CADCAM IN EDUCATION AND TRAINING

Proceedings of the CAD ED 82 Conference

EDITED BY
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Part 1: Introducing CADCAM

Editor's note:
All contributing authors were requested to supply figures of a quality suitable for reproduction – many failed to do so, and in such cases the figures have been omitted.

Readers wishing to view any of these missing figures should approach either the author or the CADCAM Association who will be happy to supply photocopies.

1. Welcoming address

H H Rosenbrock

The first thing I would like to do is of course welcome you to UMIST. It is a very great pleasure to be host here to this meeting. The subject is one in which UMIST has had an interest for many years and it is a subject which is at present only at the very beginnings of its development. What we have seen so far, I believe, is comparable to the development of the motor car up to say 1900, and the developments which are going to take place are going to have a very great impact. Technological institutions like UMIST feel that they need to be deeply involved in this kind of activity, so welcome to UMIST and I hope that your conference will prove an interesting, profitable and enjoyable one for all of you.

My own interest in CAD goes back to the 1960s when it was very young. The first contact I had was in 1963–4 when I happened to spend a year at MIT when the sketch pad programme was just terminating. My own technical work was in a very specialized area of CAD, that is to say the computer-aided design of control systems. We didn't realize it at the time but looking back on it, it was somewhat different in its development from the major development which has taken place over the last five years or so in the wider application of CAD to engineering design. We were concerned with designing control systems of the abstract things: they don't give rise by themselves to graphical output pictures and the problem was to develop a theory which gave rise to the pictures, and that's where a lot of the work went. Then of course there were all the problems of the role which the user should be given in the system. My own particular interest in the social effects stemmed from the strong feeling that I got at that time, that in giving to the user the vital role in the design process we were very much swimming against a stream which tried hard to eliminate the user, to eliminate the designer, and reduce his role to specifying what was required. The properties of the system, the constraints, the objective function, would then be put into a big computer off-line which would churn away and come out with an answer, the principle being here that the designer said what was needed and the computer came back and said if that's what you need this is how you solve your problem. Well, first of all, it's not a good way of solving engineering problems, as all of you no doubt realize. You look at the answer and say, 'That's not what I want to do'. So you then have to go back and try to re-specify the problems and the answer comes out a bit nearer to what you want. The only rational way of approaching that situation is to say that we don't really know at the beginning what is needed and we have to learn by trying to solve the problem. Defining the problem is a large part of the problem itself, and one has a good definition of the problem only at the time that it is solved. There is an essential part for the designer to play in interaction with a system which aids him, clarifies his thinking, works out for him the consequences of the decisions he makes. I think one has to recognize that in saying that, one is going counter to a very deeply held scientific attitude which holds that to rely on human skill at the time the job is done is somehow unscientific and not technologically respectable. From that, my particular interest in the social effects stemmed. Now you have a talk by Mike Cooley, which I think will certainly bear on this kind of problem. All I would like to say to you is this, in designing systems, CAD systems, which will allow a designer to do his job, you are doing many things, and you are contributing to the productivity of the designer. You are possibly creating a situation in which the things he designs will change. He now has different facilities, he can now design a different kind of thing, perhaps more advanced, more complicated. There are several other things that you are doing. You are affecting the number of jobs that there will be. Some kinds of jobs will be lost, some kinds of jobs will be created. That is a problem partly for engineers, but mostly for economists and politicians. But there is one particular thing that you will be affecting, which is very much the province of the engineer technologist, and that is the kind of work people do. The systems that you produce, the systems that you influence by your purchasing policies, the kind of thing that you buy which affects the kind of things that people will develop, will affect the kind of work the designers will do in the future and I would like to sketch two extremes that one could envisage. At one extreme we could set out to eliminate as far as possible all the initiative of the designer and do everything for him in the computer to reduce his decisions to the absolute minimum. Now that may not sound very sensible, but certainly it's what has happened on the shop floor for 150 years or more. All the initiative has been taken away from the shop floor as far as possible and given to the specialized design office. In the same way, one could envisage taking away from the designer as much as possible of his initiative. So that, for example, the geometrical information about a product was entered as quickly as possible. With a little thought, the computer system accepted this and then took responsibility for presenting that tentative design, to specialists in production methods, in corrosion, in stressing who would then make suggested changes. The computer would take the suggested changes, make sure that the final design had gone round the whole route among all these specialists without any further change before it was accepted. One could try to give the computer system great control over the design process. The other way, the other extreme, would be to accept that the computer system has quite different capabilities from the human being. The computer system can ease the designer's work but it can't make new, totally new decisions. It can't see, for example, if a product has some new way of failing which has not been experienced before. A good designer may see this and a computer system never will, and one could aim to give to the designer the maximum possible control over the situation. Giving him the CAD system as a tool for him to use, to ease his work but making him the master and the CAD systems the alternative that I have described, reverses that order. It tries to make the CAD system the master and the designer the servant, and I would suggest to you very strongly that the second way is the way one should try to go. One should accept that human beings have a different kind of ability from machines and one should set out not to eliminate the human being but to use his ability to the best effect. Now that's perhaps somewhat moralizing and the tone of your conference as I notice from the programme is largely technological, but I would like to suggest to you that in your deliberations you will be affecting not only the technology, not only the economics but also the life of people in many ways and in particular the kind of jobs that designers will do. I will stop at that point, and wish you once again a very successful conference.

