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# Advances in Materials Technology: MONITOR

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ADVANCED MATERIALS TECHNOLOGY: CAD/CAM APPLICATION

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Dear Reader,

Because of its size this Monitor is a double issue, 19/20. It is devoted to the "Advanced Materials Technology: CAD/CAM Application".

In each issue of this series, a selected material or group of materials is featured and an expert assessment made on the technological trends in those fields. In addition, other relevant information of interest to developing countries is provided. In this manner, over a cycle of several issues, materials relevant to developing countries could be covered and a state-of-the-art assessment made.

The main article "Recent Developments in Advanced Materials Technology: CAD/CAM Application" of this issue was written by Dr. Venkateswaran Sankaran from the Institute for Chemical Technology of Inorganic Materials, Technical University, Vienna, Austria.

We invite our readers to share with us their knowledge and experiences related to any aspect of materials development, production, processing and utilization. It would be a great input into strengthening developing countries' awareness to world-wide achievements in science and technology and will help them to make changes in industry and economy.

We would be grateful to receive your opinion on possible subjects for our forthcoming issues and any ideas on how to increase the value of our Monitor.

Department of Industrial Promotion,
Consultations and Technology

## ENGINEERING'S TOP TEN

In celebration of its 25th anniversary, the National Academy of Engineering (NAE) has announced what it considers to be the greatest engineering achievements of the past 25 years. The ten achievements, selected from more than 340 suggestions, includes technological breakthroughs first put into practice or commercial use since 1964. The ten achievements are the moon landing, application satellites, the microprocessor, computer-aided design and manufacturing (CAD/CAM), computerized axial tomography (CAT scanner), advanced composite materials, the jumbo jet, lasers, fibre-optic communication, and genetically engineered products. Says Robert White, NAE president, "Taken together these ten outstanding engineering achievements demonstrate how completely new technologies have transformed our lives and improved human welfare in the past 25 years." (Source: Machine Design, 8 February 1990)

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# 1. RECENT DEVELOPMENTS IN ADVANCED MATERIALS TECHNOLOGY: CAD/CAM APPLICATIONS

A REPORT

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# RECENT DEVELOPMENTS IN ADVANCED MATERIALS TECHNOLOGY: CAD/CAM APPLICATIONS

New material technologies demand new production technologies. The compound casting of light metal and ceramics in the form of fibre compound using directional long fibres opens up a new range of possibilities. Improvements in the thermal stability and resistance to corrosion can be achieved by new magnesium alloys. At room temperature, the fracture toughness and Young's modulus can be doubled, and at elevated temperatutures it is now theoretically possible to increase both values by a factor of 10, in comparison to non-reinforced light metal. These are, but a few instances, wherein CAD/CAM applications have played a decisive role in the evolution of new material technologies. The era of fast-desk top computer with parallel processing offers unprecented opportunities to make a quantum leap forward in the efficiency of materials useage. The current needs for greater productivity also have added new demands on the design process to exploit the CAD/CAM methods while being more responsive to the overall production process.

In this paper, initally, the generally understood meaning of CAD/CAM is presented, followed by a review of the state-of-the-art of some of the CAD/CAM applications, especially with regard to castings. Each section is followed by a brief report on the future trends.

## 1. WHAT IS CAD/CAM:

### A: What is CAD:

Computer aided design (CAD) is a technique in which man and machine are blended into a problem- solving team, intimately coupling the best characteristics of each. The result of this combination works better than either man or machine would work alone, and by using a multi- disicipline approach it offers the advantage of integrated team-work.

CAD implies by definition that the computer is not used when the designer is more effective, and vice versa. This being so, it is therefore useful to examine some individual characteristics of man and computer in order to identify which processes can best be seperately performed by each, and where one can aid the other. Table 1 compares the capabilities of man and computer for a range of tasks. It can be seen that in most cases the two are complementary, that for some tasks man is far superior to the computer, and that in others the computer excels. It is, therefore, the marriage of the characteristics of each which is so important in CAD. These characteristics affect the design of a CAD system in the following areas:

a) Design construction logic: The use of experience combined with logic is a necessary ingredient of the design process. The design construction must therefore be controlled by the designer. This means that the designer must have the flexibility to work on various parts of the design at any time and in any sequence, and be able to follow his own design logic rather than a stylised computer logic. The computer cannot cope with any significant learning. This is left to the designer, who can learn from past designs. The computer can, however, provide rapid recall of old designs for reference. Thus, in some ways the designer can pass on his experience to the computer, and other designers can then have access to it.

b) Information handling: Information is required from the specification before the design solution stage can proceed. Similarly, when the design solution is complete, information must in turn be output to enable the design to be manufactured. Fig.1 shows the application of this process to manual design. Information is assimilated by the designer from the input specification. The design solution process then takes place, whereby, information is passed from the designer to the paper and back again in the form of drawings and instructions is produced. Fig.2 shows the process extended to the combination of designer and computer. The design solution now includes a flow of information betweeen the designer and computer in the form of graphics and alpha-numeric characters. The initial specification must be input to the designer in order that selected parts can be communicated to the computer in a form that it can understand and use. The first role of the computer is to check the information for human errors, which must be corrected by the intervention of the designer.

c) Modification: Design descriptive information must frequently be modified to make correction of errors, to make design changes, and to produce new designs from previous ones. The computer has the ability to detect those design errors which are systematically definable; whereas man can excersise an intutive approach to error detection.

d) Analysis: A computer is very good at performing those analytical calculations of a numerical analysis nature which man finds time-consuming and tedious. As much as possible of the numerical analysis involved in the design should be done by the computer, leaving the designer free to make decisions based on the results of this and his own intutive analysis.

It can thus be seen that there exists a clear division between the functions of man and computer in CAD:

The computer SERVES as an extension to the memory of the designer, ENHANCES the analytical and logical power of the designer and RELIEVES him from repetative and routine tasks.

The designer CONTROLS the design process in information distribution, APPLIES creativity, ingenuity and experience and ORGANISES design information.

B. What is CAM:

The fields of manufacture and design are invariably separate, but it is a natural step to decrease the gap between the drawing board and the manufactured item. The way to achieve this is to ensure that work carried out in the design process is not needlessly repeated during manufacturing. Thus, many companies are turning to computer aided manufacturing (CAM) techniques, mainly in the form of numerically controlled (NC) machines, in order to provide greater flexibility in production.

Computer graphics facilities and the availability of supporting software have given the designer the tool they need to produce computerised geometrics, and several interactive graphics have been developed. In the case of a NC, a part-programmer will be given an engineering drawing of the required object and will produce a part programme manuscript. This involves the coding of the geometry of the item, followed by the coding of the statements to describe the tool motions required to carry out machining. The manuscript, when complete, will be processed by a NC processor, and if no errors are detected, a control tape will be produced. NC instructions are written in control langauges such as APT. This term APT stands for automatically programmed tools and refers to both a langauge as well as a computer programme. The APT langauge describes the sequence of operations to be performed by the NC machine. Today, systems have been developed in which NC machine tools are directly driven from the minicomputer without the need for the APT system. Such systems are called CNC or computer numerically controlled systems. A more sophisticated system is a DNC (direct numerical control) system which networks several minicomputers to a central mainframe computer. The main advantage for this configaration is that when the main-frame is temporarily down, the machine tools can continue to run off the memory of the minicomputers. Modern computer technology now makes creation and verification of the NC instructions more effecient. By checking the tooling programme with a visual CRT, for example, less machine tool time is spent in verifying cutter paths. Perhaps, more important, is that the computer itself can now generate a NC programme directly from a geometric description of the part.

C: What is CAD/CAM:

CAD/CAM involves the creation of the mathematical description of the parts or shape in 3-D space within a data base. This mathematical description can be used for the verification of fit and interference within an assembly, structural intergrity, volumetric and area properties, producing shrink factor for more concise net part production, automatic drawing creation, jig and fixture development and so on. Furthermore, this defined geometry can be used by the manufacturing personnel to simulate graphically tool motion, cutter paths etc. This simulation provides a cost effective way of getting the job done in several ways. Firsty, it provides NC/CNC information more economically than any other method. Secondly, it eliminates duplication and communication problems between the designer and the part programmer and thirdly, eliminates the need for unnecessary rework of prototypes and tryouts.

Having thus got a general idea of CAD/CAM, we shall take a look at the current state-of-the-art of its applications. But before that it must be understood that CAD/CAM is just a part of a broader Computer Aided Engineering (CAE). It is also referred to as a part of Computer-Integrated Manufacturing (CIM).

## 2. STATE-OF-THE-ART:

### 2.1 Introduction:

The past few decades has witnessed rapid strides in technology. In keeping with the technological advances, materials development and manufacturing process engineers are increasingly turning to computers as a answer to their manifold problems. One of the most spectacular developments has been in the area of CAD/CAM applications.

Today, it is common place to find arrays of graphics workstations and networks of computers in design offices, which have revolutionised drawing office practices in the design of structures and components. Thus, products can be designed and analysed 'ad infinitum' long before prototypes are manufactured and tested.
The need and availability of new materials like ceramics, metal-matrix composites etc., have brought specific challenges to the materials engineers in terms of appropriate testing procedures to be developed, interpretation of the subsequent materials data and modelling the performance of advanced materials. Effective modelling can be used to identify the potential sites of failure in the end product caused by stress or the formation of defects during manufacture.

Simulation programes enables new techniques or components to be tested at relatively low cost without incurring time penalites for the production of equipment or cost of manufacture. Manufacturing process are however, inherently non linear and involve large plastic work and/or changes in shape, making calculations very complex. To solve such problems numerically, requires the use of extremely powerful computers and unobstructed access to them. In recent years, very powerful super-work stations and mini-supercomputers have arrived on the market and has,at last, brought affordable computing to those who need it for purposes of simulation. It is possible to simulate a wide variety of forming process, from casting through forging to pressing, rolling and drawing. The most recent simulation includes the joining of metal-matrix composites. Weldability assessement of cast superalloys for turbo engines, investigations on the welding properties of titanium aluminide alloys for aerospace applications and studies on the effects of thermal and mechanical shock and/or fatigue on metal matrix composites, superalloys and other aerospace materials are also being attempted using such techniques. Thus, physical simulation techniques play an important part in materials fabrication and production and makes the possibility of meeting the demands of maximum efficiency. minimum downtime and improved quality, a reality.

As the price of CAD/CAM systems, in terms of computer horsepower and software facility, has tumbled in recent years, more and more companies are willing to look at the capabilities of these systems beyond straight design-drafting. Among the attention drawing areas are inspection and testing. Concurrent with this widening of intrest areas has been the increasing importance of quality control. It is inevitable that these two areas would be examined concurrently. The application of CAD/CAM to inspection and testing has already achieved benifity beyond what has been thought possible . CAD/CAM's implication are not a 'pie in the sky' but a 'down to earth' enhancement to the efforts of professionals in achieving their goals. We shall now review some of its recent applications.

## 2.2 CAD/CAM applications to castings:

With the ever changing needs in today's market place-new technology, competition, and increased regulations-each business firm must continually seek better ways of conducting its varied activities if it is to survive and prosper. The foundry industry is not far behind in applying CAD/CAM techniques to castings and casting production. There are a variety of economical and technological benefits which the foundryman can derive from it.

There are, however, several major scientific or engineering related 'roadblocks' to the application of computer technology in casting design. These impedimiments pertain to the geometric modelling/physical simulation problems, the provision of thermal transport data, the problem of filling transients associated with the pouring of castings, the modelling of the interfacial phenomenon, the accurate description of the interaction of the moulding medium and the solidifying casting and finally the computation system itself.

There are a variety of specialised steps in the production of casting, namely:

1) consideration of the castability of the product design itself,
2) consideration of the tradeoff between the product design objectives and castability,
3) design of the moulding technique to incorporate features of casting including the use of cores, location of parting lines, etc.,
4) design of casting rigging items and theirlocation, such as risers, gating system, use of chills, etc.

The optimum combination of these design considerations bear directly upon the productivity of the metalcasting industry, a critical industry not only in terms of its size, but also as it is highly energy intensive and many of the engineering products can be produced on an economical basis only through the castng route. Inappropriate casting design can lead to a variety of wasteful and unproductive costs, and in certain cases, component failure; unsoundness may require expensive rework or casting rejection; misruns and freeze-offs due to poor casting design result in scrap; surface quality is directly related to overall casting and gating design; and marginal feeding conditions result in sporadic porosity. In the past, and even now in many instances, the process of design decision in this area have resided in the hands of skilled and experienced foundrymen. If a competative position is to be maintained, these skills must be supplanted with a more engineering approach. Simulation of casting solidification provides an opportunity to achieve a degree of design optimisation not hetherto possible which would result in a more efficient and profitable production system. The application of CAD/CAM has been slow in its implementation in the foundry industry principally due to the aforementioned scientific or engineering road blocks.

In the foundry, three forms of CAD/CAM are available:

* CAD systems to assist the drawing office,

* CAM systems which enable conventional drawings or CAD drawings to be intrepreted for manufacture on NC tools, so assisting the planning office,

* CAD/CAM systems which enable the design office to design unique components with parting lines, draft angles and splint planes, which can be analysed and optimised for weight, stress etc., and which then allows both roughing

cutter paths and finish cutter paths to be calculated directly and which assist in tendering, planning, etc.

Let us now take a look at the foundry CAD/CAM system. Fig.3 depicits a typical CAD/CAM system and the flow of informati... ..:hin the various components. Fig.4 illustrates how a CAD/CAM system can be used in a foundry. A graphics terminal essentially consists of a digitiser combined with a CRT (cathode ray tube), a data tablet, a function key board and an alphanumeric key board and a hard copy device for printing alphanumeric or plotting graphical data.

Introduction of CAD/CAM in a foundry can be visualised as a three stage process:

1) Introduction of computer aided drafting: This is to cater to the drafting needs of the foundry. In computer aided drafting, the workstation substitutes the drawing board i.e., the display screen simulates the drawing board. The draftsman, with minimum of training, can create drawings on the display screen using a set of commands. These commands are available through a menu selection board. Further, graphic data can be input to the computer through devices like the digitiser or the light pen. Repetitive types of drawings which often encountered in foundry R&D departments can be generated with utmost ease in this fashion. Simultaneously as the picture is being created on the display, a file is also created, With suitable software, it is possible to save this file for retrieval at a future date. Once the final drawing is created with all the details, hard copies can be had through the plotter.

2) Introduction of computer aided drafting and design: This is to design feeder and gating systems by interaction between the engineer and the CAD system. Here, modelling techniques, for geometric modelling or process modelling are

used. In the foundry, modelling refers to the development of a computational technique which will:

* Design gating and feeding systems for castings,
* Specify optimum mould and pouring temperature,
* Predict residual stresses and hot tearing,
* Predict post casting processing and casting properties,
* Provide the basis for plant scheduling and production planning.

A geometric model can be constructed in three ways,

* A wire frame model in which the edges of a part are represented by lines only,
* A surface model in which a clearer interpretation of curved surfaces is facilitated,
* A solid model which is built out of a set of basic 3-D shapes like a cylinder, prism, cone, etc. These can perform several functions which are not possible using 3-D wire frame models, for eg., they can automatically produce isometric or ortographic views of the component. Mass properties such as volume, centre of gravity etc., can also be determined. Sophisticated software facilities are however required for these.

Process modelling techniques are particularly suited for foundry industries, as fundamental phenomenons like heat and mass transfer, fluid flow etc., are encountered, which can be mathematically described with a fair degree of precision. Simulation techniques using finite element or finite difference approximations are widely used to solve such problems.

3) Introduction of computer aided drafting and design cum manufacture: This is to manufacture dies and patterns. Taking into account the various design parameters and post

casting processes, the designer can prepare a NC tape on the computer, which can be used to machine a pattern or a die. A realistic estimate of the production problems, design deficiencies and production costs can be made.

An example of the benefits of introducing CAD/CAM for computerised die manufacture is given in Fig.5, which shows why CAD/CAM techniques are becoming important to the foundryman. Table 2 gives some recommendations for different types of foundries purely on what CAD/CAM systems can do; the cost effectiveness, however, has to be worked out in great detail. In Tables (3-6) are listed some of the software available for different applications. It appears as though the one developed at Foseco, called SOLSTAR is the most popular among foundrymen. This package can be used to predict and eliminate shrinkage defects in castings. It uses its own solid modeller to generate a full 3-D solid model of the casting shape, feeder and runner system. The programme carries out a combined thermal analysis and solidification simulation, to determine shrinkage defects in the casting, feeder and runner systems.

Ove Arup and partners has been developing software which can deal with specific industrial situatations such as those encountered in metal forming process or the automotive industry. These programmes are 3-D finite element codes, written specifically for the efficient solution of problems involving a high degree of material, geometric and thermal non-linearity. An example of the simulation of the solidification and cooling in a turbine blade casting is shown in Fig.6, indicating parts which solidify first and areas of the cast blade in which voids are likely to form. Fig.7 shows another example of the simulation of solidification in a structural casting.

Solid modelling computer programmes can be applied to further the design of complex castings. A solid modelling programme is similar to a computer aided drafting programme, in that both are used to define the geometry of components. A computer aided drafting performs this in 2-D whereas a solid modeller can create, display, manipulate and modify a component in 3-D.

There are significant benefits that can accure from solid modelling of castings. One feature of a solid modeller is that the component can be readily visualised from different angles. This makes it possible to minimise pattern-making errors and so reduce production lead times. Moreover, most solid modellers permit the component design to be interrogated, allowing design features to be assessed, and appropriate design changes can be made with relative ease and the new model can be redisplayed.

As an example of this approach, Fig.8 illustrates a solid model of an investment casting created from a technical drawing of an aerospace burner nozzle. Various hidden line views of the shape can be obtained and arranged in such a way as to form a first or third angle projection. It is also relatively easy to generate any cross-section of the component, Fig.9. With some solid modelling packages it is also possible to offset faces to allow for casting contraction. When the geometrical information on these views is transferred to a computer aided drafting package, the technical drawing can be dimentioned in the normal way. A solid model of a casting thus contains comprehensive geometrical information that can be automatically manipulated and used to enhance casting design and productivity.

Another novel approach to the design of a golf club head using this technique, is illustrated in Fig.10. This involved producing a club with a larger than standard area, to improve the chance of a golfer hitting the ball near the sweet spot of the club. The sweet spot is an area near the centre of gravity of the club head that the ball must strike to produce a perfect shot. The constraints in producing the new design were as follows: first, to preserve the feel of the club, the new head design had to possess the same weight as the original, second, both the loft angle and the lie of the club had to be preserved and finally the modified design had to be aesthetically pleasing to aid the marketing of the club. To do this, the original club was solid modelled, the front face of the original club w s enlarged and excess metal was removed from a raised section and this section was recessed into the back face of the club, as shown in Figs.10a and 10b. Also, the programme could track how the centre of gravity would shift as the design was altered. This illustrates the creative application of solid modelling to advance the design of a cast component for the benefit of the end user.

Mathematical modelling is a relatively new disicipline within the field of materials processing. These techniques are used for the optimisation and on-line control of existing operations and is even more important in designing the new metals and materials processing systems necessary for diversification strategies. Properly used, mathematical models can greatly reduce the experimental component of a process study, and can thus save both cost and the time of implementation.

The design of moulds for casting, die casting and other applications, including metal matrix composites, has been largely empirical and intutive, involving trial and error procedures. Considering the complexities of solidification in moulds - which involves unsteady state fluid flow and heat transfer in complex geometries, as well as thermal contraction with associated shrinkage - a purely empirical approach to these problems is quite time consuming. These issues are becoming increasingly important as new alloys are developed for critical applications where prior empirical experiences are less readily applicable. The fluid contours depicited in Fig.11 represent an important first step in modelling just one facet of these problems, but it is expected that CAD/CAM techniques will become a more significant part of new casting developments.

Fig.12 shows the computed path of tracer particles and temperature fields of a continuous casting machine, generated using this technique. Tundishes play a key role in determining steel quality since a properly designed tundish promotes the floation of inclusions, provides for the dampening of turbulence and allows improved temperature control. The results of the calculations help determine optimal tundish dimensions as well as the optimal placement of wiers and baffles to obtain desired residence time in the system.

FUTURE TRENDS: It is estimated that the introduction of CAD/CAM techniques in foundries would save atleast 10% on the weight of thin walled castings, reduce the average time to get new tooling by 25% and its cost by 10%, and reduce the cost of duplicate tooling by 25%. The cost of tool maintenence would be significantly reduced. The quality of tooling would be significantly improved, interchangeability of components and cores from duplicate tooling would be guarenteed. Collaboration between design and manufacture would greatly improve and the need for skilled pattern and tool makers would be reduced. In general, the introduction of CAD/CAM would increase the control one has over the production of a casting, allowing for a better designed and built quality casting with minimum effort and expense.

Solid modelling has the potential to significantly improve casting design productivity. It allows more complex shapes to be produced correctly first time, it introduces design flexibility and provides a systematic design component development and design. There are several propritary solid modelling codes available and it is difficult to specify what package is most appropriate for any particular firm. Consideration of which programme is more appropriate, whether it is within the budget, and what the payback will be on the investment, is of prime importance. However, the cost of some solid modelling packages is moving within the reach of many modest firms. It is vital to identify what hardware the software can run on, since this will significantly influence the price of the total system. The processing speed, the main memory and the backing store of the computer are, ofcourse, to be considered. Not all hardware and software combinations are fully compatible. As the programme capabilities of solid modelling are being continually extended, there is little doubt that such software will provide a versatile design tool for the future.

Mathematical modelling has no well proven 'recipes' as it is still a new tool and intution and creativity remain the key ingredients in sucessfully completing modelling assignments. The remarkable new development in this field is the availability of software packages which permit computations to be done in a relatively routine manner. Table 7 lists some commercially available software packages, which can be run on both personal computers as well as large machines like minicomputers and supercomputers. The hardware options, including type and capability is listed in Table 8.

## 2.3 CAD/CAM applications in impression-die forgings:

The conventional methods of designing forging dies are based on empirical guidelines, experience and intution. However, recently developed computer-aided methods may be used to a) predict forging loads and stresses, b) design the performing dies and C) manufacture the dies by NC machining. Once the die design steps are concluded, the forging dies are coventionally manufactured by a) directly machining from a die block b) making a solid model and copy milling or C) making a graphite electrode and electrodischarge machining (EDM) the dies. The graphite electrodes, in turn, can be manufactured by copy milling, abraiding using a special abraiding machine or by NC machining.

Recent applications and developments of new methods for simulating forging operations indicate that CAD/CAM can significantly augument productivity and the skill of the die designer. This is primarily accomplished by computerising area and volume calculations, by predicting the stresses and forging loads for a given die geometry and in some simple cases, by simulating metal flow during forging.

A brief outline of an integrated CAD/CAM approach to hot forging is shown in Fig.13. This approach is general and can be applied to most forgings. The most critical information needed for forging die design is the geometry. The forging geometry, in turn, is obtained from the machined part drawing by modifying this part geometry to facilitate forging. In the process of conversion, the necessary forging envelope, corner and fillet radii, and appropriate draft angles are added to the machined part geometry. Further, difficult-to-forge deep recesses and holes are eliminated.

This geometric manipulation is best done on a stand-alone CAD/CAM system. Such systems are commerically available and have the necessary software for computer aided drafting and NC machining. Such CAD/CAM systems also allow, at various levels of automation, 3-D representation of the forging and the possibility of zooming and rotating geometry display on the graphics terminal screen for purposes of visual inspection. Ideally, these systems should also allow sectioning of a given forging. An example of a 3-D representation of a connecting rod forging die is shown in Fig.14. In this figure, hidden lines are not removed. There are CAD/CAM systems and colour graphics terminals which permit hidden line removal or display of lines on various surface in different colours.

In a typical multi die forging setup, the stresses and loads are higher in the finisher die than in the blocker or preblocker dies. Therefore, it is necessary to predict these stresses and the forging load so that appropriate forgi g machine can be selected and so that the dies can be designed to avoid breakage. To analyse stresses, the computerised 'slab method of analysis' has been found to be most practical. Recently this software has also been developed for a computervision (CV) stand-alone CAD/CAM system and CV systems can now be used to prepare forging and die drawings, generate forging cross sections and to calculate forging loads and stresses.

Design of blocker dies and preform geometries is the most critical part of forging die design. At present, CAD of blocker cross sections can be carried out using interactive graphics. The main advantages are:

* Cross-sectional areas and volumes can be calculated rapidly and accurately,
* The designer can modify geometric parameters such as fillet and corner radii, web thickness,rib height and width, etc., and can immediately review the alternative design on the screen of the computer graphics terminal, as shown in Fig.15.

* The designer can zoom in to investigate a given portion of the forging (Fig.16) and can perform sectional area calculations for a given portion of the forging, where the metal flow is expected to be localised, and

* The designer may review the blocker positions in the finisher dies at various opening positions to study initial die blocker contact point during finish forging, as seen in Fig.17. The ultimate advantage of CAD/CAM in forging is achieved when reasonably accurate and inexpensive computer software is available to simulate metal flow throughout a forging operation. The plastic deformation phenomenon in hot forging is vey complex and involves nonsteady state flow, nonuniform distribution of strains, strain rates and temperatures in the deforming metal and difficulties in estimating the friction factor and flow stresses. A typical simulation of metal flow and die filling in blade forging is shown in Fig.18.

In recent years, CAD/CAM techniques have been successfully applied to precision forge straight and spiral bevel gears, which were earlier manufactured by machining in special gear cutting machines. The gears could be forged to finish machining tolerences therby eliminating the need for rough machining. The outline of the CAD procedure is given in Fig.19.

FUTURE TRENDS: In very recent years, expert systems have been developed for net-shape forging of axisymmetric shapes and hard-to-work alloys to cut manufacturing costs. In general, it is expected that the present application of CAD/CAM in forging, mainly for drafting and NC machining of forging dies, will continue to increase at a rapid rate. The principle barriers to widespread acceptance of such application seem to be a) apparent high cost of introducing CAD/CAM, b) management inertia and c) lack of trained personnel. However, the world wide forging industry is under considerable pressure to mordernise and to increase the productivity of skilled diemakers, who are becoming increasingly scarce. In addition, CAD/CAM systems are becoming relatively inexpensive. Consequently we can expect to see, in the near future, a very significant increase in the number of forge and die shops in which CAD/CAM is used.

2.4 CAD/CAM applications in hot extrusion:

Structural shapes such as T;L;Z;H;U and other shapes are usually manufactured by direct or indirect extrusion methods. In hot extrusion of of aluminium or copper alloys, container lubrication is not used and the dies are 'flat-face' type, with the die opening imparting the desired section geometry to the extrusion. In extrusion of steels, titanium alloys and other high temperature materials, glass-or-graphite-base lubricants are used. The dies have some sort of a 'smooth entry' design to provide for easy metal flow and to avoid severe internal shear, or a dead-metal zone, during extrusion. 'Smooth entry' dies are also used sucessfully for extruding composite materials.

In today's industrial practice, the design of extrusion dies, whether of the 'flat-face' or the 'smooth entry' type, is still an art rather than a science. To reduce the costs of designing and manufacturing extrusion dies, CAD/CAM systems have been developed for both non-lubricated and lubricated extrusion process.

Many years of experience lie behind the production of extrusion dies with increasing complexity of shape, thiness of section and quality of surface. Some of this experience is rationalised in empirical design rules, but much of the die design is still dependent on personal judgement, intution and experience.

A typical CAD technique for flat-face dies, where the capabilities and application of an interactive CAD programme called ALEXTR, is illustrated in Fig.20. For manufacturing the dies, either conventional EDM or wire EDM is used. In the first case, two EDM electrodes are machined via NC; one for EDM'ing the die openings from the billet entry side and the other for EDM'ing the die bearings from the exit side of the die. In wire EDM'ing, the die openings are machined using a wire electrode, while the bearing areas are machined by EDM or milled in the conventional manner.

Proper die design is critical in lubricated extrusion, especially when noncircular shapes are extruded. An effective die design must ensure smooth metal flow with consistent lubrication. Lubrication reduces load and energy requirements, reduces tool wear, improves surface finish and provides a product with nearly uniform properties. It is desirable to use 'streamlined' dies, which provide a smooth transition for the billet from round or rectangular container to the shaped-die exit.

The use of CAD techniques have been successfully applied, in recent years, for such lubricated extrusions and a typical example of the design of a 'streamlined' die for extruding a T-shape from a round billet is shown in Fig.21.

The surface of a 'streamlined' die is defined as an array of points. The practical method of manufacturing this die is to NC machine a carbon electrode and then to EDM the die. For this purpose, cutter paths for machining the electrode surface must be determined. Computer programmes developed for calculating the cutter paths contain special routines to check for undercutting and gauging. The calculated cutter centre points are plotted on the screen of graphics terminal as shown in Fig.22.

The concept of streamlined dies has been found to be extremely useful in extrusion of difficult-to-form metal matrix composite powder metallurgy materials. Such materials like aluminium alloy 2024 with 20 vol% SiC whiskers, are used for the production of aerospace structures as they weigh considerably less than those manufactured from aluminium alone. However, the sreamlined die concept cannot be used for designing highly complex dies with re-entrent sections. New techniques, like perimeter mapping techniques instead of area mapping techniques are used, and an example of complex die configarations obtained using this new CAD method is shown in Fig.23. These dies will be manufactured by EDM using NC machined electrodes,as discussed earlier.

FUTURE TRENDS : The application of CAD/CAM in extrusion is likely to be on the increase, as more and more extrusion companies are using such techniques for die making and process automation. The implementation of CAD/CAM have the following potential benefits:

* More precise estimation, and reduction in estimation costs.
* Less dependence on skilled workers.
* Reduction in the number of die failures and in die-design and manufacturing costs.
* Improved utilisation of existing press capacity by reducing die trials.
* Continous improvement of die and press technology.
* Increases in material yield and press productivity.

## 2.5 CAD/CAM applications to sheet metal:

Implementing CAD/CAM technology to sheet metal fabrication installations means relegating more of the time-consuming and tedious jobs to the computer, organising and managing projects better and producing better sheet metal parts in lesser time and cost. Information typically extracted from CAD/CAM data bases include part production counts, sheet utilization rate, percent of scrap material and machine downtime.

Computer aided modelling techniques have been widely used to speed up the design process and to improve the quality of sheet metal parts. This enables alternative die-designs to be explored and trade-offs to be evaluated, before the manufacturing engineer performs the costly and time-consuming steps of fabricating the dies and process tryouts.

Fig.24 shows the application of simulation techniques in sheet metal drawing operations on mild steel. The purpose of simulation was to predict the forces on the tool required to form the the product, the degree of pre-load on the blank-holder necessary to hold the blank without over-constraining it, and the tendency of the sheet metal to tear if friction at the blank holder stopped the materials from drawing properly. Another example is shown in Fig.25. This part represents a typical automobile component and is more irregular and complex compared to the one shown before, and in this case the simulation could help predict the areas of thinning and thickening and the material flow paths.

FUTURE TRENDS : Computer aided modelling and simulation techniques, are widely being employed in sheet metal fabrication. With the falling cost of computer hardware pointing to increased use of these techniques, it is almost inevitable that today's emerging capabilities will be viewed as commonplace in the future.

## 2.6 CAD/CAM applications in rolling and nozzling:

Rolling, extrusion and nozzling can be visualised as problems arising in the thermophysical processing of solids, in which allowance must be made to take into account structural changes, like grain growth, during the processing operations. In Fig.26 is shown the computed residual stress patterns in a thin aluminium sheet which result from the combined effect of thermal stresses and mechanical work hardening effects.

Nozzling process, as it is applied to a fire extinguisher cylinder is shown in Fig.27. The work piece is formed in the first stage operation using a back-extrusion process and the resulting closed-ended cylinder is the preform for the second stage, in which the open end is heated and then forced into a shaped die to form the nozzle end.

FUTURE TRENDS: Computerised techniques are playing an important role in automating and controlling rolling practices, from the initial breaking down of the ingot on a hot mill to the final cold rolling finishing pass on the thinnest of foils. Computerised strip shape measurements and control systems are now installed on key cold mills, and fast accurate gauging systems monitor and control thickness by computer, enabling tighter tolerences to be offered, typically as ± 0.01 mm in heavier strip gauges. CAD/CAM applications indicate it could be used as the best design aid for assessing the best means of forming high integrity components such as pressure vessels and aerospace components.

## 2.7. CAD/CAM applications in plastics:

For many years, plastics have been regarded unfavourably by the general public as low quality materials. However, present day uses include many advanced engineering applications, like in the preparation of green ceramic components for such applications like turbine blades. Recent developements in polymer processing have not been in completely new processes, but rather in the refinement of existing process control or better process modelling.

In the field of injection moulding, computer simulation of the mould filling and cooling process is becoming common. The use of computer simulation allows the designer to determine the ideal gating positions and the position of any weld lines. Modelling packages also facilitate the determination of melt pressures within the cavity, so problems such as wrapage, which arise from frozen-in-stresses, can be identified. The main benefit of such modelling process is that the designer has a better chance of getting the mould design right the first time, so reducing the costly waste of time needed to get a mould up and running when it is mounted on an injection moulding machine.

FUTURE TRENDS: The time is now ripe to apply CAD/CAM systems to design, produce, test and provide the necessary information for the manufacture of the tool. Fig.28 shows a computer integrated manufacturing scheme. The advent of microprocessors to machine control, especially in injection moulding, would enable a lot of changes to be brought about in this field.

## 2.8 CAD in molecular engineering:

The traditional design tools of a chemist are simply, pencil and paper, and molecules are represented by 2-D drawings, such as that of the antibiotic pencillin G in Fig.29. Although effective in expressing the connectivity of the molecules, they can only give a vague idea of the full 3-D shape, which must be the starting point for rational design.

Physical models can be built, but this is time consuming and the result is a poor representation of the real thing. The problem is molecules are generally quite flexible, more like lumps of jelly than frameworks of steel or plastic. Moreover, whereas a lump of jelly will tend to recover its shape after deformation, molecules usually have a number of different shapes into which they may settle. Further, at room temperature the atoms will be continously moving, while the molecules will be constantly cycling between the states. The only way in which this behaviour can be understood is by first, performing lengthy and complicated calculations, and second by finding some means of making the results intelligible to the human eye.

In theory, this has been possible for some time, but at enormous costs. The decreasing cost/performance ratio of mordern computers and the appearance of high-power graphics workstations at prices that are affordable, have led to a dramatic growth in interest in this fascinating area. Today, such state-of-the-art exists that scientists are in a position to engineer and design new molecules and products for the chemical and pharmaceuticals, ushering in a new era of molecular engineering.

A few examples of how CAD has been used, are shown in Figs. 30-33.

FUTURE TRENDS: Computer based molecular modelling (CBMM) show enormous potentials. As an example there are hopes that a cure can be found for AIDS through this and other biological techniques. Given the structure of the enzyme, there is a good chance that molecules may be designed which will block the active site, disrupt viral replication and effectively provide a cure. Surveying the potential of CBBM, it is impossible to avoid the conclusion that a revolution in chemistry is on the horizon.

3. CONCLUSIONS:

We have taken, but a glimpse into the fascinating area of CAD/CAM and its applications, and that too, in such a very small area of technology. It is, ofcourse, not possible, to cover such a broad area as CAD/CAM applications in so few words or pages; nevertheless, an attempt has been made and it is hoped that this is found to be of interest and throws some light on the current state-of-the-art.

Today, CAD/CAM, computer modelling, artifical intelligence, robotization, expert systems etc., have become frequently used terms in connection with manufacturing operations. We can say that computer-integrated manufactuting (CIM) is the foundation on which manufacturing companies in variety of industries in the world are beginning to build 'the factory of the future'. The factory of the future will find raw materials being unloded and stored by an automated storage and retrieval system (AS/RS). An automated guided vehicle (AGV) will take the raw material to the machine tool, where it is needed, and a robot will remove the workpiece and mount it on the machine tool, unload the completed part and place on the AGV. The AGV will then transport the finished part to the AS/RS or to some area of the plant for further disposition. This may sound like 'science fiction' but such systems are already in use in some places and in the not-too-distant-a-future, it is likely to become common place!

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Table 1: Characteristics of man and computer.

| | | Man | Computer |
|---|---|---|---|
| 1 | Method of logic and reasoning | Intuitive by experience, imagination, and judgement | Systematic and stylised |
| 2 | Level of intelligence | Learns rapidly but sequential. Unreliable intelligence | Little learning capability but reliable level of intelligence |
| 3 | Method of information input | Large amounts of input at one time by sight or hearing | Sequential stylised input |
| 4 | Method of information input | Slow sequential output by speech or manual actions | Rapid stylised sequential output by the equivalent of manual actions |
| 5 | Organisation of information | Informal and intuitive | Formal and detailed |
| 6 | Effort involved in organising information | Small | Large |
| 7 | Storage of detailed information | Small capacity, highly time dependent | Large capacity, time independent |
| 8 | Tolerance for repetitious and mundane work | Poor | Excellent |
| [illegible] | Ability to extract significant information | Good | Poor |
| 10 | Production of errors | Frequent | Rare |
| [illegible] | Tolerance for erroneous information | Good intuitive correction of errors | Highly intolerant |
| 12 | Method of error detection | Intuitive | Systematic |
| 13 | Method of editing information | Easy and instantaneous | Difficult and involved |
| 14 | Analysis capabilities | Good intuitive analysis poor numerical analysis ability | No intuitive analysis, good numerical analysis ability |

Table 2: Recomended CAD/CAM systems for different foundries.

