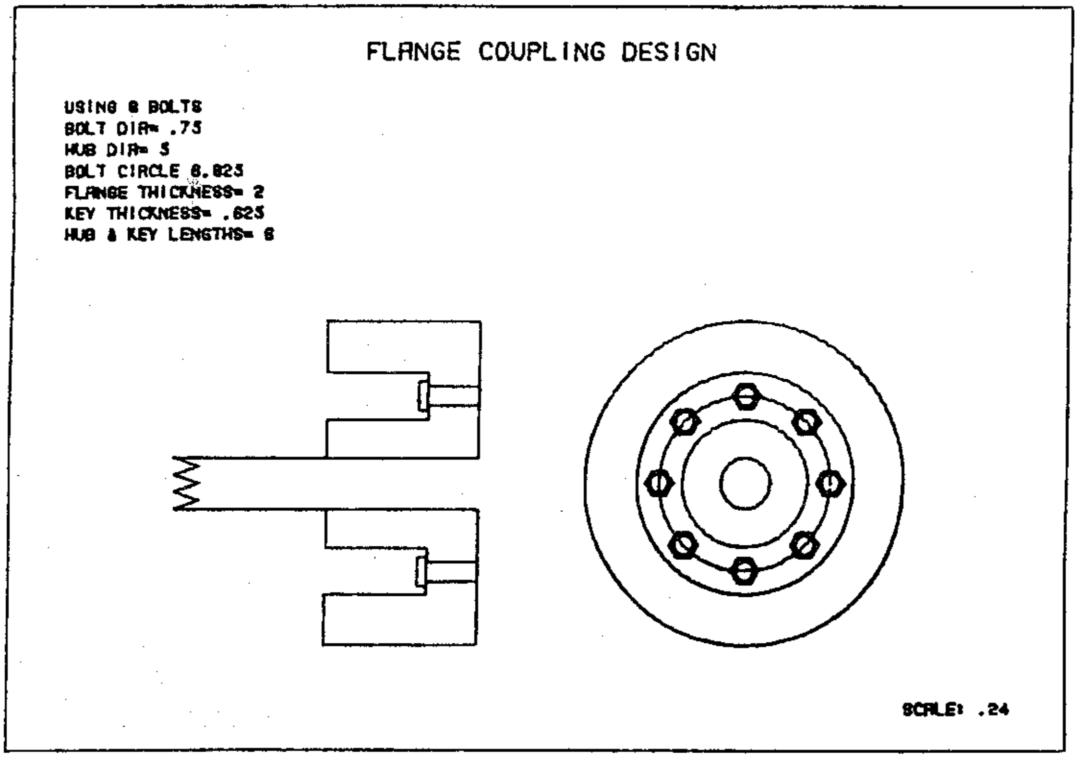


Figure 2

●EDGJ

GRAPHICS FOR FINITE ELEMENT ANALYSIS

BY

Josann Duane and Mike Khonsari
Department of Engineering Graphics
The Ohio State University
Columbus, Ohio

In the past decade, the Engineering Graphics Faculty at The Ohio State University has been incorporating computer-based graphics in engineering courses from freshman to graduate level. This paper describes the content of a graduate level course we taught in Summer 1984 on the fundamentals of graphics for finite element analysis. The course covers graphics for three distinct steps in finite element analysis: geometry modeling, mesh generation for numerical analysis, and results evaluation. Both the fundamentals of each of these aspects of graphics for finite element analysis and applications in engineering practice are presented. This paper addresses problems encountered in nonuniformity of the student's background, evaluates means of achieving a balance between fundamental concepts and use of commercial codes, and presents faculty and student evaluation of the first offering of the course. This course adds the research and analysis aspect of engineering graphics to a curriculum that now primarily presents engineering graphics as a tool for design and documentation.

INTRODUCTION

Before the widespread application of high speed digital computers to engineering problems, graphics had limited use in analysis because of lack of precise hand methods. Now interactive computer graphics is commonly used in a diverse range of industrial applications to aid engineers in formulating analytical models and in results evaluation. To bring graphical analysis methods commonly used in industrial research and development to our engineering curriculum, we teach the use of graphics as a tool for engineering analysis in courses ranging from introductory undergraduate level to graduate level (2,9). In teaching graphics for engineering analysis, the theoretical bases for three distinct applications of this subject (image analysis, geometric analysis, and interactive graphics) are developed. The application to engineering problems is presented by demonstrating the following: 1. Image analysis forms the basis for interpretation of remote sensing signals from satellites. 2. Geometric analysis using solid modeling is effective in evaluating the interrelation of parts in complex mechanical assemblies. 3. Interactive graphics makes possible creation and evaluation of geometrically complex models using the finite element method.

In Summer 1984, we taught a course which focused on the one aspect of graphics for engineering analysis: the interactive computer graphics to support finite element analysis. The rationale for developing the course, the course content, and the faculty and student evaluation of the course comprise this paper.

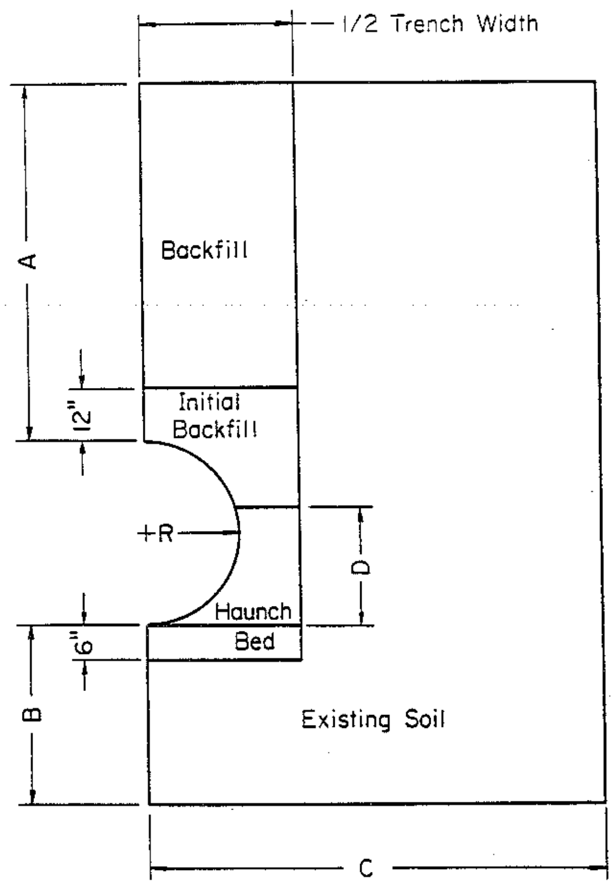


FIGURE 1. Geometry of pipe cross-section

THE FINITE ELEMENT METHOD

Finite element analysis is a numerical method that can be applied to problems which are formulated by a set of partial differential equations and boundary conditions that uniquely describe the interaction between material and fields. (3). Since the behavior of most engineering systems can be formulated in this way, the finite element method is applicable to a wide variety of engineering problems. Before the widespread use of high speed digital computers, however, engineers found few applications for this theory because: 1. extensive computational power is required to generate numerical solutions, and 2. most engineers are unable to formulate and evaluate finite element models without the aid of interactive computer graphics.

