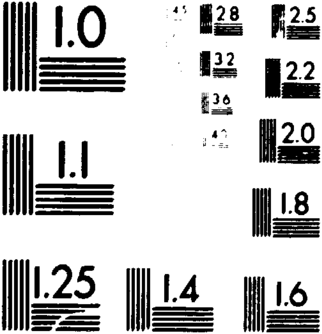

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NEW MATERIALS TECHNOLOGY AND CIM

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Dear Reader,

This is number 21 of UNIDO's state-of-the-art series in the field of materials entitled **Advances in Materials Technology: Monitor.** This issue is devoted to the "New Materials Technology and CIM" (CIM= Computer Integrated Manufacturing).

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 of this issue was written by Prof. Pablo Spinadel from the Austrian Research Centre, Seibersdorf.

We invite our readers to share with us their knowledge and experience related to any aspect of materials development, production, processing and utilization. It would greatly help strengthening developing countries' awareness of world-wide achievements in science and technology.

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

For the interest of those of our readers who may not know, UNIDO also publishes two other Monitors: Microelectronics Monitor and Genetic Engineering and Biotechnology Monitor. For those who like to receive them please write to the Editor, Microelectronics Monitor and Editor, Genetic Engineering and Biotechnology Monitor.

Industrial Technology Development Division

CONTENTS

COMPUTER INTEGRATED MANUFACTURING

by

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CONTENTS

I. INTRODUCTION

A new industrial revolution began with the development and diffusion of organizational changes and modern automation technologies. Although the first impact of this new industrial revolution is already being felt it will become increasingly strong in the years to come.

After the middle of the 1970s the demand for mass-produced goods began to decline and many manufacturing industries were forced to produce customized products. The new market requirements asked for medium to small batch product series, i.e. for flexibility in production. Thus, once again the conflict between flexibility and productivity had to be overcome (the last time this conflict appeared, the solution was found in mass production).

Until now industrial automation has developed very fast and therefore in a very chaotic way. Flexible automation requires a "complete system" idea, beginning at the single production task and extending to the global concept of the plant layout.

Many industries realized studies, showing that the benefits obtainable through technological improvements or work rationalization are reaching an asymptotical value. This means that in future only a great technological jump or structural reform will enable a new increase in productivity. The success of this concept, called Computer Integrated Manufacturing (CIM), will depend on the way in which all the separate technologies will be connected.

The key to CIM and to reaching economic benefits lies in the understanding of the rules of the game between production objectives, technical components and the organizational structure of the industry.

II. STRUCTURE OF THE PAPER

This paper intends to give an introduction to some basic concepts involved in the CIM idea and its influence in the developing and industrialized countries. It does not give all the solutions and answers, but hopefully presents some of the most significant problems and questions.

The paper is organized into five parts:

Part 1: Gives a short overview of some changes which have occurred in the industrial environment over the years and tries to evaluate the influence that will cause the introduction of organizational changes and modern automation technologies globally.

Part 2: Gives an overview of the basic so-called computer aided techniques (CA-X Techniques), showing the actual trends and future developments of the whole industrial environment.

Part 3: Gives an overview of the software developments related to the CA-X Techniques, beginning with the standard CIM software, followed by the existing tools and those under development for the different areas and ending with an introduction to future developments which will cause a new revolution in the industrial environment: AI & ES systems and decision support systems.

Part 4: The first three parts show the key role that communications will play in all applications and new developments and this part is devoted therefore to the introduction of "Computer Esperanto" and past, present and future standardization work.

Part 5: Gives a short overview of the impact of CIM components in industrialized countries and also shows the advantages and possibilities that well planned organizational changes and modern automation technologies could introduce in the developing countries. It ends with some personal ideas about this introduction.

PART 1

1. The industrial environment and CIM

1.1. Historical evolution

The real history of automation in the manufacturing process began in the early 1950s with the introduction of numerical control (NC) just at the point where many rising industries in developed countries were concerned about the lack of work forces. At the same time a lot of population development studies, specially in Japan, began to advertise the need for preparing alternative solutions for the fact that in the 1990s the increasing young workers will not keep up with industrial requirements. These studies indicate that industrial automation could solve this problem.

Starting from the application of numerical control at the single machine tool level, the development continued with the integration of more than one machine and auxiliary support devices, such as material handling systems, tool handling systems and so on. The development of industrial robots occurred practically simultaneously with the computer based NC (CNC), but although the first industrial robot was developed in 1961, they only began to become important to industrial processes towards the end of the 1970s.

With the introduction of the microprocessor the dependent situation between progress in computerized manufacturing and advances in information technology hardware (storage capacity, data processing time, reliability, cost, etc.) changed considerably and interest became focused on developments in software and communication aspects.

The logical follow-up of the manufacturing process is the use of computer technology beginning from the moment of product conception and developing according to market information, up to its final delivery to the customer.

In contrast to traditional automation, in which chains of inflexible, special-purpose equipment has to deal with the mass production of relatively homogeneous products, the new automation technology is flexible and applicable to a wide range of machine building operations.