2. Integration and implementation of computer-aided engineering (CAE) – the strategy for innovative product design in the 1980s

M A Neads

Abstract: Technologies to automate computer-aided drafting and computer-assisted NC tape preparation are available and are beginning to be used widely to help reverse the alarming trends of declining productivity in many industrial economies. However, automating isolated tasks in today's 'build-and-test' product development process, while cost-effective, will not achieve significant time savings, productivity gains and/or strategic benefits, as anticipated by most companies.

The overall mechanical product development process itself must be automated. Products must be developed within the computer. Prototypes should be built to verify and validate computer predictions, instead of being used to find out how a product performs, as is common today.

Extended reaches to improve product performance and quality can be achieved in significantly shorter time through the effective implementation and integration of existing computer-aided engineering and related manufacturing capabilities. Indeed, strategic benefits impacting a company's overall market share, quality image, return on investment and profitability can result from effective CAE implementation.

Benefits do not come easily, however. The CAE process requires change, including change in organizational structure. CAE methods cannot be implemented quickly: three to ten years are required in most companies and industries. CAE implementation and maintenance is expensive: at least 10 per cent of total product development budgets each year is required for CAE software, hardware, maintenance, support and training. An entirely new way of thinking about mechanical product development is necessary in most companies.

Pressures on design engineers

Among these pressures are that buyers are demanding improved efficiency and reliability in mechanical equipment and products; manufacturing executives are demanding design time and cost reductions; government regulations demand concentration on safety, pollution, and noise control – regulations which didn't exist ten years ago. Finally, we have the energy crisis and the demand for the preservation and conservation of our natural resources. Engineers in all industries are facing these pressures.

The other major problem, that everyone is certainly familiar with, is the problem of declining productivity. Not only does declining productivity cause problems within the United Kingdom but the UK has one of the poorest productivity records in terms of the top seven industrialized nations. All of these international competitors face pressures similar to our own, in terms of energy, inflation, etc.

Not only is labour productivity declining, but so is the productivity of our capital equipment in this country.

However, there are hopes for improved productivity, some of which are real. These include the trend toward incentives for increased capital investment in CAE intensified national efforts on research and development and innovation, and finally, the reason that we are here, the *emerging technologies* that are now becoming available to us.

Emerging technology and CAE

Great strides and changes have occurred in mechanical engineering in the last few years. Just read Gene Bylinsky's article in the 5 October issue of *Fortune* magazine entitled, 'A New Industrial Revolution is on the Way'. Most observers feel now that computer-aided manufacturing and computer-aided engineering are 'the manufacturing technologies most likely to raise productivity during the next 10 years'; (New Technologies and Training in Metal Working, National Centre for Productivity, 1978).

We are not talking about the recent advent of turnkey CAD/CAM drafting systems. While these do increase productivity of the drafting task, they do not *dramatically* reduce the time and cost involved in the overall total mechanical development process.

Rather, what we are talking about is a process called computer-aided engineering, which can reduce design time and cost by factors of 30 per cent or more; not the 4 per cent or 5 per cent that CAD/CAM systems provide. The CAE process, then, addresses the entire product development cycle, from concept to finished product.

Emerging technologies – yesterday

To understand how revolutionary technology can be, let's take a look back at only ten or twelve years ago to see what was available to design engineers at that time. You remember 1970? There were no hand-held calculators that are so common today and large resources were not available. Engineers were making only about £1,500 per year. When faced with a new design project – the development of a new car, the design of a bridge, etc – we simply assigned more engineers!

The technology available to engineers in 1970 was archaic by today's standards. We were using time-sharing computers from a 15 character per second noisy teletypewriter terminal. Few were able to get any type of graphical output of results. For mechanical design analysis, very little was available in the terms of computer-assisted design. Mostly, beam finite element models were the best simulation tools available. Very few design analysis computer programs were available; NASTRAN was not yet released to the public. By and large, most design engineers in industry relied on the old textbook approaches and the standard 'build the prototype, test it; modify it, test it: modify it, test it:' methods. Generally, design engineers in industry had very few tools for improving design process productivity.

Emerging technologies – today

However, let's look at what's available to us now. There has been an incredible explosion in the knowledge available to mechanical design engineers. How many of us have been able to keep up with the required reading and continuing education in our speciality?

By 1980, the average engineer's salary had risen to about £8,000 per year. No longer can we simply add more and more engineers to a project. Not only that, there is a shortage of qualified engineers today.

However, technology has come to our rescue, at least partially. For example, there are now minicomputer-based integrated testing systems which allow data from all kinds of vibration, stress, or noise tests to be collected, processed, and displayed in a form that design engineers can understand. No longer are they faced with the tedium of studying strip charts and large print-outs of tabulated numbers.

An excess of computer-assisted terminals, connectable via phone links to large computers, is now available to design engineers. Very complex finite element models can now be generated, analysed, and their results displayed in a matter of minutes.