The finite element method initially was used for structural analysis of air and spacecraft but since then, it has found application in analysis of radiative heat transfer, fluid dynamics and field theory. Finite element analysis is a method where geometrically complex problems are broken down into an assembly of simple problems by creating a mesh of elements. Solutions found for each element are forced to match at a finite number of points called nodes.

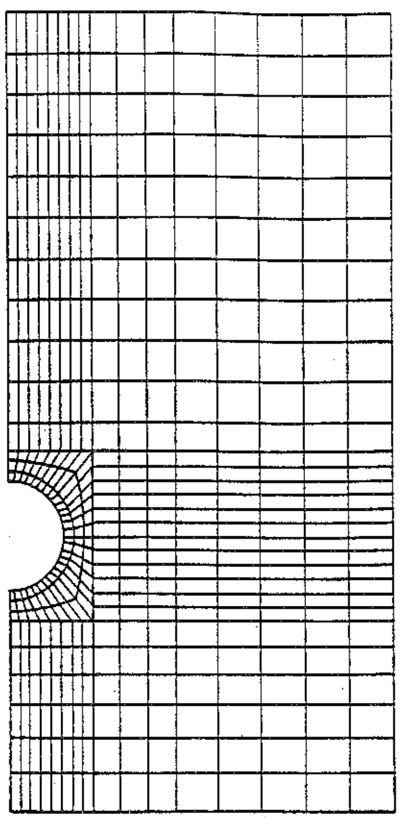


FIGURE 2. Finite element mesh

Numerical results from finite element analyses are comparable to those generated by analytical solutions. For example, a closed form solution can be obtained for stress on buried pipe resulting from soil gravity load if these simplifying assumptions are made: the pipe is infinitely long, and the surrounding soil is uniform and elastic (10). Although few pipe installations meet these requirements, the following illustrates the use of the finite element method and shows that both the closed form solution and the numerical solution to this problem yield nearly the same result. Figure 1 shows the cross section of pipe buried in the ground. In this case, since the length of the pipe is assumed to be many times its diameter, strain along the axis is negligible and the problem is reduced to two-dimensional plain strain analysis. Nodes are present at each corner of the quadrilateral soil elements and at the ends of the beam elements used to represent the pipe. Note that the elements are nonuniform and more elements are placed where the analyst expects stress concentrations to be high. Figure 3 shows strain in the pipe as it varies around the circumference of the pipe. This variation is found to be nearly identical to that from closed form solutions. As more or higher order elements are added to the problem, the analytical and numerical solutions converge.

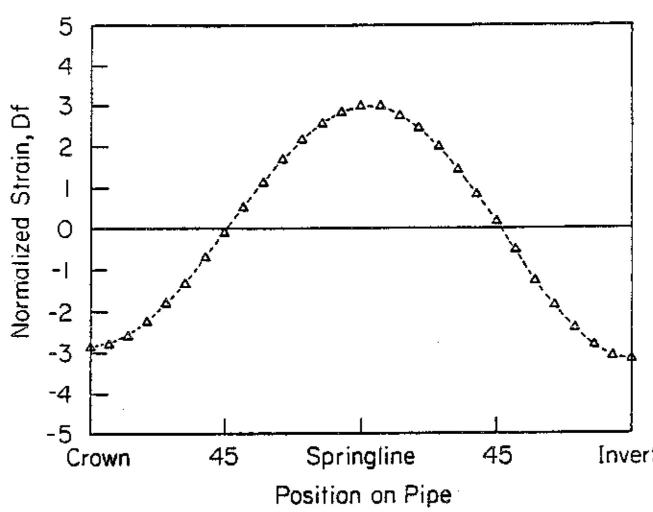


FIGURE 3. Closed form analytical solution

GRAPHICS IMPORTANCE TO FINITE ELEMENT ANALYSIS

Most practical engineering problems cannot be reduced to the simple two-dimensional problem presented above. In these cases, full utilization of the finite element method requires interactive graphics to aid in visualizing each segment of the analysis process: geometric modeling, numerical analysis and results evaluation. Figure 5 shows a geometric model of a gear generated interactively using the General Electric I-DEAS package (5, 6, ;7, 8). The geometric model is created by rotating the gear cross-section shown in Figure 4. Figure 6 shows the mesh of elements that is generated by I-DEAS once the analyst creates the geometric model. Without interactive graphics, engineers find it extremely tedious to input the nodal coordinates and element connectivity which define the three-dimensional mesh required for finite element analysis. Using hand methods, mesh generation for analysis of stress generated as a result of torque applied to the gear shown in Figure 5 requires four to five hours. With interactive graphics this mesh generation can be done in minutes.