1.2. Computer integrated manufacturing

There is no official CIM definition but the Working Group on Engineering Industries and Automation, a subsidiary body of the Economic Commission for Europe, selected the following concepts to describe CIM in their report on Software for Industrial Automation:

A closed-loop feedback system in which the prime inputs are product requirements (needs) and product concepts (creativity) and the prime outputs are finished products (fully assembled, inspected and ready for use). It comprises a combination of software and hardware, the elements of which include product design (for production), production planning (programming), production control (feedback, supervisory and adaptative optimizing), production equipment (including machines tools) and production processes (removal, forming and consolidation). (From the Proceedings of the UN/ECE Seminar on FMS in Sofia, Bulgaria).

- It is not easy to evaluate the influence that rapid technological change introduced by industrial automation will cause, it is only possible to point out some of the elements that it will change:

- Humanization: Individuals will be replaced to do unpleasant and boring work such as chemical products handling, environmental problems (noise, security, etc.), repetitive work, etc.

- Quality: Not only will a constant documented quality level be reached, but also some work which is impossible to do manually will be realized, i.e. precision, miniaturization, cleaning, etc. could be realized.

- Reduction of raw materials and in-process stocks.

- Reduction of production lead time.

- Improved control over the fulfilment of contracts and meeting of deadlines.

- Increased flexibility in meeting market demands.

1.3. Flexibility and the organizational structure

The most important factor in industrial research has been to reach higher productivity. Flexibility as an industrial factor has varied cyclically over the years, accompanied by a constant increase in productivity levels. Without an increasing flexibility almost no industry will be able to reach a new increase in productivity.

However it will be very difficult to increase the inherent flexibility of modern industrial resources which are already very flexible. Therefore the main effort must be directed towards reaching a better synchronization between the elements themselves and between the elements and products. In this field an increased flexibility seems to be possible (a better interrelationship could be reached by changing the physical and/or temporal distribution of resources).

PART 2

2. CA-X TECHNIQUES

2.1. Introduction

Today's enterprises are "forced" to develop new production strategies as a result of growing competition on national and international markets parallel to changes in manufacturing conditions, from mass production to customer-specific production. The main requirements are concentrated on a higher flexibility of the production process, higher productivity and better product quality.

New developments in semiconductor technology, enabling a broader application of computer systems and automation of the entire production process, were a precondition for many enterprises when approaching these requirements.

The rapid development of automation control techniques within the manufacturing process as well as the integration of computers with machines has led to the application of new manufacturing concepts and strategies incorporating "CA-X techniques" to a wide range of industries. The main characteristics of these techniques will be outlined in the following points.

2.1.1. CAD: Computer aided design

The design process can be regarded as the starting point within the production process. Several steps in this process (from alternative concepts and evaluations of solutions to the final design of single work-pieces), result in the preparation of data for manufacturing analysis as the subsequent area of product development. As a rule the design process is interactively accomplished, integrating economic questions as well as technical alterations to arrive at an optimal solution.

For the presentation of geometric objects, different models can be identified. Starting with two-dimensional forms of object presentation, an increased tendency towards three-dimensional presentation (solids) prevails today, due to the limitations of two-dimensional models when integrating new manufacturing methods.

At the user interface of a CAD-system the work of designers is supported by several "comfortable" instruments such as tablets, light pens or mouse techniques combined with high resolution screens. At the beginning of CAD, separate workstations were introduced, mainly for technical reasons. Frequently these stand-alone systems are connected to host computers, whose functions are reduced to the management of geometric data and piece list information.

2.1.2. CAM: Computer aided manufacturing

In contrast to conventional production where machines are operated manually according to work plans and drawings, computer controlled manufacturing works with programs, functioning as information carriers for job instructions and control measures.

The preceding area of design determines the methods for machining and assembling work-pieces or piece parts. By translating instructions into a form understandable to controllers of specific machines, robots or conveyers, a continuous flow of information from product development to manufacturing can be established.

NC-machines can be regarded as the first components for the introduction of CAM-methods, beginning with punched tapes for information transfer. To attain more flexible methods of data transfer, CNC (computerized numerical controlled) machines were developed, enabling the direct transfer of machine programmes and their variation or correction at the machine.

A more advanced form of machine organization, a DNC (direct numerical controlled system), has a number of advantages when compared to conventional NC/CNC machines, but it also has disproportionate requirements of the control system and software. At a DNC-solution several NC/CNC machines are directly controlled by a central computer which manages NC-programs and distributes them to single machines. Programming and corrections can be accomplished at this computer, as well as instructions and acquisition functions.

2.1.3. CAPP: Computer aided process planning

CAPP can be defined as the process of determining the methods and sequence of the manufacturing operations necessary to produce a finished part or component, according to design specifications and within the available manufacturing facility. Process planning is usually carried out by qualified and experienced process planners or machines. The creation of a good optimal process plan is largely dependent on the individual skill of a planner and his aptitude for the planning task, his knowledge of manufacturing processes, equipment, materials and methods which are in particular available in his production environment.

NC-programs can be regarded as detailed work-plans combined with instruction functions for numerically controlled machine tools. Work plans describe the transformation of work-pieces from raw material to the final product, including specifications such as manufacturing sequences, operating material and permitted times. As a starting-point for the preparation of the work plan, geometrical data from the design area are supplemented with technological characteristics of the work-piece. As a result, specific work plans (in the case of conventional production) or computer programs (in the case of computer controlled manufacturing) are developed, enabling a consistent linking of CAD and CAM.

2.1.4. CAQ: Computer aided quality

Nowadays, quality is a competitive factor and therefore decisive for the market position of an enterprise. Quality insurance and maintenance can be seen as an integrative part of the production process, from inspection of materials via monitoring of manufacturing to the final inspection of products.