Recommended CAD CAM systems for different foundries

| Type of foundry | Production volume | Product Mix | Machining | Drafting | Dev. of [illegible] | Post casting [illegible] | Remarks [illegible] |
|---|---|---|---|---|---|---|---|
| [illegible] | High | Small Large | Extensive | Heavy | Extensive Pattern Development | Considerable | A medium band CAD CAM system built around a super mini computer with graphics software and heat transfer software |
| " | Medium | Average | Extensive | Heavy | | – | A medium band CAD system with both FEM and graphics software |
| " | Small | Large | Moderate | Moderate | – | – | A small cum system built around a desk top computer with graphics |
| [illegible] | High | Large | Extensive | Heavy | Extensive die setting | – – | A Medium [illegible] CAD/CAM system around a mini computer |
| " | Medium | Large/ Average | Extensive | Moderate | – | – | A small CAD system around a desk top computer |
| " | Small | Small | Little | Small | – | – | Personal computer |

Table 3: Software for drafting and CAD/CAM.

| | |
|---|---|
| MEDUSA | Multidisciplinary drafting system |
| PADDS-PERA | Automatic detail drawing system |
| CADBIRD | Computer Aided Drafting 2-D drafting packge intended for the small drawing office |
| DRAGON | Computer Aided 2-D drafting system |

Software for CAD/CAM

| | |
|---|---|
| SDRC | Graphics system 2-D |
| DUCT | Computer Aided 3-D surface modelling system |
| UNIGRAPHICS | 3-D interactive graphics system for CAD automated drafting and CAM Specified modules for NC |
| ICAM | Sponsored by US Air Force |
| ECAM | Sponsored by US Army, Navy and Air Force |
| STP | Sponsored by US Navy |
| TECHMODS | Sponsored by US Armed Forces |
| IPAD | Sponsored by NASA |
| PROMO | Developed by ADEPA has modules for cutter path contouring as well as interactive graphics |

Table 4: Software packages available for heat transfer simulation and finite element analysis.

| Name | Developed by | Remarks |
|---|---|---|
| ANSYS | Swanson analysis system | FEM |
| MARC | Marc Analysis Research Corp. | FEM |
| NASTRAN | NASA | FEM |
| SINDA | cosmic Library, USA | FEM |
| SMART II | Stuttgart, West Germany | FEM |
| ASAS | and W.S. Atkins Inc. | FEM |
| ASAS Heat | | |
| BASS | | continuous system simulation facilities |
| FLHE | Lucas Logic Ltd., U.K | Steady state and transient temp. distribution in 2, 3-D. |
| FEMGEN | | Finite element mesh generator |

Table 5: Comparison ANSYS, MARC, and MITAS-II with the ideal goal for a metal casting simulation capability.

| Feature | Ideal | ANSYS | MARC | MITAS-II |
|---|---|---|---|---|
| Ability to learn how to run it on a remote computer | Easy | Difficult | Moderately difficult | Moderately difficult |
| Running cost | Low | High | High | Moderate |
| Ability to account directly for latent heat | Yes | No | Yes | Yes |
| Dedicated heat transfer code | Yes | No | No | Yes |
| Accuracy | Good | Very good | Very good | Very good |
| Pre- and post-processing capabilities | Good | Good | Good | Poor |

Table 6: Comparision of some complete risering programmes.

| | METECH/CAPRA | CRUSADER | FEEDERCALC | U. OF WISC. A.F.S. |
|---|---|---|---|---|
| BRITISH OR METRIC UNITS | NO | YES | NO | YES |
| CHILL SIZE CALC | YES | YES | YES | NO |
| SCRATCH PAD | NO | YES | NO | NO |
| INSUL RISER DATA | YES | YES | YES | NO |
| INSUL SLEEVE PRICES | NO | YES | NO | NO |
| HOT TOPPING REQUIRED | NO | YES | YES | NO |
| VAR RISER HEIGHT | YES | YES | YES* | YES |
| BREAKER CORE SIZE | NO | YES | NO | NO |
| PRINTS CSTG PATT NO ETC | YES | NO | YES | YES |
| RING RISER | NO | YES | NO | NO |
| ABILITY TO FEED ADJ SECT | YES | NO | NO | YES |

*Limited to sand risers of 1:1 and 1:1.5 height/diameter ratios. Gives two sizes of insulated riser of differing heights

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Table 7: Modelling software.

| Package | Functions |
|---|---|
| PHOENICS | Semi-implicit finite domain package, having three-dimensional capabilities; extensively used for heat flow, fluid flow and combustion problems. |
| FLUENT | Semi-implicit finite domain package, with three-dimensional capabilities for heat transfer, fluid flow, combustion. |
| SOLA-VOF | Volume of fraction, two-dimensional finite difference package, emphasis on free surface behavior. |
| MAC | Three-dimensional finite difference package, explicit, emphasis on free surface capability. |
| FIDAP | Fully implicit finite element package, three-dimensional, fluid flow, heat flow. |
| FLOW-3D | Fluid flow package, with emphasis on free surface capability, waves, filling, etc. |

Table 8: Hardware options.

| Computer | Megaflops* | Capability |
|---|---|---|
| IBM-AT w/80287[1] | .024-.07 | 2-D transient heat conduction problems with constant coefficients. No fluid flow, problems under 2600 nodes. |
| IBM-AT w/MAP[2] | 5 | 3-D transient heat conduction with fluid flow, constant coefficients. Limited only by memory and user's patience. |
| VAX 11/750 w/FPA | .12 | Small 3-D transient heat conduction; problems under 6000 nodes |
| VAX 11/785 w/FPA | 20 | Moderate 3-D transient heat conduction problems, 2-D transient heat conduction with fluid flow, small 3-D fluid flow with no heat transfer; problems under 10000 nodes. |
| VAX 8600 | 50 | Medium or moderately sized 3-D transient heat conduction with fluid flow; problems under 25000 nodes. |
| Apollo DN660 | 15 | Same as (4); problems under 9000 nodes |
| FPS-164 MAX[3] | 10 | Small 3-D fluid flow with heat transfer and with variable coefficients, virtually unlimited problems |
| FPS-264 | 30 | Fairly large 3-D fluid flow with heat transfer and with variable coefficients, virtually unlimited problems |
| CYBER 205[3] | 20 | Moderately sized 3-D fluid flow and heat transfer with variable coefficients, virtually unlimited problems |
| CRAY X-MP | 40 | Large 3-D fluid flow with heat transfer and variable coefficients, virtually unlimited problems |

[1]IBM-AT operating at 8MHz coprocessor speed
[2]IBM AT equipped with an array processor board
[3]These machines are capable of incredible speeds, near 400 megaflops. However, the authors are not aware of any programs that make use of these capabilities
*Megaflop: a million floating point operations per second—a good, but not exclusive measure of computational speed

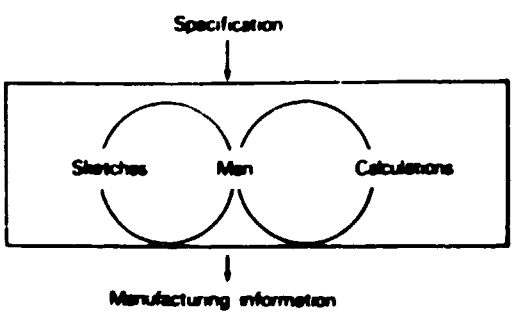


Fig. 1: The conventional design process.

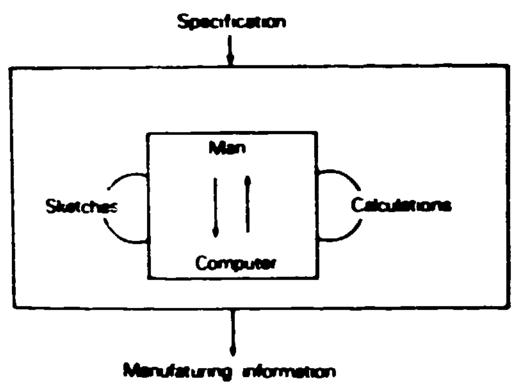


Fig. 2: Design process using CAD techniques.

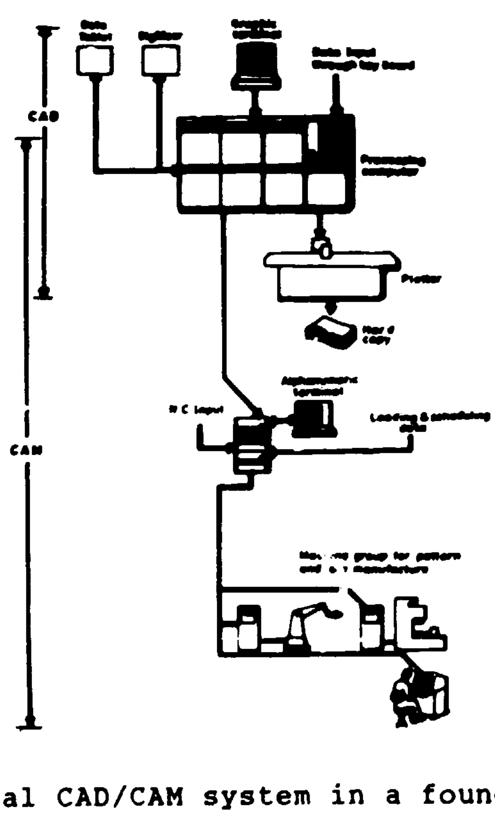

Fig. 3: A typical CAD/CAM system in a foundry.

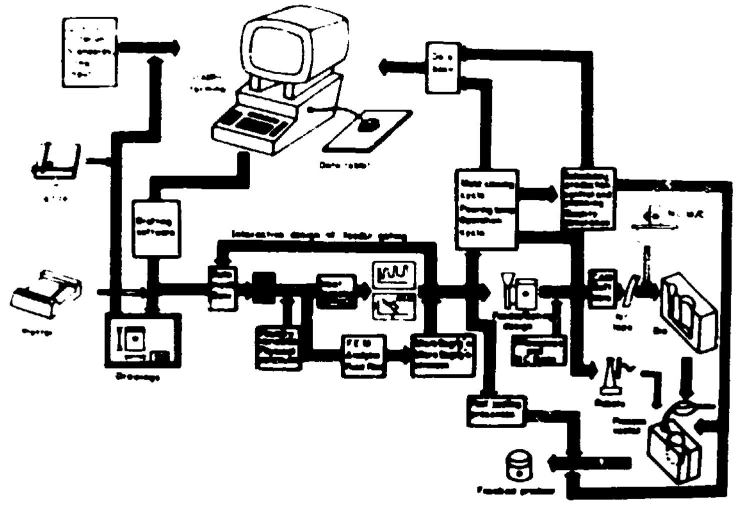

Fig. 4: Application of a CAD/CAM system in metal casting.

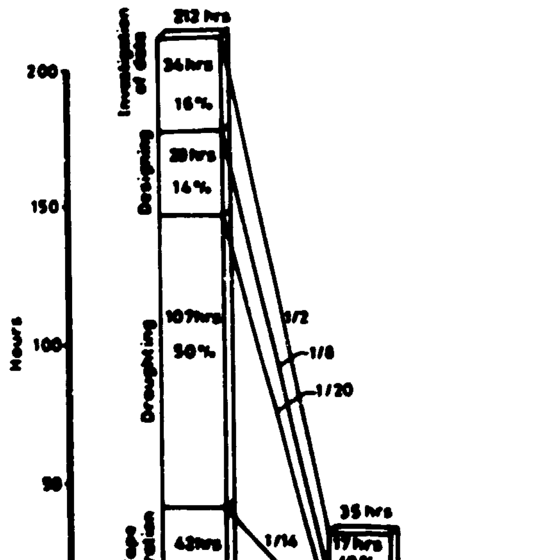


Fig. 5: An example of the benefits of introducing CAD/CAM system for computerised die manufacture.

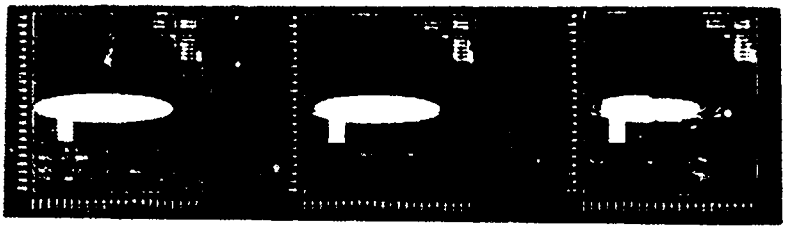

Fig. 6: Simulation of solidification and cooling in a turbine blade casting.

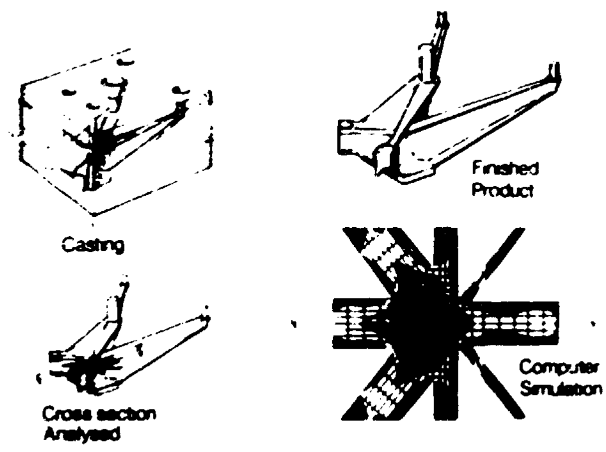


Fig. 7: Simulating the solidification process in a structural casting. The calculation tracks the progress of the solidification front.

Fig. 8: Solid model of an aerospace burner nozzle.

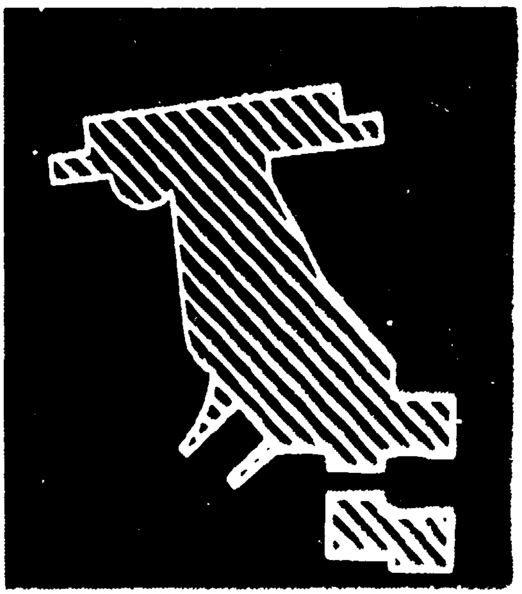

Fig. 9: Cross section through the aerospace burner nuzzle

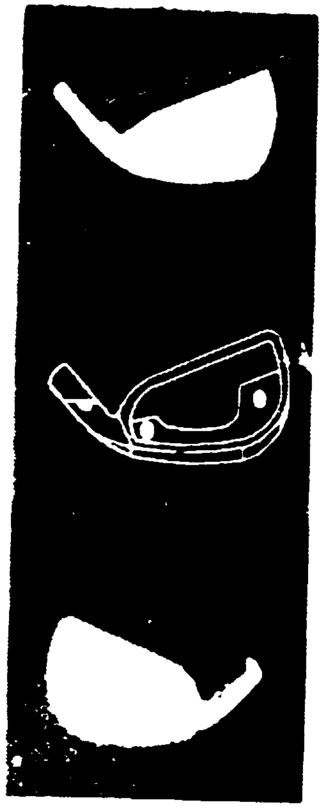

Fig. 10: Solid modelling of a golf club head: a(top), rear view of the original head, b(centre), rear view of the redesigned head, c(bottom), front view of the redesigned head.

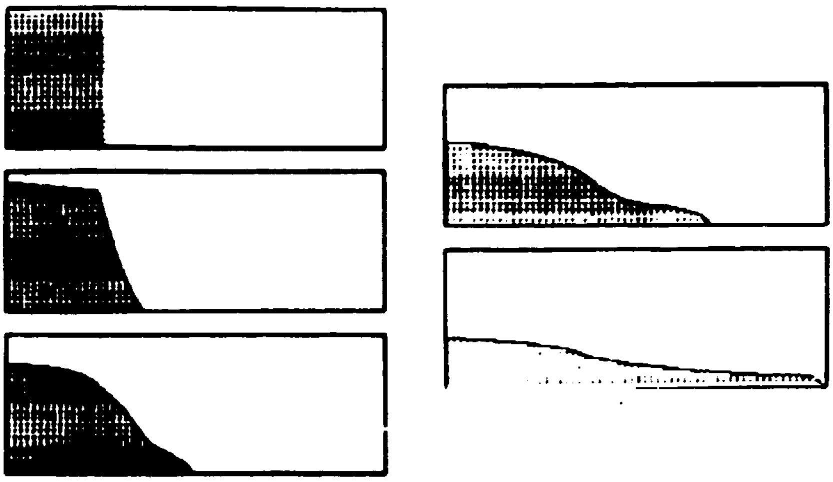

Fig. 11: The computed displacement pattern of a collapsing wall of fluid in a mould, taken at reference times of .6,.12,.18 and .24.

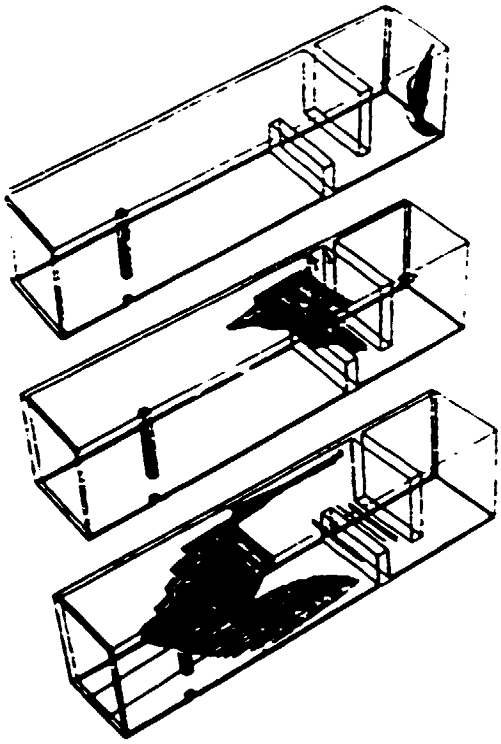

Fig. 12: The computed isotherms in a tundish: (a) 1595 °C (b) 1593 °C and (c) 1590 °C.

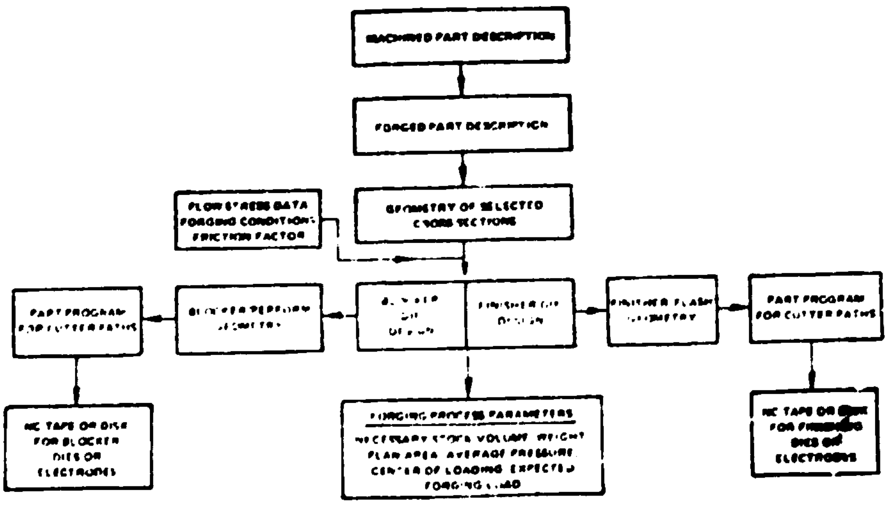

Fig. 13: Outline of an integrated CAD/CAM approach for hot forging.

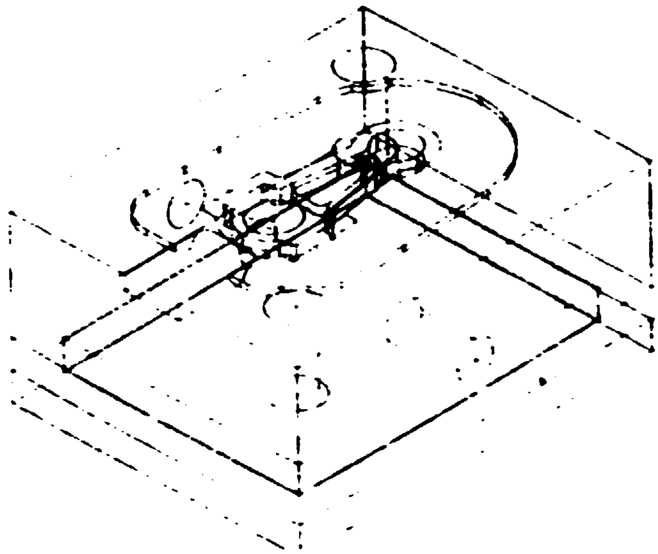

Fig. 14: Three-dimensional display of a connecting rod forging die prepared on a computervision CAD/CAM system.

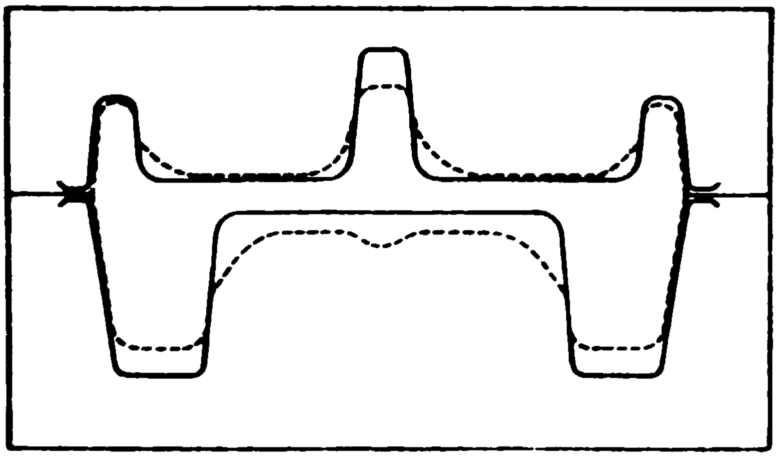

Fig. 15: A typical forging cross section and a possible blocker design displayed on a computer terminal.

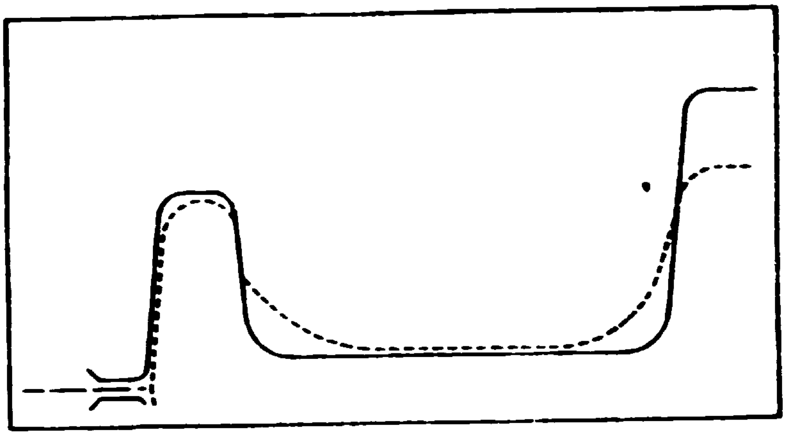

Fig. 16: Use of " zooming " to examine a small portion of the blocker/finisher cross sections in CAD.

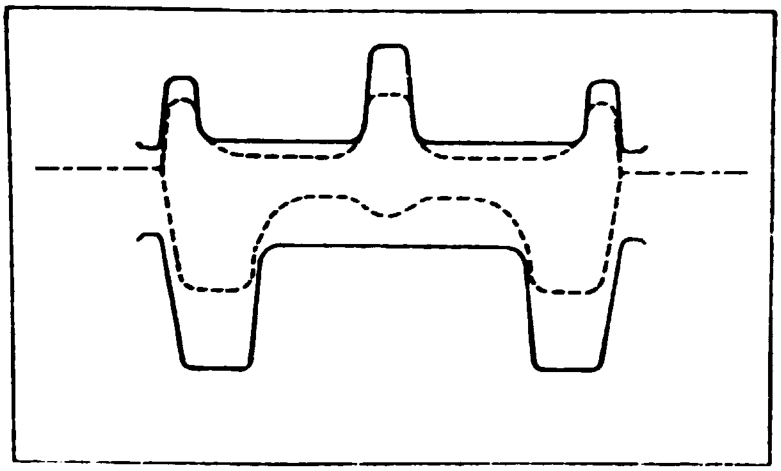

Fig. 17: Computer-designed blocker, shown with finisher dies in seperated position.

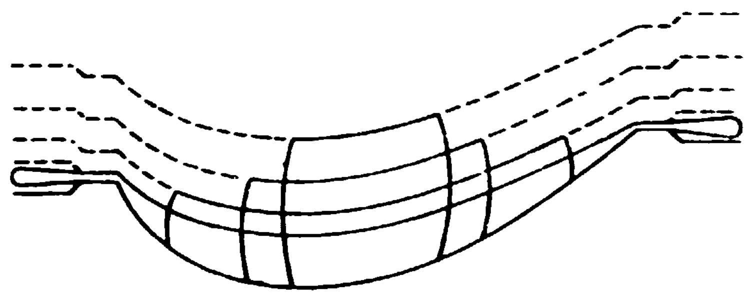

Fig. 18: Metal flow and die filling in a blade forging, as simulated by a computer programme.

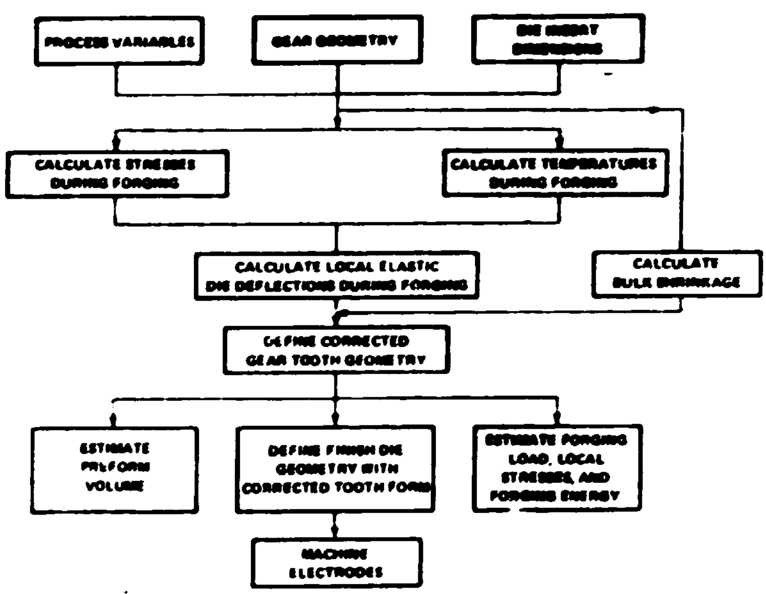


Fig. 19: Outline of a CAD procedure used for making forging dies used to produce spiral bevel gears.

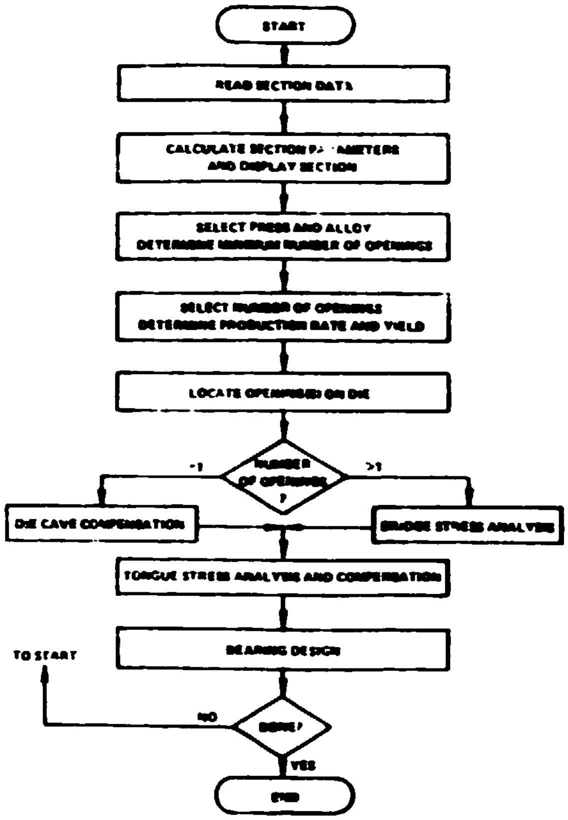


Fig. 20: General operation of ALEXTR

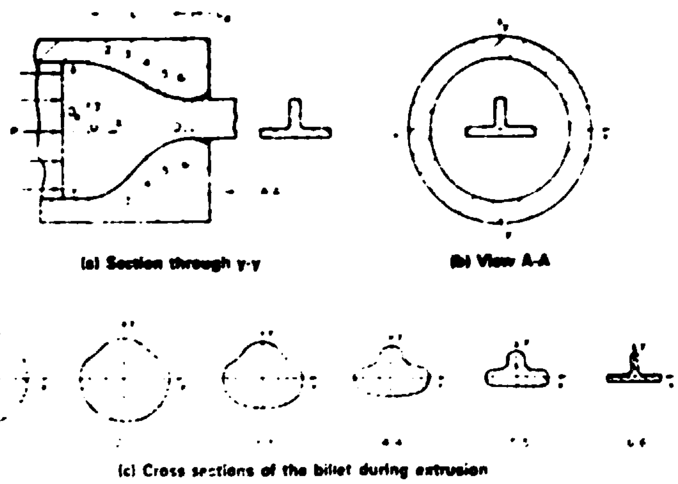


Fig. 21: Schematic illustration of a streamlined die for extrusion of a " T "-shape.

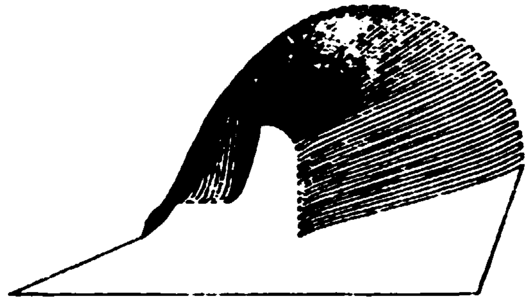

Fig. 22: Cutter path for NC machining of the EDM electrode for the streamlined " T "-shape die.

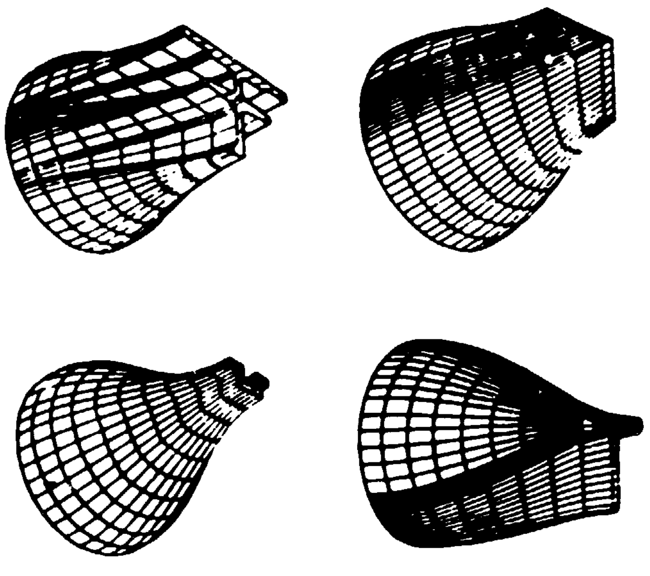

Fig. 23: Computer -designed streamlined die configaration for extrusion of complex shapes.

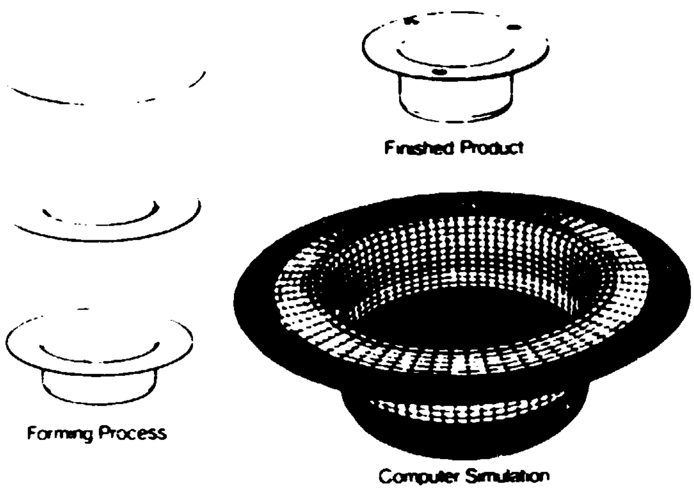


Fig. 24: Simulating the deep drawing of a sheet metal cup . The contours show different levels of strain in the finished part.

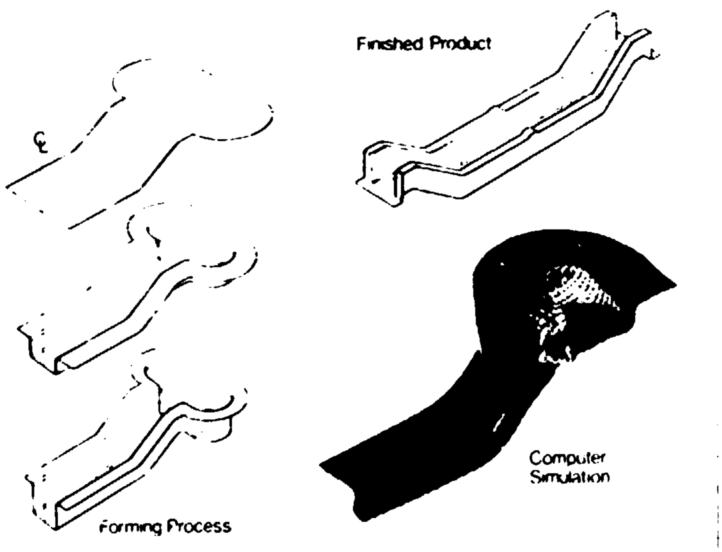


Fig. 25: Simulating the pressing of a sheet metal automotive component. Due to the symmetry, only one quarter of the component was modelled.

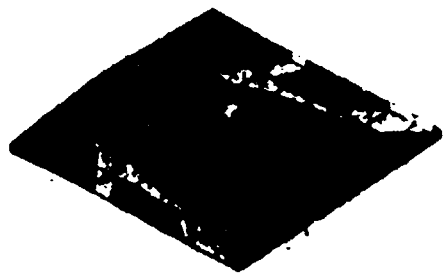

Fig. 26: The computed residual stress pattern of a thin aluminum strip showing the formation of a centre buckle which may occur in the cold rolling of aluminium.

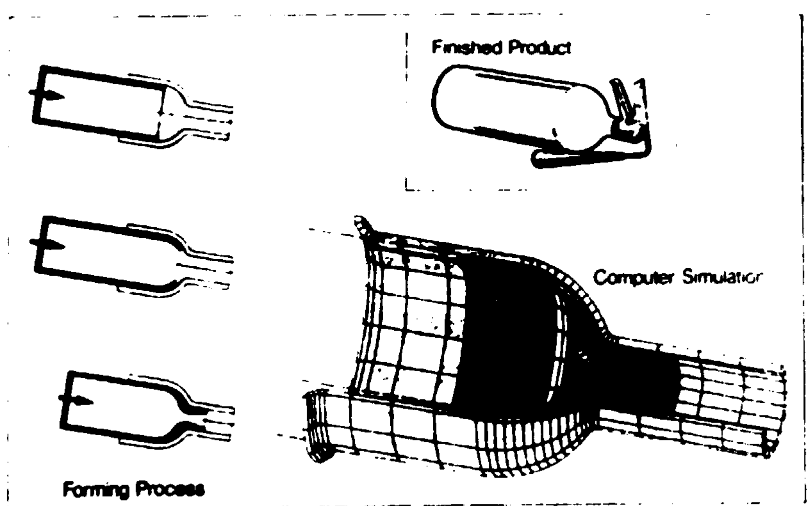


Fig. 27: Simulation of a nozzle forming operation. The contours show the strain rates that occour during the forming process.

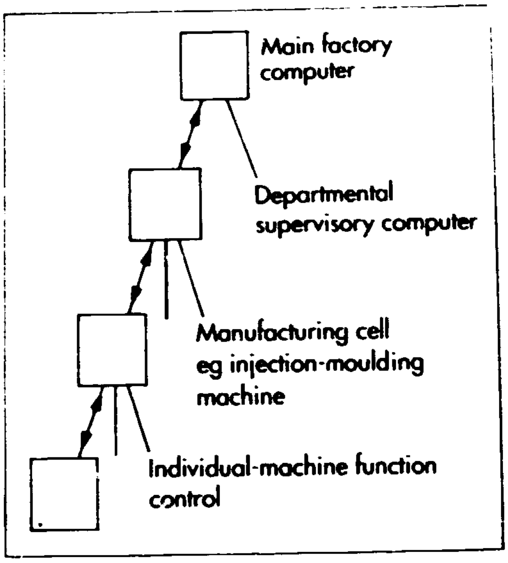


Fig. 28: Computer integrated manufacturing scheme.

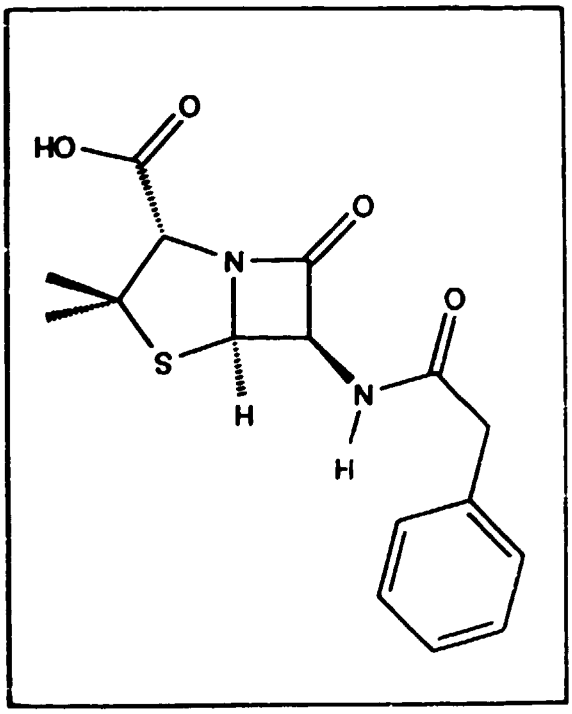


Fig. 29: The structure of penicillin G as normally drawn by a chemist.