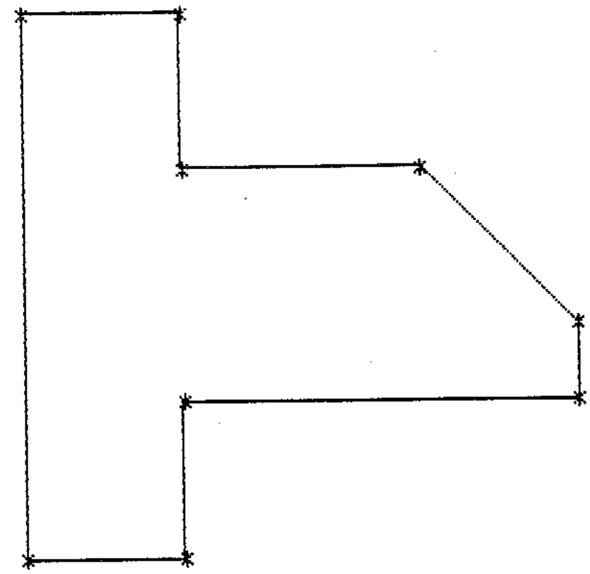


FIGURE 4. Gear cross-section

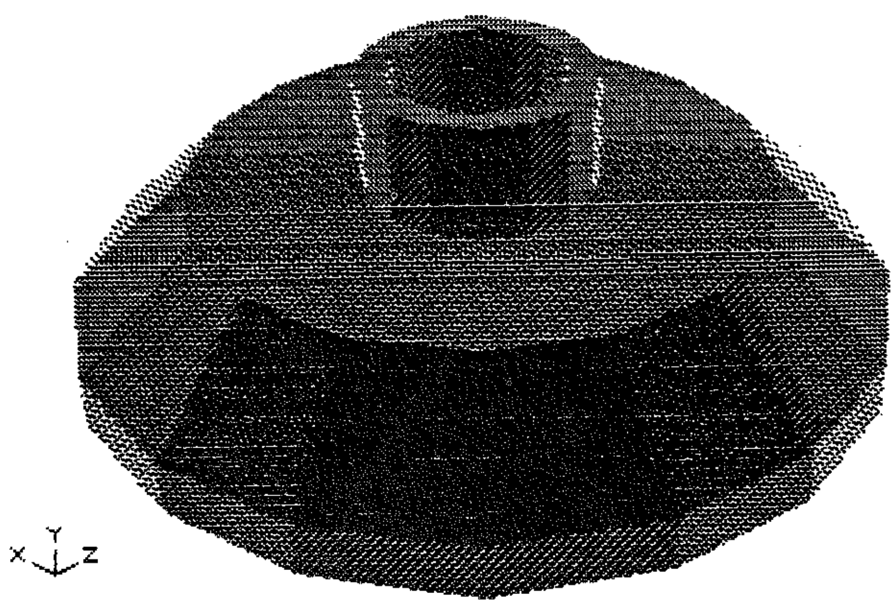


FIGURE 5. GEOMOD model from cross-section

Figure 6 shows how graphics can be used to interactively apply boundary conditions. Forces and constraints applied to the nodes are displayed using colored arrows. After boundary conditions are applied, the analyst uses I-DEAS to prepare a finite element data file for batch processing by one of many general purpose finite element codes. The gear subject to an applied torque shown in Figures 4 through 9 was analyzed using SUPERB (6).

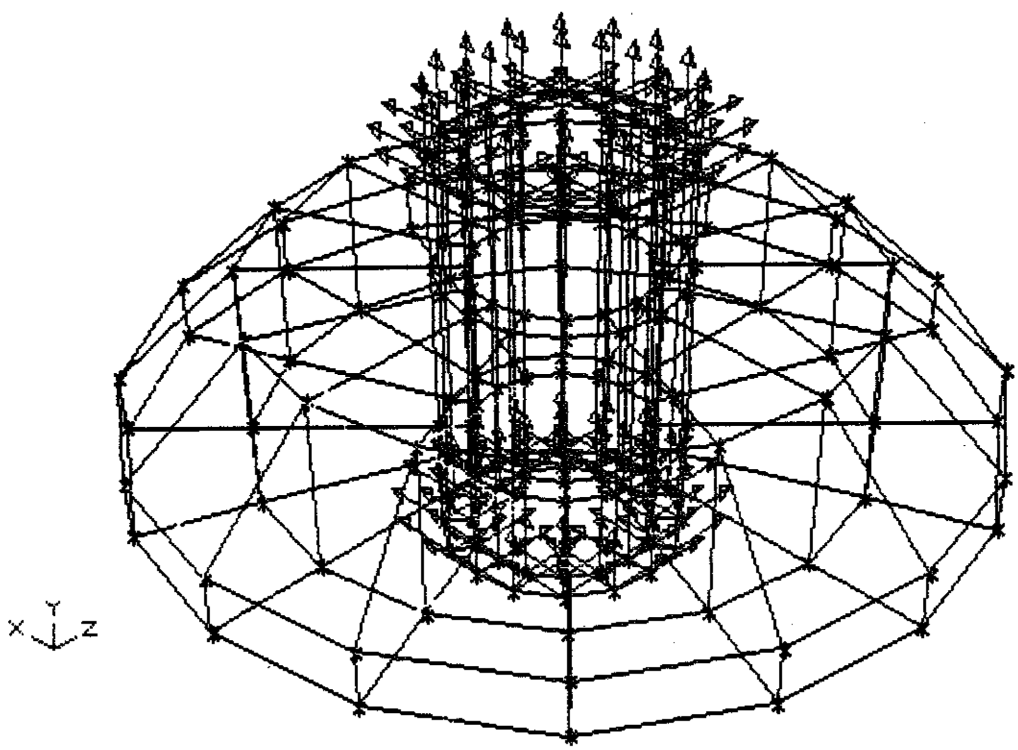


FIGURE 6. Applied torque and boundary constraints

The result of finite element analysis of the gear is a tabulation of displacements for each of the nodes, and a tabulation of stresses occurring in the elements. Before interactive graphics became available, the analyst had to interpret a two-inch thick computer printout of numerical results. Graphical interpretation required hand plots or batch process computer plotting. Figure 7 shows a plot of exaggerated distorted geometry of the gear resulting from the applied torque. Figure 8 shows von Mises stress contours on the surface of the gear. Figure 9 shows von Mises stress contours on a cross section through the interior of the gear. These plots are done interactively and displayed in color. The analyst can change display parameters such as magnification or viewing angle interactively then imediately redisplay results. Thus, interactive graphics also provides immediate feed-back on the correctness of the solution and aids the designer to improve the results by making necessary modifications to the finite element model.