Quality insurance procedures become more and more computer controlled, allowing rational and assignable associations of quality data to certain products, as well as the determination of trends in quality specification. In many cases monitoring and analysis by means of measuring equipment such as sensors or gauging machines is carried out automatically. Parallel to the hardware the planning of monitoring processes can be also optimized by means of computers, analogous to manufacturing planning.

A number of methods have been developed in the fields of statistics and operations research for the planning of quality insurance functions. In general a tendency towards integration of quality insurance into the manufacturing process can be observed (for example, if quality insurance consists of checking weights and capacities). If computer aided planning of measuring and testing is supported by administrative issues, the test program represents a part of the work plan for production planning and scheduling. For the storage of test programs, separate systems can be used, or these plans can form a separate cycle within the manufacturing work plan.

2.1.5. CAP: Computer aided planning

The application of production planning and scheduling systems (such as materials management or calculation) started when other C- techniques such as CAD-CAM were still at the development stage. Although they can be regarded as a classical field for electronic data processing within an enterprise, a number of obstacles still exist during the implementation phase. The required complex structure of the systems, as a consequence of demand to cover the entire production process, frequently necessitates company-specific solutions.

In general the concept of production planning and scheduling systems is based on single planning stages succeeding one another with a temporal and logical termination supported by basic data-management tools. These tools supply material and time management with master data, permitting the working out of manufacturing plans as a basis for the control of the manufacturing process. The managment of parts lists and work schedules, combined with (groups of) operating material, form not only the basis for planning and control, but also for the calculation of products.

2.2. Actual trends

Within a computer integrated system two fundamental types must be defined, those where a new development could be made on-line (using simulation, automatic program generation and others) and those where it could only be done off-line. A third possibility could be one where the tasks needed for new developments are planned and scheduled as any other job. This means an "on-line off-line" development. This normally decreases the flexibility of the system, because although the process is not stopped, the resource being programmed has to be disconnected. For the system it resembles a total breakdown of this resource.

2.2.1. Control levels

Industrial systems vary continuously and therefore the development and application of DYnamic Control Optimization mechanisms (DYCO), and not static ones, will be necessary. These systems can control on-line manufacturing sequences, paths and duration of cycles, while previously determined sequences can be corrected as manufacturing is in progress. In addition, error detection and correction is a necessary feature of the control system.

Different control levels of a system may be defined as follows:

(a) Electronic control: This is the level where the direct control of the electronics is realized. It has no intelligence by itself, but a high reaction velocity, meaning that as much as possible must be controlled at this level. Normally this control is done by devices such as PLCs. For example, in a robot this level would control the motors and input/output signals.

(b) Hardware control: Based on a limited logic and a group of control algorithms, the first decision will take place at this level. The most important feature of this level is to realize a good filtering of variables in order to let only that particular one pass which is useful to the upper control level. Normally this control is done by dedicated controllers built into each machine.

For example, with a robot where the point and way to reach it is known, the controller must decide which movements have to be done by each axis and introduce this to the necessary motor signal.

(c) Data transfer control: This is the first level where some intelligence is needed and also the first one affected by production planning and scheduling. At this level there is a great deal of flexibility in the system. The function of the controller at this point is to control resources. This means, for example, to load and unload programs from local memories, or to follow the elements being moved and secure a correct transfer of information without collision or time problems.

For the controller the elements will no more be robots or transport systems or some other specific device, but they must only be resources or objects with a determined group of characteristics. This will not define hardware details but a set of programs that can be done, the time needed to do them, how much each costs, e[illegible] Normally micro- or mini-computers can [illegible] found at this level. An example could be a micro-computer which distributes programs from the central memory unit to all the machines without collision, or by requirement of the upper level showing the state of each resource and each job being done.

(d) General control: This is the fundamental level of the system where functions such as the control of a consistent functioning of the resources (each one must have what is needed), dynamically resolve the fail problems that may appear, realize the alternative analysis in case of a variation on the goal schedule and control the communication of a cell with the "world". In order to secure the readiness of all elements it will need to continue functioning.

Most of the parts of the cell, such as expert systems, simulation modules, management decision supports, etc., will be located at this level. This is also the level at which all system functioning modes differing from the automatic mode, such as the starting mode, the degraded mode, the ending mode, the debugging mode, etc., must be analysed and "well done".

(e) A number of studies have shown the enormous interdependence between system functioning and the external world. Long-time suppliers wishing to sell their products could wipe out all the efficiency of an industry. A large stock is not a solution because its cost would also extinguish the savings achieved by the use of organizational changes and automation technologies.

Perhaps the only solution in the future will be to generate a higher level which includes relationships among the industrial participants. The future will most probably require a JIT-production and management system which includes all parts and even raw material suppliers linked together by a communication network.

2.2.2. Robots, transport and stock management

In a similar way as CNC/DNC machines are controlled by computers, robots or transport and inventory systems can be integrated into the production process. In many instances the use of robots within a CAM- system is limited to machine loading/unloading or the repetition of a certain sequence of operations (e.g. welding in the automotive industry). Solutions which utilize the full flexibility of a robot, combined with sensor applications, off-line programming and artificial intelligence methods allowing the execution of variable/new orders, are still only realized at laboratories or as prototypes at some large factories only. Especially in the assembly sector have sophisticated robot-systems have been introduced, where products with many variants in small batches (but at the same time of a high quality) are to be assembled automatically.