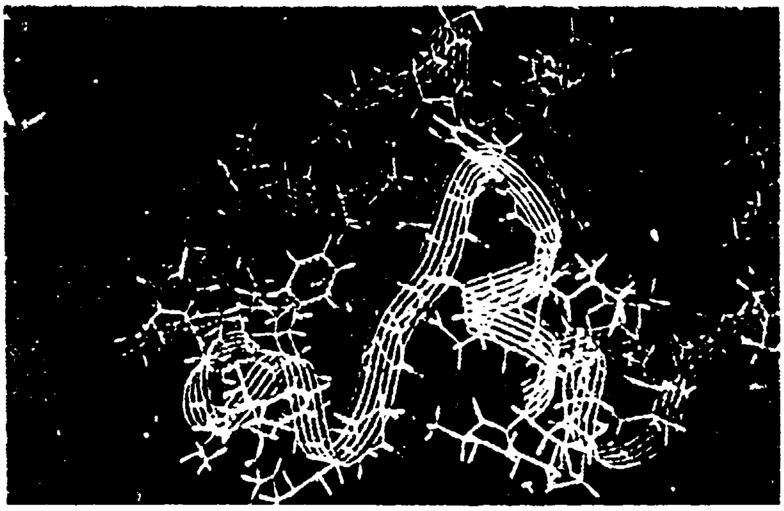

Fig. 30: Image of a protein molecule.

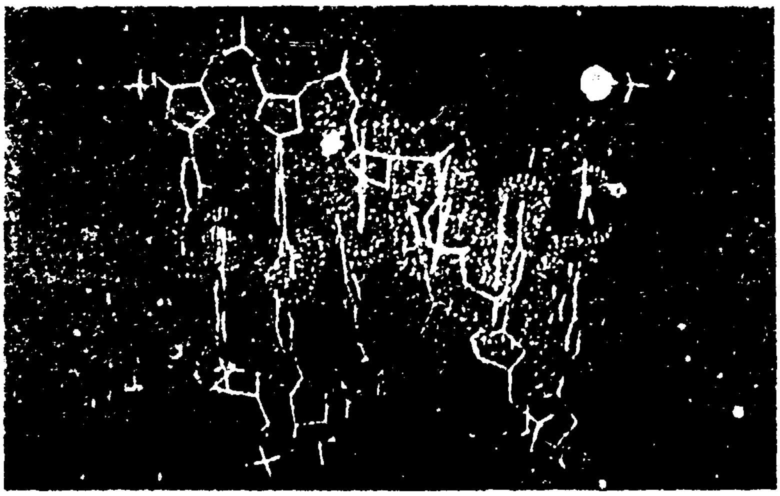

Fig. 31: A short segment of double-helical DNA, the molecule at the centre of the chemistry of life.

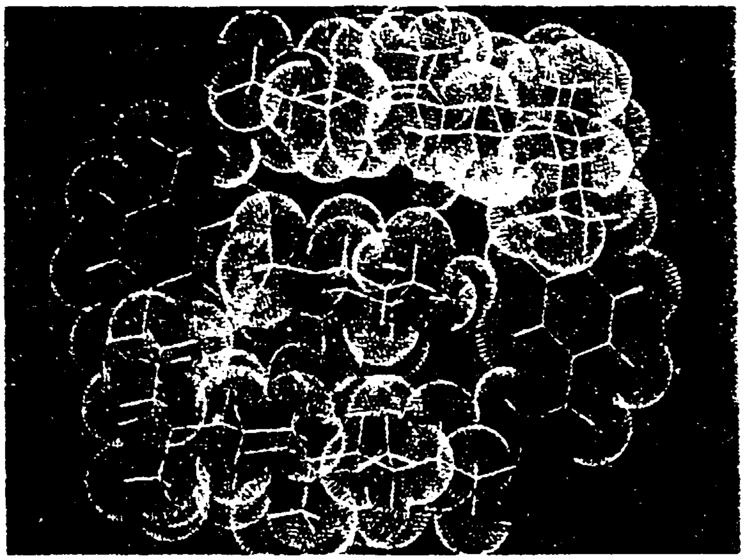

Fig. 32: Complex between a 'host' molecule and a 'guest' carbohydrate.

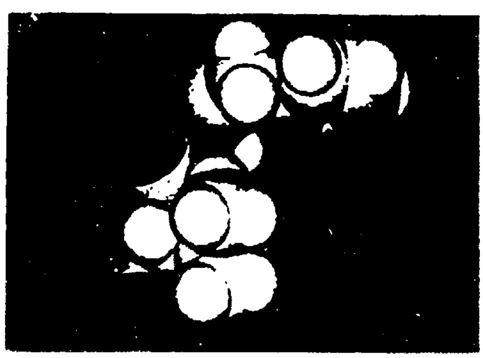

Fig. 33: Spacefilling representation of Penicillin G.

## 2. CAD/CAM - WHAT INDUSTRY NEEDS TO KNOW

In the 1980s manufacturing technology has matured to the point where advanced automation techniques such as computer-aided design and manufacture are the norm rather than the exception among the larger companies. One of the aims of this technology has been the creation of a paperless system of engineering information exchange not only within the company but also with its suppliers. Despite this, many small to medium-sized companies in Ireland who are suppliers to these companies have yet to incorporate this technology. In the past this was due to the high cost of such CAD/CAM systems and the lack of communication standards between the different CAD/CAM systems. Where standards did exist they were sometimes badly implemented and not fully supported. The fact that the larger corporations themselves had to overcome these difficulties made them more sympathetic to those of their suppliers. So much so that many supplier companies have become very complacent to the whole idea of the application of data exchange and CAD/CAM within their own companies.

This is a very dangerous complacency since the advances in CAD/CAM, data exchange software and machine controls with a lowering in real terms of the price systems means that larger companies can now realistically insist that their suppliers apply this technology. The increased involvement of supplier companies in the early stages of product development in order to improve quality, cut engineering costs and lead times, will accelerate this trend. Therefore any company which does not constantly re-evaluate its engineering methods in the light of this technology faces a loss of both a manufacturing and marketing edge on their competitors.

For any company who has not yet brought in CAD/CAM, the whole area both intimidates and raises false expectations. This is very understandable since the descriptions of this technology are either too simplistic or too technically complex to be of any value in assessing its true impact on the functioning of the company. The proliferation of jargon and buzz words serve to confuse the real issues of CAD/CAM, which are, how much will it cost, what benefits in terms of quality, productivity and marketing can be expected, what can it not do, and how will it affect the running of the company? CAD/CAM involves changes in both management and manufacturing methods and is not just the introduction of a computing resource. Ultimately it is not the best CAD/CAM system but the best utilized CAD/CAM system which brings rewards.

### CAD/CAM system types

When choosing CAD/CAM systems there are two distinct groups, those based (or were in the past) on PCs and those based on more powerful computers such as minis and workstations. While these groups are converging somewhat there is still a marked difference in price and capability.

If we take PC-based systems these are mainly 2 dimensional drafting systems which can have the ability to produce 3 dimensional visualization of objects. By visualization it means that the system will display a 3 dimensional graphic model but data on its surface is not available for analysis. This means that any form of complex 3 dimensional surfacing (necessary for 3-D machining) is not possible. Its main use would be to produce 3-D graphics for demonstration and visualization of a product. Normally the CAM system is a separate module with data being brought in from its companion CAD system. Again these are limited to 2-D contouring or punching with a limited 3-D machining capability. For any type of 2-D dimensional work which would include most drafting applications CAD/CAM PC-based systems are excellent and are very cost effective.

If you decide however that you have a 3-D design and 3-D machining requirement then your system will probably be based on a workstation, or mini-computer. Such systems are more expensive and more costly to maintain basically because of their power and accuracy and the fact that they are not as numerous as PCs. The requirement for power is essential as 3-D analysis is much more complex and computer intensive. As well as normal 2-D drafting abilities there is the ability to generate full 3-dimensional surfaces and models. These surfaces can be then used by the system's CAM functions to generate 3 to 5 axis machining paths. These also usually offer a complete range of design software and more powerful drafting features.

Most systems (this is true of all systems) tend to be stronger in particular areas, and can be surprisingly weaker in others. This has tended to happen with systems that were originally CAD or CAM only and upgraded to CAD/CAM. It is therefore very important to define your company's needs carefully, before selecting a system, and you must ensure that this selection is compatible with your company's long-term manufacturing strategy.

### Data transfer

As I have mentioned before data transfer between CAD/CAM systems is becoming more and more vital to companies. In the early 1980s this area was extremely badly supported, but in the last few years it has become more successful due to data transfer becoming a major issue with CAD/CAM system customers.

The three ways to transfer data are:

1. Compatible systems;
2. Direct translators;
3. Neutral format files.

The simplest way to minimize problems with data transfer is to purchase the same type of equipment as your customer. The obvious advantage is that your drawings are completely compatible. The disadvantages are firstly that you need to have and expect to retain a lot of business with that customer. The other problem is that a computer that is ideal for your customer's design purposes might be unsuitable for your own. (An example might be a CAD system with a poor CAM implementation).

Special-purpose translators are programmes which directly translate engineering data from one computer to another. The need occurs because different CAD/CAM systems do not have a standard format for describing drawings within their systems. These direct translators change one system's drawings into another system's format. The first problem with these translators is that they are sometimes not available because different CAD vendors are not willing to divulge information on their system to the programme writer. Due to this difficulty they can also be very expensive. This is made worse by the fact that a new translation programme must be written after every update of either of the two CAD system's software. It can be very cost effective if a large part of your business is with one customer and your engineering requirement means that you must use a different system than your customer.
(Source: AMT, October 1989)

Design, modelling, and analysis

Just a few years ago, CAD/CAM was an expensive technology affordable by only a few large firms. Today, with the advent of PCs and workstations, software to do drafting, modelling and analysis can be justified by almost all engineers.

Today, much of the basic drafting and design done by engineers is done on PCs and workstations. Until recently, most production design work done on PCs was 2D. There were a few solid modellers and 3D software packages available for desktops, but these were used primarily for visualization. However, with the advent of 32-bit-based desktop computers and powerful operating systems, 3D systems capable of doing production drawings are more common for desktop computers.

Drafting and design

Basically, all drafting software operates in the same way. Points and lines that comprise a drawing are entered into the drafting system through any number of input devices. A set of cross hairs is commonly used to indicate the starting point of drawings. The drawing process often is aided by pull-down function menus, which put the system into different modes to construct basic elements with minimal user input. For example, a rectangle can be defined by a corner point and its diagonal. Circles can be drawn in several methods, including centre and radius, or three points on the circumference. Interactive graphics often show these elements before they are actually entered into the drawing file. A circle, for example, is displayed as soon as its centre point is indicated. By moving the input device, the circle expands or contracts. When the circle is the correct size, it is entered by pushing a button on the input device.

Most drawing packages provide a number of ways to change the drawing once it is entered into the computer. A line editor deletes lines or shows line lengths and angles. A point editor moves points, makes lines parallel or makes a line intersect with another line, circle, or arc. "Undo" commands permit the last element or specific object to be deleted. A "window" can also be drawn on the screen, with all objects entirely in the window being deleted.

Many functions provided by drafting software are intended to increase ease of use. For example, a specific area can be seen in greater detail by "zooming" in on the drawing. This function can be controlled in several ways, including a percentage of zoom or zoom inside a window. A drawing can also be moved horizontally or vertically by a "panning" function. This, too, is controlled in several ways. The pan can be for a specific length, or defined by a line drawn on the CRT showing the length and angle of pan.

A series of equally spaced points called a grid can be displayed on the screen to aid in the drawing process. The spacing of this grid can be defined by the user or made as a default value. The grid helps draw straight lines and gives the operator a feeling for the scale. A related function is called snap, in which entered lines "snap" to the nearest grid point. The snap can be turned on or off, depending on what the operator is doing.

Once drawn, objects can also be interactively moved or "dragged" on the screen. A copy function also permits an object to be copied anywhere else in the drawing. Most systems also allow the user to define symbols and put them in the drawing when needed. So-called symbol libraries can be purchased for certain applications such as piping or interior design. Such a file contains dozens or hundreds of predefined objects that can be called up and placed in the drawing.

Some systems also automate much of the dimensioning required for the drawing. Through menu commands, the user can have the system compute and display distances or angles in the appropriate locations. Dimensions usually are not associated with geometry. In associative systems, however, changing geometry will change the dimension automatically. Parametric systems allow users to change geometry by making dimension changes.

Text can also be placed on the drawing through the keyboard. Several fonts typically are available, and characters can be displayed in a range of sizes and angles. The text may be centred or justified right or left and even be positioned on an irregular curve or angle. Text is located by defining a single point on the drawing.

Another important function is layering, in which the drawing is split into several distinct overlays. This function helps simplify creation of the drawing and makes plotting easier because separate layers can be easily plotted in different colors. Layers can also be plotted separately to automatically generate a variety of drawings. For example, printed-circuit boards can be plotted in layers for holes, circuits, and components. Some systems automatically generate separate layers for elements such as dimensions. Some newer systems do not use layers, per se, but allow users to group geometric elements and turn these elements on and off as required.

Many of today's drafting programs allow users to also develop wire-frame models. Wire-frame models represent 3D part shapes with interconnected line elements. Also called edge-vertex or stick-figure models, wire frames are the simplest 3D geometric representation, though not the easiest to create.

More advanced techniques such as solid modelling have evolved out of frustration with wire-frame modelling. However, wire-frame models use little computer time and memory, and they provide precise information about the location of surface discontinuities on the part. Wire frames, however, contain no information about the surfaces themselves nor do they differentiate between the inside and outside of objects. Thus, wire frames can be ambiguous in representing complex physical structures and often leave much interpretation to users.

Wire-frame models are created by specifying points and lines in space. To create the model, the interactive terminal screen is usually divided into sections showing various views of the model. Some systems use only a single view with a movable workplace on which points and lines lie.

The designer uses the CRT in much the same manner as a drawing board to create top, bottom, side, isometric, and other views of the model. The designer need not manually draw each line in a wire frame, rather, the CAD system constructs the lines based on user-specified points and commands chosen from an instruction menu.

Most lines comprising a wire-frame model are straight. To generate a line, the user may designate two end points and give the computer a LINE command. Or a line may be automatically produced parallel or perpendicular to another line or tangent to a curve. Some CAD systems produce straight-line elements with up to 40 such techniques.

Similar automatic features can also produce curved lines. Circles may be produced by a specifying point and a radius, three points on a circumference, or tangent points to two or three other curves. And conics - complex curves such as ellipses, hyperbolas, and parabolas - may be produced by specifying appropriate points. Most CAD systems can also generate splines - smooth, continuous curves fit through a series of arbitrary points specified by the user.

Many other CAD features provide additional user-modelling aids. For example, points and lines created in one view may be automatically projected in other views. And once specific details have been modelled, the system can duplicate them repeatedly at specified locations on the model. In some systems, individual lines can be deleted from the model at any time. Moreover, in working the complex models, users can temporarily erase selected lines from the screen without deleting them from the model to view more clearly the area under construction. Erased lines can be recalled to the screen at any time. Likewise, certain model areas may be enlarged and later reduced. After completing a model, users may blank out hidden lines to give the model a solid appearance.

It is important to remember, however, that not all models that look like 3D wire frames are wire-frame models. Some PC software allows users to build isometric models that appear to have Z-axis depth, but in reality do not. These systems are usually called 2 1/2D system.

Geometric modelling

Although wire-frame models are the simplest form of geometric model, the term most often is associated with surface and solid modelling. Many ambiguities of wire-frame models are overcome with surface models, which define the outside part geometries precisely and help produce NC machining instructions where the definition of structure boundaries is critical. However, surface models represent only an envelope of part geometry, even though features such as automatic hidden-line removal make the model appear as a solid.

Surface models are created by connecting various types of surface elements to user-specified lines. The entire model may be comprised of different types of interconnected surfaces. With surface modelling, however, an entire structure may provide more detail than necessary for many applications, so some models combine surfaces for detailed faces, with wire frames representing the rest of the part.

CAD systems provide extensive surface menus from which to model. Typical surface menus include planes, tabulated cylinders, ruled surfaces, and surfaces of revolution, along with sweep, fillet, and sculptured surfaces.

The plane is the most basic surface type. The system merely creates a flat plane between two user-specified straight lines. A tabulated cylinder is the projection of a free-form curve into the third dimension.

A ruled surface is produced between two different edge curves. The effect is a surface generated by moving a straight line through space with the end points resting on the edge curves. A surface of revolution is created by revolving an arbitrary curve in a circle about an axis. This capability is especially useful in modelling turned parts and parts with axial symmetry. The sweep surface is an extension of the surface of revolution. Sweep surfaces, however, sweep an arbitrary curve through another arbitrary curve instead of a circle.

The fillet surface is a cylindrical surface connecting two other surfaces in a smooth transition. This is a tedious, subjective operation that has been done manually in industry for years. But CAD systems solve the problem of blending surfaces with the precise mathematical continuity required by many applications.

Sculptured surfaces are the most complex surface representation. There are many types of sculptured surfaces, including curve-mesh, free-form, B-spline, and cubic-patch surfaces. A sculptured surface is a differential surface created from two families of curves. These families are not restricted to being orthogonal, nor are the curve types fixed. Curves need not even be parallel. The two curve families intersect one another in criss-cross fashion, creating a network of interconnected patches.

Sculptured surfaces are complex contours that cannot be described with the usual lines and curves of conventional modelling. Typical structures containing such contours range from helicopter blades and automobile bodies to camera cases and glass bottles.

Solid models unambiguously define geometry and volume, providing the ultimate way to describe mechanical parts in the computer. Unlike other approaches, such as wire-frame or surface modelling, solid models provide the accuracy needed for precise mechanical design. And, solid models hold the potential to create a base of data that provides a complete description of the part to downstream applications.

Traditionally, however, solid models have been used primarily in stand-alone manner to calculate mass properties, simulate operation of critical components, and create realistic images. Although these applications represent great leaps over manual design, they are only a hint of the benefits that can be had by using solid models.

Indeed, the latest generation of solid modellers are now built specifically for their largest group of potential users - mechanical engineers. These programs are made to act as the primary tool used by mechanical designers, and potentially form the core of an integrated approach to engineering.

Solid models are constructed in two ways: with primitives or with boundary definition. Both of these methods develop complex geometries from successive combinations of simple geometric operations.

The Constructive Solid Geometry (CSG) method, or primitive approach, allows elementary shapes such as blocks and cylinders to be combined in building-block fashion. The user positions these primitives as required and then creates a new shape with the proper Boolean logic command (union, difference, or intersection).

With boundary definition, two-dimensional surfaces are swept through space to trace out volumes. A linear sweep translates the surface in a straight line to produce an extruded volume. A rotational sweep produces a part with axial symmetry, while a compound sweep moves a surface through a specified curve to generate a more complex solid. Another boundary construction technique called gluing joins two previously created solids with a common surface. Tweaking makes local changes to an overall shape.

Each of these construction methods is best suited to a particular class of shapes. Most industrial parts, for example, consist of planar, cylindrical, or other simple shapes and are readily modelled with primitives. But components with complex contours, such as automobile exhaust manifolds and turbine blades, are more easily modelled by boundary definition. Because the two modelling methods each have specific limitations, some advanced programs combine primitive and boundary-definition techniques to unified packages.

The speed of a solid modeller refers to the time it takes to display, manipulate, and build a model. Early solid modellers worked in batch mode, which limited their use as interactive modellers. Although these solid modellers could be made fast by allowing them to approximate edges and surfaces, the inaccurate models they produced made them inadequate for engineering design and manufacturing.

Today's solid modellers attempt to provide interactive operation while maintaining accuracy. Developers are revamping their software or writing entirely new programs that take advantage of today's powerful workstations. The goal is to produce interactive solid-modelling systems that work faster than even wire-frame techniques.

Graphics hardware made especially for solid modelling has recently become available to help reach this goal. For example, some workstations allow each stage of the graphics "pipeline" to operate independently for faster operation. In addition, VLSI chips are used to eliminate bottlenecks, and functions such as light sources, shading, hidden-surface removal, and B-splines are implemented in hardware and microcode.

## Finite-element analysis

Finite-element analysis (FEA) is a computer-based technique for determining stresses and deflections in a structure. Essentially, the method divides a structure into small elements with easily defined stress and deflection characteristics. The finite-element method is based on arrays of large matrix equations that can only be realistically solved by computer. Most often, FEA is performed with commercial programs. In many cases, these programs require that the user only knows how to properly prepare program input.

The finite-element method is applicable in several types of analyses. The most common is static analysis, which solves for deflections, strains, and stresses in a structure under a constant set of applied loads. Material is generally assumed to be linear elastic in FEA, but nonlinear behaviour such as plastic deformation, creep, and large deflections can also be analysed.

Natural-frequency analysis calculates the free-vibration natural frequencies and associated mode shapes of a structure. This analysis predicts critical operating conditions for machinery and is used in conjunction with experimental signature analysis.

Transient-dynamic analysis determines the time-response history of a structure subjected to a forced displacement function. The structure may behave linearly, or in some cases, friction plasticity, large deflections or gaps may produce nonlinear behaviour. Once the time response history is known, complete deflection and stress information can be obtained for specific times. A similar method is forced-harmonic response analysis, which calculates the steady-state response of a structure to a continuous set of sinusoidal loadings. Complex displacements and phase angles are calculated. Deflections and stresses may again be calculated at specific times.

Heat-transfer analysis can solve steady-state and transient heat-transfer problems. In most cases, thermal-output data are applied as input to a structural-analysis problem to determine thermal deflections and stresses.

The first step in finite-element analysis is creation of a model that breaks a structure into simple standardized shapes or by a common co-ordinate grid system. The co-ordinate points, called nodes, are locations in the model where output data are provided.

More than one type of element can be used in a model, including two-dimensional elements where all forces and displacements act in a plane. Axi-symmetric elements for solids of revolution are also two dimensional but have node displacements in radial and axial directions. Three-dimensional solid elements are used where forces and displacements act in all three directions or when a structure has a complex geometry that does not allow two-dimensional analysis. Finally, specialty elements such as shells, plate, and beam types are used where sections of a structure behave according to conventional shell, plate, and beam theory.

Elements with nodes at vertices generally model only a linear variation of displacement with constant strain. Elements are also available, however, with nodes between the vertices. These elements can model high-order variations in displacement and strain within an element. Elements with nodes along their sides are isoparametric. Additional nodes allow element sides to form curved boundaries. Isoparametric models can cut model construction times, but require more processing time per element.

Nodal stiffness properties for each element are calculated by the finite-element program and arranged into matrices within the computer. These parameters are then processed with applied loads and boundary conditions for calculation of displacements, strain, natural frequencies, or other data specified by the program.

Generally, the finer the mesh, the more accurate the analysis. In many cases, finite-element models are developed for prototype designs for which experimental data can be obtained. Once finite-element analysis results and experimental data are correlated, design modifications are made, and these subsequent changes are often tested through finite-element analysis before being implemented on actual prototypes.

Finite-element results predict relative changes in deflection and stress better than they predict absolute deflections and stress. If models of two similar structures are compared by finite-element analysis, the results will predict the proportional difference between the two more accurately than they will predict the absolute stress in either one.

Accurate predictions of relative deflection are useful in design work where modification to a structure or machine is contemplated. A finite-element baseline analysis can be made for an existing structure for which stress or deflection data are known. A comparison is made between finite-element results and known experimental data to calibrate finite-element results and provide a baseline. Proposed design modifications then can be compared to the baseline model

Kinematics

Often, engineers assume kinematics analysis and synthesis are synonymous, which is not true. Kinematics analyses motion in a defined mechanism. Synthesis, on the other hand, comes up with the best definition of the mechanism through iteration. In synthesis, the designer describes the parameters of the mechanism and the program develops alternatives.

Synthesis is a more difficult problem than kinematics. Unlike kinematics analysis, which starts with a mechanism design, synthesis starts with the basic description of a mechanism - number of links, number of joints and joint types, connectivity of links and joints, and specification of which links are grounded. Basic linkage types are defined within programs as kinematic chains. Component dimensions are not specified. The synthesis program then determines mechanism structures required to perform specific tasks. Synthesis also analyses how well certain mechanism structures will satisfy design objectives.

Kinematic synthesis programs are used principally to design four-bar linkage, although some also synthesize six-bar linkages. The four bar, however, is one of the most versatile types of mechanisms for providing complex motion. Most synthesis software, however, solves only certain classes of problems. First, the required mechanism must be classified as being either planar or spatial. Most mechanisms are planar, but contrary to popular belief, a planar mechanism does not necessarily lie in a single plane. Instead, its moving components - such as a parallel set of hinges - trace curves that lie in parallel planes. Spatial mechanisms have points whose paths are three dimensional and do not lie in parallel planes.

Some kinematic synthesis programs use graphics to make the software easier to use. Typically, the user specifies points and motion vectors with interactive graphics, which can be easily moved about the screen. After a number of points have been specified, the program will display possible locations of additional points to complete the mechanism.

After a mechanism has been synthesized, it may be animated on the screen to check for mechanical action. Viewing this animation allows users to judge criteria such as clearances of the moving links. Some systems permit these animations to be made with shaded images so the mechanism looks more realistic. For clarity, the display is usually colour coded to differentiate links, fixed pivots, moving pivots, motion paths, and other elements.

## Mechanical analysis

Mechanical analysis determines the way systems composed of mechanisms behave while moving or at rest. Several analysis options are available in these programs.

Kinematic analysis calculates large displacements, velocities, and acceleration of mechanisms without regard to the forces or mass properties acting on them. In kinematic analysis, the mechanism is driven by some outside force. Kinematic analysis assumes zero degrees of freedom, which means that each co-ordinate is constrained to a particular type of motion. Many times, mechanisms are constrained by tying their end points to ground.

Static-equilibrium analysis combines motion analysis with mass properties and force data to determine positions and joint-reaction forces of mechanisms at rest. Static analysis can also be done on mechanisms at various points in their range of movement, when zero velocity is assumed. Static models can have multiple degrees of freedom. Motion and force are uncoupled in this type of analysis. That is, the forces that act on the mechanisms are not a result of motion.

Dynamic analysis uses mass properties and forces to calculate positions, velocities, accelerations, and joint and constraint-reaction forces of all model parts when motion is coupled to forces in the system. Models may have any number of degrees of freedom. Dynamic analysis does not assume equilibrium in mechanisms. Analyses are done at discrete steps within a specified time interval. Each degree of freedom in a dynamics model is associated with an independent co-ordinate for which the analyst must specify both initial position and velocity.

Most dynamic-analysis programs are tailored to solving a certain class of problems. Many of the programs will solve kinematic problems as well, but software specifically designed for kinematic analysis is usually more efficient for this type of evaluation.

Large-displacement analyses are the most common type of dynamics problems. Large-displacement analyses are often non-linear. They include many discontinuous effects, making mathematics extremely complicated. Software for handling these complex problems often uses sparse-matrix methods and stiff-system numerical-integration algorithms.

The sparse-matrix approach solves for a large, but sparse set of first-order differential equations. Numerous equations are used to describe the structure, but only a few finite terms occur in each equation. As a result, time and cost of processing these equations is much less than would ordinarily be involved.

Computer models for dynamic analysis include geometric data and mass properties of the structure as well as applied forces. The model often is created through part, joint, marker, force, and generator statements typed by the user at the terminal.

Part statements define geometry, mass, and moment of inertia of each rigid part of the structure. Joint statements describe contacts between moving parts that hold the assembly together. Joints can be specified as providing translational and rotational movement including those of revolute, spherical, screw, universal, cylindrical, and translational joints, as well as motion of a rack and pinion. Marker statements provide a point or co-ordinate system fixed on each part, orienting it to other parts and together defining the overall configuration of the system.

Internal-reaction forces in the system are selected from a library of standard force elements such as dampers and linear springs. In addition, user-written routines can be used to define other parameters.

Graphics pre- and post-processing tools for mechanical-analysis programs are not as well developed as they are in finite-element analysis. Part of the reason for the slower development is that mechanical-dynamics programs do not require detailed geometric input. All that is required are three points of geometry for each mechanism link, which are the two ends and centre of gravity. Mass and inertia must also be defined for each centre of gravity. However, despite the fact that the geometric models are simpler, it is still easier to visualize mechanisms and get geometry correct with graphics than by scribing the geometry with part statements.

Basic geometric data can be sent from CAD programs through direct interfaces. Interfaces from modellers and CAD programs to dynamics programs are not done through such standard interfaces as IGES because a critical component of a kinematics and dynamics model – the centre of gravity – is not available through IGES except with specialized files that are difficult to use.

Because a complete geometric description is not required, mechanical analysis can be used early in the design cycle, before the final system shape is known. Engineers can design a system knowing only the mass and inertia characteristics.

However, complete geometric descriptions are required to properly postprocess a kinematics and dynamics model. Postprocessed models are used primarily as debugging tools to check for interferences. Realistic animation can be used to see motion that might be missed in a series of still pictures.

Dynamic-analysis output is also typically available in tabular form. Graphics may also be produced showing output quantities such as force versus time, or force versus displacement.

Most dynamic analysis can be done assuming rigidity, but in some cases, the ability to model flexibility can come in handy. Computational demands of flexible-body analysis are intense, however, so until recently, this type of analysis could not be done effectively because of hardware limitations. Often, engineers would assume flexibility and change accordingly the results of a rigid-body analysis, while at other times, a model is broken into parts, and bushings and springs loaded between the parts. Both these methods are considered inelegant and imprecise by experts.

Today, two methods are being used to model flexibility more accurately. One method uses finite-element data to model flexible structures, while another includes beam-element theory directly in the dynamic-simulation code. Using finite-element data to model flexibility requires conversion of data formats between the finite-element and dynamics codes. However, this method may be more accurate in some circumstances than the method that uses beam elements. Yet, analysis with beam elements may be faster and easier to implement.

## Electronic design

Electronic CAD has, over the years, become increasingly more integrated. Today, most electronic design is done on computers, and manufacturers are working together to perfect standard interfaces such as the Electronic Design Interchange Format (EDIF). In addition, the link between electronic and mechanical design is receiving more attention.

Tools to design printed-circuit boards (PCBs) and integrated circuits (ICs) have become more automated. Today's high-speed PCB boards, with their densely packed chips, for example, must be routed more precisely than in the past. This means that tools must make connections both accurately and automatically.

Workstations and PCs are typically used for electronic design. Software available for workstations now does all CAD tasks and product documentation. Most often, workstations are networked together, with different nodes performing different design tasks. Engineers working on the same project can communicate among themselves, share information, and off-load highly analytical tasks to powerful computers.

The greatest benefit of electronic CAD is the ability to forward and back annotate during design. For example, the engineer can specify the critical circuit requirements on a schematic and forward annotate them to the CAD layout designer. Electronic CAD tools are now able to transparently implement and check constraints such as minimum or maximum wire length, required via diameter, and net routing requirements. Once the design is complete, the design data can be back annotated to the schematic so that signal-delay analysis can be done.

Printed-circuit boards are getting smaller, but because of improvements made in IC packaging and layout technologies, they must hold an ever-increasing number of ICs. Efficiency of a PCB design system is now judged by the ability to generate a functioning, manufacturable board design.

Because of forward and back annotation, schematic capture, which is the entry of a conceptual design into the computer, and netlist extraction, which is the generation of a text file defining pin connections, are inexorably linked with PCB routing and placement. PCB design software can automatically place components based on the netlist. To compare the placement of components and gates, the CAD system counts the number of circuit crossings. Once placement is made, components, gate, and pin swapping can be done. All swaps are made within design rules defined prior to placement.

Routing algorithms are used to connect pins as designed by the netlist. A maze-search router can route a great percentage of the connections on most PCBs. Pattern routers are used to route regular areas such as memory arrays. Other programs can route diagonal bends in wires. Routing of diagonal bends is required to save board space and meet the speed requirements of some IC designs, such as those of emitter-coupled logic designs.

Depending upon the complexity of the board and the computational resources, routing may be 100 per cent. Some systems do not route 100 per cent of the connections, leaving the few remaining routes to be made manually.

Most routers define a 25 or 50-mil grid to ease the routing task. Some gridded routers permit some traces to be made off the grid to increase the number of successful connections. In contrast, gridless routers make inter-connections without regard to a predefined space. A problem with gridless routers is that editing wires located on fine-grid increments is difficult. Multi-grid and non-uniform grid methods allow route-channel saturation and relatively simple wire editing.

With automatic routing, routing time must be balanced with the percentage of routes completed. For example, it may be better to manually finish routing a board that has been 95 per cent routed, a task taking a few hours, then to wait four or five days until the board has been entirely automatically routed. (Source: Machine Design, November, 1989)

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## CAE in design for production

Computer-aided engineering has provided engineers with the opportunity to analyse new designs whilst they are still on the drawing board, thus reducing the risk of manufacturing problems at a later date and the costs of wasted tooling or raw materials. This article discusses the current capabilities of CAE and gives examples of its use in simulating metal forming processes.

Engineers have used computer-aided methods in stress analysis for many years. These methods have revolutionized drawing office practices in the design of structures and components and the new language of Computer Aided Engineering (CAE) has emerged as a result. Today, it is commonplace to find arrays of graphics workstations and networks of computers in the design offices of large and small companies alike and products can be analysed ad infinitum long before prototypes are manufactured and tested.

However, the stress analysis revolution does not yet seem to have reached those engineers who are responsible for developing the manufacturing processes which match the product. The design of tools and the development of manufacturing techniques continues to be addressed on the basis of trial and error and learning by experience; this can be both expensive and time-consuming. It does not make sense for a company to produce a better design of product through the use of modern methods if it is still incurring cost penalties and time delays on the run-up product launch because of a dogged reliance on the traditional approach to tool design and development. If modern techniques can assist with the better design of tooling at the drawing-board stage, there is clearly an incentive to employ them to reduce the risk of manufacturing problems at a later date. To be able to simulate the production process itself, using the computer to track the development of stresses, strains and temperatures in the tools and workpiece, would be a considerable step in the direction of "design for manufacture". This type of application is a good example of where modern stress analysis techniques could begin to make their mark on manufacturing technology.

Manufacturing processes are inherently non-linear, involving large amounts of plastic work and/or changes in shape and making the calculations very complex. To solve such problems numerically requires an extremely powerful computer and unobstructed access to it. Within the last few years, very powerful super-workstations and mini-supercomputers have arrived on the market and these have, at last, brought affordable computing to those who might need it for the purposes of simulation. This has, in turn, precipitated the rapid development of those computer programs which are necessary for the resolution of the non-linear problems outlined above. The "simulation toolkit" has, therefore, only just arrived.

If these simulation techniques are applied successfully at the pre-production stage, a number of advantages result:

- Reduced tool design time (fewer "trial and error" cycles),

- Improved quality of product (through the reduction or elimination of forming defects), and

- Reduced wastage (through the development of near net shape processes).

These factors can be translated directly into reduced costs, improved productivity and increased quality.

It is possible to simulate a wide variety of different forming processes, ranging from casting through forging to rolling, pressing and drawing. A number of examples are described below.

### Sheet metal pressing

Drawing operations on mild steel sheet are shown in figures 1 and 2 on page 67. The purpose of the simulation in figure 1 was to predict the forces on the tools required to form the product, the degree of pre-load on the blank-holder necessary to hold the blank without over-constraining it, and tendency of the sheet metal to tear if the friction at the blank-holder stopped the material from drawing properly. A series of simulations was carried out in which the blank-holder friction was varied and the associated behaviour of the sheet metal was studied. From the analysis, it was also possible to identify areas of thinning and thickening in the sheet metal and areas where excessive compression might lead to wrinkling.

The part shown in figure 2 represents a typical automotive application. The geometry is irregular and complex and, in this respect, it presents a much more difficult exercise than the component shown in figure 1. However, the mathematical considerations are identical, in principle, and the purpose of the analysis was to determine how the blank would respond during the forming process. In particular, the analysis was aimed at the investigation of splitting and wrinkling (which is likely to occur when attempting to press a complex shape in a single operation). Areas of thinning and thickening in the sheet metal could also be identified, and material flow paths could be predicted. Studying the movement of the material as it draws from the blank-holder during the pressing operation can be of great help to the tool designer in attempts to improve the performance of a troublesome tool.

The program used for these simulations allows the analyst to address completely arbitrary three-dimensional shapes and, if necessary, the effects of planar and normal anisotropy can be included.

### Nozzling

The nozzling process as it is applied to the formation of a fire extinguisher cylinder is illustrated in figure 3 on page 68. The workpiece is formed from a blank in the first stage operation using a back-extrusion process. The resulting closed-ended cylinder is the preform for the second stage, in which the open end is heated and then forced into a shaped die to form the nozzle end.

The nozzle is then drilled and tapped to take the machined parts through which the extinguisher is charged and discharged.

The coloured diagram shows contours of strain-rate in the neck of the fire extinguisher. There is a relationship between the strain-rates incurred during forming and the metallurgical structure (e.g. grain-size) in the finished product. Good correlation has been observed between predicted strain rates and grain size/location, lending confidence to the proposition that this technique could be used as a design aid for assessing the best means of forming high integrity components such as pressure vessels and aerospace components. A series of parametric studies has also been carried out to investigate the effects of factors such as interface friction between the workpiece and the tool and pre-heat temperature.