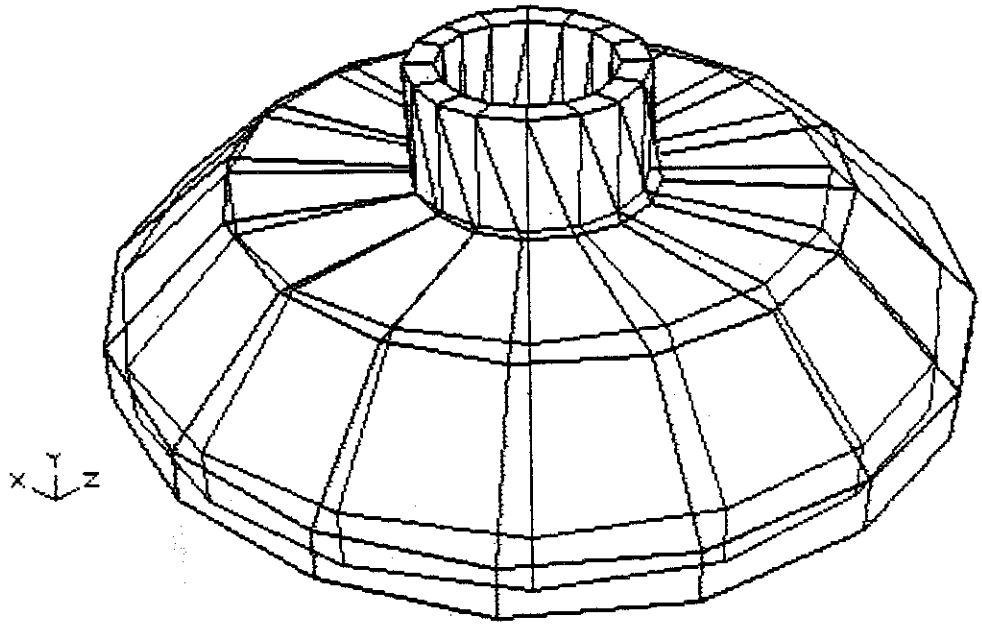


FIGURE 7. Exaggerated distorted geometry

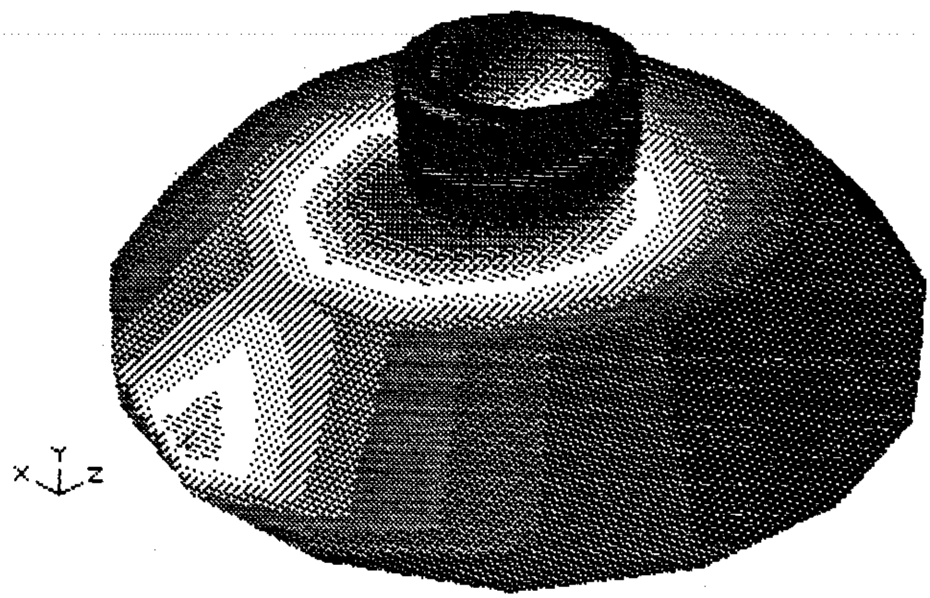


FIGURE 8. Von Mises stress contours

COURSE CONTENT

Civil, mechanical and engineering mechanics graduate students enrolled in the course we offered on graphics for finite element analysis. Students came to the course with a background in numerical methods and FORTRAN programming. This background included an understanding of the fundamentals of numerical analysis particularly the finite element method.

The course presented the fundamentals and engineering applications of interactive programming, graphics programming and the finite element method. Readings form Fundamentals of Interactive Computer Graphics by Foley and Van Dam (4) were used to augment lectures and laboratory exercises on interactive graphics.

In the first part of the course the students were introduced to the fundamentals of writing interactive programs. They learned how to write software for menu driven interaction, create appropriate commands to provide feedback to the user and generate code to trap both input and computational errors. Students incorporated graphics in their interactive programs by using Tektronix PLOT10 FORTRAN addressable graphics primitives.

Next we presented design of the basic components of graphic systems and discussed the differences between raster and vector graphic systems that the students used in the laboratory section of the course. Students ran graphics applications programs on storage tube vector (Tektronix 4014), refresh vector (Evans and Sutherland PS300), and raster color (Tektronix 4105 and Lexidata 2410) terminals linked to three VAX 11/750 computers in our lab. Some terminals in the lab such as the Lexidata and the Evans and Sutherland have microprocessors that provide stand alone graphics capabilities.

After the student gained some experience in writing simple graphics application programs and using a variety of graphics terminals and input device, we returned to the basics. Teaching of principles behind picture generation included a discussion of Bresenham's (1) algorithm for raster line generation, color lookup tables operation, graphics data file organization and realistic image generation. With an understanding of the basics, students no longer found viewing operations such as zooming and rotation to be computer magic.

In teaching the finite element method, it was assumed that students had some prior experience with the method. We reviewed the fundamentals and explained the importance of graphics to the effective implementation of this method. Evaluation of the advantages of using general purpose commercial finite element codes such as SUPERB (6) and MARC (11, 12) versus writing special purpose codes led to several lively class discussions.

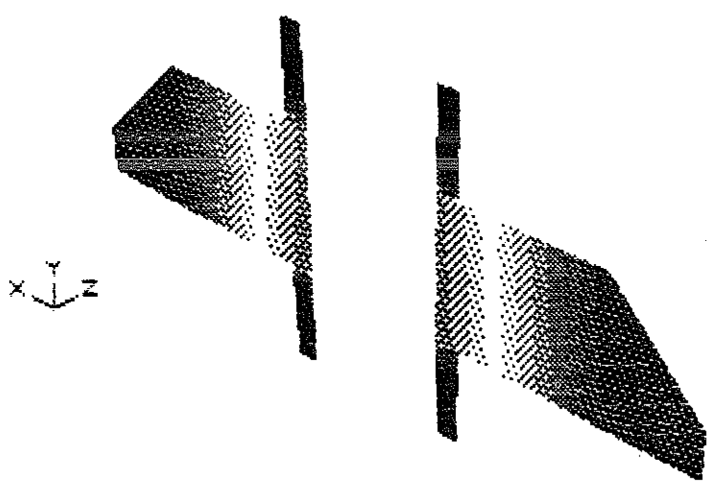


FIGURE 9. Von Mises stress contours on cross-section

Because solid modeling has greatly enhanced graphics potential as an aid to finite element model creation and results evaluation and has amongst other benefits opened the possibility for automation of routine finite element mesh generation, we included a brief presentation of the theory of solid modeling in the course. Theoretical concepts underlying solid modeling such as constructive solid geometry using Boolean operations were presented. Students gained an understanding of the Boolean operations by using PADL-2 (13) core graphics to generate solid models. Students were able to see the power of solid modeling applied to finite element analysis by using the GEOMOD segment of the General Electric I-DEAS package to model the gear shown in Figures 4 through 9.