With regard to computer aided transportation and stock management, some industrial applications have reached a high level of integration. Combinations of automated transport and inventory systems can help to improve factory logistics, directed at a reduction of transport and buffer times. As a result, the flow time of orders can be reduced a great deal.

2.2.3. FMS: Flexible manufacturing systems

Developments in the NC-techniques sector have been mainly concentrated on the machining (cutting) sector, resulting in the introduction of flexible manufacturing systems (FMS). This can be seen in an early definition of Kearney and Trecker: "FMS combines the existing technology of NC manufacturing, automated material handling, and computer hardware and software to create an integrated system for the automatic random processing of palletized parts across various work stations in the system".

Today, many researchers consider that FMS is an approach to a particular set of manufacturing problems rather than a single technological configuration. The Economic Commission for Europe attempted to define it in 1986 as "an integrated computer-controlled complex of NC machine tools, automated material and tool-handling devices and automated measuring and testing equipment that with a minimum of manual intervention and short change-over time can process any product belonging to certain specified families of products within its stated capability and to a predetermined schedule". This definition includes the human element, although making clear the tendency of the international efforts to reach a quite unmanned FMS.

Although the idea of FMS was created almost 20 years ago, it only started to be of significant interest to the research community in the early 1980s. This can be measured by the number of books and papers published and the conferences hald (IFS Publishing Ltd. and North Holland Publishing Co. have annually published proceedings of the International Conference on FMS's since 1982).

FMS cannot be regarded as a new technology which can be installed and operated as traditional machine tools, aiming at a reduction of labour costs. FMS is rather a new philosophy, utilizing data processing methods to "transfer" the advantages of industrial scale production to small-lot or job-production also. The decisive factor "flexibility" characterizes the ability of the system to be automatically adaptable to different manufacturing conditions (products) at minimal set-up times.

Assembly systems and machining systems have many common problems, such as control and scheduling of material flow or the importance of distributed storage of work-in-process or the difficulties in predicting performance, although, they must be analyzed separately and with different theories and mechanisms because they use a different time unit for the system analysis.

Until now practically all the FMS models were developed for machining systems, probably because the high costs of such systems enable financial support by industries. The same holds true for most of the problems investigated, such as machine balancing, aggregate planning, resource grouping, etc., all of which apply to large industries only. It is important to differentiate between FMSs, because the development of new machining centres have advanced so much that all the cell work is done inside the machining centres. This transforms the cell problems into internal machine problems.

The main components of an FMS are:

- CNC/DNC machine tools or machining centres;
- Automatic transport and handling devices for tools and work-pieces
- Measuring/monitoring systems (integrated or as separate machines)
- Central computer for automatic control of all FMS-components (CAM), linked with preceding areas CAD, CAP via Local Area Networks (LAN).

2.2.3.1. Types of FMS

Some of the most important FMS types are:

(a) Flexible manufacturing cells: Several machine tools are interlinked and operated according to a fixed process sequence. As a simple version a single machine tool is linked with an industrial robot to load and unload work-pieces from a transport pallet to the machine tool.

(b) Flexible manufacturing systems: These systems also consist of several machine tools or machining centres, with software capacities which allow a variable and optimized feeding of work-pieces. Equipped with a central computer and algorithms for parts identification, automatic set-up, etc., a high degree of flexibility can be attained enabling the economic production of small lots.

(c) Flexible transfer line: Similar to conventional transfer lines operations are accomplished at a "rigid" street, according to a fixed sequence and applying special machines at different working places. Different to conventional solutions, at flexible transfer lines machines are numerically controlled and linked to a central computer.

2.2.3.2. FAS: Flexible assembly systems

Assembly as a part of the production process obtains a central position in production if short processing times and low in-process supplies are to be realized at the same time.

Technical conditions for obtaining these aims can be provided by means of flexible assembly that can be regarded as one of the main bottlenecks in the manufacturing process. By integrating flexible assembly into this process, organizational conditions are provided by linking areas such as computer aided design, production planning, parts manufacturing and quality control to the assembly area.

The main requirement for assembly, including transport of parts to and from the system, feeding, inspection, etc., can be outlined as follows. Flexibility has to be increased in those assembly areas which apply specific methods and techniques for the manufacture of different products, which are not anticipated at the planning stage of the plant. Otherwise an assembly cell has only limited flexibility and can be used for a certain amount of variants of a certain product only.

The configuration of assembly components has a direct consequence on the realization of this principle. The technology oriented stations concept, which may be found in the article "The technology approach to flexible assembly" (published in this Monitor), represent one possible configuration of the assembly components in an FAS.

2.2.4. CAP methods

In the middle of the 1970s many Japanese companies began to experiment with, and adopt, a whole range of new manufacture management approaches (developed in the 1960s at the Toyota company in Japan), to improve overall productivity and eliminate waste. This new approach was first called the "Ohno System" (in honour to Taiichi Ohno, who masterminded the Toyota system), or simply the "Toyota Manufacturing System". In trying to find a "better" name, the idea was mostly misnamed. Some of these examples are the "Kanban System" (referring to one of the main elements of the system that was a pull scheduling technique using "Kanbans", meaning "container" in Japanese), "Zero Inventories" or "Stockless Production" (referring to the stock reduction, but a misnomer since no process can run without stock), "World Class Manufacturing" and "Continuous Flow Manufacturing". Actually, the correct term which has become most widely used is Just-in-Time/Total Quality Control (terminology from R.J. Schonberger).