Casting

Of all the forming processes, casting is probably the most difficult to simulate. The interaction between mechanical and thermal effects is very strong; the fluid phase during pouring is followed by a transition to the solid phase during cooling in the mould, and there are metallurgical effects which have a first-order effect on the finished product (i.e. variations in metallurgical structure can have a dramatic effect on mechanical integrity).

Unfortunately, at present it is not possible to include all of these interacting effects in a single, comprehensive simulation. Parts of the problem can be addressed; the liquid/solid transition and the subsequent cooling which takes place once the mould has been filled can be simulated. For example, the temperature-time histories throughout a component and the progress of the solidification front have been tracked, figure 4 on page 68. Since the metallurgical structure of the end-product is dependent on the temperature history experienced during solidification, the outputs from a computer analysis of this kind could be used to infer the ultimate mechanical properties in various different parts of the structure. Developments are now in hand which will allow the software to predict the locations of shrinkage defects, warping, hot-tearing, and the effects of mould expansion or contraction.

Adopting the CAE approach

The potential advantages of CAE may be attractive, but making successful use of it requires technically competent people, software capable of handling a very wide range of mechanical and thermal phenomena, and hardware which is sufficiently powerful that useful calculations can be completed within reasonable timeframes. Having the right people with the right attitudes is the key to success and this, in turn, requires clearly stated objectives and sound technical training.

With regard to software, unfortunately a perfect system does not yet exist. There is no commercially available system that can handle all aspects of all forming processes. There are some very effective software packages that can deal with a sub-set of the problems at hand, as has been illustrated by the examples cited above. These problems are complex and the software required to address them can be expensive, therefore it is well worth seeking expert advice before making a purchase.

With hardware, it is clear that the more powerful the equipment, the better the result. However, there are natural constraints on this philosophy, notably from the cost point of view. The most powerful supercomputers can cost several million pounds and this price bracket is well beyond the reach of most potential users. It is not always necessary to go to these extremes and it is possible to run some software on workstations costing as little as £10,000-20,000.

Generally, the cheaper the hardware, the slower it runs, with the consequence that a calculation which takes one minute on a supercomputer could take two hours on a workstation. At the bottom end, the types of simulation described in this article might take anything up to 50 hours for the most complex problem, figure 2, although for a hardware expenditure in the order of £20,000-30,000, these times can be improved by a factor of five or six. The trend of increasing performance and reducing cost is likely to continue for the foreseeable future and therefore the outlook for those wishing to adopt simulation techniques is bright. Indeed, one of the brightest prospects is the transputer which, if it fulfils its promise, will deliver supercomputer performance at workstation prices in a few years time.

Conclusions

The costs associated with tooling-up for production can be very large. Simulation techniques can earn their payback many times over if they lead to shortened development programs and minimization of the trial-and-error process. Likewise, a reduction in the use of raw material or a reduction in scrap rates for defective parts can also provide a very rapid payback for the initial effort. It may take several weeks and several thousands of pounds to perform an analysis, but if it leads to time savings of months and cost savings of hundreds of thousands of pounds, the investment speaks for itself.

With the falling cost of computing hardware pointing to increased use of these techniques, it is almost inevitable that today's emerging capabilities will be viewed as commonplace within the next five years. (Source: Metals and Materials, July, 1989)

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Enhanced forging through computer simulation

The primary objective of manufacturing research and development is to determine the most efficient and optimum method of producing high-quality products with minimum material waste. Also important is the need to increase production rates and reduce lead times. Proper design and control of the manufacturing process require a clear understanding of all process parameters and their influence on metal-flow characteristics. Computer simulation of a manufacturing process, such as forging for example, helps predict process behaviour, allowing effective process design and control without going through a costly and time-consuming pre-production trial-and-error forging operation. One such computer-simulation code, ALPID (analysis of large plastic incremental deformation), is used to simulate the forging process. This finite-element method-based code provides information on material flow during deformation and predicts the required deformation load, stress distribution, effective strain, and effective strain rate.

Friction first

The interface-friction factor is one of the most important process parameters that must be identified prior to simulating any metal-working process. Friction significantly influences material flow, forming-load requirements, and formation of surfaces and defects in any metal-forming process. Thus, a detailed knowledge of both frictional effects on and frictional stresses in the tool/workpiece interface is necessary.

Two methods are used to obtain a quantitative measure of the friction co-efficient. In one approach, the co-efficient of friction according to Coulomb's law of friction is determined by the equation:

$$\mu = \tau/N$$

where $\tau$ is the shear stress at the tool/workpiece interface, and N is the stress normal to the interface. Coulomb's law of friction depicts sliding friction at the interface, and generally is considered valid for situations where the normal stress at the workpiece/die interface is low. As the workpiece is compressed, material flows outward laterally causing shear stresses at the die contact surfaces. The natural radial flow of the material is opposed by surface shear, which is directed toward the centre of the workpiece.

The alternative approach to Coulomb's law of friction is termed the law of constant-shear friction, which defines friction in a hot metal-working process more appropriately. A common situation encountered in a hot-working process is "sticking friction", which results from the absence of relative motion between the tool and the workpiece. In this instance, the interface friction between the tool and workpiece is regarded as a material of constant shear stress. The interface-shear stress is considered to be a constant fraction of the yield stress in shear. The interface-friction coefficient factor, $m_f$, is the ratio of interface shear stress, $\tau_s$, to the yield stress in shear, $Y_s$: $m_f = \tau_s/Y_s$.

The interface-friction factor has a value from zero to one. A value of zero represents perfect sliding; i.e., there is no shear or friction at the tool/workpiece interface. A value of one represents sticking friction; the interface-shear stress equals the yield stress of the material in shear. For hot metal-working processes involving large plastic deformation, it generally is better to use the interface-friction coefficient factor to describe the effects of friction. The interface-friction factor is a constant for a particular tool/workpiece interface and is independent of velocity.

One of the most common techniques used to measure the interface-friction coefficient factor is the ring compression test, in which a flat, ring-shaped specimen (1.5-in. O.D., 0.75-in. I.D., and 0.5 in. thick) is compressed by flat dies. The interface-friction factor is determined by measuring the per cent change in the internal diameter of the ring for a specific per cent reduction in ring height. This is possible because the change in the internal diameter of the ring depends largely on $m_f$.

In this study, the interface-friction factor between an aluminium-alloy workpiece and steel dies using a molybdenum-disulfide lubricant was determined by simulating a ring-compression test. Processing conditions used for the ring-compression test must be the same as those used in the actual metal-forming process for which the interface-friction factor will be quantitatively determined.

Eleven different ring-compression tests having interface-friction factor values from 0 to 0.5 were simulated using ALPID. Processing conditions of the top die, such as temperature and velocity, are the same for each simulation. The simulations were carried out until the compression of the ring reached 60 per cent of its original height. Geometrical symmetry of the ring makes it necessary to simulate only a one-quarter portion of the ring. Nodal co-ordinates of the corner nodes of the ring were extracted (making sure that the possibility of "folding" at the corner node points did not exist) and were used to calculate the percentage height reduction and the percentage increase in diameter.

Friction calibration curves are plotted using these values, allowing a comparison of different lubricants, which helps in the selection of the most suitable lubricant for a particular application. Actual ring-compression tests can be conducted using each of the lubricants until the predetermined reduction in height of the ring is attained. The friction factor for each test condition can be determined by measuring the percentage change in the internal diameter of the ring. A comparison of experimental data with the calibration curves derived from the ALPID simulations shows that a friction factor of 0.35 is an appropriate value for these ring tests, and was used for all the forging simulations in this study.

### Simulating a forging process

The fine-element analysis code, ALPID, is applicable to both rigid/plastic and rigid/viscoplastic materials under either isothermal or non-isothermal processing conditions. The results of isothermal-forging analysis provide information on material flow during deformation, and this information can predict the required deformation load, the distribution of stresses, effective strain, and effective strain rate.

Application of the finite-element method and computer simulation of a forging process using ALPID helps to achieve a better understanding of material behaviour during forging and the forging process itself. Information derived from the ALPID simulation, such as grid-distortion plots, load-stroke relationships, prediction of effective strain, effective stress, and effective strain-rate distribution (in the form of contour plots) helps to design the process and to determine material formability.

Some forging operations must be controlled within a very narrow temperature range to develop certain required microstructures and properties. In conventional non-isothermal forging, one of the major problems is a loss of heat in the workpiece due to chilling by the colder tooling. Die chilling severely limits permissible reductions and shape complexity because the resistance of the workpiece to flow increases with decreasing temperature. In isothermal forging, both the workpiece and dies are at the same temperature, and the forging is done at low strain rates to minimize changes in temperature.

Closed-die, flashless, isothermal forging is one of the most efficient ways to form high-precision, net-shape or near-net-shape parts, which are preferred by users to conserve materials and reduce machining costs. In closed-die forging, the material is formed by bringing the dies together so that the workpiece is entirely enclosed. The impression for the forging can be either solely in one of the dies or can be divided between the dies, and complex shapes can be forged within very close dimensional tolerances.

Because rib/web sections are widely used as aircraft structural components, isothermal, flashless, closed-die aluminium rib/web forgings were simulated using ALPID in this study. An L-shaped section having equal web thickness and rib width was selected for simulation. The objective of closed-die, isothermal forging simulation of a rib/web section is to predict deformation requirements for the process. Such a simulation can provide some insight regarding preform design - if preforms are necessary - as well as information about die filling, metal flow, and load requirements. Computer-input preparation is accomplished by generating finite-element meshes using any commercially available mesh-generator packages; meshes generated must adequately represent the workpiece geometry. In addition, information on dies, such as geometry, friction at die/workpiece interface, velocity, and the direction of die movement must be specified. Further information required includes correct implementation of boundary conditions and the provision for flow stresses of the workpiece material as a function of strain, strain rate, and temperature.

The deformation mode is plane-strain, a valid assumption in this study because the L section is relatively long. The temperature of the dies and the billet was maintained at 425°C (800°F). Large deformations encountered during process simulation cause the workpiece to deform to a degree such that workpiece-mesh geometry is unacceptable, thus requiring a reconstruction of the deformed workpiece mesh. Mesh reconstruction is accomplished by extracting the boundary information of the deformed workpiece and constructing the new mesh using the same procedure used to construct the initial workpiece mesh. The field variable is strain interpolated in a manner such that the distribution of field variables at the old and new meshes are the same. Large local deformations are observed around the corner radius, which causes a negative Jacobian determinant.

The load increases gradually with the die stroke, but a sudden surge in the load occurs for a very small stroke increment toward the end of the process. During this particular phase of the process, the load requirement is almost doubled, and this can be attributed to the fact that the material tries to fill the die corners, which, in this instance, is the upper right corner of the rib. It is conceivable that toward the end of the process, complete die filling can be achieved only by further increasing the load as the resistance to the material flow increases. Depending on the capability of the forging press and several other factors, such as die filling, required properties, cost, time, and effort involved in preform design, a compromise should be reached on whether it is necessary to adopt a preform design.

Material flow is predominant in the rib region as reflected by the magnitude of the nodal velocities in that region. Strain-rate values are higher in the vicinity of the rib/web corner, and the distribution of the strain rate is more predominant in the web section. The average strain rate variation for the L-section forging ranges from 0.1 to 0.15 $sec^{-1}$. The maximum strain value encountered in this process is 1.59, which is not uncommon in a forging process. Higher strain values are observed close to the upper dies in the rib section, reflecting larger local deformations in those areas. (Excerpt from *Advanced Materials and Processes*, February, 1990, article written by S. N. Dwivedi and R. Shankar, West Virginia University, Morgantown, W. Va., USA)

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## Cadfibre: an intelligent tool for designers of composite parts

Despite the attractions of fibre-reinforced plastics composites in such demanding industries as aerospace, transportation, and general engineering, progress in replacing traditional metals has been slow. The reasons are that engineers and designers have limited experience of composites, there are no rules, models, or design methods for RP parts available, and production techniques have been restricted to low volume methods which makes for expensive fabrication.

Great progress has of course been made in the aerospace industry, where a number of highly qualified experts are involved in producing high technology parts in small or medium-size runs. But in the automotive and machine industries, there is a lack of designers experienced in the use of RP. In comparison with conventional "steel" thinking engineering, a designer has to deal with additional rules for development of composite parts. The following aspects have to be taken into account:

- Composites have anisotropic properties, being stiff and strong in the fibre direction and weaker and more compliant in the transverse direction, sometimes with properties worse than those of the matrix material.

- Properties are influenced by processing conditions. For instance, the fibre content is influenced by the tension in the filament, the pressure in the parts, and by the resin flow. Air voids greatly reduce the dynamic properties of parts, especially under shear stress.

- Different material failure modes might occur, e.g. cracks may occur due to fibre failure, matrix failure, or rupture of the matrix/fibre interface. Additionally, if the interlaminar shear strength is exceeded, delamination occurs.

To solve these problems, rules need to be set to aid the designer in systematically laying out a composite part without neglecting any critical factors. CAD and CAE programs are an essential tool in achieving this. With CAD, safe predictions can be made within reasonable time frames, minimizing expensive trial-and-error experiments.

### Systematic construction

The general design procedure involves four phases. In the planning phase basic facts about the new parts and suitable materials are considered. A requirements list is drawn up and rough pre-dimensioning of the part is carried out by verifying its applicability. In the concept phase the production procedure and the main possibilities for its achievement are researched. In the design phase the part concept is transformed into a geometrical and materialized design. After material selection, which the non-expert can only do with the aid of a data base, dimensioning according to various optimized strategies takes place. In the final working phase the construction results are documented and prepared for the subsequent steps of readying for production.

The Cadfibre program is being developed to enable the non-specialist designer to handle composites. It enables him to design a part completely, and to simulate a process on minicomputers. The aims are:

- Reduction of development times;
- Reduction of expensive trial and error experiments during prototyping;
- Optimizing a part technically and economically;
- Building a pool of know-how in design and production;
- Improving planning and control during construction;
- Storing operational knowledge and experience.

The software package comprises four modules: data base, construction and dimensioning, process simulation, and quality assurance. From the material data base, the user selects materials with the right property profiles. In the construction and dimensioning module, simple programs enable calculation of thermal expansion or swelling strains, e.g. as a result of moisture absorption, and estimations of working life under dynamic stress. Typical force introducing elements of parts are optimized for stiffness or strength. Frequently occurring elements are stored in the system as standard predimensioned "macros."

The process simulation module enables the user to assess, for example, the winding of a previously constructed shape, testing whether the fibre orientation is retained, or what degree of coverage is achieved. This module also provides machine setting data. The last part of the program, the quality control, checks whether the required properties can be achieved within the specified tolerances.

Material data base

First step in part design is choice of material. A great advantage of RP is that different combinations of fibre and matrix can be tailored to produce the appropriate property mix. Working in the traditional way, the designer analyses mechanical stress, environmental conditions, cost and weight targets, then looks up data charts and selects the material.

By using computer-aided data base systems, he can determine the required material quicker and more objectively. In the materials selection stage, single-point values of parameters such as tensile strength or modulus are mainly required, whereas in the dimensional functioning stage, temperature or time dependent properties are needed. For this reason Cadfibre distinguishes between primary and secondary data bases.

In the primary data base, single-point values for individual materials are stored for mechanical, physical, thermal, electrical, optical, and chemical properties, together with a description of characteristics such as delivery form, storage, and processing.

The data base has a three-level hierarchical structure. At group level are the fibre type, matrix type, and semi-finished products (prepregs). The type level comprises the type of reinforcement - glass, carbon, aramid, etc., and the type of matrix material - epoxy, thermoplastics, etc. On the commercial level is information on brand names and manufacturers.

This data base structure speeds up selection by immediately eliminating some materials. The user can vary the number and type of features of each material to suit his requirements. The primary data base offers two possibilities: material analysis or search profile analysis.

In the material analysis mode, important properties for the required material are made available according to the specified groups, ordered under "data sheet." The search profile analysis is the main core of the primary data base. The designer can compile his search profile according to the criteria of the basic specification, the optimum value, the tolerance zone, and a weighting factor. Using this information, the system selects suitable materials and grades them according to effectiveness.

In the secondary data base, functional correlations can be stored either digitalized as curve formulae or as mathematical functions. This secondary data base is called up after the material pre-selection in the dimensioning stage. Important parameters here are primary mechanical properties as functions of time, temperature, etc.

The advantage of storage as functional dependent variables is shown if the data have to be dimensioned. Instead of overall reduction corrections for conceivable environmental factors, the real material data are fed into the calculations through functional correlations, and can therefore contribute to increased effectiveness of the material, to cost and weight reduction, and to greater security.

A further alternative is the storage of processing parameters such as viscosity functions or pressure and temperature curves in processing, e.g. in autoclave cycles.

Graphic display and correlation of important characteristics can provide valuable support to the designer. He can select a suitable matrix material for a given fibre and the expected service temperature from a display of glass transition temperature over fracture strain for various matrix materials.

Temperature considerations are dictated by the condition that glass transition temperatures of matrix materials must be greater than the expected service temperature of the composite. If for instance a highly strain-resistant carbon fibre with a fracture strain of 1.5 per cent is selected and the service temperature is approximately 180°C, only modified epoxies, polyimides, and polyethersulfones will be suitable.

Further important comparisons are for example Young's modulus and tensile strength, from which an optimization between stiffness and impact behaviour can be estimated. These options are currently being researched. The Cadfibre data base is an open system which currently contains 120 material characteristics. It is designed to allow the user to add data on other materials or properties.

Construction and dimensioning

Composites have over metals the advantage that certain properties such as modulus, strength, or thermal expansion are readily tailored to requirements through manipulation of fibre type, content, and orientation, laminate make-up, and choice of matrix.

In the computer-aided design of large parts, stresses and deformations are normally calculated from continuum theory. The designer with less experience of anisotropic materials can still undertake optimizations of the laminate construction by user-friendly programs. Analytical calculation possibilities exist for estimation of thermal or swelling strains under media influence for various laminate types. The thermal expansion that is controllable through fibre orientation and content is an important design variable for precision parts such as measuring devices, antenna structures, or even machine components that must resist high thermal loads.

In addition to the methods for estimation of properties of various laminate structures, there are simple construction programs to aid the designer. Composite parts often contain identical or similar construction groups, the calculation of which is dependent only on the variation of a few geometrical or mechanical parameters; the calculation process itself follows schematic rules.

For frequently occurring basic geometries, program segments have been developed that take over the dimensioning of individual constructional groups or segments. These so-called "macros" in the Cadfibre program include spring elements, shafts, tubes, plates, and sandwich constructions. They can be called up quickly without the need to specify each point, line, or surface. Two macro programs exist to enable construction of vessels and leaf springs. The construction of leaf springs is done according to the "constant edge fibre strain" criterion of the differential equation of bending beam theory.

A further group of macros comprises the stress-inducing elements. Their function is to apply point, linear, or surface forces into the part, according to the application. Bore holes, attachments, or clamping elements are typical of such macros.

For very complex geometries or for the safety-factor-related fine dimensioning of heavily loaded parts, more time consuming and complicated calculation methods such as the finite element method (FEM) are used. These call for interfaces for coupling commercial FEM software.

## Process simulation and production

Cadfibre programs are available for filament winding, and a program is under development for SMC compression moulding. The SMC program is part of another project sponsored by the Forschungsvereinigung Automobiltechnik (FAT). Interfaces between this program, the Cadfibre material data base, and the user interface guarantee a close connection to the Cadfibre programs.

The filament winding program allows comparison of various part geometries and different laminate build-ups, and further enables the effect of alteration of winding angle to be assessed (3, 4, 5, 6,)). The three-dimensional CAD/CAM package provides interfaces to programs for design, calculation, materials data bank, machine data, production parameters, and quality assurance. It enables rapid optimization of machine motion parameters.

The process sequence is sub-divided into the main steps of core design, laminate layout and generation, and determination and optimization of core-related winding co-ordinates, followed by production and testing. The individual processes and the overall process are run iteratively.

The structure of the winding core is based on convex frames, offering a wide range of windable shapes. The so-called wire model developed at the IKV is especially suited to winding simulation, needing only low operator involvement yet with great flexibility and minimal internal data capacity requirements. Other available basic elements are rotational solids and prisms, which can be generated and manipulated using specific commands. This allows matching cores to be merged.

The CAD/CAM laminate layout program, exploits the fact that the roving touches the network structure at pre-calculated contact points during winding, and is stretched over triangular areas, running from edge to edge in a series of steps. In small zones, points on the core surface should automatically be approached at the desired winding angle. The laminate can be built up in layers and zones, and sub-windings linked with one another. Axial displacement of a winding on a non-rotationally symmetrical body is not possible, therefore every single feed-eye position has to be calculated. Special variations of the winding pattern are possible.

The inputs for laminate build-up are the overall wall thickness resulting from the dimensioning phase, the number of layers, and the appropriate winding angle. The designer will also enter tolerances for filament lifting from the core surface of the required coverage on individual core segments.

As a basis for determination of control data, the enveloping surface of the wound part is defined as a neutral interface. Winding co-ordinates referred to the enveloping surfaces (environmental co-ordinates) are shown as points at which the tangents of the filament lay pierce a given enveloping surface, and initially represent interfaces with the various production machines.

Environmental co-ordinates so obtained are converted into axial co-ordinates by indicating the appropriate machine configuration. Proces, parameter-dependent speed optimization of machine motion axes and roving spin-off force and roving spin-off are envisaged. The feed-eye positions generated for machine control should also be displayed as an aid to collision testing. The programs are realized on a VAX 750/11 and transferred in simplified form to an IBM PC/AT.

The CAD/CAM package is intended to enable users to wind even complex part geometries with fibre composites in cases previously feasible only with manual laying or using other materials. Typical is an S-bend part with a cross-section varying over its length. Machine production in fibre composites has been feasible only with a winding robot and wide tapes, control data being, acquired via a teach-in routine. The fibre orientation is however far from optimal; filament winding allows more favourable implementation of the calculated winding angle. Further examples benefiting from simulation are robot arms and non-rotationally-symmetrical pipe fittings.

## SMC compression moulding

Properties of SMC compression moulded parts are affected by fibre orientation or knit lines that occur during the moulding process. Programmes for simulation of the mould filling stage can reduce the high development costs for the part and the mould. Results of such calculations are flow front profiles, fibre orientation, mechanical stress in the mould, and position of knit lines. The Cadfibre user is offered an interface for application of these programs. The simulation program is independent of the material in use, hence can be applied equally to thermoset SMCs or to thermoplastic GMTs.

## Quality assurance

Uncertainties about material behaviour in RP often leads to over-dimensioning. The designer must on the one hand have available appropriate materials guidelines, and on the other hand be able to assess the effects of production parameters on part properties through quality assurance measures. These measures must comprise incoming goods control, production monitoring, and end product control.

For incoming goods control, programs are used for statistical processing of test data. Characteristic values according to amplitude and spread are recorded with statistical probability. In aerospace technology for example, a differentiation is made between A and B values. The A figure gives a material value of 99 per cent at a statement probability of 95 per cent; the probability for the B values is 90 per cent at a statement probability of 95 per cent. Safety-critical parts are designed according to A values, secondary parts according to B values. The spread factor is also important, a high spread resulting in a steep decrease of the parameters.

$$A = \bar{x} - k_a \cdot s$$

where $\bar{x}$ = arithmetical average value (e.g. 1550 MPa)

$s$ = standard deviation (e.g. 70 MPa)

$k_a$ = safety coefficient (e.g. 3)

Example: the A value of a material of tensile strength 1550 MPa is 1340 MPa.

During the process control, parameters such as pressure and temperature can be checked and compared with values from the secondary data base. The correlation between process parameters and mechanical properties aids in the optimization of the production process.

Properties of the finished part can be determined in the final check. Here, destructive tests, e.g. of the interlaminar shear strength, as well as non-destructive methods are used. The goal is to detect inhomogeneities such as air voids or deviations from the desired laminar structure. The production conditions are to be determined and given to the designer as a basis for future calculations in the development of the part.

## Coupling of CAE programs and expert systems

In addition to supporting the composite parts designer through construction systems and CAE programs, expert systems also have the facility of storing "composite know-how". Specifically, in the complex correlations in the area of materials and in the iteration between design and production, there exists a large amount of knowledge and experience in the form of rules, logical correlations, and analogies with other processes. CAD programs are capable of processing only that knowledge existing as algorithms, whereas expert systems also process knowledge gained from experience in empirical form.

Expert systems comprise several components. In the knowledge base - the core of the system - facts and rules, e.g. in "if/then" form, are stored. In the inference or problem-solving components, the work is undertaken by rules. The explanation components aim at making the problem-solving process understandable, i.e. the user is given the opportunity to carry out the line of reasoning at any time. With the aid of the knowledge acquisition components, the expert with less knowledge of the program will be able to create or change knowledge bases himself.

Expert systems cannot replace human expertise, rather they should build on existing expertise. They present a program system, which is different from conventional systems in that the sequence of the solving of the problem is not fixed. The use of systems such as this is ideal for complex problems that are not describable with algorithms; it is particularly useful where large amounts of data and rules have to be processed quickly and accurately. The rules need not be set in a logical correlation right from the beginning, but can be entered arbitrarily into a computer.

So-called shells can be used to assist in the compilation of these expert systems. Shells are universal tools, regarded as expert systems without a specific knowledge base, extended to tools for the implementation of the knowledge base. They contain inference methods, knowledge representation formalisms, aids for the compilation and maintenance of the knowledge base, and explanation and dialog components. (Source: Modern Plastics International, October, 1989)

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## Laboratory simulation of materials fabrication processes

The physical simulation of materials fabrication processes in a laboratory environment provides an economical and effective means of studying new process techniques and refining existing methods. The cost savings of using simulation can be significant, in both lower research costs and higher production yields as a result of the research. The Gleeble system is a machine designed specifically for the physical simulation of a variety of metal working processes, including forging, rolling, welding, casting, and other processes involving the application of thermal and mechanical energy to metals. The Gleeble provides a well-instrumented test unit for the precise control of the experimental process simulation and easy measurement of the results of the simulation. Over 150 Gleeble systems have been installed world-wide, providing laboratory physical simulation systems for diverse applications.

Welding process simulation has been carried out for more than three decades, and has proved invaluable for the study of HAZ phenomena, hot cracking and weldability assessment of new materials. The Gleeble system is currently being used in a number of applications. At Beijing University, a new technique for roll bonding copper to aluminium to create a clad plate product has been developed by first physically simulating the process on a Gleeble system, and subsequently transferring the process results and parameters to a rolling mill operation. Simulation work at Ohio State University is concentrating on the weldability of non-ferrous alloys, stainless steels, nickel-based alloys, aluminium-lithium and titanium. Research projects under way include the determination of weldability of cast superalloys for turbine engines, investigation into the welding properties of titanium aluminide alloys for aerospace applications, and melting and solidification studies of aluminium-lithium alloys. Similar work at The Alcoa Technical Centre, Pennsylvania, uses a Gleeble system to characterize the elevated temperature properties of aluminium-lithium alloys for aerospace applications.

The most recent simulation applications include the joining of metal-matrix composites (MMCs). The high cost of the materials, and the lack of data and experience in welding them, make laboratory simulation particulary desirable. The high heating and cooling rates (greater than 10,000°C) permitted by the closed loop thermal system also make the Gleeble ideal for studying the effects of thermal and mechanical shock and/or fatigue on metal-matrix composites, superalloys and other aerospace materials. Numerous research programmes are currently under way to determine the effects on the composite matrix of repeated heating and cooling cycles under alternating compressive and tensile loads, to reproduce the end use applications such as airframe and engine components. The physical simulation provides a low cost method of determining the suitability of the material for a specific end use without the need to fabricate the final parts. This provides a far shorter period of testing time, using only small amounts of material, thus providing substantial cost savings.

The use of small amounts of material to gather extensive data also provides savings in hot rolling, forging and forming simulations. A research programme is under way at Nippon Steel Corporation to study the hot rolling and forging characteristics of titanium alloys. Results of the physical simulations are transferred to production processes to reduce cost and improve quality. Varying thermal histories, strain rates, and total strain are simulated quickly and easily. Since the Gleeble closed loop servo-hydraulic system is responsive and fast (rates greater than 1ms), multiple stage rolling simulations can be performed in a single experiment. Three or four stages of deformation are typical. However, as many as 15 stands have been simulated in a single experiment on the system.

The ability to quench material at any time during the simulation allows the freezing of microstructures to examine the process at specific points in the simulation. Good correlation between physical simulation and actual rolling mill results has been achieved.

As demands for maximum efficiency, minimum downtime and improved product quality increase, the value of physical simulation of metal working processes becomes even greater. Processes can be optimized off line, thus allowing mills to continue producing at full capacity. New materials can be tested for applications suitability, and fabrication techniques can be examined without the expense of building the actual end products. The economics and efficiencies achieved by correct use of physical simulation techniques make simulation research an important part of materials production and fabrication. (Source: Metals and Materials, April, 1989)

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New 3-D CAD/CAM program simplifies, speeds parts design

New to the United States, an advanced computer imaging program called DUCT (Design Using Computer Techniques) is a British system that lowers the cost and speeds the modelling and machining of complex surface shapes. Much like a computerized patternmaker, this system allows the rapid design and manufacture of tooling that can produce accurate parts at minimal cost.

The system can model the interior and exterior surfaces of the most complex shapes. Unlike the "wire frame" systems most often associated with CAD/CAM imaging, it uses 3-D model representations, basically using two and three-dimensional sectional data, to produce 3-D surface shapes.

In operation, open or closed sections of the part to be modelled are positioned relative to each other within a 3-D space. This is done by placing the sections at an operator-defined curved or straight line in the space called a "spine" and defined by at least two points, each with x, y and z co-ordinates. Each section of the part must have the same number of points, where each point is fixed in relation to the co-ordinates.

When the number of sections equals the number of "spine" positioning points, the program takes over and automatically blends between the sections to create an optimally smooth surface. It utilizes a modified version of Bezier mathematics which assumes that the representative sections and surfaces are essentially plastic and able to be manipulated at will.

As the computer operator alters the contours of any part surface requiring modification, DUCT dynamically alters the model's surface. If a section does not exist in the area modified, the program creates one for the operator. In effect, the operator can freely design or modify the most complex surface shapes.

Blending surfaces

Multiple geometry components, comprised of surfaces by the program, make up a part to be designed. The operator first models the various surfaces to their nominal dimensions and true position in the 3-D space, then, using the system's blending power, he moulds the various surfaces into a completely modelled part.

Once modelled, he can use the system's visualization mode to call up a sophisticated, coloured and shaded image of the complete part shape just as it will actually appear. With the model's exterior and interior surfaces shaded in different colours, critical aspects like blend quality, surface integrity, discontinuities and the like are quickly evident.

In addition, the system simulates multiple light sources, dynamic rotation, multiple simultaneous views and solid shading. These provide the necessary visual tools for a computer operator and the part's designer to completely analyse the design. The operator's VDT displays the part exactly as it will turn out after actual machining.

Foundary application

The system has particular application in the foundry industry, where tooling is so critical and costly. Provisions for locating and validating gating, risers, surface area, volume, weight and cross sectioning at critical mould points are essential mould design considerations for the parts designer. This system eliminates much of the trial and error approach to mould design, and can reduce significantly the cost of producing patterns for manufacturing.

In addition, the system has an extensive data base to aid the foundry pattern department. Some examples include:

- Parting lines: establishing parting lines with and without natural or radial draft;

- Shrink: determine uniform and anisotropic shrink allowances to produce a nominally dimensioned, uniform part;

- Accuracy: precisely determine essentials like wall thickness and part weight, keys to producing interchangeable parts;

- Checking/reverse engineering: the system's data base can interface with co-ordinate measuring machines (CMMs), digitizers, laser scanners;

- Change orders: geometry changes from customer or production can be accommodated quickly;

- Pattern repair: maintains tooling at set dimensions to reduce scrap;

- Production estimates: the system's volume, surface area and cross section calculations aid in overall cost control and verification;

- Analysis: provides interface with Finite Element Analysis (FEM) and simulation programs to predict part usability/manufacturability;

- Customer communication: it supports effective neutral data graphic exchange specifications for easy communicating with other CAD systems;

- Product lead time: lead times can be reduced as much as 33 per cent.

The program offers a unique 3-D modeller for developing complex shapes, from initial concept to completed design, subsequently converting design geometry into precise sets of machining specifications. (Source: Modern_Casting, November, 1989, Phil Muhlfelder, Delta-Cam, Inc., Eastlake, Ohio, USA)

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## Rethinking the design process

The use of fibre reinforced plastics for primary load carrying structures has grown rapidly in the past decade. This is largely because such composite materials allow designers to tailor the properties of the material to carry imposed loads efficiently: products can be developed with very high specific strength and stiffness values. The related drawback is that, with such a wide choice of material combinations, processing methods, fibre distributions and product shapes on offer, composites present perplexing design problems.

Recently there have been significant advances in the automation of composites production, but moves to computerize the design phase have failed to keep pace.

The key considerations for composite design are listed in the design block of the simplified product development loop shown in figure 5 on page 69. All of these elements will have an impact on the product, although some will have higher priorities than others.

It is essential that the product is designed with a process in mind. Each composite method, from hand lay-up to computerized filament winding, has its own advantages and disadvantages. The important parameters to consider include: component geometry, production volumes and rates, reinforcement type and orientation, matrix type, proportion of matrix to reinforcement, tooling requirements and last, but not least, economics.

The geometry of the component has a major effect on the choice of process and reinforcement lay-up. The geometry may be rigidly fixed in the component specification, for example if a direct replacement of a metal component is required. This poses severe limitations, and ideally there should be freedom to adjust the shape. If modifications are allowed, however small, then there will be scope for altering the lay-up to meet strength/stiffness and processing requirements. Often a space envelope is provided for the component to operate within. This is usually more restricted when the design is for a moving part or when it is close to other moving parts. In some situations it will be possible to take full advantage of using composites by consolidating several metal parts into fewer composite components.

External loads are normally fixed in the component specification. However, if a metal-to-composite substitution is involved, the weight and inertial loads of the part itself may well be reduced. This may have a knock-on effect for the rest of the system, with a possible de-rating of connected components.

When selecting from the vast range of reinforcement/matrix combinations on offer, a variety of parameters should be considered. These include cost, processability and mechanical properties. In most cases, the design aims will be to minimize weight and cost and to improve performance by efficient material utilization. However, the emphasis will vary from application to application: in a component for a production car, cost will be the priority, whereas in an aircraft, weight will be more important.

The basic design method for composite materials is to orientate the fibre reinforcement in the direction of the principal stresses, and select the fibre to resin ratio to manage the stresses. If the reinforcing fibres cannot be aligned exactly with the principal stress direction, then the ratio of fibre to resin can be increased to take account of this.

There are a large variety of reinforcement types, but for high specific strength structures, continuous fibres are needed. These transmit the applied load or stress from the point of application to the reaction via a continuous load path. If non-continuous fibres are used, then the matrix must transfer the load from one fibre to another at the discontinuity points. Applying such loads to the weaker matrix material results in a composite with a lower load carrying capacity.

To analyse composite structures, the following simplifying assumptions are normally made:

- The reinforcement and matrix materials strain equally;

- A good bond exists between the reinforcement and matrix materials;

- The composite exhibits elastic behaviour under load; and

- The interface shear stresses are very small.

Several theories exist for analysing composites, such as orthotropic analysis and netting theory, which assumes equal and constant stress in each fibre with no load carrying capacity in the resin. Without the aid of computers, the theories rapidly become unmanageable as the complexity of the lay-up and structural geometry increase.

Originally developed for plywood, laminate analysis is useful for studying flat multi-layer laminates. The analysis permits calculation of the in-plane and flexural stiffness of laminated flat plates built up from thin orthotropic laminae or layers. These may have different properties, thicknesses and orientations of their principal axes of orthotropy. Using stiffness matrices, the stress/strain relationships for each layer are readily obtainable.

If the reinforcement is woven, rather than in discrete undirectional layers, the analysis can still be used. However, the effects of fibre crossover on strength and deformation need to be taken into account. Theoretical methods are available for predicting the effects of fibre-crossover, but most designers resort to using the mechanical properties for the woven lamina and assume it to be a discrete layer. In matrix form, the analysis is easily adapted to computer based methods, allowing rapid appraisal of different materials and lay-ups to meet certain criteria.

Computer algorithms, such as that shown in figure 6 on page 69, for analysing composite laminate structures allow a designer to look at a structure's stress/strain behaviour section by section, modifying lay-ups and materials until the desired properties are achieved. There are several commercial laminate software packages on the market such as Lamanal, Laminate and Coala.

There are limitations in using laminate analysis, but methods are being developed to allow the study of curved and closed shapes of variable thicknesses. Where designs are too complex for laminate analysis, simplifications may be incorporated to allow laminate analysis to provide input data to a more sophisticated finite element analysis (FEA) method. This technique processes the data into nodal displacements and rotations which are subsequently translated into stresses and strains. There are many commercially available FEA packages available with composite elements, such as Pafec, Nisa and Cosmos.

Figure 7 on page 69 shows a suggestion for an integrated suite of connected computer programs for the design analysis of complex composite structures. The design system comprises a set of interactive modules, both practical and theoretical, linked via computer programs. The overall system would be more complicated than shown, and under the control of a management system. Stand-alone systems, such as computer aided design, could be interfaced with the system.

The suite of programs is arranged on different levels – the analysis can start or finish at any level depending on the structure's complexity and the accuracy required. At level one, the structure, which may be simplified in shape, is assumed to be isotropic. The direction of the principal stresses will influence the initial lay-up and provide input data for level two.

At level two, use is made of laminate analysis in order to assess the various lay-ups. The output from this stage may be sufficient for immediate design use. However, test data may also be required to check the output. The tests may lead to design modifications.

At level three, FEA is carried out using the output from level two, along with any relevant test data. The output from this stage can be subject to further tests or even a re-run at level two.

The constituent parts of the design system are all commercially available as separate computer programs for carrying out different analysis methods. However, there does not appear to be a complete package of connected programs to enable the designer to take the component geometry and material properties and be guided through a series of interactive steps and iterative loops to produce a working design of a composite component.