In teaching graphics for finite element analysis we are faced with providing a balance between graphics fundamentals and applications. We found that graphics fundamentals and applications could be brought together by giving students the opportunity to modify commercial codes. For example, we were able to permit students to use basic principles in modifying the source code to a commercial program, PADL-2. This gave them the opportunity to see the results of their coding displayed by PADL-2, which is available to universities for under $1,000.

Experience the students gained in using commercial codes, such as the General Electric I-DEAS package, helped them to understand theoretical concepts presented in the course. At course conclusion, students had gained an understanding of the fundamentals of graphics for engineering analysis and were able to: 1. write simple interactive graphics application programs. 2. use a variety of commercial graphics programs for finite element model preparation and results evaluation. 3. evaluate the merits and weaknesses of both the software and hardware components of commercially available graphics systems for aid in finite element analysis.

CONCLUSIONS

Numerical analysis and graphics were (until now) treated as two separate subjects and, therefore, taught by separate departments. This caused a lack of uniformity of undergraduate curriculum in both graphics and numerical analysis. The lack of uniformity in the undergraduate graphics curriculum was brought out by the great diversity in backgrounds of the graduate students who enrolled in the course. We found that mechanical engineering students were much better prepared for the course than students from other departments. They previously had written elementary interactive graphics programs and were experienced in the use of commercial graphics application programs. Civil engineering students, in contrast, had no classroom experience with interactive programming.

Graphics at the freshman level at Ohio State is the only uniform college requirement and even that requirement is not met in the same way by all students. Currently, some students study batch programming and traditional instrument drawing while others study interactive programming and computer graphics.

Graphics beyond the freshman level is taught by a variety of engineering departments. Engineering Graphics teaches an advanced undergraduate course on computer-based engineering graphics. Computer Science teaches courses on programming graphics primitives and graphics system architecture. In a mechanical design course, faculty members demonstrate the principles of engineering design using commercial graphics application programs. Because none of these courses have as their objective to teach engineering graphics, the subject is not developed as a whole. Some essential parts of engineering graphics are not taught; graphic theoretical development is merely glossed over.

ZOOMING AND ROTATION WERE NO LONGER COMPUTER MAGIC

In addition the wide variation in computer graphics facilities between departments contributes to the nonuniformity in students' graphics backgrounds. For example, the Mechanical Engineering Department (over a period of time) had almost exclusive access to the Advanced Design Methods Laboratory, where Tektronix 4014 and other similar graphics terminals linked to VAX 11/750s give these students experience in using many commercial graphics systems. In contrast, the Civil Engineering Department (until recently) had no interactive graphics systems available to undergraduate students. This is now being changed. Departmental graphics facilities are being opened to all students and faculty members in the College of Engineering.

In summary, we find that graphics has become an integral part of the finite element method, which through a shared geometric data base forms a rapid and broad communication channel between the analyst and the computer. Unfortunately, at present, graphics for engineering analysis is not well established in the engineering curriculum at The Ohio State University. This presents the following challenge for engineering educators: Develop the educational strategy and courses to incorporate modern graphics into the engineering curriculum at all levels.

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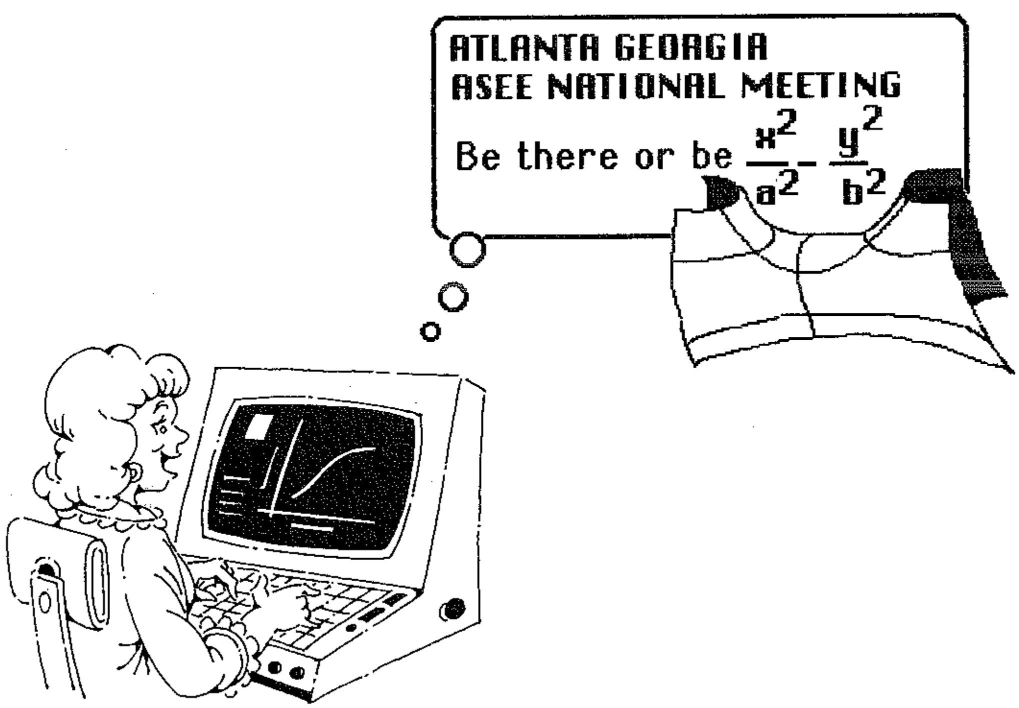

IMPROVING INSTRUCTION OF ENGINEERING GRAPHICS WHILE UTILIZING MICROPROCESSORS

by
David E. Roth
Asst. Professor of Engineering
Behrend College of Penn State University

Co-authors:
John N. Grode
Asst. Professor of Engineering
Behrend College of Penn State University

David L. Huggins
Asst. Professor of Engineering
New Kensington Campus of Penn State University

ABSTRACT

At Behrend College of Erie, and New Kensington Campus of New Kensington, both of the Pennsylvania State University, two pilot courses in engineering graphics have been taught using a mixture of manual and computer techniques. This paper shares our experiences in improving our instruction of introductory engineering graphics using microprocessors.