2.2.4.1. Total quality control

During the first half of the 20th century customers expected to pay extra for quality. However in the competitive business climate of the late 1980s, quality is no longer an option; it is a positive requirement without which an organization cannot survive. Companies deciding to embark upon the "Total Quality Road" will reap great rewards such as improved productivity, committed customers or improved certainty in operations. However, one of the decisive factors to achieve results such as these is through a commitment by the management, starting from the chairman. Total quality must be management-led, company-wide in implementation, dedicated to continuous improvement and the responsibility of every employee.

The new style which has emerged has three basic features: first, "customer-oriented", i.e. everything is driven by customer needs. Next, it concentrates on managing the "process" in the business, which deliver to these customer needs (such as products, services etc.). Third, it focuses on the "people" who work the process, inspiring and empowering them to produce ever-better results for their customers. Thus, total quality depends on total organization. It relies on every individual passing on to the next individual quality parts, quality services and quality information.

Following these statements, computer integrated quality - CAQ, as already outlined - can serve as the technical pre-supposition to meet the requirements of total quality. The integration of these two ways of approaching higher quality, from the technical side and from the management side, can be regarded as the key to a CIM-oriented quality strategy.

2.2.4.2. Just-in-time

The key philosophies of JIT are simplification and continual improvement. It is an approach for the cost-effective production and delivery of only the necessary quantity of parts, at the right time and place, at the right quality, while using a minimum amount of facilities, equipment, materials and human resources.

JIT is dependent on the balance between the supplier's flexibility and the user's flexibility. It is accomplished through the application of elements which require total employee involvement and teamwork.

Prof. C.A. Voss, in the preface of "Just-in-Time Manufacture", ranked the main benefits of JIT in the United Kingdom as: work-in-process reduction, increased flexibility, raw materials/part reduction, increased quality, increased productivity, reduced space requirements and lower overheads.

He also grouped the most important techniques and approaches associated with JIT into three main areas: manufacturing techniques, production/material control and inter-company JIT. The following points give a short description of these main areas.

2.2.4.2.1. Manufacturing techniques

(a) Set-up time reduction: like Shingeo Shingo's SMED system (single-minute exchange of die) that introduces the concept of external (off-line) set-up times in order to reduce the internal (on-line) set-up times.

(b) Kanban or pull scheduling: By the Kanban system the preceding production stages generate new manufacturing orders, just when its stock of finished products has come down to a safety stock quantity. In practice, by means of special transport Kanban-containers the supply of material is organized for a predetermined amount of piece parts. Thereby each container carries his order-card, showing a specific parts quantity. By handing over this card, the planning process can be realized. In this way the last production stage determines the further "suction" of products into manufacturing. The successful introduction of Kanban is closely connected with two requirements to production: high stability of production quantities and high quality standards.

Other principles also associated with pull scheduling include the principle of the use of the smallest possible machine, the "preventive maintenance", the "Poka-yoke" (Japanese for proof-mistake, consisting of foolproof devices, such as a checklist, to prevent unadvertised mistakes and defects), the automatic stopping of the production equipment when abnormal conditions are suspected or occur, etc.

(c) Cellular manufacturing: including group technology.

2.2.4.2.2. Production/material control

(a) JIT-MRP: MRP (materials requirements planning) and JIT can, with some changes, mutually support each other.

(b) OPT (optimized production technology): A scheduling technique developed in Israel to allow JIT production in an environment characterized by complexity and known bottlenecks.

(c) Schedule balance and smoothing: using techniques such as "under capacity scheduling", "visible production control" or "load-oriented release of orders" (based on the principle that only a certain amount of those orders are released which can be manufactured within a certain period. As a result a more "anticipating" release of orders can be attained, preventing an overload of manufacturing with subsequent high inventory and processing/machining times).

(d) Simultaneous material and time management: At traditional production planning and scheduling systems, material and time management are not sufficiently connected. As a characteristic of the simultaneous method, critical orders are released first by forward-termination, getting a higher priority in relation to other orders. Afterwards non-critical orders are adjusted to fixed terms by means of backward termination. As a result, the entire order system can be reduced to manufacturing orders, probably increasing already existing bottlenecks and orders to be allocated to non-critical capacities.

2.2.4.2.3. Inter-company JIT

(a) JIT-purchasing: application of the JIT principle on an inter-company basis, requiring that goods are supplied in small quantities, exact amounts, at frequent intervals and at 100 per cent quality. The techniques utilized include single sourcing, use of standardized containers, supplier quality certification, point-of-use delivery, family of part sourcing, purchasing kanban and above all mutual trust.

2.2.5. Layout planning and simulation

The layout planning process has to be supported by computer aided methods to gain high productivity with capital intensive manufacturing equipment such as FMS, which kind of manufacturing organization will yield optimal results for which part program will have to be analysed. Not only isolated manufacturing units but "co-operating" cells and systems should be investigated by simultaneous planning of all components and operations involved. Different variants of layouts and capacities have to be analysed in order to aim at the optimal solution.