In principle, the design system could be installed on any system from the more powerful personal computers to a mainframe. The size of computer needed is normally dictated by the component complexity, scope of analysis and the required speed of computation.

Such a suite of programs would eliminate the tedium of longhand calculations and provide a more rapid and accurate iterative loop to an optimum design. This is vital if the design process is to keep pace with the recent advances made in the automation of composites processing and manufacture. (This article written by Dr. Kevin Edwards, chief designer with Darchem Composite Structures, Redwongs Way, Huntingdon, Cambridgeshire PE18 7HB, UK, Tel. No. (0480) 453537, was first published in Engineering Magazine, London, September 1989)

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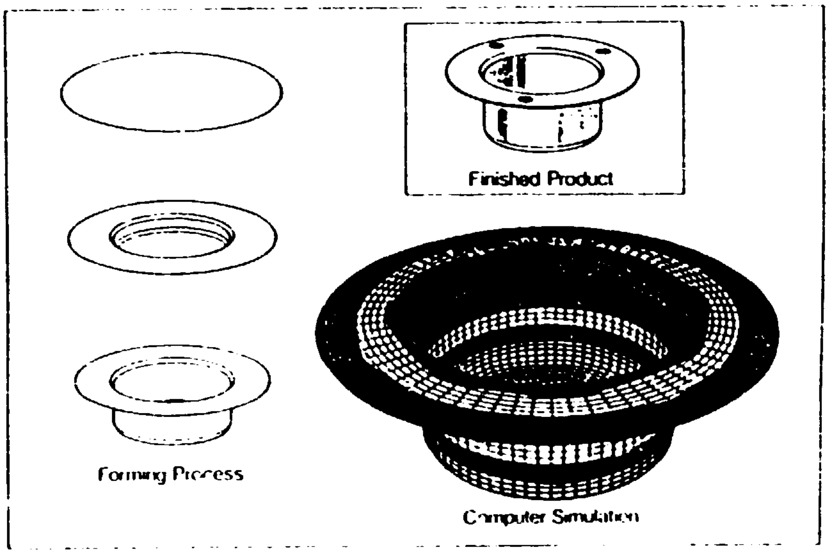


Figure 1. Simulating the deep drawing of a sheet metal cup. The coloured contours show different levels of strain in the finished product

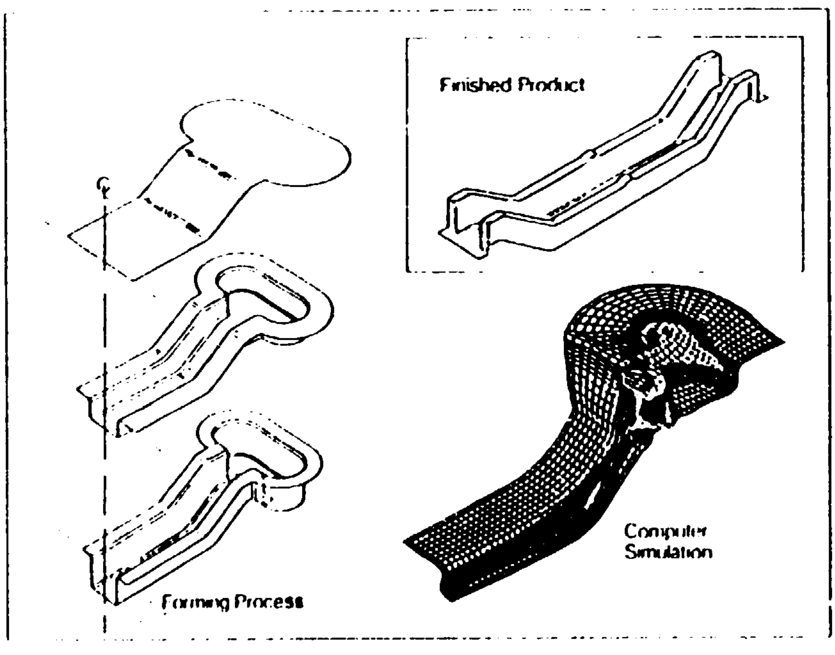


Figure 2. Simulating the pressing of a sheet metal automotive component. Due to symmetry, only one quarter of the component has been modelled

(Source: Metals and Materials, July 1989)

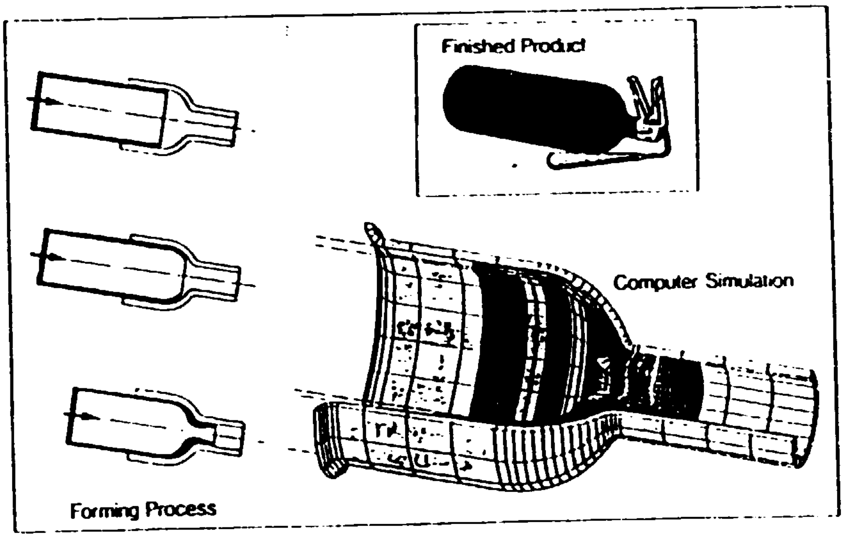


Figure 3. Simulation of a nozzle forming operation. The shaded contours show the strain rates that occur during the forming process

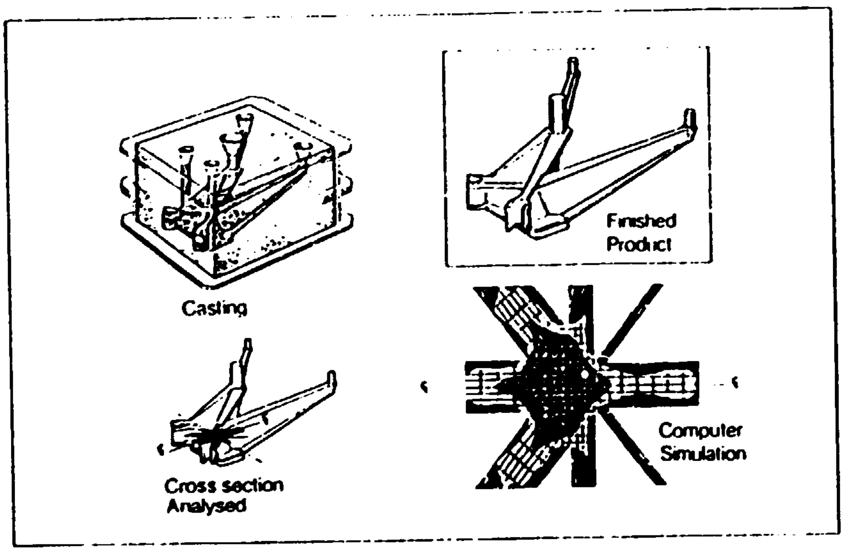


Figure 4. Simulating the solidification process in a structural casting. The calculation tracks the progress of the solidification front (the coloured contours show different temperatures within the casting)

(Source: Metals and Materials, July 1989)

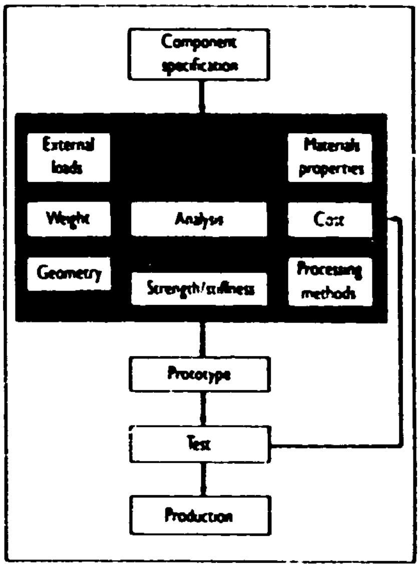


Figure 5. A simplified design loop for developing a product in composite materials

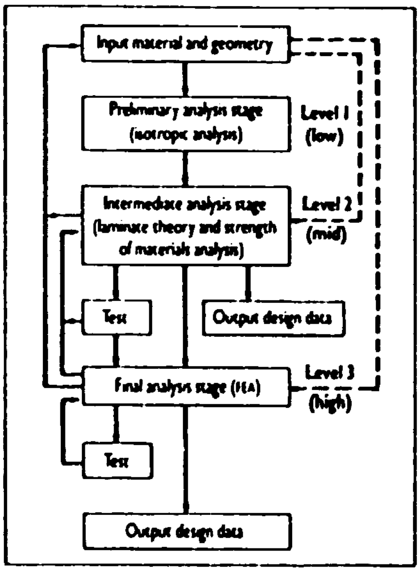


Figure 7. A suggested structure for an integrated suite of computer programs

(First published in Engineering Magazine, London, September 1989)

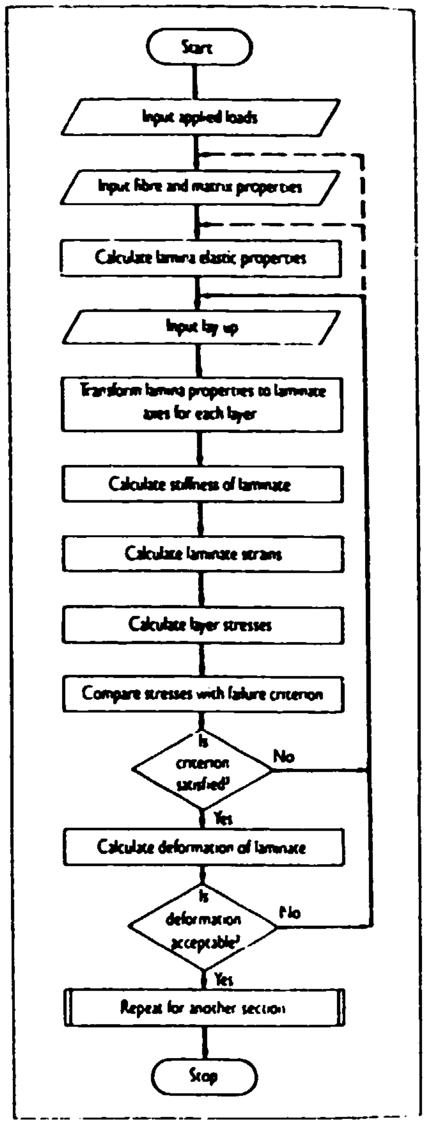


Figure 6. A flow diagram for a computer program which analyses laminate strength and deformation

## Research on molecule designing CAD system technology

National Chemical Laboratory for Industry

The development of new physiologically active substances for use in pharmaceuticals and agricultural chemicals necessitates the development of technologies for analysing and determining the stereoscopic structures of molecules. Subtle changes in part of the structure of large molecules greatly affect the activities of physiologically active substances, so determining the stereoscopic structures of molecules is indispensable for developing new physiologically active substances.

In most cases, however, examining these stereoscopic structures by such means as nuclear magnetic resonance (NMR) spectrometry and X-ray diffraction analysis is difficult, so the most widely used method is to estimate the stereoscopic structures of molecules by simulation with a computer, specifically by molecular mechanics analysis. In this method, the molecule's stereoscopic structure is estimated by approximation of the molecule into a sphere (atom) and springs (bondings), and the positions of the respective atoms are adjusted to minimize their energy levels represented by classical mechanics.

Molecules in the amino group and some other functional groups cannot be calculated by conventional molecular mechanics analysis. Thus, molecular mechanics analysis could not be used to analyse the stereoscopic structures of physiologically active substances.

In its research on molecule designing CAD system technology, the National Chemical Laboratory for Industry clarified the respective parameters to enable calculation of such molecules. As a result, it is now possible to use molecular mechanics analysis to determine the structure of molecules in such functional groups as amino, nitro, aniline, and halophenyl, conspicuously expanding the range of this method's use. By clarifying these parameters, the analysis and determination of the stereoscopic structures of physiologically active substances, including the amino group, has contributed immensely to promoting research to develop physiologically active substances for use in pharmaceuticals and agricultural chemicals. (Source: JETRO, December 1989)

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## 3D CAD package updated

Two new versions of the Silver Screen DOS-based 3D CAD and solids-modelling package have been released. Version 1.10 includes the ability to import and export IGES drawings and output to 3D Systems stereolithography equipment. Version 1.10X also permits extended memory use of up to 16M bytes of RAM. CAD system features 3D drawing, solids modelling including Boolean operations, shading, presentation graphics, and associative dimensioning. (Schroff Development Corp., Box 1334, Shawnee-Mission, KS 66222, USA.)

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## Packages analyse moulds and fluid flow

Moldflow, a plastic-part design package, and Flotran, a computational fluid dynamics package that solves heat-transfer and fluid-flow equations, have been introduced. Moldflow can be used to analyse stress, cavity flow, material selection, shrinkage, warpage, and cooling of moulds for design of plastic parts and moulds. It is available in stand-alone mode on several types of computers or in conjunction with many CAD/CAM systems. Flotran finite-element-based software analyses 2D and 3D fluid flow and heat transfer. It blends finite-element geometric concepts with finite-difference numerical techniques to solve a wide range of realistic problems. (Kit Corp., 1355 Mendota Heights Rd., St. Paul, MN 55120, USA.)

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## The limits of group technology

The first approaches to the concept of part features were in the treatment of parts by group technology systems. Nearly all of them took a hierarchical approach to describing a part's features and significant relationships. This usually began with simply enumerating the existence of simple features and then further describing them as to quantity, shape and size. Different systems then did various things with this feature-based input. Some assigned the conglomeration of features a classification number and pigeonholed the part with all of the others sharing the same class code number. Unfortunately, this approach lost visibility of the individual part features and information about them.

Other systems were designed to retain detailed part feature information as it is entered by a part coder. It is made available for future extraction and analysis by way of keywords and/or data base tools. This type of system uses a data base which is a precursor to a full features data structure. It can be used by some of the downstream applications to provide feature input.

In several instances, computer-aided process planning systems or modules use such GT data bases as the source of input, but due to the lack of complete feature detail they are forced to rely on additional planner input or interpretation. For example, a good GT data base would be able to tell you for a sheet-metal part that it has three holes, that two are round and one is square, and that the largest is 3 in. and the smallest 0.25 in. But you are unable to determine if the largest is a round or square or exactly where on the part any of these holes are located. This becomes even more of a problem for an application such as automated NC programming which relies heavily on geometric details as well as basic feature data. The full features data base closes this gap by combining the powerful featured-based information from GT with the relevant geometric detail from CAD. (Source: Machine Design, November 1989)

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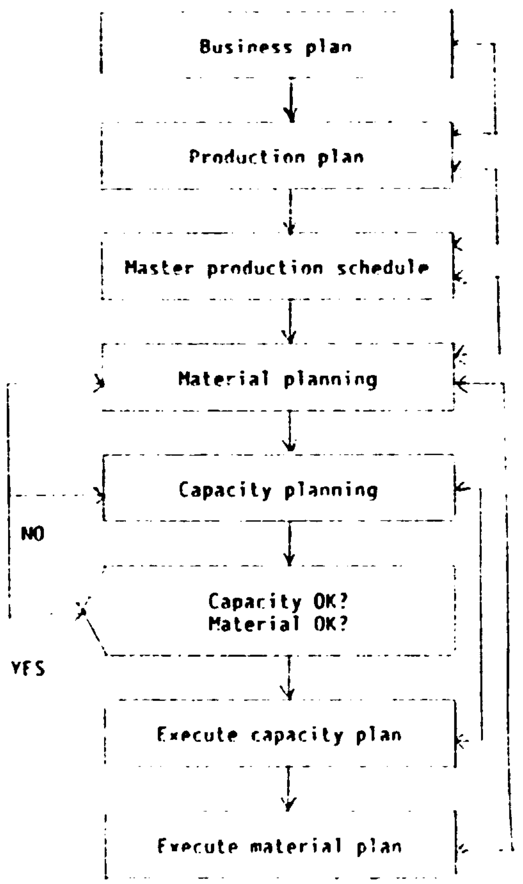
## MRP in the factory

Software for factory management generally involves control of both inventory and production. These programmes assist in planning for all resources of a manufacturing company, with separate modules covering scheduling, capacity planning, shop-floor control, and purchasing. Other sections cover engineering change orders, cost control, and even sales and marketing.

The first of these programmes to achieve widespread use was packages for materials resource planning, called MRP. With this approach, software determines when to order parts based on inventories and sales orders. From this beginning, packages grew more comprehensive and became manufacturing resource planning (MRP-II), which starts with business and sales planning and includes master production scheduling, capacity-requirements planning, and sometimes process planning.

MRP-II touches on almost every function in a factory, acting as a central planning and control system. For example, CAD/CAM and MRP-II can share a substantial amount of data such as part specifications, bills of materials, process plans, and group technology coding. Since MRP-II typically runs on a separate computer, linking it to other systems has proved difficult and, so far, is limited in application. Such links are vital, however, to create a "closed-loop" system in which production results can be fed back almost instantly to planning functions.




(Source: Machine Design, November 1989)

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## Look-In software leads news on CAD data exchange

Software from C-TAD Systems Inc., Ann Arbor, MI, USA, can simultaneously display models from different CAD systems. CAD Look-In lets engineers mix and match models that may be stored in different data formats.

For example, tires designed on IBM/CATIA can be superimposed on wheels designed with Prime Computervision and viewed in conjunction with a car body figured on a Ford PDGS system. The software runs on IRIS workstations and costs $10,000.

Also new from C-TAD Systems, a leader in graphics translation software, is a product that will help engineers transfer files between systems using incompatible IGES entities. Although IGES was supposed to make it easier for graphics systems to exchange geometric data, it has not lived up to expectations because the specification is ambiguous. IGES supports many different entity types, but not all vendors support all entities. For example, some PC CAD systems support IGES surface 114, while minicomputer-based systems usually support surface 128. While these two entities are similar, they are not interchangeable.

C-TAD System's solution is the IGES Integrator that translates between different geometric representations. The product will read circle/arc entity 100, for instance, but may write the circle/arc as entities 106, 112, or 126. The IGES Integrator is currently available. (Source: Machine Design, 25 January 1990)

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## Solid modeller has new capabilities

ModelMATE PLUS+, version 4.0, for MS-DOS configurations, features new user-interface, construction, entity selection, and conversion capabilities. The mouse-driven interface adapts to over 100 video graphics boards, provides pop-up windows, phong and Gouraud rendering, and display and analysis features. CAD system 2D geometry can be imported on to 3D planes and converted to 3D surface geometry. Version 4.0 has functions for selecting polygons and allows groups of objects to be called up using a single assigned name. Shape generating primitives can be combined for new primitives or custom-built with other solid functions. Convertors, including IGES and DXF formats, are provided for conversion with other CAD programs. Conversion software produces 2D entities and silhouettes for exporting 2D drawing views. Price is $2,495. Control Automation Inc., 2350 Commerce Park Dr. NE, No. 4, Palm Bay, Fl 32905, USA. (Source: Machine Design, 25 January 1990)

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## File conversion for AutoCAD

AutoConvert version 4.0 will translate AutoCAD release 10 and Generic CADD and 3D drafting files to and from Drawing Exchange Format (DXF). The file-conversion utility translates Generic CADD and 3D drafting files to DXF, which AutoCAD can read, and allows users to revise and plot or print a drawing using AutoCAD. The software supports metric units, can convert entire directories, and allows 2D and 3D translation to and from the DXF format. Batch capabilities provide on-screen status reports and support the use of wild cards when entering file names. Generic Software Inc., 11911 North Creek Parkway S, Bothell, WA 98011, USA. (Source: Machine Design, 25 January 1990)

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## Software simulates robotic manufacturing

ROBCAD allows engineers to model, modify, and evaluate concepts for automating their manufacturing process. The system generates designs using libraries of robots, automation components, and user CAD files. Capabilities include solid, surface, wire-frame, and 2D modelling, Boolean editing commands, and automatic generation of inverse kinematic solution for customized robots and other kinematic devices. Users can view the simulated operation from all angles, analyse cycle times of individual movements and overall simulation, and generate drawings of workcells and components. The program can be down-loaded to controllers on the shop floor. CAD files can be read through IGES, VDAFS, or GEOMOD interfacing protocols. Technomatix Technologies Inc., 39750 Grand River Ave., Suite A-3, Novi, MI 48050, USA. (Source: Machine Design, 25 January 1990)

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Ford sets up CAD/CAM policy for suppliers

In the first step towards paper-free communication between its network of subcontractors, Ford has introduced a new policy which will encourage all suppliers to adopt two particular computer-aided design and manufacture (CAD/CAM) systems. The intention behind the Ford Supplier CAD/CAM Data Exchange Policy is to accelerate the exchange of engineering design information and shorten lead times.

Ford has used two major CAD/CAM systems for many years - PDGS (Product Design Graphics System) and CADDS (Computer Aided Design and Drafting System) - and says that these have contributed significantly towards improved quality, reduced lead times and costs. It now hopes to achieve further improvements by relying more on its suppliers for the design of components and facilities.

At the moment, communication between Ford and most of its suppliers is via paper drawings, partly because communication between different CAD/CAM systems can be inaccurate, slow and expensive. The specification of similar systems over the whole network of suppliers will mean a change to electronic communication. (This article first appeared in Engineering Magazine, London, December 1989)

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Hardware/software packages for specific CAD applications

CADD Solutions are 17 system packages that combine Sparc-based workstations and CADDS software for specific CAD/CAM applications. Fifteen packages are based on the Prime WS42C workstation and two are based on the Prime WS40C workstation. WS42C-based applications include 2D drafting, wire-frame or surface modelling, NC or CMM program generation, electrical interconnect packaging, mapping, and models for HVAC, structural steel and concrete, and architectural design. WS40C-based packages are for creating surface models and performing design analyses. Prime Computer Inc., Prime Park, Natick, MA 01760, USA. (Source: Machine Design, 7 December 1989)

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New CAM module for 3-D surface sculptures

Hard on the heels of Hurco Europe's launch of its modular TDM 2500+ CAD/CAM system comes news of a new TDM 3000 CAM module, described "as an important development at the top end of Hurco's range of powerful CAD/CAM packages".

The TDM 3000 module contains all the features of the TDM 2500+ CAM system but has additional capabilities for the production of full three-dimensional sculptured surfaces.

This allows interrogation of sections of a surface and alteration if required; the introduction of offsets for mould and cavity die forms; while surface machining can be limited by area selection or by two-dimensional boundaries.

The new three-dimensional system is menu-driven with all options and commands "mouse selectable", while a quick-create mode enables fast and accurate geometry creation from minimal operator input.

According to Hurco Europe, the new module is supplied on DEC multi-task Vaxstation hardware with an IGES interface, DNC and three-axis post-processor included as standard. (Source: Machinery and Production Engineering, 2 February 1990)

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MCAE simulation tool

Dynamic Analysis and Design System (DADS) version 6.0 is a modular software tool to simulate and predict behaviour of mechanical systems prior to manufacture. Version 6.0 features an interactive, icon-based pull-down menu based on X Windows and a 3D interactive graphic-animation module that includes transparency, smooth and Gouraud shading, interactive colour selection, and multiple light-source definitions. DADS performs joint and part-assembly feasibility; static, kinematic, inverse dynamic, and dynamic analyses; and interactive animation. Software interfaces with AutoCAD, PDA/Patran, MSC/Nastran, and Ansys and runs on PC, mini, micro, and mainframe computers. CADSI, Box 203, Oakdale, IA 52319, USA. (Source: Machine Design, 25 January 1990)

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CAM interface to AutoCAD available

A new version of CAM Connection for AutoCAD/SmartCAM 3D Machining has been released by Point Control Co., Eugene, OR. Features include AutoCAD 3D surfaces support, interchangeable User Co-ordinate System, feature-based design, and extended memory support. Surfaces created in AutoCAD translate directly into SmartCAM, where a tool path is created including offsets. Surfaces can be intersected and intersections blended. Resulting geometry can be sent back to AutoCAD. Co-ordinate systems are automatically converted between AutoCAD and SmartCAM. AutoCAD 3D blocks translate directly into SmartCAM, permitting entire drilling operations, for example, to be translated automatically. Extended memory lets users design more complex parts.

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Fourth version of CAD/CAM software can now be run on an inexpensive workstation from Silicon Graphics. Called the Personal Iris, the workstation is said to allow Strim 100 CAD/CAM software to provide complete two- and three-dimensional design functions, finite element analysis, high-precision two- through five-axis machine tool pathing, and complete rheological analysis for moulding operations, all in real time. The software is designed to run on all Iris 40 series workstations. Cisigraph Corp., 33533 West 12 Mile Rd., Suite 100, Farmington Hills, MI 48331, USA. (Source: Modern Plastics International, February 1990)

Stereolithography interface, for the Sabre-5000 CAD/CAM/CIM product line, is said to allow the production of part prototypes in-house, from three-dimensional surface models created with Sabre-5000. Stereolithography is a technique developed by 3D Systems, Sylmar, CA, USA, for making prototypes without tooling. Gerber Systems Technology, 425 Sullivan Ave., S. Windsor, CT 06074, USA. (Source: Modern Plastics International, February 1990)

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Twin keyboards handle CNC and CAD/CAM training

An important feature of the new Denford MIRAC CNC training lathe is that the control system has two keyboards which cover requirements for CNC and CAD/CAM operation.

The first keyboard enables program data to be entered manually, and is designed to simulate the main features of the most widely used control systems. With a separate QWERTY keyboard, the user can interface the lathe with CAD/CAM, the Denford CAM Designer and other computer software to give facilities for training operators in the latest programming techniques.

Other control features include a high resolution monitor for colour graphics displays, floppy disc program storage, and input/output ports for interfacing with printers, plotters and additional monitors.

With a swing capacity of 250 mm diameter over the bedways, the MIRAC lathe will turn components up to 160 mm diameter by 180 mm long, and has a 1 hp driving motor which gives spindle speeds from 0 to 4,000 rev/min. (Source: Machinery and Production Engineering, 2 February 1990)

3D design on Unix

Professional Cadam is a new 3D design module for Unix-based workstations. The software features 3D wire-frame and surface construction, feature-based modelling, exploded assembly visualization, mass properties, and volumetric analysis. The module adheres to the nonuniform rational B-spline (NURBS) standard for representation of curved surfaces and supports ANSI PHIGS and PHIGS + graphics standards. The IGES translator provides multivendor exchange with other CAD/CAM/CAE systems. The software runs on Unix, Sun, and Apollo workstations. (Cadam Inc., 1935 N. Buena Vista St., Burbank, CA 91504, USA) (Source: Machine Design, 8 February 1990)

Software features updated CAD/CAM modules

Gibbs Version 3.20 software for generating NC programs includes four updated modules. The ncCAD module is an interactive 3D graphics CAD application to create shapes from imported geometry. The module supports English and metric phrases and additional machines such as lasers, EDM, plasma, and flame cutters. The ncCAM module is a 3-axis application that creates a machine program from the ncCAD shapes. The module has expanded selections of tool and path color patterns and lathe operations. The ncSurfaces module extends ncCAM to allow the definition and machining of revolved, ruled, swept, and sculptured 3-axis surfaces. The ncPOST module translates the ncCAM document into specific languages for CNC machines. The updated module processes data 200 to 500 per cent faster than prior versions. (Gibbs & Associates, 9320 Deering Ave., Chatsworth, CA 91311, USA) (Source: Machine Design, 8 February 1990)

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Computer-aided design gets down to business

Computer design is an integral part of the engineering equation, and vendors have begun to realize it. Instead of trying to wow the masses with computer special effects, product pitchmen seem more willing to describe in detail the advantages and possible disadvantages of hardware and software in specific applications. And vendors are quick to point out that their products, despite seemingly flawless appearance, "don't do everything".

This computer glasnost is as much a reaction to customer sophistication as it is a result of enlightenment on the part of sellers. It is much tougher to pull the wool over a customer's eyes than it was in the past. Many users are putting in their second or third CAD/CAM installation, and they have learned from their mistakes.

The Partnership for Integration display at Autofact reflected a new attitude toward computers. Co-ordinated by Deere Technical Services, the demonstration clearly showed that incompatible hardware and software can be made to communicate. Vendors also seem eager to demonstrate how well their products work with equipment from strategic partners. Apple Computer Co., for example, is touting its link with Digital Equipment Corp.

The success of CAD/CAM implementations at large companies has led to more acceptance of simultaneous or concurrent methods in engineering. Simultaneous engineering is not a new idea. The Japanese, with their emphasis on interdepartmental co-operation, have in effect been implementing it for years. But in the US, simultaneous engineering has taken on a pronounced high-tech look.

US firms are looking to simultaneous engineering as the way to cut product design cycles. Computers are promoted as the means to keep track of information in systems where product design and manufacturing are done concurrently.

Hard choices

But implementation problems abound. The wide variety of hardware and software products available makes it difficult to put together the well-integrated systems required for simultaneous engineering.

Hardware choices alone are confusing. Customers can pick from mainframes, supercomputers, workstations, personal computers and any combination of the above, all connected to a variety of proprietary and industry-standard graphics systems. These basic categories are further broken down into subdivisions according to processing style and microprocessor type. For example, some companies offer single processor systems, while others rely on multiple or parallel processing.

Microprocessors separate into Complex Instruction Set Computing (Cisc) CPUs - which include the Motorola 68000 and Intel 80286, 386, and 486 chips - and Reduced Instruction Set Computing (Risc) microprocessors - which include Sun Sparc and Hewlett-Packard Precision Architecture.

Graphics choices also abound. PCs are basically tied to EGA and VGA graphics, but users can soup up their machines with special boards that contain chips for fast processing of graphics entities and bit maps. High-end workstations from Silicon Graphics and Stardent, for example, include special software, hardware, and firmware to speed display of shaded images. Still more companies are moving to support so-called industry-standard graphics based on subroutine libraries such as Phigs and Phigs+, and window managers based on the X Window model.

Software also is diverse. Most vendors supply proprietary and standard ways to format data. And some suppliers, such as PDA Engineering and SDRC, are optimizing their codes to run on certain types of hardware. It seems that vendors are choosing sides in the interface war, with the Open Software Foundation Motif, AT&T Open Look, and IBM Presentation Manager all garnering significant support.

To make matters worse, most engineering functions do not share a common data base, and simultaneous engineering implies data sharing. Today, design might share geometry with manufacturing, but other information essential to the product description is stored separately.

In addition, engineering data do not mesh well with other important manufacturing information. Most manufacturing data can be stored in relational data bases, which keep short records in spreadsheet-like form. Because engineering data are primarily geometric, they cannot be easily stored this way, although some vendors have found ways to access geometry from relational data bases.

Systems that handle both types of data must be massive, requiring mainframes and complex software. This is an expensive proposition, which is out of line with the budgets of most manufacturing firms. On the other hand, linking smaller systems storing different types of data requires special expertise, and may be just as expensive.

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The Derbyshire CAD/CAM company, Superdraft, has formed a combined company with Dicon Industries of Munich, Federal Republic of Germany. The partnership company, Superdraft-Dicon, will supply an extensive range of computer-aided products, including what is claimed to be Europe's most advanced system for DNC. (Source: Metalworking Productions, January 1990)

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A growing number of chemical and engineering companies are using computer-aided design (CAD) to reduce design time, work out the bugs before construction begins and speed start-up. Process modelling packages offer flowsheet simulation; when used with economic and business information, they create a rigorous mathematical model of how a specific process plant will respond to changes in conditions.

ChemShare's (Houston, TX, USA) ProCAM on-line system helps find the optimum operating conditions for a process plant. Aspen Technology (Cambridge, MA, USA) marketing director estimates that the market for process modelling tools has been growing 20 per cent/year for the past 7-8 years. (Extracted from Chemical & Engineering News, 20 November 1989)

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## CAD software makes linkage design easier

A software package that frees engineers from the tedious trial-and-error process of designing linkage systems has been developed by Schlumberger Technologies Inc., Ann Arbor, MI. The Bravo3 Mechanism Optimal Synthesis Tool (BravoMost) is part of Version 3 of the company's Bravo3 CAD/CAM tool. The software automates the process by modifying the number of linkage parts needed to meet a design objective.

Current kinematic-analysis packages only generate the path a particular linkage will trace. However, if the trace is not what a design engineer is looking for and the linkage geometry is changed, the analysis package once again only generates a new trace. Unless you are an expert in linkage design it is very difficult to visualize or estimate how a design will affect the trace, says the product manager of mechanical design application products at Schlumberger CAD/CAM Division.

BravoMost, on the other hand, automatically changes part dimensions to come up with the required trace. The heart of BravoMost consists of algorithms that minimize the difference between the original and target curves. The algorithms are based on optimization theories developed by Schlumberger Technologies.

A design engineer first inputs linkage data into BravoMost, which then, similar to current linkage packages, creates a trace. If this trace differs from what the design engineer is looking for, he or she can indicate the exact trace the linkage must follow. BravoMost then modifies the lengths of each linkage so the new trace will pass through the designated points. The lengths of specific links can remain unchanged if required. If the specified path is physically impossible, BravoMost will provide the closest answer.

BravoMost speeds the design of linkage systems by eliminating the trial-and-error process.

Industry experts say it takes months to come up with a new suspension geometry but with BravoMost they can now do it in a day. Other applications include factory machinery and aircraft systems. Cost of BravoMost software, which runs on VAX series computers and VAXstation series workstations, is $23,000. (Source: Machine Design, 7 December 1989)

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## CAD/CAM system handles sheet metal tasks

Metalsoft (UK) is marketing the Fabricam CAD/CAM system developed in the US for programming punch presses and laser/plasma profiling machines from CAD data. The system will also produce workpiece drawings with full dimensions.

Based on an IBM compatible computer, Fabricam can recognize obround, single D, double D and other regular shapes used in sheet metalworking, and will automatically select tools needed for producing a component. (Source: Machinery and Production Engineering, January 1990)

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## Upgraded CNC for lathe and machining centre work

Available for two- and three-axis operation, the new upgraded Emcotronic TM 02 CNC system from Emco Maier provides continuous-path control for turning and milling.

Soft keys, combined with an extended range of automatic machining cycles, ease data entry for programming, and high-power graphics can be displayed on the 12-in. monitor screen.

Memory capacity can be expanded up to 1 Mbyte for handling 3-D graphics, which can simulate a machining cycle with displays covering all stages

The system is supplied as standard on the Emcoturn 242 lathe and VMC-100/VMC-200 machining centres. It can also be used for off-line programming, and has an RS 232 port for interfacing with a CAD/CAM system. (Source: Machinery and Production Engineering, January 1990)

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## NC verification software

Vericut software version 1.2 supports IBM PS/2 Models 55, 70 and 80 as well as the IBM 8514 colour monitor. Package, which also runs on many workstations and 80386-based PCs, interactively simulates, verifies and displays the metal-removal process of an NC tool path. Users have complete control of length, width, height, location and orientation of the rectangular block of rough stock, as well as the ability to include the fixturing or clamp holding the stock. Program also lets users import parts files from CAD programs. Package depicts both milling and drilling with three- to five-axis motion. (CGTech, 22706 Aspan St., Suite 310, El Toro, CA 92630, USA) (Source: Machine Design, 7 December 1989)

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Deltacam Systems of Birmingham has won an order worth £200,000 for its specialist CAD/CAM system from Sligo Regional Technical College, the Irish Republic's national training centre for the toolmaking industry. The package supplied comprises DUCT and DUCTdraft software running on seven Apollo workstations together with a DNC link to machine tools. (Source: Machinery and Production Engineering, 2 February 1990)

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Vickers Shipbuilding and Engineering is buying a £250,000 integrated CAD/CAM system from Schlumberger. The order includes BravoNC software for programming. VSEL plans to install £7.5 million-worth of sophisticated machine tools for both heavy and light engineering, including a flexible manufacturing cell capable of five-axis machining. (Source: Machinery and Production Engineering, 2 February 1990)

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## CAD/CAM

Johnson Radley is one of a handful of British companies selected to assess new developments of a CAD/CAM software package. Two years ago, the company purchased IDM 3000 software from NC Graphics Ltd. of Cambridge and have now been invited to receive advance versions of updates to the programme: comments will enable NC to maintain the standard of its product.

Further information: This may be obtained from Johnson Radley Ltd., Grangefield Industrial Estate, Pudsey, Leeds LS28 7XN, England: telephone (0532) 579021. (Source: Glass Technology, Vol. 31, No. 1, February 1990)

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## Simulating metallurgical processes

Computer-aided technology is being used increasingly as a means of improving the efficiency of processes in manufacturing industry. Effective simulation programs enable new techniques or components to be tested at relatively low cost without incurring time penalties for the production of equipment or the cost of manufacture. Modelling can also be used to identify potential sites of failure in the end product caused by stress or the formation of defects during manufacture. However, many manufacturing processes are non-linear and it has been difficult to find models which are sufficiently precise to be of use.

Ove Arup and Partners have been developing software which can deal with specific industrial situations such as those encountered in metal-forming processes or the automotive industry. These programs are three-dimensional finite element codes, written specifically for the efficient solution of problems involving a high degree of material, geometric and thermal non-linearity. They were originally written by Hallquist and Shapiro at the Lawrence Livermore Laboratory in the USA and Ove Arup are co-operating with the authors in these new developments.