INTRODUCTION

If engineering graphics is to take a viable part in the education of future engineers, it is absolutely necessary to incorporate an effective form of computer based instruction into the curriculum. This paper briefly discusses the following topics which are some of the experiences of Behrend College in Erie, and New Kensington Campus in New Kensington, Pa., both of the Pennsylvania State University:

I. General Considerations for Implementation of CAD
II. Hardware and Software Systems Selected
III. "Phasing In" Microprocessors
IV. Instructional Innovation
V. Evaluation for Improvements

GENERAL CONSIDERATIONS FOR IMPLEMENTATION OF CAD

Colleges and universities throughout the world are installing computer based systems that range from sophisticated mainframes to much less powerful microcomputer based systems. The authors of this paper believe that as much, if not more, consideration should be given to instructional techniques as has routinely been given to hardware and software consideration. This is not, however, to minimize the importance of hardware and software selection. The literature relating to computer aided drafting contains much discussion of the factors that need to be considered when evaluating hardware and software. This is certainly understandable given the expense involved to purchase and install even one workstation.

The costs of mainframe interactive CAD systems have been reduced over the last few years, but still range in the hundreds of thousands of dollars for a couple of workstations. An example of mainframe CAD is the Computervision System. Their capacity far exceeds the needs of introductory level computer based engineering graphic instruction. The mini computer systems packages may cost slightly less, but still range above the hundred thousand dollar level for 3D wire frame and solid modeling systems such as the Prime Computer minis. Minis range down to the area of $30-$40,000 for a stand alone system such as the Apollo Computer.

As the micros' capabilities are constantly increasing, along with the enhanced versions using micros tied to a Winchester or hard drive, we see the costs of a stand alone system approaching $15,000 for a single workstation. It is therefore apparent that equipment costs become one of the most critical factors in achieving the goal of teaching engineering with CAD or simulated CAD systems.

Most universities cannot absorb the costs of these purchases into already squeezed engineering budgets. Universities offering a range of engineering curricula are being pressured by employers of potential graduates. High entry level salaries for graduating engineering students with BS degrees are tending to create two distinct problems. First, the number of students opting for engineering is exploding; and second, these salaries are causing a number of engineering faculty to go to industry where salaries are higher. Because of these trends, engineering programs have found it necessary to increase incoming faculty salaries proportionately, resulting in additional strains on budgets.

COMPUTER SYSTEMS SELECTED

A computer system was chosen and software was developed within the parameters of low cost and introductory level instruction. Using Apple IIe computers as a base, a lab with sixteen stations was developed at a total cost of $25,000. Each station contained a computer, monitor and disk drive. Two plotting stations are also included in this price. This takes into account educational discounts typical with Apple equipment. A software program was developed with the ability to create 2D graphics at any designated scale . The cost of the software is not considered in the package but would be under a few hundred dollars.

Three distinct input modes were developed to be incorporated onto a single 5 1/4" floppy disk. The system uses vector notation oriented for easy transference to a digital plotter for hard copy record, and/or grading.

Modes:

a. The first is a graphic digitizing mode utilizing the Houston Instruments graphic tablet. All commands are achieved on the tablet with an overlay that includes an active screen area for digitizing. This allows creation of a new drawing or input of an existing drawing to computer or disk data storage.

b. The second input mode incorporates the use of a set of game paddles or a trakball tied to the game port. This is used to move the reference cursor around the drawing area. It has an accept command and cancel command button on the paddle or trakball. The input graphic commands would be entered from single key functions designated from an overlay for the Apple.

c. The third input mode utilizes the computer for all graphic commands and the movement of the cursor by specific keys grouping.

There are additional software commands on this single disk allowing interaction with a digital plotter, printer and even the ability to merge separate files simulating a form of layering.

Any one of these modes can be activated from the main menu. The system is very user friendly and can be productively used by students with less than two hours of group class instruction. Indeed, the use of this software within the constraints of a three credit engineering graphics course is an acceptable "package" for its intended purposes.

The integration of Computer Aided Graphics into the engineering curriculum should be accomplished in a way that does not distract from the effectiveness of standard instructional techniques. It needs to be done by implementing into the curriculum the ability to simulate techniques and concepts used in industry. It should be cost effective or realistic in terms of dollar value returned for actual student contact time spent on the system. It should look at the type and value of the time spent by the student while working with the software.

It is easy to see how hardware and software considerations become all consuming when a college or university imposes such costs on an already tight engineering education budget. Great care must be taken to insure that the system selected is cost effective and realistic in terms of dollar value return for actual student contact hours spent on the computer based system. Thus it is apparent that equipment costs become one of the critical factors in achieving a school's goal of some hands-on contact with a computer aided drafting system.

The authors of this paper regrettably recognized that while fully supported 2 - and 3-dimensional graphics systems were desirable, the hard reality of budget consideration would preclude the purchase of such a powerful system. To minimize any shortcomings in the educational computer system they were going to use, the authors chose to concentrate on improving their instructional techniques while utilizing the computer to enhance the delivery of traditional topics in engineering graphics.

"PHASE IN" OF CAD

A practicable but conservative plan consisted of a gradual "phase in" of computer graphics rather than a total conversion to computer graphics with the elimination of most, if not all, manual drafting. This plan was chosen for four reasons: one, the limited availability of software to support all topics normally taught in the course; two, the limited budget which restricted the number of workstations that could be purchased immediately; three, to provide many important skills for those students who may still need manual drafting skills for their professional employment; and four, to allow the necessary time for the development of instructional techniques.