Computer simulation can be regarded as a rational way to optimize planning, and in a more advanced form, also the operation of complex production plants. It is an appropriate tool to investigate component locations, inventory sizes, transport methods or buffer-capacities. Simulation allows the quantitative determination of different objectives, depending on the structure of the plant and the system-parameters. Different variants can be contrasted and evaluated. Subsequent to the definition of the system structure, simulation also supports the location of maximum operation levels and the optimal layout of the plant control system.

Simulation methods are mostly used as a means of layout planning only, but they will have to be integrated more intensively into the entire production planning process as an addition to production planning and scheduling systems. As an example, the simulation of different orders could at an early stage show when and where bottlenecks may occur and an optimal solution could be found by computer-supported investigating of different variants of orders and machines without interrupting the real production process.

2.2.5.1. Analytical and evaluative models

Traditional batch manufacturing systems were criticized because of the elevated levels of work-in-process (WIP) and because the jobs spent most of the time "waiting for something to happen to them" (WFS-Time). These two elements depend strongly on logistics and planning and scheduling (P&S) and also on the hardware and its layout.

Some very interesting advances were made in order to reduce the WFS time, for example in the machining area a better understanding of the internal and external set-up times (see SMED or POKA YOKE) or the CAD/CAM coupling.

In the same were achieved way techniques such as JIT, or the new possibilities opened by simulation programs, suggest ways of reducing the WIP levels.

These new techniques provoked developments of flexible manufacturing systems (FMS) models, using operational research theories for performance evaluation and programming and control theory for the development of scheduling and operating procedures.

Simulation models are of great value in evaluating specific systems designs, but analytical models are superior in terms of the amount of insight they give. They enable the key parameters and their influence to be clearly identified and suggest directions for system improvement. The extent of abstraction from the real system which must be made in order to solve them overall, generate slow developments, although they can lead to a significant improvement in our understanding of how complex systems function.

The analytical models that have been developed enable the establishment of basic design problems and provide an insight into a number of key design issues, such as central versus distributed storage or machine grouping. They have been used to address some wider issues such as the meaning of flexibility, or the value of dynamic routing and scheduling.

The analytical models can also be used to determine how the overall production capacity of the system is affected by the product-mix, the number and capability of the resources, the lot-sizes, the number of pallets, machine breakdowns, etc. This makes the models very useful at the preliminary design stage when it is desirable to determine the main features of the system.

Some of the main models used to evaluate FMS performance are:

- Static allocation models for feasibility and sizing studies;

- Queueing network models for interactive preliminary decision values for design and operation problems;

- Computer based discrete event-simulation for more detailed decision values for design and operation problems;

- Perturbation analysis for fine-tuning, efficient and real-time values for design and operation;

- Extended Petri nets for design, operation, modelling and real-time control of the system.

2.3. Future developments

2.3.1. Machining sector

The machining sector is the most advanced area within enterprises, but it is limited on the one hand to a few manufacturing technologies (such as turning, milling, grinding) and on the other hand, in many cases, to a mere NC-programming. CAD/CAM has not truly fulfilled its promise and the underlying reason is a lack of communication among CAD-systems, CNC-machine tools and co-ordinate measuring machines. While there is certainly communication between CAD-systems and CNC-machine tools, this communication is limited and there is virtually no communication anywhere else.

Future developments in the machining sector will not focus on machine tools only, but also on the communication side, fixturing and tool monitoring, the integration of measuring tools, and the application of knowledge-based systems. The communication side will be discussed in another chapter.

2.3.1.1. Fixturing

Numerical control of machining paths do not account for the position of the part on the machine tool. This means that the part must be "locked" in a specific position by the fixture unique to the part. To meet these requirements, product-specific fixtures have to be designed and manufactured parallel to the products to be clamped and organized as specific tools of the machine. Fixturing has to be integrated with tool-management, with similar monitoring and identification devices. The development of "fixturing-standards" for work-piece families could help reduce the high expense combined with "CIM-oriented fixturing".

2.3.1.2. Machine tool managment

Critical to unmanned machining is tool management. Unmanned machine tools require a considerable number of monitoring systems in order to operate effectively. This is the case in areas such as tool wear monitoring, identification of tools, setting tool offsets, error correction caused by thermal drift, etc. Some form of sensor has to be included in the system, whatever the monitored function requirements will be.

As one answer to some of these requirements, a so-called "intelligent" tooling approach has been introduced by the application of microchip memories (as a read/write facility) embedded in the tool holder. The organizational integration as well as the full utilization of the advantages of this approach for an optimal tool management has not yet been optimally realized.

2.3.1.3. Monitoring, sensing and controlling

Adaptive control is another field of interest related to unmanned machine tool systems. It describes the in-process adjustments of operating parameters, such as spindle speed, or more usually, feed rate based on the actual process characteristics. Two main adaptive control systems can be distinguished adaptive control optimization and adaptive control constraint. There are some advantages in the second, the so-called "tongue controlled" system which makes a feed-back loop where continuous monitoring by sensors and updating of the CNC using adaptive control produces optimal cutting conditions for the combination of the tool work-piece.

For any unmanned machining operation it will be essential to provide an in-process tool breakage sensing system. Tool breakage detection using the acoustic emission principle while applying the direct piezoelectric effect is now emerging as a reliable method.