The Excel suite has already been used to model a number of metal-forming processes. In the example of turbine blade casting, the simulation can take a section through the blade mould and then model the process of solidification and cooling. This shows up those parts which solidify first and areas of the cast blade in which voids will be likely to form. The software can also be used for modelling the locked-in stresses and strains which occur during drop forging, using the exact parameters of the machine in question. The parameters can then be modified on the model to examine whether the stresses bands produced in the drop forged part can be reduced or otherwise modified. It is also possible to predict the buckling and tearing which may be caused during deep drawing. The Excel suite has been used to model the HAZ as it develops during welding; this could be particularly useful for large or complicated items requiring unusual shaped welds.

The finite element models can be adapted to a wide variety of process routes and offer the potential to improve the efficiency of operations. (Source: Metals and Materials, January 1989)

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## Integrated CAD/CAM/DNC gives sub-contract potential

The recent introduction of a CNC punching and nibbling machine at Horsell Engineering has not only enabled the Leeds-based manufacturer to close the CAD/CAM loop in its sheet metal activities, but also provided a toe-hold in the sub-contract arena.

Combined with a Radan CAD/CAM system and DNC link to the shop floor, the new Pullmatic 3015/6 Compact works alongside a Pullmax/Ursviken 60-ton press brake to "eliminate some of the more mundane aspects of shop floor work", says manufacturing systems manager David Simpson.

Producing graphic plate processing equipment, and industrial ovens and washing machines, "the set-up also allows us to avoid potential sources of error, without de-skilling the factory", adds Simpson.

Horsell's Compact is the first to be supplied with Pullmax's C400 CNC system, a 32-bit system that offers quick block preparation times and reduced servo update.

Its touch sensitive screen offers extensive diagnostics facilities, and a tool optimization routine searches forward to the next part or next program then compares the tooling required with that held.

The control includes an add-on module that looks after the machine's OptiTool/OrbitTool indexable punch head system. OptiTool enables any tool in any of 15 stations to be rotated to any angle anywhere on the work table.

Combined with OrbitTool, which carries eight punches and tools, Horsell has 22 available tool stations.

The company's first move towards automated manufacture was the purchase of the Radan system and a DNC link from design and R&D to the shop floor. The choice of the Pullmatic was clinched by the machine's 1.5 m throat depth.

The capability to punch and bend components up to 6 mm thick at six times the rate possible with the older equipment has meant that Horsell has reduced lead times to four weeks. (Extracted from Machinery and Production Engineering, January 1990)

## Personal CAD

Daikin Industries Ltd. has developed a graphic workstation (GWS) and a graphic display terminal (GDT) for a 2-dimensional CAD/CAM having fast display speeds. By incorporating a basic software in combination with the GWS and GDT, the company has developed a three-in-one CAD system, called DILCAD Station, that is produced to order. This system incorporates a simple language and enables parametric graphic drawings.

A 2-dimensional CAD/CAM system must be independently usable by the drafter, be suitable for various high-performance drafting tasks, and be usable with ease. For this, it is imperative to develop a basic CAD system for various tasks that enables a broad range of uses with ease.

The new GWS and GDT incorporate four new types of LSI circuits, by which 300,000 1-inch lines per second can be displayed to fully respond to the demand for CAD/CAM systems capable of processing huge amounts of data for use in machinery and building designing.

At the same time, for use with this hardware, the company developed a practical 2-dimensional CAD system for providing the basic software for kanji and graphic processing. Thus, there is no need of constructing a new system: all that is necessary is to prepare the application software suitable for the various tasks to be performed.

The COMTEC5625 system's domestic sampling price is from ¥ 5,900,000, depending on its specifications, and the GWS and GDT units are also being marketed independently. (Daikin Industries Ltd., 2-6-1, Nishi Shinjuku, Shinjuku-ku, Tokyo. Tel: 03-344-8061) (Source: Jetro, June 1990)

## Italian CAD/CAM market surveyed

Italy's booming economy has produced a promising 32 per cent growth in the local CAD/CAM market (see table). This means Italy's share of the European market has increased from 9 to 11 per cent.

The Italian market stagnated in 1987 but, within the last two years, the market has doubled in value and trebled in the number of workstations shipped.

Italian CAD/CAM market

| | 1987 | 1988 | 1989 |
|---|---|---|---|
| Systems revenue (in billion lira) | 364 | 546 | 709 |
| Service revenue | 36 | 61 | 95 |
| Total | 400 | 607 | 804 |
| Installed Base (seats) | 12,700 | 23,200 | 36,800 |

Source: Teknibank

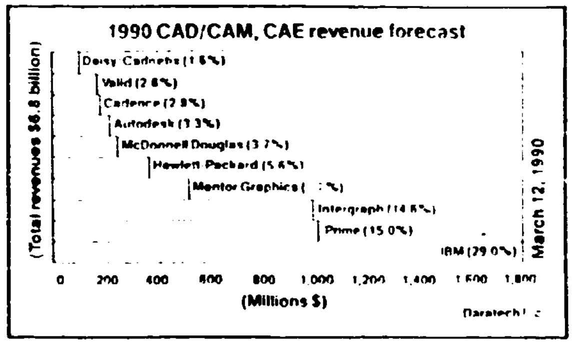
This picture emerges from a report on the Italian CAD/CAM market by market-research company Teknibank of Milan supplemented by a tour of the fifth Ico. Graphics exhibition in Milan. (Excerpt from: Finitech-Advanced Manufacturing, 26 March 1990)

CAD growth remains strong in a down year

Global sales of CAD/CAM and CAE systems and software are projected to grow 12.1 per cent in 1990. But although revenues will reach an all-time high of $6.8 billion, industry growth will be down compared to 1989, according to Daratech Inc., a market research firm.

Projected growth is based on sales of low-cost systems based on workstations and personal computers, according to the survey. Growth is expected to be below 1989's 14.3 per cent level for several reasons. These include falling workstation prices because of increased competition, increased sales of PC-based CAD software, and the transition to unbundled software sales underway at some former turnkey vendors. In addition, Daratech blames the continuing inability of vendors to build effective reseller channels capable of handling advanced technical solutions for slow growth.

The survey also cites the growing importance of personal computers as CAD tools. Examples include the increasing number of Microsoft Windows applications for PCs, new os/2 applications, and the growing interest in Apple Computer's Mac IIfx. The 800-page report titled CAD/CAM CAE: Survey Review and Buyers Guide, costs $495 and is available from Daratech Inc., 140 Sixth St., Cambridge, MA 02142, USA. Tel: (617) 354-2339




(Source: Machine Design, 21 June 1990)

## 6. FUTURE OUTLOOK OF CAD/CAM

CAD/CAM is one of the most dynamic growth areas in the computer industry. It has registered an annual growth rate of over 30 per cent in recent years and is forecasted to grow at 50 per cent in the coming years.

Over the past decade, CAD/CAM has provided hope and excitement about the prospects for the manufacturing industries. CAD/CAM technology has responded to industry needs for sophisticated interactive graphics, computer-controlled machine tools, intelligent robots, improved inspection techniques, and a host of other innovations to do manufacturing better. It is contingent upon management to make the most of this new technology, so that its full promise can be realized in the future.

Future prospects for CAD/CAM are greatly enhanced by developments in communications, microprocessors and associated software. Improved communication techniques will result in greater exchange of information among people, machines and computers. One of the manifestations of better communication will be the systems that permit engineers and operating personnel to access powerful computing techniques from a terminal which can be far removed from a large computer. The terminal might be as small as a conventional pocket calculator but will have the capability to communicate with a large computer.

Another clear trend that will have an impact on CAD/CAM is the greater use of microcomputers and microprocessors to construct a new generation of machines (for example, machine tools, inspection device., robots and computer terminals) with built-in intelligence. The motivation behind this is improved utilization of equipment. For example, in CAD, a greater amount of local intelligence built into the design work stations translates into a larger number of these terminals that can be shared by one minicomputer. The same result occurs in the case of plotters and other peripheral devices. If the plotter contains sufficient local intelligence, it is capable of drawing complicated shapes based on relatively simple concise instructions from the minicomputer. The trends in this direction indicate that, within a few years, all the intelligence and computer power now present in today's CAD/CAM systems will be available at every terminal in the system. The use of these intelligent terminals in distributed systems will constitute the new family of CAD/CAM systems. With the trend towards lower computational costs, future CAD systems based on local intelligence will be cost-competitive with current systems. At the same time, the capability of the CPU, enhanced by distributed processing, can be expected to increase considerably.

The use of localized intelligence through the use of microprocessor-based systems will also influence manufacturing. The use of intelligent robots, machine tools, and inspection devices, connected to a host computer, will provide an important boost to automation. It will provide greater flexibility in production systems to deal with a variety of different products. Manufacturing and inspection instructions which have been prepared automatically on the host computer can be downloaded to the appropriate machine on the shop floor for execution.

The cost of computer storage continues to drop and this will have implications in CAD/CAM. It will become feasible to store tens of thousands of drawings on-line instead of the limited number characteristic of present systems. At some point in the future, the computer itself may become the principal storage component in file systems rather than relying so heavily on secondary storage. Secondary storage will be utilized principally in a back-up fail-safe role.

Graphics display technology is improving and this will affect other areas of operation within a company in addition to CAD. The price and performance of raster systems will become more and more favourable. High performance (that is, high resolution and fast response) is costly in these systems currently, but it is expected that hardware costs will continue to decline in the future. With this peformance, the raster-type CRT will be the dominant graphics display device during the present decade and perhaps beyond. Competing display technologies include flat panels based on plasma or liquid crystal displays. The advantages offered by flat panel displays over the CRT are as follows:

(a) Much less depth and volume;

(b) Greater ratio of viewing area to depth;

(c) Better linearity and accuracy;

(d) Lower voltage required to operate; and

(e) Potentially greater resolution and contrast.

Because of the great market potential in home television, research in flat-panel technology will probably yield commercial products which are eventually competitive with raster-type CRTs.

The use of colour and solid modelling in computer graphics will become significant in design and other applications (industrial art, movie making, technical and other publications). New plotters and hard-copy units with enhanced colour capabilities will emerge to support the growth in colour and solids.

Another future trend which involves the combination of data base management systems with CAD systems is very limited at the present time. Advances in storage technology will influence this trend.

Voice recognition and vision systems technology will be refined and improved over the next decade. Computer terminals will be equipped to recognize and accept speech input as a means of speeding the input process. Future speech input systems will be included in the CAD/CAM environment. Vision systems will be used increasingly in computer-aided inspection systems. Vision is also an important emerging technology in robotics. Many future intelligent robots will be furnished with vision capability to perform their various industrial tasks.

Accompanying the technological innovations and improvements described above, there must also be a change in the way business is done in the manufacturing industries. With new communication techniques, there will be opportunities to have computers from different companies place purchase orders and communicate engineering data and specifications. With improvements in computers, there will be opportunities for non-technical persons to use them.

Among the many changes in the operations of a manufacturing firm which are forced by the introduction of CAD/CAM, there will be a gradual dissolution of the traditional separation between design and production. Indeed, at some time in the distant future, it may be possible to look back at the impact of CAD/CAM on industrial progress and conclude that it was the integration of the design and manufacturing functions that was the most significant achievement of this technology.

The continuous advancement of CAD/CAM technologies is pushing industries to lower manufacturing cost and to enhance productivity. Design and production take the major amount of time in the manufacturing process. CAD/CAM ability can be best utilized in engineering applications, especially in the metalworking and plastic industries. The technique of solid modelling enables the manufacturer to analyse a new product under development without building a prototype.

As the sophistication of CAD/CAM systems increase, the manufacturing industries are realizing the cost-saving advantages associated with computer-aided production system. These production facilities can thus be gradually tied together to form an integrated production system to determine planning, engineering and manufacturing functions.

In order to make enterprises totally responsive to market demand, CAD/CAM has pushed not only the enterprises in developed countries to catch up with the new technologies, but enterprises in the NICs are also actively considering the utilization of CAD/CAM capabilities.

As the cost of hardware and software has been coming down and interest in CAD/CAM systems has risen considerably, minicomputers-based software packages have made the system more financially feasible for small- and medium-scale enterprises. (Excerpt from UNIDO General Studies Series "Planning and Programming the Introduction of CAD/CAM Systems" - A reference guide for developing countries, 1990)

## 7. GLOSSARY OF CAD/CAM TERMS

### A

ABSOLUTE ACCURACY - Accuracy as measured from a reference which must be specified.

ABSOLUTE DIMENSION - A dimension expressed with respect to the initial zero point of a co-ordinate axis.

ACCEPTANCE TEST - A series of tests which evaluate the performance and capabilities of both software and hardware.

ACCESS TIME - The time interval between the instant at which information is: (1) called for from storage and the instant at which delivery is completed, i.e., the read time; (2) ready for storage and the instant at which storage is completed, i.e., the write time.

ACCURACY - (1) Measurement of the difference between the actual position of the machine slide and the position demanded; (2) conformity of an indicated value to a true value, i.e., an actual or an accepted standard value. The accuracy of a control system is expressed as the deviation or difference between the ultimately controlled variable and its ideal value, usually in the steady state or at sample instants.

ACTIVE STORAGE - That part of the control logic which holds the information while it is being transformed into motion.

ALGORITHM - A rule or procedure for solving a mathematical problem that frequently involves repetition of an operation.

ALPHANUMERIC OR ALPHAMETRIC - A system in which the characters used are letters A to Z, and numerals 0 to 9.

ALPHANUMERIC DISPLAY - Equipment, such as a cathode ray tube, which is capable of displaying only letters, digits and special characters.

AMT - Advanced manufacturing technology.

ANALOG - The term applied to a system which utilizes electrical voltage magnitudes or ratios to represent physical axis positions.

ANALOG DATA - The information content of an analog signal as conveyed by the value of magnitude of some characteristics of the signal such as amplitude, phase or frequency of a voltage, the amplitude or duration of a pulse, the angular position of a shaft or the pressure of a fluid.

ANALOG-TO-DIGITAL (A/D) CONVERTER - A device that changes physical motion or electrical voltage into digital factors.

APT (Automatically programmed tools) - A universal computer-assisted program system for multi-axis contouring programming. APT III provides for five axes of machine tool motion.

APPLICATION PROGRAMS - Computer programs designed and written to value a specific problem.

ASCII (also USASCII) (American Standard Code for Information Interchange) - A data transmission code which has been established as an American Standard by the American Standards Association. It is a code in which seven bits are used to represent each character.

ASSEMBLER - Computer program that converts user-written symbolic instructions into equivalent machine-executable instructions.

ASSEMBLY - The fitting together of a number of parts to create a complete unit.

ASSEMBLY DRAWING - The drawing of a number of parts which shows how they fit together to construct a complete unit.

ASYNCHRONOUS TRANSMISSION - The transmission of information in irregular sections, with the time interval of each transmission varying and each section being identified by a start and stop signal.

ASYNCHRONOUS - Without any regular time relationship.

ATTRIBUTE - A quality that is characteristic of a subject.

AUTOMATION - The technique of making a process or system automatic. Automatically controlled operation of an apparatus, process or system, especially by electronic devices. In present-day terminology, usually used in relation to a system whereby the electronic device controlling an apparatus or process is also interfaced to and communicates with a computer.

AUXILIARY FUNCTION - A function of a machine other than the control of the co-ordinates of a workpiece or cutter - usually on-off type operations.

AXIS - (1) A principal direction along which a movement of the tool or workpiece occurs; (2) one of the reference lines of a co-ordinate system.

### B

BACKGROUND - In computing, the execution of low-priority work when higher-priority work is not using the computer.

BACKGROUND PROCESSING - The automatic execution of computer programs in background.

BASIC - Beginner's All-Purpose Symbolic Instruction Code. An algebraic language used for problem-solving by engineers, scientists and others who may not be professional programmers.

BATCH - A number of items being dealt with as a group.

BATCH PROCESSING - A manufacturing operation in which a specified quantity of material is subject to a series of treatment steps. Also a mode of computer operations in which each program is completed before the next is started.

BAUD - A unit of signalling speed equal to the number of discrete conditions or signal events per second; one bit per second in a train of binary signals, and three bits per second in an octal train of signals.

BEHIND THE TAPE READER (BTR) - A means of inputting data directly into a machine tool control unit from an external source connected behind the tape reader.

BENCHMARK - A standard example against which measurements may be made.

BINARY CODED DECIMAL (BCD) - A number code in which individual decimal digits are each represented by a group of binary digits; in the -8-4-2-1 BCD notation, each decimal digit is represented by a four-place binary number, weighted in sequence as 8,4,2 and 1.

BINARY DIGIT (BIT) - A character used to represent one of the two digits in the binary number system, and basic unit of information or data storage in a two-state device.

BILL OF MATERIALS (BOM) - A listing of all the parts that constitute an assembled product.

BLOCK - A set of words, characters, digits or other elements handled as a unit. On a punched tape, it consists of one or more characters or rows across the tape that collectively provide enough information for an operation. A "word" or group of words considered as a unit separated from other such units by an "end of block" character (EOB).

BOOLEAN ALGEBRA - A process of reasoning using a symbolic logic and dealing with propositions or on-off circuit elements. It employs systems such as "and", "or", "not", "except", "if" and "then" to permit mathematical calculation.

BOOTSTRAP - A short sequence of instructions, which when entered into the computer's programmable memory will operate a device to load the programmable memory with a larger, more sophisticated program - usually a loader program.

BSPLINE - A mathematical representation of a smooth curve.

BUFFER STORAGE - (1) A place for storing information in a control for anticipated transference to active storage. It enables a control system to act immediately on stored information without waiting for a tape reader; (2) a register used for intermediate storage of information in the transfer sequence between the computer's accumulators and peripheral devices.

BUG - An error or mistake.

BULK MEMORY - A memory device for storing large quantities of data, e.g. hard disk, floppy disk or magnetic tape.

BUS - A conductor used for transmitting signals or power between elements.

BYTE - A sequence of adjacent bits, usually less than a word, operated on as a unit.

## C

CALIBRATION - Adjustment of a device, such that the output is within a specified tolerance for particular values of the input.

CAMBRIDGE RING - A type of network for linking computers together which has been perfected by Cambridge University.

CANCEL - A command which will discontinue any canned cycles or sequence commands.

CANNED CYCLE - A pre-set sequence of events initiated by a single NC command, e.g., G84 for NC tape cycle.

CANONICAL FORM - A standard numerical representation of data.

CAPM - Computer-assisted production management.

CAPP - Computer-assisted process planning.

CARTESIAN CO-ORDINATES - Means whereby the position of a point can be defined with reference to a set of axes at right angles to each other.

CATHODE RAY TUBE (CRT) - A display device in which controlled electron beams are used to present alphanumeric or graphical data on a luminescent screen.

CENTRAL PROCESSING UNIT (CPU) - The portion of a computer system consisting of the arithmetic and control units and the working memory.

CHANNEL - A communication path.

CHARACTER - One of a set of symbols. The general term to include all symbols such as alphabetic letters, numerals, punctuation marks and mathematical operators. Also, the coded representation of such symbols.

CHIP - A single piece of silicon which has been cut from a slice by scribing and breaking. It can contain one or more circuits but is packaged as a unit.

CIM - Computer-integrated manufacture.

CLDATA - Cutter location data (see CLFILE).

CLFILE - Cutter location file (see CLDATA).

CLOSED LOOP - A signal path in which outputs are fed back for comparison with desired values to regulate system behaviour.

CNC (Computer (computerized) numerical control) - A numerical control system wherein a dedicated, stored program computer is used to perform some or all of the basic numerical control functions.

COMMUNICATIONS LINK - The physical means of connecting one location with another for the purpose of transmitting and receiving information.

COMPATIBILITY - The interchangeability of items.

COMPILER - A program which translates from high-level problem-oriented computer languages to machine-oriented instructions.

COMPONENT - One of the parts of which an entity is composed.

COMPUTER - A device capable of accepting information in the form of signals or symbols, performing prescribed operations on the information and providing results as outputs.

COMPUTER-AIDED ENGINEERING (CAE) - The use of computing facilities in the integration of all aspects of design and manufacture to create an integrated engineering facility.

COMPUTER-AIDED DESIGN (CAD) - A process which uses a computer in the creation or modification of a design.

COMPUTER-AIDED MANUFACTURE (CAM) - A process which uses a computer in the management, control or operation of a manufacturing facility.

COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURE (CAD/CAM) - The integration of computer-aided design and manufacture.

COMPUTER OUTPUT ON MICROFILM - Direct output from a computer to microfilm.

COMPUTER PROGRAM – A series of instructions or statements in a form acceptable to a computer and prepared in order to achieve a certain result.

CONSOLE – Part of a computer system used for communication between the operator and the computer.

CONFIGURATION – The manner in which items are arranged.

CONTINUOUS PATH OPERATION – An operation in which rate and direction of relative movement of machine members is under continuous numerical control. There is no pause for data reading.

CONTOURING – An operation in which simultaneous control of more than one axis is accomplished.

CO-ORDINATE DIMENSIONING – A system of dimensioning based on a common starting-point.

CORE MEMORY – A high speed random access data storage device utilizing arrays of magnetic ferrite cores, usually employed as a working computer memory.

CROSSHAIRS – A horizontal line intersected by a vertical line to indicate a point on the display whose co-ordinates are desired.

CURSOR – Visual movable pointer used on a CRT by an operator to indicate where corrections or additions are to be made.

CUTTER PATH – The path described by the centre of a cutter.

CYCLE – (1) A sequence of operations that is repeated regularly; (2) the time it takes for one such sequence to occur.

CYCLE TIME – The period required for a complete action. In particular, the interval required for a read and a write operation in working memory, usually taken as a measure of computer speed.

## D

DATA – Facts or information prepared for processing by, or issued by, a computer.

DATA BASE – Comprehensive files of information having a specific structure such that they are suitable for communication, interpretation and processing by both human and automatic means.

DEBUG – To detect, locate and remove mistakes from computer software or hardware.

DECODER – A circuit arrangement which receives and converts digital information from one form to another.

DEDICATED – Devoted to a particular function or purpose.

DIAGNOSTIC ROUTINE – A program which locates malfunctions in hardware or software.

DIGITAL – Representation of data in discrete or numerical form.

DIGITAL-TO-ANALOG (D-A) CONVERSION – Production of an analog signal, whose instantaneous magnitude is proportional to the value of a digital input.

DIGITIZE – To obtain the digital representation of a measured quantity or continuous signal.

DISK – A device on which information is stored.

DISK MEMORY – A non-programmable, bulk-storage, random-access memory consisting of a magnetizable coating on one or both sides of a rotating thin circular plate.

DISPLAY – Lights, annunciators, numerical indicators or other operator output devices at consoles or remote stations.

DISCRETE – State of being separate or distinct, as opposed to a continuously varying state or condition.

DISTRIBUTED COMPUTER NETWORK – A collection of computers which can communicate with each other.

DISTRIBUTED PROCESSING – The processing of information on a distributed computer network in such a manner as to improve the overall efficiency of the task.

DNC (Direct (distributive) numerical control) – Numerical control of machining or processing by a computer.

DOCUMENTATION – The group of techniques necessarily used to organize, present and communicate recorded specialized knowledge.

DOUBLE PRECISION – The use of two computer words to represent a number.

DOWN TIME – The interval during which a device is inoperative.

DRUM PLOTTER – Plotter which draws an image on paper or film which is mounted on a drum.

DUMP – To copy the present contents of a memory on to a printout or auxiliary storage.

## E

EBCDIC – Extended binary coded decimal interchange code.

EDIT – To modify a program or alter stored data prior to output.

EDITOR – A computer program which provides the ability to edit.

EIA STANDARD CODE – Any one of the Electronics Industries Association standard codes for positioning, straight-cut and contouring control systems.

EMULATOR – A device or program which behaves like another system and produ[illegible]entical results.

ENCODER – An electrome[illegible] transducer which produces a serial or pa[illegible]digital indication of mechanical angle or dis[illegible]ent.

ERROR DETECTING – A data code in which each acceptable term conforms to certain rules, such that if transmission or processing errors occur, false results can be detected.

EXECUTE – To carry out an instruction or run a program.

EXECUTIVE – Software which controls the execution of programs in the computer, based on established priorities and real-time or demand requirements.

F

FEEDBACK - The signal or data fed back to a commanding unit from a controlled machine or process to denote its response to the command signal. The signal representing the difference between actual response and desired response that is used by the commanding unit to improve performance of the controlled machine or process.

FEEDBACK CONTROL - Action in which a measured variation is compared to its desired value, with a function of the resulting error signal used as a corrective command.

FEEDBACK DEVICE - An element of a control system which converts linear or rotary motion to an electrical signal for comparison to the input signal.

FEEDBACK LOOP - A closed signal path, in which outputs are compared with desired values to obtain corrective commands.

FEEDBACK RESOLUTION - The smallest increment of dimension that the feedback device can distinguish and reproduce as an electrical output.

FEEDBACK SIGNAL - The measurement signal indicating the value of a directly controlled variable, which is compared with a set point to generate a correction command.

FEED FUNCTION - The relative motion between the tool or instrument and the work due to motion of the programmed axis or axes.

FINITE ELEMENT MESH GENERATION - Engineering method for determining the structural integrity of a mechanical part by mathematical simulation. Automatic mesh generation automatically creates grid points and elements for specific regions of a model allowing creation of data necessary for finite element analysis programs.

FLATBED PLOTTER - Plotter that draws an image on paper or film which is mounted on a flat table.

FLOPPY DISK - A flexible disk which is used for storing information.

FONTS-LINE - Repetitive pattern used to give meaning to a line, e.g. solid, dashed or dotted.

FONTS-TEXT - A complete set of one character set.

FOREGROUND PROCESSING - Execution of real-time or high-priority programs which can pre-empt the use of computing facilities.

FORMAT - The arrangement of data.

FORMAT CLASSIFICATION - A means, usually in an abbreviated notation, by which the motions, dimensional data, type of control system, number of digits, auxiliary functions etc. for a particular system can be denoted.

FORMAT DETAIL - Describes specifically which words of what length are used by a specific system in the format classification.

FIRMWARE - Programs or instructions stored in read only memories.

FIRST GENERATION - (1) In the NC industry, the period of technology associated with vacuum tubes and stepping switches; (2) the period of technology in computer design utilizing vacuum tubes, electronics, off-line storage on drum or disk and programming in machine language.

FORTRAN - Acronym for Formula Translator, an algebraic-procedure-oriented computer language designed to solve arithmetic and logical programs.

FULL DUPLEX - Allows the simultaneous transmission of information in both directions.

FUNCTION KEY - Specific key which causes a predefined function to be requested of the system whenever the key is depressed.

G

GAIN - The ratio of the magnitude of the output of a system with respect to that of the input (the conditions of operation and measurements must be specified, e.g., voltage, current or power).

GENERAL-PURPOSE COMPUTER - A computer designed and capable of carrying out a wide range of tasks.

GKS - Graphics Kernal System, a standard for graphics software.

GRAPHICS - The use of a computer to interactively create a drawing displayed on a terminal.

GRAPHICS TABLET - A surface through which co-ordinate points can be transmitted by identification with a cursor or stylus.

GRID - Network of uniformly placed dots on an input device used for locating position.

GROUP TECHNOLOGY - The grouping of machines and of parts based on similarities in production requirements such that the parts may be produced more efficiently.

H

HALF DUPLEX - Allows the transmission of information one way at a time.

HARD COPY - Any form of computer-produced printed document. Also sometimes punched cards or paper tape.

HARDWARE - Physical equipment.

HIDDEN LINES - Line segments that would be obscured from view in the display of a solid three-dimensional object.

HIGH-LEVEL LANGUAGE - A programming language that generates machine codes from problem- or function-oriented statements. Fortran and Cobol are commonly used high-level languages. A single high-level statement may translate into a series of instructions in machine language, in contrast to a low-level language in which statements translate on a one-for-one basis.

HOST COMPUTER - Computer attached to a network providing services such as computation, data base management and special programs.

HOUSEKEEPING - The general organization of programs stored to ensure efficient system response.

I

IEEE - Institute of Electrical and Electronic Engineers (United States).

IGES - International Graphics Exchange Standard.

INCREMENTAL DIMENSION - A dimension expressed with respect to the preceding point in a sequence of points.

INCREMENTAL SYSTEM - Control system in which each co-ordinate or positional dimension is taken from the last position.

INHIBIT - To prevent an action or acceptance of data by applying an apppropriate signal to the appropriate input.

INITIALIZE - To cause a program or hardware circuit to return a program, a system, or a hardware device to an original state or to selected points within a computer program.

INPUT - A dependent variable applied to a control unit or system.

INSTRUCTION - A statement that specifies an operation and the values or locations of its operands.

INSTRUCTION SET - The list of machine language instructions which a computer can perform.

INTEGRATED CIRCUIT (IC) - A combination of interconnected passive and active circuit elements incorporated on a continuous substrate.

INTEGRATOR - A device which integrates an input signal, usually with respect to time.

INTELLIGENT TERMINAL - A terminal which has its own local processing power.

INTERACTIVE GRAPHICS - Ability to carry out graphics tasks with immediate response from the computer.

INTERFACE - (1) A hardware component or circuit for linking two pieces of electrical equipment having separate functions, e.g., tape reader to data processor or control system to machine; (2) a hardware component or circuit for linking the computer to external I/O device.

INTERLOCK - To arrange the control of machines or devices so that their operation is interdependent in order to assure their proper co-ordination.

INTERLOCK BY-PASS - A command to temporarily circumvent a normally provided interlock.

INTERPOLATION - (1) The insertion of intermediate information based on assumed order or computation; (2) a function of a control whereby data points are generated between given co-ordinate positions to allow simultaneous movement of two or more axes of motion in a defined geometric pattern, e.g., linear, circular and parabolic.

INTERRUPT - A break in the execution of a sequential program or routine, to permit processing of high priority data.

I/O (Input/Output) - Input or output or both.

ISO - International Standards Organization.

ITERATION - A set of repetitive computations, in which the output of each step is the input to the next step.

J

JCL - Job control program.

JOB - An amount of work to be completed.

JOYSTICK - A data entry device for manually entering co-ordinates in specific XYZ registers.

K

KEYBOARD - The keys of a teletypewriter which have the capability of transmitting information to a computer but not receiving information.

L

LAN - Local Area Network.

LAYER - Logical concept to distinguish subdivided groups of data within a given drawing. May be thought of as a series of transparencies which may be displayed in any order.

LAYOUT - A visual representation of a complete physical entity usually to scale.

LIGHT PEN - A photosensing device similar to an ordinary fountain pen which is used to instruct CRT displays by means of light-sensing optics.

LINEAR INTERPOLATION - A function of a control whereby data points are generated between given co-ordinate positions to allow simultaneous movement of two or more axes of motion in a linear (straight line) path.

LINE PRINTER - A printing device that can print an entire line of characters all at once.

LINKAGE - A means of communicating information from one routine to another.

LOG - A detailed record of actions for a period of time.

LOG OFF - The completion of a terminal session.

LOG ON - The beginning of a terminal session.

LSI - Large-scale integrated circuit.

M

MACHINE LANGUAGE - A language written in a series of bits which are understandable by, and therefore instruct, a computer. The "first-level" computer language, as compared to a "second-level" assembly language or a "third-level" compiler language.

MACRO - A source language (q.v.) instruction from which many machine language instructions can be generated.

MAGNETIC DISK STORAGE - A storage device or system consisting of magnetically coated metal disks.

MAGNETIC TAPE - A tape which is constructed from plastic and coated with magnetic material which is used to store information.

MAIN FRAME - See central processing unit.

MANUAL DATA INPUT (MDI) - A means of inserting data manually into the central system.

MANAGEMENT INFORMATION SERVICE (MIS) - An information feedback system from the machine to management and implemented by a computer.

MASS PROPERTIES - Calculation of physical engineering information about a part, e.g., perimeter, area, volume, weight and moments of inertia.

MASS STORAGE - Auxiliary or bulk memory that can store large amounts of data which is readily accessible to the computer.

MEMORY - A device or medium used to store information in a form that can be understood by the computer hardware.

MEMORY PROTECT - A technique of protecting stored data from alteration, using a guard bit to inhibit the execution of any modification instruction.

MENU - Input device consisting of command squares on a digitizing surface. It eliminates the need for input keyboard for common instructions.

MICROPROCESSOR - A single integrated circuit which forms the basic element of a computer.

MICROPROGRAMMING - A programming technique in which multiple instruction operations can be combined for greater speed and more efficient memory use.

MIRRORING - A graphics construction aid - the ability to create a mirror image of a graphic entity.

MNEMONIC - An alphanumeric designation, designed to aid in remembering a memory location or computer operation.

MODEL - A geometrically accurate and complete representation of a real object stored in a CAD/CAM data base.

MODEM - A contraction of modulator demodulator. The term may be used with two different meanings: (1) The modulator and the demodulator of a modem are associated at the same end of a circuit; (2) the modulator and the demodulator of a modem are associated at the opposite ends of a circuit to form a channel.

MODULE - An independent unit which may be used on its own or in conjunction with other units to form a complete entity.

MONITOR - A device used for observing or testing the operations of a system.

MOUSE - A manual device for use in information input and in accessing differing portions of a screen.

MULTIPLEXER - A hardware device which handles multiple signals over a single channel.

N

NETWORK - Two or more central processing units which are interconnected.

NOISE - An extraneous signal in an electrical circuit capable of interfering with the desired signal. Loosely, any disturbance tending to interfere with the normal operation of a device or system.

NUMERICAL CONTROL (NC) - A technique of operating machine tools or similar equipment, in which motion is developed in response to numerically coded commands.

NUMERICAL DATA - Data in which information is expressed by a set of numbers that can only assume discrete values.

O

OBJECT PROGRAM - The coded output of an assembler or compiler.

OCTAL - A characteristic of a system in which there are eight elements, such as a numbering system with a radix of eight.

OFF-LINE - Operating software or hardware not under the direct control of a central processor, or operations performed while a computer is not monitoring or controlling processes or equipment.

ON-LINE - A condition in which equipment or programs are under direct control of a central processor.

OPEN LOOP - A signal path without feedback.

OPEN LOOP SYSTEM - A control system that has no means of comparing the output with the input for control purposes (no feedback).

OPERATING SYSTEM - Software which controls the execution of computer programs and the movement of information between peripheral devices.

OPTIMIZE - To establish control parameters which maximize or minimize the value of performance.

ORIGIN - A reference position whose co-ordinate values are zero.

OUTPUT - The transfer of information out of a computer; it may be output to punched tape or magnetic tape, to another computer, etc.

OUTPUT DEVICE - A device for producing output, e.g., printer, plotter or paper tape punch.

OUTPUT SIGNAL - A signal delivered by a device, element or system.

OVERLAY - A technique of repeatedly using the same area of computer store when handling different stages of a problem.

P

PAN - To move an image on a display to the left, right, up or down.

PARALLEL - The simultaneous transfer and processing of all bits in a unit of information.

PARAMETER - A characteristic of a system or device, the value of which serves to distinguish various specific states.

PARAMETRICS - High-level graphical applications language used to build variable geometric constructions and solve problems.

PARITY CHECK - A test of whether the number of ones or zeros in an array of binary digits is odd or even to detect errors in a group of bits.

PART PROGRAM - Specific and complete set of data and instructions written in source languages for computer processing or written in machine language for manual programming for the purpose of manufacturing a part on an NC machine.

PART PROGRAMMER - A person who prepares the planned sequence of events for the operation of a numerically-controlled machine tool.

PASSWORD - A word the operator must supply in order to meet the security requirements and gain access to the computer.

PATCH - Temporary coding used to correct or alter a routine.

PERIPHERAL EQUIPMENT - The auxiliary machines and storage devices which may be placed under control of the central computer and may be used on-line, e.g., card reader and punches, magnetic tape feeds, high-speed printers, CRTs and magnetic drums or disks.

PHOTOPLOTTER - Device used to generate artwork photographically.

PLOTTER - A device used to make a drawing of a display.

POINT-TO-POINT CONTROL SYSTEM - An NC system which controls motion only to reach a given end-point but exercises no path control during the transition from one end-point to the next.

POLAR CO-ORDINATES - A mathematical system for locating a point in a plane by the length of its radius vector and the angle this vector makes with a fixed line.

POSITION READ-OUT - A display of absolute slide position as derived from a position feedback device normally attached to the lead screw of the machine.

POSITION SENSOR - A device for measuring a position, and converting this measurement into a form convenient for transmission.

POST-PROCESSOR - The part of the software which converts all the cutter path co-ordinate data (obtained from the general-purpose processor and all other programming instructions and specifications for the particular machine and control) into a form which the machine control can interpret correctly.

PRECISION - The degree of discrimination with which a quantity is stated, e.g., a three-digit numerical value discriminates among 1,000 possibilities. Precision is contrasted with accuracy, i.e., a quantity expressed with 10 decimal digits of precision may only have one digit of accuracy.

PREPARATORY FUNCTION - An NC command on the input tape changing the mode of operation of the control (generally noted at the beginning of a block by "G" plus two digits).

PREPROCESSOR - A computer program which prepares information for processing.

PREVENTIVE MAINTENANCE - Maintenance specifically designed to identify potential faults before they occur.

PROCESSOR - A computer program which processes information.

PRINTED CIRCUIT - A circuit for electronic components made by depositing conductive material in continuous paths from terminal to terminal on an insulating surface.

PROGRAM - A plan for the solution of a problem. A complete program includes plans for the transcription of data, coding for the computer and plans for the absorption of the results into the system. The list of coded instructions is called a routine. Thus, programming consists of planning and coding, including numerical analysis, systems analysis, specification of printing formats, and any other functions necessary for the integration of the computer into the system.

PROGRAMMABLE - Capable of being set to operate in a specific manner, or of accepting remote set point or other commands.

PROTOCOL - Set of rules governing message exchange between two devices.

PUCK - Manually operated directional control device used to input co-ordinate information.

PUNCHED CARD - A piece of lightweight cardboard on which information is represented by holes punched in specific positions.

PUNCHED PAPER TAPE - A strip of paper on which characters are represented by combinations of holes.

R

RANDOM ACCESS MEMORY (RAM) - A storage unit in which direct access is provided to information, independent of memory location.