1. Limited Software Initially Available

Traditional graphics courses may contain a wide variety of general topics; for example, axometric drawings, charts and graphs, descriptive geometry, tolerancing, as well as a variety of orthogonal drawing topics. The software chosen for use on the computer may not lend itself completely to the instruction of all these varied topics. Because the initial computer software may have limitations, the traditional manual techniques should initially compliment the computer graphics. The graphics course can thereby be expanded in its importance by the use of computers, rather than replacing key topics of the course with less significant concepts which the software will support.

...does not distract from the effectiveness of standard instructional techniques

2. Limited Budgets

The second reason for choosing a gradual conversion was the limited number of workstations which could be made available to the students early in the conversion process. Additional workstations are needed to drive plotters and to replace a unit if repair is necessary. Optimally, each student should have the personal use of a workstation during class instruction. Just as individual learning and development could be hampered by students sharing a drawing board with a partner and completing all assignments as a team, so too it is believed that . . . "sharing a drawing workstation on a continuous basis is undesirable." Using a drawing laboratory with only half the optimum number of workstations forces a "team" approach to problem solving. In using the team approach to the computer aided graphics, it was observed that most students enjoyed being in pairs at a workstation. There was much enthusiasm, cooperation, and a great deal of interaction between the members of the team in sharing ideas and reasons for a particular solution. Because the student response is as acceptable to its team effort, the "pairing" of students at a workstation is considered a good mechanism for instruction.

Regardless of the acceptable and even encouraging response by the students for a team effort in learning, students must be given class time to attempt to think through and draw a solution on an individual basis. While team efforts can remain as a catalyst for the learning process, many of the concepts of an engineering graphics course need to be practiced independent of student interaction.

3. Manual Skills Still Marketable

A conversion program utilizing drawing boards as well as computer drawing workstations has another advantage. Skills in manual drawing techniques are currently very desirable for many engineering graduates, and especially engineering technologists. This is truly a marketable skill for those graduates desiring employment in industries which are not large enough to afford the computer hardware and support expenses. Since these industries still need engineers, engineering technologists, and technicians who can draw by conventional means, a dual program still allows many of these manual drawing skills to be introduced.

4. Allow Time to Develop Software

The gradual conversion also provided time to develop exercises suitable for computer instruction. This time is necessary to develop and expand CAD from a "mechanical tool" to an "instructional tool". Although the proper care and use of drawing instruments is part of every basic engineering graphics course, the concepts of engineering graphics comprises the major emphasis of the course. Knowledge in creating multiview projections, proper dimensioning techniques, informative sections, and many other topics make up the thrust of the first course in graphics; and as such, the computer software optimally needs to address these thrusts. Simply drawing lines, arcs, circles, etc., by computer is utilizing only a small part of its total potential for classroom use. Graphic concepts, such as developing skills in visualization, need to be re-evaluated by the instructor so that software programs can be developed which help instruct the concept.

INSTRUCTIONAL INNOVATIONS

At Behrend College, the authors have effectively used the versatility of the microprocessor to improve instruction in engineering graphics. Several problems have been preprogrammed for the students for each of the major topics within the course (except descriptive geometry). The correct answer has also been preprogrammed to allow the student to review the correct answer either during or after the student's own solution. The student can thereby discover errors quickly, and have an immediate feedback of the correct solution. Students can build confidence in solving harder problems if it is realized that the easier problems are done correctly. Students can work at their own pace, solving many mini-problems, using the computer software to "draw" the solution quickly and neatly. Instructor time spent correcting large numbers of drawing projects between classes is reduced because the students are essentially correcting much of their own work in a truly worthwhile manner.

This method of saving a drawing and retrieving the answer is completely different from simply providing a "copy" of the solutions. Students would use the paper copy without giving much original thought to their own solution. The inconvenience of "saving" a current file and "retrieving" the file with the answer is just enough trouble to combat an "unleashed" use of the answers. This method of instruction also encourages the student to "learn" the correct answer when they see it on the screen, because the student will need to "clear" the answer, retrieve their own solution file, and finish their solution by what they have seen. The instructor can also control the use of the file containing the answer by providing a coded name to that file. The students can therefore retrieve the answer only if the instructor supplied the code name to the answer file.

Therefore, valuable time is afforded by "phasing" CAD into the introductory graphics course. The software available for the course is tailored to teach specific concepts which are inherently visible in manual drawing techniques. As an example, graphical concepts dealing with direct projection from adjacent views. The size of the computer screen may force a very small scale to adequately show more than one view of an object. Therefore, these concepts dealing with direct projections are often time consuming and cumbersome. Other examples of important lessons inherently taught in manual drawing courses which the computer software would need to address could be: professional presentation through line quality, drawing placement, and overall neatness, visualization abilities, tracing overlay advantages, and the use of some instruments such as the various types of scales.

IMPROVING CAD AS AN EDUCATIONAL TOOL

A questionnaire that was answered by all the students at New Kensington Campus and Behrend College who completed the pilot courses. The goal of the questionnaire was to determine if CAD was perceived by the students as being effective as a learning tool when compared to conventional manual techniques. More specifically, the questionnaire needed to help determine exactly how CAD was an effective learning tool; or conversely, exactly why it was not effective.

The information gathered by this questionnaire can also be used to help instructors on many key issues.

1. Is the current software adequate?

   Are topics best handled by conventional drawing techniques, and can they be taught as effectively using CAD if proper software were developed?

   What areas of instruction need development and improvements if a complete conversion to computer assisted drafting were made?

   What additional software and hardware purchases need to be considered?

   What level of sophistication, expense, and versatility is necessary to meet the requirements of student needs, and the courses to be taught.

ENGINEERING GRAPHICS 50

COMPUTER AIDED DRAFTING QUESTIONNAIRE

****
*   YOUR RESPONSES TO THE FOLLOWING STATEMENTS WILL PLAY AN IMPORTANT   *
*   ROLE IN THE CONTINUED DEVELOPMENT OF EG 50 AND ITS COMPUTER AIDED   *
*   DRAFTING COMPONENT. YOU NEED TO SIGN YOUR NAME IN CASE YOUR   *
*   RESPONSES ARE SIGNIFICANTLY OUT OF ACCORD OF THE NORM. IT IS   *
*   TRULY IMPORTANT THAT A CLEAR AND NEARLY UNANIMOUS OPINION OF THE   *
*   ENTIRE CLASS IS REACHED FOR THIS QUESTIONNAIRE TO BE MOST SUCCESSFUL.   *
****

NAME____________________ DATE____________________

To properly evaluate your responses, please provide the following personal background information.