Today, integrated computer-aided design and drafting equipment accessing software systems for computer-aided engineering allow engineers, through a data-base approach, to be able to go from component design concepts, through component analysis, system performance and evaluation, component evaluation, drafting and documentation, computer-aided manufacturing and advanced prototype performance evaluations.

Total CAE computer facilities are available. The recommended approach involves a hierarchy and distributed data-processing computers, beginning at the lowest level with local user stations. These include 'dumb' graphics terminals and/or graphics terminals with local intelligence (from microprocessors or minicomputers), such as those included in the turnkey systems mentioned earlier. Today's user stations, however, are not standalone, but are connected to higher level computers, either the so-called midrange or product level computers such as the DEC VAX 11/780, or an IBM 4300 series; or may connect directly to mainframe computers such as the CDC Cyber 170 series, or the IBM 3000 series.

Finally, the installation of in-house computers and computer networks does not obviate the worth of world-wide commercial computer networks such as General Electric Information Services. These world-wide networks can provide electronic information for all of the vendor-supplied equipment used by virtually every manufacturer of mechanical systems today. In addition, networks can provide the back-up facilities needed for overflow of corporate mainframes. They also allow the interconnection of a corporation's computers at various locations as well as allow access to data-bases world-wide.

CAE – a designer's revolution

We believe that computer-aided engineering advancements have put mechanical engineers on the threshold of a revolution. It is not surprising that this revolution should finally occur for mechanical engineers in much the same way that the electronics industry underwent the revolution from the 1940s through to the 1970s, transforming large vacuum tube computers that took rooms of space to the VLS integrated circuit familiar to us today.

Design examples

With strong emphasis on computer graphics, computer-aided engineering today allows us to design rapidly this robotic manipulator. Not only can we have a wire frame display, but also a three-dimensional solid geometric model (Figures 1 and 2), which allows us to put a design completely through its paces before anything is committed to hardware (Figure 3). Once we have put the system concept through its initial design

Figure 1 *(see page 9)*

Figure 2 *(see page 9)*

Figure 3 *(see page 9)*

phase, we can concentrate on individual components such as a portion of the robot arm. Using the geometric data-base, it is possible to generate automatically complete finite element meshes, submit this design to a larger computer where the finite element code itself resides and bring the results data back to the graphics display and portray the stress contour output in forms easily understood by the designer (Figure 4). Once we are satisfied with the various components, we can call on the CADCAM drafting systems to produce shop-ready drawings completely dimensioned, with bills of materials.

CAE and computer graphics are now being applied to other mechanical industries, such as the refinery and plant design process business. Computer graphics are being developed to replace the expensive and extensive plastic modelling of new plants (using plastic models of vessels, pipes, etc) to get rid of all the interferences possible in such a complex design. With the addition of colour, added understanding can be provided.

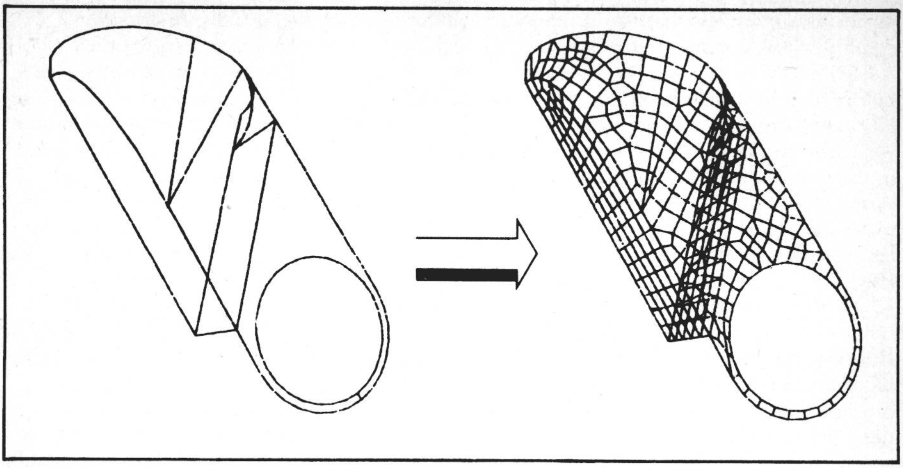

Figure 4 *Boundary edge description of a robot component (left), automatically generated finite element model (right)*

With the solid graphical representation, the equivalent of the hard plastic models, can be generated (Figure 5).

Figure 5 *(see page 9)*

Conclusion

The future is very exciting, and the importance of CAE and its positive impact on engineering design quality and productivity is beyond question. The new CAE approach is computer-based and not only encompasses both CAD and CAM activities, but also goes much further. It automates the entire product development process from conceptual design to release to manufacturing.

If engineering management and top management is willing to measure up to the challenge of integrating and implementing the CAE concepts we will have a promising future. Companies must have a cognizant corporate strategy, based on a five-year plan to achieve this.

Without question, CAE implementation is the 'challenge of the eighties' for most engineering and manufacturing professionals. Implementation of CAE philosophies into product development and manufacturing activities is one process most likely to achieve massive productivity gains and improve the quality of working life.

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