It is all very well to have a sophisticated cutting tool monitoring system, but some care has to be taken over work-piece identification, set-up and gauging. During machining time there are a number of ways in which the parts' quality can be assessed such as in-process gauging (mainly used in grinding applications) or in-cycle gauging (on turning and machining centres within FMS). One method used to overcome errors in the machine tool by way of compensation, is to use the so-called "footprint" method of part inspection. Another method, which is still controversial, is the "deterministic metrology technique", which predicts and corrects for errors, based on trying to anticipate machining errors in a real-time situation and thereby correcting them. This technique is still confined to the laboratory but will have a considerable impact on work measurement and its control.

Apart from all the diagnostic sensing devices used to monitor a machine tool, there are a variety of other sensors to maintain a status quo of consistent part quality. For example, thermal sensing is used to compensate "machine growth" caused by heat in motors and bearings. It is possible to close-the-loop by feeding these errors into the machine tool, allowing for more consistent part quality.

Monitoring systems such as those outlined, cost a considerable amount of money and are an indirect production cost, but they are necessary because of the lack of human involvement in the machining cycle, in order to achieve high quality products and as a step in the direction of "zero defect quality".

2.3.2. IR, assembly and sensor technology

2.3.2.1. Industrial robots

The International Organization for Standardization proposed the following definition: The industrial robot (IR) is an automatic position-controlled, reprogrammable, multi-functional manipulator with several degrees of freedom and capable of handling materials, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks. It often has the appearance of one or several arms ending in a wrist. Its control unit uses a memorizing device and sometimes it can use sensing and adaptation appliances that take account of environment and circumstances. These multi-purpose machines are generally designed to carry out repetitive functions and can be adapted to other functions without permanent alteration of the equipment.

Industrial robots were originally developed for handling and process application. The control principles used were pure positional or path control from taught or pre-programmed action patterns. This concept has dominated until today.

2.3.2.2. Assembly process

The final result of an assembly process depends on the quality of the parts to be assembled and of the correct performance of all operations. Every part must be gripped, transported, fed, inserted and joined so that the final result fulfils a given function within its tolerances. It is of great importance that the parts are positioned in the gripper within given permissible tolerances to permit the consecutive sub-operations to be correctly performed. Even if parts to be assembled have the correct quality, an unfavourable turn-out of the dimensions may make the fitting impossible or give a faulty result.

2.3.2.3. The IR in the assembly process

A robot work station with magazines, fixturing tools and work-pieces is not allowed to vary outside given tolerances. These are given by, for example, fixtures, i.e. magazines designed to each specific work-piece, or tools and work-pieces which have to be manufactured with close tolerances to avoid uncertainty of part positions. Unexpected states during program execution are not allowed at all.

Robots have a limited positional repeatability and could be affected by wear resulting in drift. The same thing holds true for other system components. Thus there is a need for supervision at the different stages of the process by means of sensor technologies.

2.3.2.4. Tactile sensing

Optimum sensor compliance is a severe problem in factory floor applications of tactile sensor arrays. The human skin has the ability to adapt its compliance when grasping an egg as well as to that of a brick. To mimic this remarkable property in a tactile sensor implies high complexity as well as high cost. In industrial applications, different tactile sensor arrays have to be used with different degrees of compliance for different tasks, i.e. one type for the egg, another type for the brick.

For a future extension of the range of application, tactile sensing should be combined with other senses - vision and also proximity sensing - if the function of a sensor-controlled adaptive robot is to be optimized. The sensor units must be easily and rapidly interchangeable. The combination of several senses (sensors), results in synergetic effects when compared to the use of a single sense, even if the latter is of the outmost sophistication (e.g. 3D-vision).

Many laboratories working in the field of assembly automation are today engaged in the development and application of sensor technology. In spite of this engagement only a few sensor-based solutions (single sensing) such as vision-systems are applied for practical use in industry. As a main obstacle to a broader application of sensor-technologies, the lack of communication support as well as suitable/standardized sensor interfaces to robot controllers and users should be mentioned.

Future developments in this area should concentrate on:

- The improvement of robot control systems concerning sensor signal processing;

- The improvement of integration capabilities of sensors and robots;

- The development of task-oriented strategies for evaluating sensor signals for systems programming and process-guidance.

The integration of sensor-guided assembly with industrial robots into a CIM-environment is still very far from realization. It will take a couple of years to reach standard solutions, which permit the introduction of structures at the assembly area at a similar level to that already achieved in the machining sector.

PART 3

3. SOFTWARE DEVELOPMENTS: PAST, PRESENT AND FUTURE

The optimal selection of software elements for an industry is a technical prerequisite for the successful implementation of integrated automation. It is sometimes even more important than the installation of powerful hardware.

Like most of the CIM related technologies and tools, a software solution requires a prior complex analysis of the industry. Omitting this step will result in the incorporation of existing organizational deficiencies into the software solution to be elaborated. Expensive trials on the shop floor can be minimized by taking full advantage of the opportunities of modelling.

The selected software must be capable of operating under both regular manufacturing conditions and adapting to emergencies. The success of integrated automation depends on the clearly defined hierarchical classification of responsibilities and tasks in the management process. The tasks should not be adjusted to the existing management structure, but vice versa, the management structure should be adapted to the tasks.

3.1. Flexibility and software

In the last few years it has been easy to see a reduction in lot-sizes, an increase in the complexity of the required manufacturing techniques and at the same time in the number of product variants and the need for a fast reaction to market changes. All these changes could be summarized by saying that production began to be more and more flexible.