1. How many years of mechanical drafting have you had prior to this course?

   a. More than 3 years
   b. 3 years
   c. 2 years
   d. 1 year
   e. 1/2 year or less

2. How many years of computer programming have you had?

   a. More than 3 years
   b. 3 years
   c. 2 years
   d. 1 year
   e. 1/2 year or less

3. What computer languages do your know? (several answers possible)

   a. APL
   b. BASIC
   c. FOR-

The following questions pertain to the effectiveness of the current software as a "learning" tool.

Assuming drawings of equal difficulty were assigned to you, how would you compare with the regular "manual" drafting techniques with the computer aided drafting. Place an x in the proper column for your answer.

1. Compare the "speed" in accomplishing the drawing (please include the time in plotting the drawing too).

TOPIC	COMPUTER DRWG FASTER	MANUAL DRWG FASTER	NO DIFFERENCE
a. Lettering..................	____	____	____
b. Three view drawing.........	____	____	____
c. Finding and adding missing lines...........	____	____	____
d. Isometric drawing..........	____	____	____
e. Oblique drawing............	____	____	____
f. Charts and graphs..........	____	____	____
g. Dimensioning...............	____	____	____
h. Sectioning.................	____	____	____
i. Drawing arcs and circles...	____	____	____

2. Compare the "ease" of learning a new topic.

FIGURE 1

The students met for four hours in a traditional drawing board laboratory and for two hours in the computer assisted drawing laboratory. Therefore, the students used these mixed laboratory classes as a basis for comparing the effectiveness of each method in helping them to learn a specific topic. The questionnaire included numerous items to contrast student perceptions of manual vs. computer graphics. Currently, several areas have been identified by the faculty to be relevant in learning graphics concepts. The questionnaire focused on evaluating the students' perception for each of these areas. These areas are described as follows:

a. Ease of learning new concepts - If a topic is perceived to be easier to learn while using one method over another, then a significant advantage of that method is identified. An example whereby CAD would provide ease of learning would be if problems/solutions were available or a programmed step-by-step instructional package were part of the computer software.

b. Enjoyment of learning - A technique of drawing may simply be more fun to use. Additionally, one of the two methods could prove to be more enjoyable because it is more versatile in providing inherent aids conclusive to learning the topic.

c. Concentration on graphical concepts - If a "tool" to be used to draw a solution to a problem is so cumbersome to use, it may actually distract the student from concentrating on the principles involved. One of the two drawing methods may allow more thought to be given to the problem rather than to the "tool" by which it must be solved.

d. Speed - One method of drawing may simply be faster than the other. This would allow more examples to be solved and perhaps more topics to be covered in the same time period.

This section of the questionnaire deals with the level or significance that you feel computer graphics may be for your future.

1. The engineering profession will probably use computer graphics

   a. not much, if ever
   b. in 5 years
   c. in 2 years
   d. in the near future, if not now

2. In your opinion, is computer graphics here to stay?

   a. very definitely
   b. most likely
   c. maybe
   d. probably not
   e. no

3. Do you feel that the information which you saw and learned on the computer graphics system is important for your future as you perceive it?

   a. extremely important
   b. important
   c. maybe important
   d. probably not important
   e. not important at all

4. The computer aided drafting portion of EG 50 (assuming the equipment is available) will most likely be ___________ to you in later courses.

   a. extremely important
   b. important
   c. maybe important
   d. probably not important
   e. not important at all

e. Presentation or Quality of Drawing - One method may be superior in allowing the student to experience a great deal of pride and satisfaction from a good quality drawing. These feelings are important to encourage students to enjoy what they are studying.

f. Student attitude - A high degree of student interest and enthusiasm for a course is extremely important in motivating students to learn. Although enthusiasm is difficult to evaluate, a series of questions were asked which dealt with the student's attitude toward computer assisted drawing. It is our belief that if a student perceives that one method of drawing is more advantageous to his/her future in comparison to another method, then enthusiasm will be present in studying that method. In particular the questions attempted to measure the students' perception of importance of CAD in relation to the following:

1. future courses in the engineering curriculum
2. marketability of skills as an engineering graduate
3. pı eparation to meet future trends in engineering design and manufacturing.

A typical question from the questionnaire is shown in Figure I which is a summary question relating to the student's overall preference.

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6. The "blend" of the manual drafting techniques and the Apple graphics in the same course is

   a. very desirable and helpful
   b. desirable
   c. no opinion
   d. of little help and often confusing
   e. a hindrance in learning the material

7. Select the method which you feel is best for you in "learning" the concepts necessary in this course.

TOPIC	ONLY COMPUTER TECHNIQUES	ONLY MANUAL TECHNIQUES	A MIXTURE OF COMPUTER AND MANUAL TECHNIQUES
a. Lettering..................	____	____	____
b. Three view drawing.........	____	____	____
c. Finding and adding missing lines...........	____	____	____
d. Isometric drawing..........	____	____	____
e. Oblique drawing............	____	____	____
f. Charts and graphs..........	____	____	____
g. Dimensions.................	____	____	____
h. Sectioning.................	____	____	____
i. Drawing arcs and circles...	____	____	____

8. On an average, how much time did you spend outside of each class to complete the assigned computer projects?

   a. No extra time
   b. 15 minutes
   c. 30 minutes
   d. 45 minutes
   e. One hour
   f. One hour and 15 minutes
   g. One hour and 30 minutes
   h. More

CONCLUSION

It is the experience of New Kensington Campus and Behrend College of The Pennsylvania State University that introducing computer aided graphics into the engineering graphics classes on a gradual basis has certain advantages. Although this is a conservative approach to eventually converting to a total computer assisted drawing laboratory, it satisfies the present concerns of students and faculty, and also addresses itself closely to the needs of industry.

The implementation of CAD equipment should be done with proper instruction in mind. New teaching methods, new instructional tools, and new projects need to be created in this computer based graphics course so that the student can learn more graphical concepts, and at the same time learn these concepts far easier than with conventional manual techniques. The CAD environment offers the educator a tremendously versatile environment for innovative and creative instruction. To expand CAD from a mechanical tool to an instructional tool needs to be a major emphasis in every school wishing to convert their drawing board laboratories into computer assisted drawing laboratories.

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Continued from Page 40

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When
you can
measure
what
you are
speaking
about,
and
express it
in numbers,
you know
something
about it.

Lord Kelvin

Ann Tiber
Washington Technical College
Marietta, Ohio

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