RASTER DISPLAY - A display in which the entire display surface is scanned at a constant refresh rate.

RASTER SCAN - Line-by-line sweep across the entire display surface to generate elements of a display image.

READ - To acquire data from a source. To copy, usually from one form of storage to another, particularly from external or secondary storage to internal storage. To sense the presence of information on a recording medium.

READER - A device capable of sensing information stored in an off-line memory medium (cards, paper tape, magnetic tape) and generating equivalent information in an on-line memory device (register, memory locations).

READ-ONLY MEMORY (ROM) - A storage device generally used for control programs whose content is not alterable by normal operating procedures.

REAL TIME CLOCK - The circuitry which maintains time for use in program execution and event initiation.

REAL TIME OPERATION - Computer monitoring, control, or processing functions performed at a rate compatible with the operation of physical equipment or processes.

REFRESH - CRT display technology which requires continuous restroking of the display image.

REPAINT - Redraws a display on a CRT to reflect its current status.

REPEATABILITY - The closeness of agreement among multiple measurements of an output, for the same value of the measured signal under the same operating conditions, approaching from the same direction, for full-range traverses.

REPRODUCIBILITY - The closeness of agreement among repeated measurements of the output for the same value of input, made under the same operating conditions over a period of time, approaching from either direction.

RESOLUTION - (1) The smallest distinguishable increment into which a signal or picture etc. is divided in a device or system; (2) the minimum positioning motion which can be specified.

RESOLVER - (1) A mechanical to electrical transducer whose input is a vector quantity and whose outputs are components of the vector; (2) a transformer whose coupling may be varied by rotating one set of windings relative to another. It consists of a stator and rotor, each having two distribution windings 90 electrical degrees apart.

ROLLER BALL - A manual data input device.

ROBOT - An automatic device which performs functions ordinarily ascribed to human beings.

ROUTINE - A series of computer instructions which performs a specified task.

RUBBER BANDING - A technique for displaying geometry which has one end fixed and the other end following a stylus or some other device.

RUN - The execution of a program on a computer.

S

SCALE - To change a quantity by a given factor, to bring its range within prescribed limits.

SCALE FACTOR - A co-efficient used to multiply or divide quantities in order to convert them to a given magnitude.

SCHEDULE - A program or timetable of planned events or of work.

SCULPTURED SURFACE - A mathematically described surface.

SCROLL - To move an image on a display to the left, right, up or down.

SECURITY - Prevention of unauthorized access to information or programs.

SENSITIVITY - The ratio of a change in steady state output to the corresponding change of input, often measuring in percentage of span.

SERIAL - The transfer and processing of each bit in a unit of information, one at a time.

SIGN - The symbol or bit which distinguishes positive from negative numbers.

SIGNAL - Information conveyed between points in a transmission or control system, usually as a continuous variable.

SIGNIFICANT DIGIT - A digit that contributes to the precision of a numeral. The number of significant digits is counted beginning with the digit contributing the most value, called the most significant digit, and ending with the one contributing the least value, called the least significant digit.

SIMULATOR - A device or computer program that performs simulation.

SOFTWARE - The collection of programs, routines, and documents associated with a computer.

SOURCE LANGUAGE - The symbolic language comprised of statements and formulas used to specify computer processing. It is translated into object language by an assembler or compiler, and is more powerful than an assembly language in that it translates one statement into many items.

STABILITY - Freedom from undesirable deviation, used as a measure of process controllability.

STAND-BY POWER SUPPLY - An energy generation or storage system, that can permit equipment to operate temporarily or shut down in an orderly manner.

STATIC GAIN - The ratio of steady state output to input change.

STEADY STATE - A characteristic or condition exhibiting only negligible change over an arbitrarily long period of time.

STORAGE - A memory device in which data can be entered and held, and from which it can be retrieved.

STORAGE TUBE - A CRT which retains an image for a considerable period of time without redrawing.

STYLUS - A hand-held device by which co-ordinate information may be input to a display unit.

SUBROUTINE - A series of compute instructions to perform a specific task for many other routines. It is distinguishable from a main routine in that it requires, as one of its parameters, a location specifying where to return to the main program after its function has been accomplished.

SURFACE OF REVOLUTION - Rotation of a curve around an axis through a specified angle.

SURFACE MACHINING - The ability to output 3-, 4- and 5-axis NC tool paths using 3-dimensional surface definition capabilities.

SYMBOL LIBRARY - A library of commonly used graphical symbols.

SYNCHRONOUS - A fixed rate transmission of information synchronized by a clock for both receiver and sender.

SYNTAX - The rules which govern the structure of words and expressions in a language.

T

TABLET - An input device which allows digitized co-ordinates to be indicated by stylus position.

TABULATED CYLINDER - The translation of a curve along a direction line with upper and lower limits on the distance of translation.

TAPE - A magnetic or perforated paper medium for storing information.

TAPE TRAILER - The trailing end portion of a tape.

TAPE LEADER - The front or lead portion of a tape.

TAPE PREPARATION - The act of translating command information into punched or magnetic tape.

TASK - A unit of work.

TERMINAL - A device by which information may be entered or extracted from a system or communication network.

TIME SHARING - The interleaved use of a sequential device, to provide apparently simultaneous service to a number of users.

TOOL PATH - The geometry of the path a tool will follow to machine a component.

TRACK - The portion of a moving storage medium, such as the drum, tape or disk, that is accessible to a given reading head position.

TRUNCATE - To terminate a computational process in accordance with some rule, e.g., to end the evaluation of a power series at a specified term.

TRUTH TABLE - A matrix that describes a logic function by listing all possible combinations of inputs, and indicating the outputs for each combination.

TUNING - The adjustment of co-efficients governing the various modes of control.

TURNKEY SYSTEM - A term applied to an agreement whereby a supplier will install an NC or computer system so that he has total responsibility for building, installing and testing the system.

V

VDU - Visual display unit.

VLSI - Very large-scale integrated circuit.

W

WINCHESTER - A type of hard disk memory storage unit.

WINDOW - A rectangular area on a display screen selected by the operator.

WINDUP - Lost motion in a mechanical system which is proportional to the force or torque applied.

WIRE-FRAME - A three-dimensional drawing created by the projection of the points of intersection of the geometry.

WORD ADDRESS FORMAT - Addressing each word in a block by one or more characters which identify the meaning of the word.

WORD LENGTH - The number of bits or characters in a word.

Z

ZERO - One of the two symbols normally employed in binary arithmetic and logic, indicating the value zero and the false condition, respectively.

ZERO SUPPRESSION - The elimination of non-significant zeros to the left of significant digits usually before printing.

ZERO SYNCHRONIZATION - A technique which permits automatic recovery of a precise position after the machine axis has been approximately positioned by manual control.

ZOOM - To enlarge or decrease proportionally the size of the display. (Source: UNIDO General Studies Series "Planning and Programming the Introduction of CAD/CAM Systems" - A reference guide for developing countries, 1990)

Computer-aided welding technology and non-destructive testing

Short description: This high technology course is designed to bring to the attention of fabrication, welding and NDT personnel the state-of-the-art developments in computer applications. Particular emphasis will be placed on software for welding technology, ultrasonic aspects of critical flaw sizing and expert systems. Commencing date: 24 September 1990. Duration: 4 weeks. Qualifications: Higher national certificate, diploma or degree or equivalent; experience in fabrication, welding and quality control. English. Deadline for application: 24 August 1990. Fees: £1,000.

Organizer: Scottish School of Non-Destructive Testing
Paisley College of Technology
High Street, Paisley
Renfrewshire PA1 2BE, Scotland
United Kingdom

Manufacturing technologies and management

Short description: Design: quality management; production management; robotics; assembly automation; CAD, FMS, CIM. Commencing date: to be arranged. Duration: -. Qualifications: Some industrial experience. English. Deadline for application: -. Fees: To be arranged.

Organizer: Advanced Manufacturing Technology Research Institute (AMTRI)
Human Resources Division
Hulley Road, Macclesfield,
Cheshire SK10 2NE
United Kingdom

Advanced computer-aided design

Short description: CAD course structured to give good theoretical and practical experience to architects, electrical, mechanical and civil engineers; 2D and 3D design; bill of materials preparation, construction and implementation of CAD data bases; graphics input/output devices and plotting techniques. Commencing date: To be arranged. Duration: 6 months. Qualifications: Architects and engineers. English. Deadline for application: 1 month before commencing date. Fees: To be arranged.

Organizer: Chattaway (UK) Training Services
Pool Chambers
26 Dam Street, Lichfield,
Staffordshire WS13 6AA
United Kingdom

Computer-aided design (CAD)/computer-aided manufacturing (CAM)

Short description: A balanced course from traditional design techniques through the application of CAD and post processor to CAM. Commencing date: Throughout the year. Duration: 4-8 weeks. Qualifications: English. Deadline for application: To be arranged. Fees: £250 per week plus VAT.

Organizer: East Kilbride and District Engineering GTA Ltd.
Nerston Industrial Estate
3 Law Place
East Kilbride, Scotland
United Kingdom

CAD/CAM fundamentals

Short description: Fundamentals of computing; hardware/software configurations associated with CAD and CAD/CAM systems; graphic manipulations; storage of graphic data; CAD/CAM hardware/software; CAD/CAM data bases; the use of mainframe and microcomputer-based software in the design of graphics and mapping applications; CAM programming; NC and APT programming; tool path simulation; and pre- and post-processor development; case materials. Commencing date: January, May, September. Duration: 12 weeks. Qualifications: Participants should have experience in design and manufacturing, graphics and/or mapping applications. English. Deadline for application: 30 days before commencing date. Fees: $US 2,700.

Organizer: AIT/RLC
P.O. Box 2754
Bangkok 10501, Thailand

Industrial applications of personal computers

Short description: Personal computer hardware and software; industrial applications in management; production control; maintenance and repair; computer-aided design and manufacturing; demonstration; practical training; industrial visits. Commencing date: April 1990. Duration: 2 weeks. Qualifications: Managers, engineers; degree, preferably in economics, management, electronics; at least 3 years of experience. English. Deadline for application: 15 February 1990. Fees: -.

Organizer: UNIDO-Czechoslovakia Joint Programme for Co-operation
Metallic Industries
Inorga Institute, Letenská 17
118 06 Prague 1, Czechoslovakia

Industrial technology

Short description: Short courses on: automation technology; CAD/CAM technology; textile and garment technology; plastic technology; building and construction; microcomputers; systems analysis and programming; microprocessors; computer operations; advanced computer technology; data communications, data security, industry-related application software; product design and development; watch design and manufacture; management techniques. Commencing date: To be arranged. Duration: -. Qualifications: Technical personnel. Chinese, English. Deadline for application: -. Fees: To be arranged.

Organizer: Hong Kong Productivity Council
World Commerce Centre
12/F, Harbour City
11 Canton Road
Kowloon, Hong Kong

CAD/CAM in clothing

Short description: Theoretical and practical training in CAD/CAM techniques in the clothing industry. Commencing date: To be arranged. Duration: 2 weeks. Qualifications: English. Deadline for application: -. Fees: To be arranged.

Organizer: TNO Clothing
Postbus 671
7500 AR Enschede, Netherlands

Computers for engineers

Short description: Short courses on: computer-aided engineering; "C" programming for engineers; software engineering. Commencing date: To be arranged. Duration: 3-5 days. Qualifications: English. Deadline for application: 2 weeks before commencing date. Fees: £450-800.

Organizer: Nene College
St. George's Avenue
Northampton NN2 6JD
United Kingdom

## 9. UNIDO PAPERS ON COMPUTER-AIDED DESIGN AND COMPUTER-AIDED MANUFACTURE SINCE 1985

PLANNING AND PROGRAMMING THE INTRODUCTION OF CAD/CAM SYSTEMS
A REFERENCE GUIDE FOR DEVELOPING COUNTRIES

General Studies Series: ID/SER.O/1
UNIDO Publication, Sales No.: E.89.III.E.7;
ISBN 92-1-106236-5; 02500P.

UNIDO Publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

Personal Author: Shaw, K.

Corp. Author: UNIDO

Title: Bulgaria. Computer-aided design. Advanced manufacturing and engineering methods. Technical report. Vienna, 1985, 14 pages.

Doc. Number: UNIDO-DP/ID/SER.A/560

Abstract: Expert report on training assistance in computer-aided design in Bulgaria - covers (1) data base management information systems; customers graphics interfaces; two-dimensional draughting systems, three-dimensional design systems; computer-aided manufacture; engineering analysis; computer graphics standardization; computer programs (software) development, etc.; (2) a universal CAD system.

Langages: English

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Personal Author: Bessant, John

Corp. Author: UNIDO

Title: Flexible manufacturing systems: an overview. Vienna, 1985, iv, 72 pages, diagrams.

Doc. Number: UNIDO-UNIDO/IS.539

Abstract: UNIDO publication on flexible systems of computer-aided manufacture (FMS) - covers (1) definition of FMS; its relationship to the manufacturing spectrum; (2) FMS configurations; influences on configuration; future trends in and benefits of using FMS; diffusion factors; employment issues. Bibliography, diagrams. Additional reference: electronics.

Languages: English

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Personal Author: Skjorten, Einar

Corp. Author: UNIDO

Title: Bulgaria. Development and utilization of CAD system. Technical report. Vienna, 1986, 25 pages.

Doc. Number: UNIDO-DP/ID/SER.A/668

Abstract: UNIDO publication. Expert report on assistance in development and use of computer-aided design at a laboratory in Bulgaria - covers (1) organizational aspects of work performed at the CAD-Scientific Laboratory in Sofia; management; know-how; equipment, computers, computer programs; financial aspects; industrial services, consulting. Appendices. Additional reference: engineering.

Languages: English

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Personal Author: Vandersluis, M.

Corp. Author: UNIDO

Title: Bulgaria. Computer-aided design (Part II). Technical report. Vienna, 1986, 19 pages.

Doc. Number: UNIDO-DP/ID/SER.A/706

Abstract: UNIDO publication. Expert report on training assistance in computer-aided design in Bulgaria - covers (1) training programmes organized for staff of a CAD laboratory with attention to CAD products, international standards, software portability, graphics system, data base design, large software projects, software development procedure, and future trends in CAD; (2) seminars held in Varna and Sofia; observations. Recommendations. Additional reference: computer programs.

Languages: English

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Personal Author: Roulston, D.J.

Corp. Author: UNIDO

Title: India. Computer-aided design of Darlington power transistors (Part II). Technical report. Vienna, 1987, ii, 8 pages.

Doc. Number: UNIDO-DP/ID/SER.A/807

Abstract: UNIDO publication. Expert report on assistance in computer-aided design of high power semiconductor devices for transport equipment at a research centre in India - covers (1) testing and using updated versions of two software packages obtained from a university in Canada, namely for CAD of bipolar transistors and for CAD of non-linear circuits and the interface routine W model; (2) seminars and technical discussions held. Recommendations.Additional reference: computer programs.

Languages: English

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Personal Author: Wightman, Eric J.

Corp. Author: UNIDO

Title: India. Training in microprocessor applications in industrial control. Technical report. Vienna, 1987, 22 pages.

Doc. Number: UNIDO-DP/ID/SER.A/832

Abstract: UNIDO publication. Expert report on training in computer-aided manufacture and process control in India - covers (1) delivery of lectures on sensor technology, process control instrumentation and CAM as part of training programmes for representatives of industry and national organizations; (2) suggested future measures for promoting microprocessor applications. Recommendations, summaries of lectures, agenda, list of participants. Additional references: microelectronics, instruments, automation.

Languages: English

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Personal Author: Bossak, Maciej

Corp. Author: UNIDO

Title: Sri Lanka. Establishment of a CAD/CAM centre. Technical report. Vienna, 1987, 26 pages.

Doc. Number: UNIDO-DP/ID/SER.A/909

Abstract: UNIDO publication. Expert report on assistance in setting up a training centre for computer-aided design and computer-aided manufacture in Sri Lanka - covers (1) requirements for setting up the CAD and CAM centre at the Department of Mechanical Engineering of the University of Moratuwa; relevant visits and discussions; visits to local industrial enterprises; lectures given; development programme; (2) levels of CAD and CAM activities; tasks involved and staff skills required; forms of training and technical education indicated; proposed changes in the curriculum. Recommendations, documentation. Additional references: computer, computer programs, automatic control, machine tools.

Languages: English

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Personal Author: Wightman, Eric J.

Corp. Author: UNIDO

Title: India. Automation and control methods for steel industry. Technical report. Vienna, 1987, 28 pages.

Doc. Number: UNIDO-DP/ID/SER.A/928

Abstract: UNIDO publication. Expert report on assistance in development of automation and computer-aided manufacture for iron and steel industry in India - covers (1) activities undertaken at research centres in Pune, Ranchi and Delhi, in connection with modern automation methods, production control, process control, systems design, computer programs, etc.; (2) includes abstracts of lectures given as part of training programmes. Recommendations. Additional references: microelectronics, testing, sensors, instruments.

Languages: English

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Personal Author: Wadsworth, David

Corp. Author: UNIDO

Title: Pakistan. Introduction to computer-aided design to heavy mechanical complex. Technical report. Vienna, 1988 79 pages, table, diagram.

Doc. Number: UNIDO-DP/ID/SER.A/1056

Abstract: UNIDO publication. Expert report on development of computer-aided design at a heavy engineering complex in Pakistan - covers (1) background of proposed introduction of computer methods to the engineering design department of the Heavy Mechanical Complex producing equipment and machinery for various industries; (2) identification of hardware and software requirements; design of computer programs for specific jobs; training of designers in CAD systems and procedures. Recommendations, diagram, relevant annexes, notes on benchmarking.

Languages: English

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Personal Author: Bhalla, A.S., Hirschler, Robert

Corp. Author: UNIDO

Title: China. Review of current level of technology in the silk-processing industry, preconditions for introducing CAD/CAM techniques and socio-economic effects of applying such techniques in the silk industry. Technical report. Vienna, 1988, i, 64 pages, tables.

Doc. Number: UNIDO-DP/ID/SER.A/1072

Abstract: UNIDO publication. Expert report on introducing computer-aided design (CAD) and computer-aided manufacture (CAM) in the silk processing industry in China - covers (1) application of computers in silk dyeing, printing and textile finishing; (2) social aspects and economic aspects of applying CAD/CAM techniques in the Chinese silk industry; (3) methodology; technical assistance need. Statistics. Additional references: quality control, management information system, textile industry, electronic data processing, microelectronics, capital costs, competitiveness, process control.

Languages: English

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Personal Author: Stadler, K.

Corp. Author: UNIDO

Title: Albania. CAE/CAD selection for PCB design and layout. Technical report. Vienna, 1988, 19 pages, tables, diagram.

Doc. Number: UNIDO-DP/ID/SER.A/1097

Abstract: UNIDO publication. Expert report on the selection of electronic instruments for computer-aided design (CAD) and engineering (CAE) of integrated circuits in Albania - deals with the choice of technology and of computer programs for design and computer-aided manufacture of printed circuit boards, giving specifications of various computer equipment. Additional references: automation, process control, laboratory.

Languages: English

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Corp. Author: UNIDO, ESCAP, TECHNONET ASIA

Conference: Workshop on CAD/CAM systems for small and medium-scale engineering industries in selected ESCAP developing countries, Singapore, 1988.

Title: CAD/CAM systems for small and medium-scale engineering industries in selected ESCAP developing countries. Working papers in industrial planning No. 1. Vienna, 1989, iii, 44 pages, tables.

Doc. Number: UNIDO-IO.28

Abstract: UNIDO publication. Report of a meeting on computer-aided design and computer-aided manufacture for small and medium-scale machinery industry(s) in ESCAP developing countries - covers (1) organization of the workshop; (2) issues considered; (3) presentations concerning: overview of CAD-CAM and of automatic control (NC); computer and distributed numerical control; CAD; post processing; NC and CAM interface considerations; initiating use of CAD-CAM. Recommendations, agenda, list of participants, list of documents, table outlining technical assistance needs in ten countries of Asia.

Languages: English

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Corp. Author: UNIDO

Conference: Expert group meeting on technical assistance in the field of maintenance and CAD/CAM, Oslo, 1989

Title: Report. (Meeting on CAD/CAM). Vienna, 1989, ii, 20 pages.

Doc. Number: UNIDO-IO.32

Abstract: UNIDO publication. Report of a meeting on technical assistance in the fields of maintenance and repair as well as computer-aided design and computer-aided manufacture - covers: computers, computer programs; know-how, technology transfer; equipment; factory management; development centre. Recommendations. Appends list of participants.

Languages: English

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New software takes the pain out of mechanical design

Two new mechanical-engineering software libraries handle most of the tedious technical detail associated with power-transmission or conveyor system design. The software programs, developed by the Dodge Division of Reliance Electric, Greenville, SC, USA serve as an alternative to manual selection and drawing of mechanical components.

One set of modules does the calculation necessary to choose correct components, and then provides the engineer with a list of component options that match the specified requirements. The other set automatically evokes detail drawings of the components on a CAD/CAM drafting system for personal computers.

The objective is to put the entire 2,000 pages of catalogue into knowledge-based software. It is expected that the software will be a big hit in the engineering community because it eliminates just about all of the grunt work that designers find so onerous.

The component-selection system, called DMR Software, chooses from the various lines of Dodge bearings, gearmotors, speed reducers, couplings, belts, sheaves and conveyor components. The drafting module, called First Line, consists of "electronic templates" that automatically put detail drawings of the components into systems being designed on an AutoCAD drafting system. About 50 per cent of the Dodge product lines are handled by the software.

The First Line software templates are AutoCAD files accessed through an interface to the drafting program. Dodge spokesmen believe the interface is patentable. It is written in AutoLisp, the programming language that comes with AutoCAD. The interface allows engineers to page back and forth through component listings. It was designed to eliminate the need to type in commands.

Each component-selection module costs $24, except for the conveyor version, which sells for $300. The electronic templates vary in price from $70 to $80, with all 13 modules available for $885.

The software runs on IBM and compatible PCs. In the selection module, the user enters requirements such as power, loads and fixed geometries of the systems. The software then reviews inventories of components to see which are optimum. Once the hardware is established, the template modules provide all of the detailing required for an engineering drawing. (Source: Machine Design, 7 December 1989)

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Computers for engineering

"CIE Perspective" newsletter provides several articles geared to engineers who use computers in their work. Engineering software products, telephone expertise, training systems, and software development news are typical topics of discussion. Product reviews highlight a CAD program for PCs, high-powered version of CADAM for 386-based computers, a facility manager, a general-purpose finite-element analysis program, and a structural analysis package. Newsletter is published quarterly. Information Systems Div., Fujitsu America Inc., 3055 Orchard Dr., San Jose, CA 95134, USA.

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PC-board design features

"Digital Design Lab" brochure explains how system runs, tests and debugs circuits before prototypes are built. Four-page brochure details functions of logic analyser, oscilloscope, word generator, ROM/PAL programmer, in-circuit emulator and others. Personal computer flexibility, test pattern generation and block-level/system design modes also are noted. Second brochure reviews a comprehensive PC-board layout software package for boards with up to 500 equivalent ICs, schematic capture, interactive layout and a variety of design options. Placer, router, design kit and other components are outlined. Personal CAD Systems Inc., 1290 Parkmoor Ave., San Jose, CA 95126, USA.

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Random-vibration control

Model 2550 integrated digital random-vibration controller connects to electrodynamic or electro-hydraulic shakers and amplifiers for integration with vibration test equipment. Eight-page colour brochure outlines controller design, performance characteristics, options, military requirements and nine control frequency ranges and potential cost savings. Supplementary brochure brings additional information on identifying and eliminating quality problems, environmental stress screening and other uses. Structural Test Products, Gen-Rad Inc., 510 Cottonwood Dr., Milpitas, CA, USA.

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CAD/CAM workgroups

Network systems and software for CAD/CAM/CAE applications lets users link desktop CAD stations to form a CAD/CAM workgroup with shared plotters, drawing files and management tools. Data sheet explains networking options, compatibility and use of popular systems such as Auto-CAD, Cadkey and others. Additional sheets describe engineering data-management system that upgrades ordinary networks to support CAD/CAM use, plus company's Ethernet 2.2 system for improved CAD/CAM workgroup performance. ACS Telecom, 25825 Eshelman Ave., Lomita, CA 90717, USA.

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Specialty modelling options

System Plus 4.0 solid modeller with advanced user interface and high-end rendering is presented in a four-page summary. Use of constructive solid-geometry techniques, modelling of intricate objects and integration elements are described in detail. Several illustrations show typical models and screens. Advanced display characteristics, expanded graphics manipulation language and enhanced construction also are covered. Control Automation Inc., Box 160100, Altamonte Springs, FL 32716, USA.

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Sheet-metal applications

CAD/CAM system designed for the sheet-metal industry features menu-driven operation, three-dimensional design with or without thicknesses, flat-pattern development aids, NC machine-control data generation and parametric design tool kit. Four-page colour brochure reviews design steps, special features and practical manufacturing advantages. Unisys Corp., 2970 Wilderness Place, Boulder, CO 80301, USA.

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Modular design software

Anvil-5000 brochure provides several colour reproductions of various CAD/CAM design software modules and functions. Three-dimensional design/drafting, solids modelling, surface modelling, finite-element modelling, NC machining and five-axis NC machining are explored in detail. The 16-page guide illustrates operations such as viewing and manipulation, curve and section analysis, drafting steps, model development and options and machining modes. Manufacturing & Consulting Services Inc., 6 Hughes, Irvine, CA 92718, USA.

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Individual work station power

Data sheet explains features of Model 386-33 personal work station system for finite-element analysis, three-dimensional CAD, solid modelling, and related uses. Brief descriptions review Intel 80386-33 processor, math coprocessor, 160 M-byte hard drive, 1.2 M-byte floppy drive, I/O ports, mouse and other elements. Colour graphics, case construction, operating speeds, memory features and compatibility with popular operating systems are discussed. Structural Analysis Engineering Corp., 10925 Reed Hartman, Cincinnati, OH 45242, USA

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Integrated design systems

Cost-effective, integrated programs for engineering design and analysis are presented in an eight-page fold-out guide. Geometric modeller with interactive three-dimensional mesh generator, PC-board analysis system, linear-dynamic analysis functions, three-dimensional static-magnetic calculations, and linear-static-analysis modes are illustrated. Heat transfer analysis, advanced dynamic study, model optimization, non-linear-static analysis, fluid study and analysis using shell of revolution elements also are described in detail. Structural Research & Analysis Corp., 1661 Lincoln Blvd., Santa Monica, CA 90404, USA.

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Three-dimensional CAD

Literature packet introduces Cadkey version 3.5 three-dimensional design software with multiple viewports, dynamic rotation, pop-up menus, associative three-dimensional cursor interaction, seamless construction and interactive screen imaging. Brochure reviews process steps, design advantages, system interaction and hardware requirements. Additional pieces focus on the solids package with multiple curved entity shading and segmentation, speed improvements and full integration with Cadkey. User-controlled display manipulation, solids modelling elements and rendering features are highlighted. Several typical models and screens are shown. Cadkey Inc., 440 Oakland St., Manchester, CT 06040, USA.

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Problem-solving software

Specialty software for solving mathematical and statistical problems are listed in a handy pocket-sized reference brochure. Special functions for engineering and documentation also are covered. Comprehensive brochures offer extensive background material on software for linear programming and for solving partial differential equations. Typical problems and solutions are illustrated. Additional brochures offer summaries of supported environments and company's interactive documentation facility. IMSL, 2500 City West Blvd., Houston, TX 77042, USA.

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Solids-based software

Ease of design and streamlined engineering are two features of company's solids-based CAD/CAM/CAE system highlighted in a six-page colour brochure. Topics discussed include the use of three-dimensional solid models from the earliest stages of design, details of geometric and non-geometric parameters, data-sharing capabilities and features of CIM integration. VAX system orientation, applications and examples of design options are reviewed. Matra Datavision, 2 Highwood Dr., Tewksbury, MA 01876, USA.

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NC/CNC part programs

Disk-based part program memory system eliminates paper tape and interfaces with most NC/CNC control or CAD/CAM systems. Four-page brochure outlines performance advantages, programming applications and operating elements. Supplementary sheets detail a part program management system and other applications. Greco Systems, 372 Coogan Way, El Cajon, CA 92020, USA.

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CAD software family

Literature folder is full of individual data sheets on CAD and related software programs. Brochures describe CATIA software on popular work stations, systems integration, drafting, three-dimensional design, library, advanced surfaces, solids geometry, image design, schematics, robotics, graphics interface, NC control and many other options. Colour photographs show typical screens and design advantages. Dassault Systems USA, 777 Terrace Ave., Hasbrouck Heights, NJ 07604, USA.

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PCB design software

Suppliers of printed-circuit-board engineering and design tools compatible with company's systems are listed in this 132-page directory. Different sections detail service bureaus, training centres, compatible products and other pertinent information. Product listings cover graphics drivers, interface software, printers/plotters, libraries, special report generators and output drivers from 110 US and international vendors. P-CAD, CADAM Co., 1290 Parkmoor Ave., San Jose, CA 95126, USA.

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Wire-frame modeller

Editor three-dimensional wire-frame modeller is the subject of this colourful, four-page review. The discussion explains how system lets users create and modify complex designs quickly and easily. Design process advantages, drafting features, simplified editing, integration and flexible use are stressed. The brochure also reviews individual functions such as temporary geometry construction for simplified modelling, dimensioning options, library and referencing structure. CAD/CAM Div., Schlumberger Technologies Inc., Box 986, Ann Arbor, MI 48106, USA.

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CAD/CAM software data

Advanced features of Prompt CAD/CAM software are explained in an eight-page guide. The text details operation under Unix systems with use of a special graphic systems interface. Design, drafting, machining, 2D and 3D modes are covered in depth. The brochure also explores use of software to control parts programming, NC/CNC machining and other applications. Weber Systems Inc., 2505 N. 124th St., Brookfield, WI 53005, USA.

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CAD to DMC software

Software tool translates AutoCAD or equivalent files to digital motion-control commands. The four-page brochure reviews PC compatibility, package, contents, hardware and software requirements and several functions. Description covers simplified design process and improved motion specification capabilities. Drawings show several application examples and typical operations. Galil Motion Controls Inc., 1054 Elwell Court, Palo Alto, CA 94303, USA.

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AutoCAD display software

Drawing Librarian enhancements include faster multiple display of AutoCAD drawings, slides and DXF files, and the ability to print them. Release 1989.9 offers enhanced display accuracy, as well as HP LaserJet and dot-matrix print capability. Users can zoom in on and print drawing details, and hardcopy red-lining is simplified. AutoCAD users can quickly view drawings and select one to automatically load to AutoCAD for editing or plotting. Users can zoom, pan, rotate, copy, erase or convert displayed AutoCAD drawings. Users of other CAD systems can display an AutoCAD file and convert it to DXF without requiring AutoCAD. SoftSource, 301 W. Holly, Bellingham, WA 98225, USA.

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Micro-based CAD/CAM

A pocket-sized brochure summarizes the company's development of micro-based CAD/CAM products available as software or complete software/hardware systems. Programs for mechanical design and analysis, NC programming and machining, electrical engineering and specialty systems are reviewed. Realistic shaded images, 3D modelling and instantaneous pan and zoom modes are featured. Computer-Vision Div., Prime Computer Inc., 100 Crosby Dr., Bedford, MA 01730, USA

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Software for EDM equipment

The data sheet explains how a software module supports up to four axes of CNC-controlled wire EDM equipment. Simple use, elimination of programming errors, interactive graphics and flexible operation for use as CAD/CAM work station or specialized CAM module are described. The sheet also covers operation with IBM PC/AT systems, simple operation and other requirements. Bridgeport Machines Inc., 500 Lindley St., Bridgeport, CT 06606, USA.

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SADT: Structured Analysis and Design Technique
Marca, David A. & McGowan, Clement L.
NY: McGraw, 1987, 393 p., $44.95
004.2'1 QA76.9 87-15307 ISBN 0-07-040235-3

Contents: Concepts of activity modelling. Authoring activity models and diagrams. The SADT review process. Finishing and managing a modelling effort. Workshops - developing an activity model and a specification. Applications of SADT, index.

Note: First full-length book on Structured Analysis and Design Technique (SADT), one of the most widely used system engineering methods. Applications include telephonics software, system maintenance and diagnostics, CAD/CAM, personnel training, financial management and inventory control. Standardization by the US Department of Defense under the name IDEF0 has resulted in SADT being used by hundreds of military and industrial organizations. For users of SADT systems, as a training and reference guide.

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Integration of mould die design and manufacturing process by means of a local area network
Asada, K. (Ricoh Co., Ltd.): Ricoh Tech. Rep. (ISSN 0387-7795) [18], 72-78('88)

The study deals with development of a computer system to unify mould die design processes and manufacturing processes by utilizing a local area network (LAN). The system is composed of several subsystems, which are linked with LAN and commonly use product data generated by UNIX-based CAD/CAM system. The subsystems, running on work stations, can produce data necessary for manufacturing activities. The system is proved to have the potential of offering the environment and application fundamentals to construct computer integrated manufacturing systems (CIMs).

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Development of a process planning system using knowledge engineering and geometric processing
Uemura, N., Yokoi, S., Hisatomi, Y., Inagaki, K. (NEC Corp., Kawasaki, Japan): NEC Res. Dev. (ISSN 0547-051X) [91], 111-115('88)

Knowledge engineering and geometric processing are key technologies for the computerization of process planning. A prototype of an automated process planning system for machining has been developed, and the system achieves the integration of CAD and CAM. The expertise for process planning is incorporated into the system as rules. The rules can reference geometric data directly. Sixteen samples of mechanical components were actually manufactured using the data from the process planning system with CAD and CAM, and the process plans by the system were found to be as good as those made by experts.

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Development of total CAD/CAM system for steel frame for buildings
Kobayashi, K., Tarutani, S., Saito, I. (Ishikawa jima Harima Heavy Industries Co. Ltd.): Ishikawa jima Harima Giho (Ishikawajima Harima Engineering Review) (ISSN 0578-7904) 29[1], 1-7('89)

A steel frame is one of our traditional products and in the steel-frame work, high quality and accuracy are very important. Moreover in recent years the corresponding ways of fulfilling the lack of designers and keeping the appointed date of delivery are extremely important. In these conditions, a total CAD/CAM for the steel frame for buildings with the following characteristics has been developed:

1. By using the three-dimensional process, we make real models of steel frame in the data base;

2. Constructed data base is used consistently at the stage of not only designing but also fabrication.

This system has been used as an effective tool at our Sunamachi Works since April 1987.

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Sheet metal CAD/CAM system

Tsukahara, M., Takebe, H., Kishi, H., Kassai, S., Tanabe, A. (Japan Radio Co., Ltd.): Nippon Musen Giho (JRC Review) (ISSN 0287-1564) [27] 41-46('88)

A CAD/CAM system for the NC Turrent Punching Press System that is in operation on FMS line in the JRC Mitaka Factory has been developed. This system runs on a μ-VAX-II 32-bit super-minicomputer under the VMS operating system and can directly send NC processing data to the FMS line connected to the LAN in the Factory. This system is supported by the NWX-237 graphic display terminal and the JAX-303A hardcopy unit as a work station. The entire system consists of two sub-systems: one is a CAD sub-system to support easy operation with various functions on Japanese menu, and the other is a CAM sub-system to provide unique functions such as easy flat pattern generation in 2-D, many CNC commands and high-speed post-processor.

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Computer simulation in materials science
Edited by R. J. Arsenault; J. R. Beeler, Jr., D. M. Esterling, 1987, 372 pages, ISBN: 087170-296-7; Proceedings of 1986 Materials Science Seminar; ASM Conference Book

From these conference proceedings you will learn how computer simulation techniques can be used in materials science and all about the complexities of conducting experiments.

Contents: Interatomic potential development; atomistic models; thermodynamics of metallic solids from molecular dynamics simulation; grain-boundary modelling; thermally activated motion of dislocations; finite-element method; friction modelling in forging; constitutive equations for high-temperature deformation; synthesis of atomistics and continuum modelling to describe microstructure.

List £99; ASM members £69. (ASM International, Metals Park, Ohio, USA. Available in Europe through: American Technical Publishers Ltd., 68a Wilbury Way, Hitchin, Herts. SG4 0TB, UK)

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About CAD/CAM used personal computer

Yamada, T., Aoyagi, K., Tomite, C. (Ichinoseki Technical College): Ichinoseki Kogyo Koto Senmon Gakko Kenkyu Kiyo (Research Reports of Ichinoseki Technical College) (ISSN 0385-4140) [23], 39-52('88)

Recently, in many mass production factories, CAD (Computer Aided Design) systems have been introduced for easy and accurate drafting of factory products. Drafting works by CAD systems are able to make short drafting work as compared with that work as usual. On the other hand, various automatic machine tools (Numerical Control Machines) have been introduced in many factories. At present, the NC operator converts drawing data to manufacturing data. As an example, CAM (Computer Aided Manufacturing), authors tested automatic translation of drawing data to NC paper punch tape. This report is not enough to CAD/CAM yet authors report about one of the results for CAD/CAM software.

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English-German dictionary

From Springer Verlag comes an enlarged edition of its German-English/English-German Iron and Steel Dictionary. The book now contains around 13,100 entries in each language.

Continuous Casting of Steel by Hans F. Schrewe, translated by Paul Knighton; 194 pp; ISBN 3-514-00389-0; price DM 130, hardback. Iron and Steel Dictionary, edited by the German Iron and Steel Institute (VDEH), 5th enlarged edition; 481 pp; ISBN 3-514-00406-4; price DM 48, hardback. Available from Verlag Stahleisen mbH, PO Box 82 29, D-4000 Düsseldorf, FRG. Include DM 13 for air mail.

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Networking of materials data bases

ASTM, Philadelphia, PA, USA, has published Computerization and Networking of Materials Data Bases (STP 1017), by J. S. Glazman and J. R. Rumble, Jr. Intended for use by engineers who use computers and materials scientists, the publication (hardcover, 360 pp) gives general information on national and international projects to integrate and harmonize data systems. Engineering plastics, composites, corrosion, welding information, ceramics, and tribology data bases are discussed.

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Materials expert system directory

A directory of expert systems for materials engineering is being updated by a collaboration of the European Federation of Corrosion (EFC) with the American National Association of Corrosion Engineers (NACE) and the Materials Technology Institute (MTI). The directory will cover material selection and performance, corrosion, systems engineering and engineering life prediction.

Both completed systems and those under development will be included to replace the 25 entries in the current directory.

The European office of NACE is in Guildford, UK. Tel.: (0483) 37771.

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Materials and Processing - Move into the 90s is the proceedings of the 10th International European Chapter Conference of the Society for the Advancement of Materials and Process Engineering, Birmingham, UK, July 1989. Edited by S. Benson, T. Cook, E. Trewin and R. M. Turner, the volume (380 pp) is offered by Elsevier Science Publishers BV, Amsterdam, Netherlands.

Practical and theoretical information is given on thermoplastics, special materials applications, manufacturing, modelling and analysis, aerospace applications, adhesives and adhesion and advanced metallics.

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Materials for maintenance

Nearly 100 plant-maintenance tips and products are summarized in this data folder. Typical problems covered include hot or frozen bearings, improving engine performance, corroded bolts, rust removal and frozen brake cables. Alphabetical listings and product descriptions make this a useful reference guide. Rust removers, lubricants and industrial specialty chemicals are highlighted. Kano Laboratories Inc., 1000 S. Thompson Lane, Nashville, TN 37211, USA.

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PC Systems Handbook for Scientists and Engineers - Data Acquisition and Instrumentation features over 1,000 products that can be used to adapt 8088, 80286 and 80386 PCs into specialized units. Sections concentrate on turnkey systems for various applications, compatibility, design ideas, configuring for specific engineering functions such as motion control or automated test systems, and company expertise. Data acquisition, analysis, control, communications and engineering support are discussed at length. CyberResearch Inc., Box 9565, New Haven, CT 06536, USA.

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Science, Technology and Development: Edited by Atul Wad, this new book features essays on science and technology that would be of interest to policy-makers in developing countries. Chapters include: "Market structure and technological behaviour in developing countries", "In search of a strategy for a national science and technology poli y in Africa" and "Facing the future: The need for international technology intelligence and sourcing". Westview Press, 5500 Central Avenue, Boulder, Colorado 80301, USA.

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Keep on top of technology: Keeping up with the new technology requires all the help we can get. Here are two sources:

A new multi-client programme at Battelle, "Mastering new technologies", focuses on technology watching. The programme includes results of a survey to be taken of 15 non-subscriber companies on how they collect current, reliable information on emerging technologies and their impact, and how they effectively use the results of this monitoring. Subscription to the programme costs SFr 50,000 (about $32,000).

Details: Dr. Michael P. Manahan, Battelle, 505 King Ave., Columbus, OH 43201, USA. Phone: 614-424-5998. In Europe, Dr. Gary S. Stacey, Battelle European Operations, Geneva Research Centres, 7 route de Drize, CH 1227 Carouge-Geneva, Switzerland. Phone: 41-22-270-270.

Corporate growth strategies: How to find and exploit new technologies/products, a new report from Technical Insights, publisher of Inside R&D, is a complete how-to on exploiting all of the technology developed outside your firm. Some topics covered: staffing requirements for technology transfer, identifying important technologies, monitoring competition's R&D, equity in start-ups, acquisition, understanding university researchers, government research, licensing dangers and contract R&D. The report will be available in late February for $350.

Details: Marketing Dept., Technical Insights, Inc., PO Box 1304, Fort Lee, NJ 07024, USA. Phone: 201-568-4744.

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European Advanced Ceramics Directory 1990: The new Source Book of the European Advanced Ceramics Industry

The first Directory of its kind gives invaluable and comprehensive details concerning the advanced ceramics industry in Europe.

In all, the Directory contains over 200 detailed pages of information. As there is no advertising in the Directory, each page concentrates on providing editorial information. There are over 400 individual company entries and over 100 university and research centre entries.

Commercially available products listed in the Directory include: advanced ceramics, advanced ceramic composites (including metal matrix composites), advanced ceramic coatings, electronic materials (substrates, piezoelectrics, sensors, etc.), refractories, abrasives and abrasive products, glass ceramics and technical glasses, raw materials for all sections of the advanced ceramics industry, production and laboratory equipment.

The Directory also features two overview articles, one concerning the ceramic raw materials position in Europe and the other the finished ceramic components position in Europe.

The European Advanced Ceramics Directory 1990 is available at £90 or $US 150 from Materials Technology Publications, 40 Sotheron Road, Watford, Herts., England, WD1 2QA. Tel.: (0923) 37910. Fax.: (0923) 225885. International Fax.: +44 (0) 923 225885.

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Superconducting ceramics
R. Freer (Ed.)
Stoke-on-Trent (GB), 1988, A-5, 297 pp, numerous illustrations, bound, English, approximately £48.

In "Proceedings 40", the British Institute of Ceramics presents a compendium of a 1987 conference held in Canterbury by the European Ceramic Society.

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Experimental ceramic binders

Form 192-1070-88 AMS explores physical properties, blending and solution preparation steps and selection criteria for company's experimental ceramic binder. Solubility in various solvents, plasticizer characteristics and additives review also are covered. The 16-page handbook details sample results from dry pressing of alumina powder, compaction characteristics, green strengths and other useful data. Dow Chemical Co., Box 1206, Midland, MI 48641, USA.

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High-temperature materials

This 52-page guidebook covers physical, thermal and chemical properties of many materials for use from 400 to 4,000° F. Machinable ceramics, high-temperature tapes, pourable ceramics, conductive materials, adhesives, high-temperature epoxies, ceramic cloths, fibre products and many others are listed. The text covers selection of proper insulation thickness, instructions for machining, and casting guidelines. Cotronics Corp., 3379 Shore Parkway, Brooklyn, NY 11235, USA.

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Heat-resistant ceramics

Over 100 heat-resistant ceramic and plastic components for appliances, foundries, investment casting, electrical distribution and automotive uses are the subject of this product manual. Listings give specifications, sizes, configurations and performance ratings. Vacuum, compression and injection-moulding methods for ceramics are discussed. The guide also explains features of engineered thermoplastics and thermoset materials. Akron Porcelain & Plastics Co., Box 3767, Akron, OH 44314, USA.

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Innovations in polymer technology, Issue 2 uses a magazine format to discuss a variety of engineering topics. The 12-page guide features articles on applications in sailing, vinyl recycling developments, vinyl tile performance, uses of vinyl gloves for medicine and automotive design advantages. Chronology of technological developments also reviews vinyl products. B. F. Goodrich Co., 6100 Oak Tree Blvd., Cleveland, OH 44131, USA.

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Advanced polyimide materials

The four-page brochure outlines elements of advanced polyimide materials available as copper clad laminate 0.028 in. thick and higher, copper clad laminate less than 0.031 in. thick, and custom-made prepregs. Discussion explores copper cladding, properties and performance, handling considerations, other metallic cladding and ordering. Data sheet details polyimide processing and lamination cycle. Nelco, Park Electrochemical Corp., 1661 N. Raymond Ave., Anaheim, CA 92801, USA.

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Engineering thermoplastics for metal replacement devotes 24 pages to coverage of the competitive advantages of thermoplastics, differences between metal and plastics, and selection guidelines. Processing methods, product requirements, design considerations and specialty assemblies are discussed in detail. Many photographs and illustrations accompany the text. Design formulas, handling data and related topics are included. Plastics & Rubber Div., Mobay Corp., Mobay Rd., Pittsburgh, PA 15205.

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Polymers for advanced technologies
Ed. M. Lewin
Weinheim: VCH 1988
Pp xvi + 953, £92, ISBN 0 89573 293 9

Many of the significant changes which have taken place in industrial developments in the past 20 years
have centred around polymers. The impact which the electronics, computers and aircraft industries have made could not be envisaged without the development in polymeric materials for those industries.

This book presents a comprehensive discussion of developments in the preparation, characterization and application of polymers in a variety of advanced technologies. In addition to discussing recent developments, each chapter highlights new avenues for opportunities to satisfy the requirements of the next century.

The 51 chapters cover aspects of radiation-sensitive and -modified polymers, photo- and electro-conductive and piezoelectric polymers, and polymers for advanced structures, including liquid crystals, polymer networks, polymer blends, composite adhesives and elastomers. Each chapter is written by outstanding authors from the international scientific community with clear illustrations and references to the scientific literature published up to 1987.

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Answers to your questions about automotive structural composites offers 16 pages of information about major polymer composite processes, applications and performance benefits. The text reviews compression moulding of sheet-moulding compound, structural-reaction injection moulding, resin-transfer moulding, preshaped glass reinforcements and preforms. Design options and tooling considerations are featured. Automotive Materials Group, Dow Chemical Co., Midland, MI 48674, USA.

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Thermoplastic polyester

TPPE thermoplastic polyester is said to exhibit high temperature performance, good flow and processibility, toughness and useful mechanical properties. The pocket-sized brochure reviews each advantage for this line of application-specific thermoplastics, plus specific applications in electronics, small appliances and automotives. Charts show physical properties and performance benefits for nine material types. Phillips 66 Co., Box 14BP, Bartlesville, OK 74004, USA.

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Plastics for industry

The updated version of this catalogue offers 236 pages on over 12,000 industrial plastic products. New product listings focus on 62 items such as industrial sealants and plastic pumps. Other sections detail tubing and hose, process pipe and fittings, drainage pipe, pumps and pump filters, extrusions and sheet, flowmeters, sensors, tanks and drums. Prices and chemical resistance data are included. Ryan Herco Products Corp., 2509 N. Naomi St., Burbank, CA 91504, USA.

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Who's who in world petrochemicals and plastics, 7th edition, Paper: 8 1/2 by 11 inches, 238 pages. Who's Who Information Services, 17 South Briar Hollow Lane, Suite 401, Houston, Texas, 77027, USA. $125.

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New composites encyclopaedia is launched

Touted as "the first ever A-Z encyclopaedia of composites", the first of the six-volume International Encyclopaedia of Composites is now on sale. The other volumes will become available during 1990. The work, produced by the Federal Republic of Germany's VCH Publishers, covers all areas of composites and related process technology, including future industrial developments. Chapters authored by experts centre on such diverse topics as adhesives, plastics and polymers, soil science, spacecraft and space effects, and testing methodologies. The 12-member international editorial board is headed by editor-in-chief Stuart M. Lee, who is editor of the Journal of the Society for the Advancement of Material and Process Engineering.

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Materials programs developed for NASA

Programs for metallurgy and composites analysis are available from Cosmic, Athens, GA, USA. The Fecap finite-element composite analysis program for HP9000 computers was created for Langley Research Center. It solves for both nodal displacements and element stresses and strains. The Metallurgical Programs Set for IBM PCs and compatibles includes three programs which calculate solutions to common metallurgical problems. Programs calculate the mass of an alloy given weight fractions, densities and total volume; calculate alloy densities; and convert atomic per cent to weight per cent.

The price is $100 for Fecap; $50 for Metallurgical Programs.

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Advanced ceramic-matrix, metal-matrix and carbon-carbon composites - Current and potential markets: Rapidly growing markets for advanced inorganic composites

A new multi-client market report from Materials Technology Publications examines the rapidly developing markets for ceramic-matrix, metal-matrix and carbon-carbon composites. It contains over 200 pages of detailed information, plus 60 tables and an appendix giving names and addresses of companies and research centres.

For further details concerning the report, price: £640 or $US 1,075, please contact Marketing Department, Materials Technology Publications, 40 Sotheron Road, Watford, Herts., England, WD1 2QA. Tel.: (0923) 37910. Fax: (0923) 225885. International Fax: +44 (0) 923 225885.

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Microstructural characterization of high-temperature materials
E. Metcalfe (Ed.)
London, 1988, 348 pp, 15 x 21 cm, paperback. English, approximately $US 60.

These are the proceedings of a first seminar which is to be continued with six further ones. The aim is to present the testing processes for high-temperature materials (mostly metals). After a few introductory words on crystallography in general, optic microscopy, electron microscopy, X-ray diffraction and several special methods for testing microstructures are discussed. Both theoretical basics and practical problems are dealt with. In each case, the limits for application and the levels of precision are given. Especially the chapter on specialized testing methods (neutron beam analysis, acoustic microscopy tests, etc.) demonstrates the latest developments in the field of microstructure tests. Consequently, the book is of great interest, not only to scientists and students, but also to those employed in R&D in the industry.

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Inspection of metals: destructive testing
Robert Clark Anderson, ASM International, 423 pp (1988)

This useful book provides a comprehensive overview of the tests for determining the mechanical and metallurgical properties of metals.

It describes the equipment used, specimen preparation, as well as the tests used for hardness, tensile strength, impact, fatigue, metallography, pressure, chemical analysis, and fracture mechanics.

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New test equipment guide published

Comprehensive coverage of equipment required for polymer testing is now available through Rapra's recently published Guide to rubber and plastics test equipment. With details of the test equipment available from over 250 mamanufacturers this guide is an invaluable source of information for any laboratory contemplating the purchase of test equipment.

Edited by Roger Brown, manager of Rapra's testing and analytical services and editor of the Polymer Testing journal, this publication is designed to give as complete a coverage as possible of the test equipment and procedures currently available for polymeric materials.

The guide is priced at £29 in the UK and £35 overseas.

For further details and an order form please contact Julie Scanlon at Rapra Technology Ltd., Shawbury, Shrewsbury, Shropshire, SY4 4NR, UK.

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PVREG - A photovoltaic voltage regulation investigation tool: program reference manual. D. L. Garrett, T. R. Sims, R. A. Jones, S. M. Jeter, Sandia National Laboratories, Albuquerque, NM, USA, 89 pp, DE89013333/WDE, $15.95 paper copy, $6.95 microfiche.

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PVREG - A photovoltaic voltage regulation investigation tool: PVREG user's manual. D. L. Garrett, T. R. Sims, R. A. Jones, S. M. Jeter, Sandia National Laboratories, Albuquerque, NM, USA, 146 pp, DE89013346/WDE, $21.95 paper copy, $6.95 microfiche.

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Photovoltaic Program Branch Annual Report, FY 1988, Solar Energy Research Institute, Golden, Colo., USA, 303 pp, DE89000898/WDE, $36.95 paper copy, $6.95 microfiche.

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Proceedings of the Annual Solar Thermal Technology Research and Development Conference, W. A. Couch, Sandia National Laboratories, Albuquerque, NM, USA, 282 pp, DE89010538/WDE, $28.95 paper copy, $6.95 microfiche.

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Short circuit withstand capability of the photovoltaic relay studies relays based on a smart power IC called a bidirectional output switch field effect transistor, which has two power MOSFET structures on the same chip with fast turnoff and gate protection circuits. LED at input effects also are studied. The paper explores applications, operating flexibility, 14 graphs of performance conditions, and various ranges. International Rectifier, 233 Kansas St., El Segundo, CA 90245, USA.

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Non-equilibrium superconductivity, edited by V. L. Ginzburg (Nova Science Publishers, New York 11725-3401) 1988, 289 pp. price $106, ISBN 0 941 743 09 8.

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Switch, sensor products

This 16-page catalogue gives updated information on several low-pressure switch and sensor products. Listings focus on pressure, differential, vacuum actuated and weatherproof components. Miniature solid-state relays, adjustable pressure switches and ultralow-differential pressure sensors are among the featured items. Drawings and technical data are included for each model. World Magnetics, 810 Hastings St., Traverse City, MI 49684, USA.

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Sensor source book

This 200-page guide surveys six lines of precision sensing products, including encoders, capacitive sensors, mechanical switches, ultrasonic sensors, inductive proximity sensors and photoelectric sensors. Listings encompass over 35,000 items and provide design data on operating specifications and selection criteria. Photographs and engineering drawings accompany descriptions. Baumer Electric, 122 Spring St., Southington, CT 06489, USA.

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Flange-mounted sensors

Bulletin SB-51 highlights flange-mounted reaction torque sensors that resolve restraining or reaction torque. Comparison chart shows 24 models rated from 10 to 1,500,000 lb-in. of force. Description covers applications in motor mounts, pump mounts and related areas. Technical specifications, recommended installation procedures, metric options and other torque sensors are covered. Sensor Developments Inc., Box 290, Lake Orion, MI 48035, USA.

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## 11. PAST EVENTS AND FUTURE MEETINGS

The Institute of Metals' meeting on "Simulating solidification in casting processes", 14 November 1988, London, UK was the first of what is expected to be a regular conference. The foremost objective of the meeting was to aid communication between academics and industrialists so that results of academic research could be more readily applied to industrial practice in the UK.

The technical session started with a survey of existing computer-aided technology for casting processes by Prof. M. Cross. He began by identifying two important requirements for successful implementation of computer-aided technology in the casting industry. Firstly, the software should be capable of rapid design alteration, and thus enable customizing of products. Secondly, the software should have on-line access to up-to-date design data. Additionally, the analysis should incorporate fast, accurate solid modelling with automatic optimum meshing, and fast, accurate and robust solution procedure. Interpretation and use of the software is dependent on good graphics facilities, and ease of use to make design changes. Of course, the need for a good, accurate materials data base cannot be overemphasized, since a flaw in the data fed to the computer will inevitably produce wrong results. Considering all these requirements, the conclusion was that a lot of progress remains to be made before ideal software can be produced. Nevertheless, some of the existing packages do provide a useful tool for casting design. Of all the software packages surveyed, it appeared as though the one developed at Foseco called SOLSTAR was the most popular among foundrymen.

The successful application of computer-aided technology to casting processes requires close co-operation between the designer and the manufacturer. This is because the design has to meet certain engineering specifications, and manufacturing costs and capabilities. If a design fails to meet these requirements, then it cannot be a viable option even if the computer results suggest that it is the best design.

SOLSTAR solidification simulation software can be used to predict and eliminate shrinkage defects in castings. It uses it own solid modeller to generate a full 3D solid model of the casting shape, feeder and runner system. The program carries out a combined thermal analysis (modelling heat flow between adjacent elements of the various metals in the solid model), and solidification simulation (modelling the solidification wavefronts and the dynamics of redistribution of the remaining liquid metal), to determine shrinkage defects in the feeders, runner system and casting.

Prof. J. Berry of the University of Alabama, stressed that co-operation among product designers, methods designers and process designers is vital in order to carry out successful casting practice. Also, despite significant developments in computer technology, at present no computer software can originate or create a rigging design, and most programs require the methods engineer to set up a trial system.

Prof. Berry's group has foreseen this challenge, and attempts are under way, through a collaborative project led by the University of Alabama, to develop a computer software for rigging and casting design optimization involving a knowledge-based system called CADCAST.

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| Oct. 1989<br>Linz, Austria | CAD/CAM '89<br>Institute of Industrial Innovation, Magazingasse 6, A-4020, Linz, Austria |
| 21-23 Nov. 1989<br>Kortrijk, Belgium | CAD/CAM - International Fair for Computer-based Design and Production<br>De Hallen, Doorniksesteenweg 21b, B-3500 Kortrijk, Belgium |
| 19-22 Dec. 1989<br>New Delhi, India | INCARF '89 - International Conference on CAD/CAM, Robotics and Factories of the Future,<br>Prof. K. K. Pujara, Indian Institute of Technology Hauz Khas., New Delhi, 110 016, India |
| 26 Feb. - 1 Mar. 1990<br>Chicago, USA | 1990 National Design Engineering Show and Conference |
| 27-29 Mar. 1990<br>Birmingham, UK | CAD/CAM Show (EMAP International Exhibition) (Sponsored By: CADCAM International Industrial Computing, the CGSA (The Daily Telegraph)) |
| 25-27 Apr. 1990<br>Brussels, Belgium | CADCOMP '90 - Second International Conference: Computer Aided Design in Composite Materials Technology (CADCOMP, Secretariat, VUBTW (KB), Pleinlaan 2, B-1050 Brussels, Belgium) |
| 29 May - 1 June 1990<br>Stuttgart, FRG | Computer-aided Technologies, International Exhibition and User Congress, (Stuttgarter Messe- und Kongress GmbH., PF 10 32 52, D-7000 Stuttgart 10, FRG) |
| June 1990<br>Toronto, Canada | CAD/CAM and Robots Exhibition, (Reed-Macgregor Exhibition, 800 Denison St., Unit 7, Markham Ontario L3R 5M9, Canada) |
| 17-24 Oct. 1990<br>Bilbao, Spain | CAD/CAM<br>Feria Internacional de Bilbao<br>Apto. 468 - 48080 Bilbao, Spain<br>Tel: (34+4) 4415400/4416700/4417500<br>Telex: 32617 FIMB-E<br>Fax: (34+4) 4424222 |

<u>Other meetings</u>

MAY 1990

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| 20-24 May<br>Concord., Ohio, USA | Workshop on the Science and Technology of Diamond Thin Films, (org. by Case Western Reserve University and the American Carbon Society. For information: Prof. John C. Angus, Department of Chemical Engineering, Case Western Reserve University, Cleveland, OH 44106, USA) |
| 21-24 May<br>Long Beach, California, USA | AeroMat '90 - The Advanced Aerospace Materials/Processes Conference and Exposition, (ASM International, Materials Park, Ohio 44073, USA) |
| 29 May - 1 June<br>Strasbourg, France | 1990 Spring Meeting of the European Materials Research Society, (Centre de Recherches Nucleaires, E-MRS 1990 Spring Conference, B.P. 20, F-67037 Strasbourg Cedex, France) |

JUNE 1990

10-18 June
Helsinki, Finland
1st European East-West Symposium on Materials and Processes with High Industrial Potential, (F. Attila, Teknolink Oy, Hietalahdenkatu 2B, SF-00180 Helsinki, Finland. Tel: +358-0-6801505; Fax: +358-0-6801599)

12-14 June
Paris, France
International Rubber Conference - IRC '90, (Société de Chimie Industrielle, IRC 90, 28 rue Saint Dominique, F-75007 Paris, France)

24-27 June
Tama-City, Japan
Fifth Japan-United States Conference on Composite Materials, (Sponsored by the Japan Society for Composite Materials, co-op. U.S. organizations i.e. ASC, ASME and ASTM; Info: US Organizing Committee, Fifth Japan-US Conference on Composite Materials, 120 Patton Hall, Virginia Polytechnic Institute, and State University, Blacksburg, Va. 24061, USA)

20-22 June
Amsterdam, The Netherlands
International Conference of Advanced Aluminium and Magnesium Alloys - covering processing aspects, physical metallurgy and mechanical property evaluation of alloys - (European Council of ASM International and Bondvoor Materialenkennis: ASM Europe Secretariat, rue de l'Orme 19, Olmstraat, B-1040 Brussels, Belgium)

JULY 1990

2-6 July
Edinburgh, UK
Congress of the Council of Mining and Metallurgical Institutions (Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR, UK)

9-12 July
Columbus, Ohio USA
Conference on NDE of Modern Ceramics (The American Ceramic Society and the American Society for Non-destructive Testing; more info: National Institute of Standards and Technology, A329/223, Gaithersburg, Md. 20899, USA)

AUGUST 1990

19-23 August
Denver, Colorado, USA
World Congress of the International Solar Energy Society (American Solar Energy Society, 2400 Central Avenue, Ste. B1, Boulder, Colorado 80301, USA)

SEPTEMBER 1990

3-7 September
Groningen, The Netherlands
Sixth Europhysics Top Conference: Lattice Defects in Ionic Materials (Solid Physics Laboratory, Melkweg 1, NL-9718 EP Groningen, the Netherlands)

3-7 September
Roskilde, Denmark
11th Riso International Symposium on Metallurgy and Materials Science focus on "Structural Ceramics - Processing, Microstructure, and Properties". Oxides, nitrides, carbides, borides, and composites will be covered. Subthemes include ceramic processing microstructures, mechanical and other engineering properties, mechanisms of strengthening, and novel testing techniques. Details are available from the Secretariat, 11th Riso International Symposium, Metallurgy Dept., Riso National Lab, Postbox 49, DK-4000 Roskilde, Denmark. Tel. 45 42 371212, Fax: 45 42 351173.

5-6 September
Gwent, UK
Market led materials developments (Institute of Metals, Carlton House Terrace, London SW1Y 5DB, UK)

5-7 September
Glasgow, UK
Polymer Degradation Group Meeting "Thermal Stability and Flammability of Polymers and Composites" (Department of Chemistry, John Dalton Faculty of Technology, Manchester Polytechnic, Chester Street, Manchester M1 5GD, UK)

5-7 September
Brussels, Belgium
Symposium on Mixed Structures - Including New Materials (International Association for Bridge and Structural Engineering, ETH-Honggerberg, CH-8093 Zurich, Switzerland)

10-13 September
Houston, Texas, USA
Second World Congress on Superconductivity, (World Congress on Superconductivity, P.O. Box 27805, Houston, Texas 77227-7805, USA)

10-14 September
Garmisch-Partenkirchen, FRG
Second International Conference on Plasma Surface Engineering, (Deutsche Gesellschaft fuer Galvano- und Oberflaechentechnik e.V., Hononplatz 6, D-4000, Duesseldorf 1, FRG)

10-20 September
Fort Collins, Colorado, USA
NATO Advanced Study Institute on Applications of Metallic and Ceramic Superconductivity, (AFOSR/NE, Boling AFB, Washington, D.C., 20332-6448, USA)

17-19 September
Hoboken, New Jersey, USA
MRS Second International Conference on Electronic Materials (ICEM-II) (Materials Research Society, 9800 McKnight Road, Pittsburg, PA 15237, USA)

18-20 September
Reading, UK
Northsun-90: International Conference on Solar Energy at High Latitudes, (Department of Engineering, University of Reading, Whiteknights, P.O. Box 225, Reading RG6 2AY, UK)

23-28 September
Reading, UK
World Renewable Energy Congress (Department of Engineering, University of Reading, Whiteknights, P.O. Box 225, Reading RG6 2AY, UK)

24-28 September
Aspen, Colorado, USA
1990 Applied Superconductivity Conference, (ASC/90 Centennial Conferences, 5353 Manhattan Circle, Suite 103, Boulder, Colorado 80303, USA)

OCTOBER 1990

1-3 October
Vasteras, Sweden
COPPER '90 - Refining, Fabrication, Markets, (Institute of Metals with co-op. of a number of international associations, Institute of Metals, 1 Carlton House Terrace, London SW1Y 5DB, UK)

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| 1-4 October<br>Bournemouth,<br>UK | Third European Electric Steel Congress, (Institute of Metals, 1 Carlton House Terrace, London SW1Y 5DB, UK) |
| 1-5 October<br>Sorrento,<br>Italy | III European Polymer Federation Symposium on Polymeric Materials, (EPF90 Secretariat, Sorrento, Palace Hotel, Conference Centre, via S. Antonio, 80067 Sorrento, Italy) |
| 3-6 October<br>Blacksburg,<br>Virginia, USA | Fourth Technical Conference on Composite Materials, (American Society of Composites, RSM Department, Virginia Tech., Blacksburg, Virginia 24061, USA) |
| 8-10 October<br>Detroit,<br>Michigan, USA | ASM Conference on near net shape manufacturing for the automotive industry, (Sponsored by the Materials Shaping Technology Division of ASM International, Materials Park, Ohio 44073, USA) |
| 8-11 October<br>Detroit,<br>Michigan, USA | Materials Week '90, (ASM International, Materials Park, Ohio 44073, USA) |
| 9-12 October<br>Frankfurt, FRG | Seventh International Solar Forum - Rational Use of Energy and Use of Renewable Resources of Energy in Regional and Municipal Domains. In which manner can they support to repel climatic threat?, (Language will be German, singular lectures may be held in English), (Deutsche Gesellschaft fuer Sonnenenergie e.V., Augustenstrasse 79, D-8000 Muenchen 2, FRG) |
| 10-12 October<br>Atlanta,<br>Georgia USA | Thirteenth Energy Engineering World Congress, (Association of Energy Engineers, Ste. 340, 4025 Pleasantdale Road, Atlanta, Ga. 30340, USA) |
| 14-19 October<br>Pohang, Korea | New smelting reduction and near net shape casting technologies for steel (Institute of Metals and Korean Institute of Metals, Institute of Metal, 1 Carlton House Terrace, London SW1Y 5DB, UK and Dr. Y.K. Shin, RIST, Box 135, Pohang 680, Korea) |
| 25-27 October<br>Seattle, WA<br>USA | Technology for Tomorrow (S. Laurich-McIntyre, Pacific Northwest Section, American Ceramic Society, c/o University of Washington, Roberts Hall FB-10, Seattle, WA 98115; Tel: (206) 781-2663 |
| 28 October -<br>2 November<br>Beijing,<br>PR China | Second International Conference on HSLA steels, (Chinese Society of Metals, 46 Dongsixi Dajie, Beijing 100711, PR China) |

NOVEMBER 1990

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| 6-9 November<br>Paris, France | Fourth International Conference on Surface Modification Technologies, (Sponsored by Société Française de Metallurgie; Co-sponsors: The Minerals, Metals and Materials Society, Institute of Metals, Federation of European Materials Societies. Info: Société Français de Metallurgie, Immeuble Elysees La Défense, 19, Le Parvis-Cedex 35, 92072 Paris La Défense, France) |
| 13-15 November<br>Orlando,<br>Florida, USA | Second International Ceramic Science and Technology Congress, (American Ceramic Society, 757 Brooksedge Plaza Drive, Westerville, Ohio 43081, USA) |
| 14-16 November<br>San Antonio,<br>Texas, USA | Symposium of Wear Testing of Advanced Materials, (ASTM Committee; Info: The Carborundum Co., Niagara Falls Technology Division, P.O. Box 832, Building 10, Niagara Falls NY 14302, USA) |
| 20-21 November<br>London, UK | Advanced Materials - Bridging the Gap, Concentrating upon the automobile and aerospace industries, this conference is aimed at a technically-minded audience but presented with a strong market input. Delegates will have the opportunity to assess the pace of change, examine new developments of the metal manufacturer, and look into the future for potential products and markets. Info: Conference Manager, Metal Bulletin plc, Park House, Park Terrace, Worcester Park, Surrey KT4 7HY, England. Tel: (01) 330 4311, Tlx: 21383; Fax: (01)337 8943. |
| 26-30 November<br>Kyoto, Japan | Fifth International Photovoltaic Science and Engineering Conference, (Sponsors: The Japan Society of Applied Physics, the Institute of Electrical Engineers of Japan, Foundation for Advancement of International Science. Info: Secretariat of International PVSEC-5, c/o Japan Convention Services Inc., Nippon Press Centre Building, 2-2-1 Uchisaiway-cho, Chiyoda-ku Tokyo 100, Japan) |
| 26 November -<br>7 December<br>Trieste, Italy | Workshop on Superconductors An Experimental Workshop on High-Temperature Superconductors and Related Materials. Info: Contact International Center for Theoretical Physics, P.O. 586, I-34200 Trieste Italy. Tel. 22401, Fax: 224163. |

DECEMBER 1990

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| 1-9 December<br>Brussels,<br>Belgium | EUREKA International Fair for Innovations, Research and Industrial Renovations (Faire Internationale de Bruxelles ASBL Parc des Expositions B-1020 Brussels, Belgium) |
| 3-8 December<br>Paris, France | EMBALLAGE International Fair for Packaging Machinery and Material (SEPIC, 17 rue d'Uzès, F-75002 Paris, France) |

1991

FEBRUARY

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| 10-15 February<br>Melbourne,<br>Australia | POLYMER 91-Polymer Materials: Preparation, Characterization and Properties (GB Guises, RACI Polymer Div., P.O. Box 224, Belmont, Victoria, 3216 Australia. Tel: 052 47 2695; Fax: 052 47 2657) |

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| 16-22 February<br>San Diego, CA<br>USA | OFC-Optical Fibres Communications Conference (Lasers and Electro-Optics Society, 445 Hoes Lane, P.O. Box 1331, Piscataway NJ 08855-1331; Tel: (201) 562-3895; Fax: (201) 981-0027) |
| 28 February -<br>1 March<br>Washington, DC<br>USA | WASHINGTON MATERIALS FORUM<br>Superconductors and Semiconductors<br>Co-Sponsoring Societies:<br>American Ceramic Society (ACerS);<br>[illegible]n Chemical Society (ACS);<br>American Physical Society (APS);<br>- Division of Condensed Matter Physics;<br>- Materials Physics Topical Group;<br>ASM International;<br>American Vacuum Society (AVS);<br>Federation of Materials Societies (FMS);<br>Materials Research Society (MRS)<br>(Info: Contact Jane Stokes at MRS Headquarters: Washington Materials Forum c/o Materials Research Society 9800 McKnight Road Pittsburgh, PA 15237.<br>Tel: (412) 367-3003<br>Fax: (412) 367-373 |

MARCH

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| 12-13 March<br>Zurich,<br>Switzerland | Bonding and Repair of Composites II (K. Royle, Rapra Technology Ltd., Shawbury, Shrewsbury, Shropshire SY4 4NR, England;<br>Tel: 44-939-250383;<br>Fax: 44-939-251118 |

APRIL

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| 7-11 April<br>Orlando, FL<br>USA | International Conference on Wear of Materials-91, Info: L. Friedman, Meetings Dept, ASME.<br>345 E.47th St., New York, NY 10017 |
| 8-12 April<br>Lisbon,<br>Portugal | 10th European Photovoltaic Solar Energy Conference and Exhibition, (Sponsored by Commission of the European Communities Ministério da Indústria e Energia. Info: Prof. A. Luque/Prof. G. Sala, Instituto de Energia Solar - UPM, ETSI Telecomunicación. E-28040 Madrid-SPAIN.<br>Tel: (International 34) 1/244 10 60<br>Fax: (International 34) 1/544 63 41<br>Telex: 47430 etsit e<br>Future Conference Announcements: WIP, Sylvensteinstr. 2, D-8000 Muenchen 70, Federal Republic of Germany<br>Tel: (International 49) 89/7201232;<br>Fax: (International 49) 89/7201291<br>Telex: 5212186 haha d |

MAY

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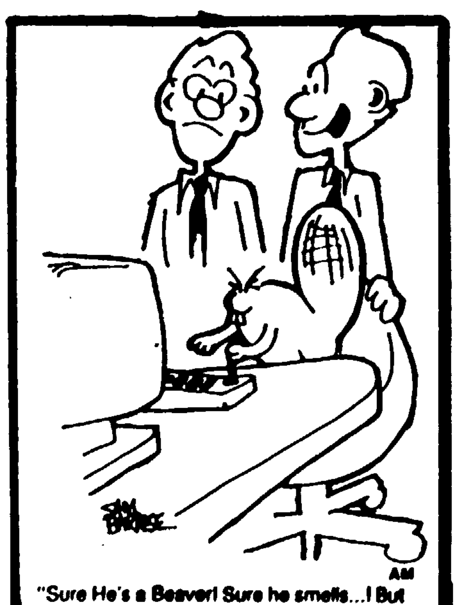
| 5-11 May<br>Budapest,<br>Hungary | 3rd European Conference on Crystal Growth, E. Lendvay, Research Inst. for Technical Physics, (Hungarian Academy of Science, Ujpest 1, PF. 76, Budapest, Hungary 1325)<br>Tel: 36 (1) 698-037 |
| 21-24 May<br>Amsterdam,<br>The Netherlands | 1st ASM Europe Heat Treatment Conference and Exhibition.<br>The Conference and Exhibition is aimed at providing a European and international forum for the exchange of information on new technologies in heat treating.<br>- Heat Treatment - process optimization; microstructural control; new ferrous and nonferrous alloys and their heat treatment; new developments in heat treating equipment; environmental control; future trends;<br>- Surface Engineering - production, microstructure and properties of coatings and surface layers produced by CVD, PVD (including plasma-assisted processes), laser and electron beam treatments, ion implantation and induction hardening; substrate requirements; diffusion treatments; and compounded surface layers/combination of processes.<br>Info: W.A.J. Moerdijk, chairman, or Roger Speri, vice chairman, ASM Europe, rue de l'Orme 19 (ECCO), B-1040, Brussels, Belgium |



"Sure He's a Beaver! Sure he smells...! But he knows CAD/CAM!"

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Advances in Materials Technology: Monitor; Code 504
Editor - Room D1950
P.O. Box 300
A-1400 Vienna, Austria

## Advances in Materials Technology: Monitor
## Reader Survey

The Advances in Materials Technology: Monitor has now been published since 1983. Although its mailing list is continuously updated as new requests for inclusion are received and changes of address are made as soon as notifications of such changes are received, I would be grateful if readers could reconfirm their interest in receiving this newsletter. Kindly, therefore, answer the questions below and mail this form to: The Editor, Advances in Materials Technology: Monitor, UNIDO Technology Programme at the above address.

Computer access number of mailing list (see address label):

Name:

Position/title:

Address:

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Do you wish to continue receiving issues of the Advances in Materials Technology: Monitor?

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Is the present address as indicated on the address label correct?

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How many issues of this newsletter have you read?

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### Optional

Which section in the Monitor is of particular interest to you?

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Which additional subjects would you suggest be included?

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Would you like to see any sections deleted?

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Have you access to some/most of the journals from which the information contained in the Monitor is drawn?

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Is your copy of the Monitor passed on to friends/colleagues etc.?

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Please make any other comments or suggestions for improving the quality and usefulness of this newsletter.

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| ORGANIZATION | |
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| CITY AND STATE OR PROVINCE | |
| COUNTRY | |

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CITY ☐☐☐☐☐☐☐☐☐☐☐

## Reader's comments

We should appreciate it if readers could take the time to tell us in this space what they think of the 19/20th issue of Advances in Materials Technology: Monitor. Comments on the usefulness of the information and the way it has been organized will help us in preparing future issues of the Monitor. We thank you for your co-operation and look forward to hearing from you.

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| Issue No. 5 | Composites |
| Issue No. 6 | Plastics |
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