The concept of flexibility is usually associated with the capacity of a production system to "correctly and quickly" adapt to alternative constellations. Two types of flexibility may be distinguished, dynamic flexibility, which principally determines the term "quickly", and static flexibility, mainly responsible for the term "correctly". A production system can adapt itself to several product variants by means of the control system. The greater the number of different variants, the greater will be the chance for the system to achieve economic solutions for new products. Thus flexibility can be regarded as a dimension of different variants co-existing in a production system.

According to the tenets of control theory, the complexity of a system, and thus the time necessary for the computation of a new solution, increases exponentially with the number of alternatives. This means that the complexity of a software structure, used to achieve the dynamic optimal solution, increases exponentially with flexibility. Although most of the systems may actually be guided to a dynamic optimal solution with traditional methods (as system flexibility increases), software control structures become more and more the key to the optimal functioning of the system.

3.2. The "Standard CIM software"

A static problem in the production system does not exist. When increasing productivity by solving a problem, the structure of the factory changes at the same time and so a new system has to be analysed. This means there is no solution that allows the reaching of a higher productivity level without at the same time being confronted with a new problem to be resolved.

A static industry is a dead industry, therefore the only solution is a continuous search for new solutions. There is no such thing as an "off-the-shelf" software package unless there is a standard factory, because this does not exist.

There is no sense by trying to find a standard software package for CIM. With enough money a special development adapted for a factory could be made and it will be an optimal solution until it is installed, because for that moment the structure will change and so also will the need to change the software package.

The problem will always be the same: to operate a flexible production system that reacts dynamically to the market requirements, a flexible software package and not a static one is necessary. But what does it mean to have a dynamic, flexible software system? It means that the system will only be a decisions support, only a tool whereby one may find the answer to questions faster or increase the working speed in some special area of the industry. These two possibilities are given by decision support systems for the first and specially developed software tools for the second.

3.3. Software tools

It is not within the scope of this paper to make a survey of software developments for industrial automation. Only a survey of the areas where software tools could be applicable will be given (based mostly on the document of the Economic Commission for Europe: "Software for Industrial Automation").

3.3.1. NC tools

The numerical control (NC) programs prepared manually in production planning are very rarely used nowadays. Considerable importance, especially with respect to unattended manufacture, is being given to the computer-aided NC-program generation.

The main areas of software for computerized-NC (CNC) are:

- Function data bases that permits a geometric information processing for an easy use of complex work processes (e.g. given only two points and the ratio, generating the corresponding circle sector);

- User interface software that could guide the operator in the conversational mode using windows and menuing techniques or symbolic programming and also a graphic support as a help in understanding the work;

- The service software for support of diagnosis and maintenance of data input/output control;

- The adaptative control software for controlling the influence of continuously varying process parameters (e.g. temperature and forces) and also for tasks such as prediction of tool failure.

The development of Direct NC (DNC) was initiated to make possible the control of machine tools from a central computer using the time sharing capacity of digital computers. The most important element of the DNC software is the data transfer. This transfer could take place between the computer, the NC-machine, the programming device and other different functional complexes of the system.

Future developments in this field will enable a better utilization of the CAD/CAM systems for NC-machines, a better interrelationship between the NC-machine and the entire production by an on-line communication and the integration of process-accompanying monitoring systems.

The next step in this development is to have groups of NC machines acting as one optimized flexible machine and controlled as a single unit.

3.3.2. IR tools

From the given definition one of the most important areas for software application by the IR is the programming of the device. Programming could be done manually with the help of mechanical stops or hard-wired control, or it could be done with the help of microprocessor based systems.

Using microprocessor based controllers, programming could be done in the form of teach-in programming where the user moves the IR to the successive wanted positions which the system memorize, or it could be done by a classical programming method similar to that used by general-purpose computers. For this kind of classical programming several languages have been developed (almost every robot manufacturer has one) with some adaptation of existing languages (e.g. Pascal or C). Some of those already existing are also used (e.g. assembler languages).

The actual trends in IR-application software are basically:

- Rational program generation through the utilization of high-capacity computer techniques;

- Reduction of unproductive idle time of the IR;

- Integration into CAD/CAM systems;

- Automatic program generation;

- Self-optimizing IR with the help of sensors (e.g. vision systems).

Special problem-oriented programming languages are designed to minimize the demands of programming using high-level commands or macros, similar to those normally used by a man during assembly, and at the same time to retain all the powerful properties of high-level languages. Different approaches are based on operator/system dialogue with a special operator panel and it can be supplemented by a camera and screen for object identification. This kind of language requires further development in fields such as environment description modelling or decision-making methods.

The current highest level on robot programming is represented by off-line programming languages. They may be seen as the task of technological planners using techniques for the description of manufacturing systems. The aim of these developments is to transfer the programming activities to the technological planner and ensure that the programs thus developed can run in the production process with minimal changes. Graphic simulation when used with a mathematical description of the robot environment and the kinematic of the involved elements, is a tool which can be applied effectively to prevent collisions.

3.3.3. Material handling and transportation tools

This field includes automatic guided vehicles (AGV), automated storage systems and integrated storage and inventory control. The main concept for those kinds of tools are:

- To collect and maintain information on the material flow;

- To answer questions on the location, quantity or status of the materials in the factory;

- To calculate and optimize the material routing.

The objective of such systems is mainly to perform a service for other software packages and transform planned material movements at the model level into material movements at the real world.

3.3.4. CAD tools

Two dimensional CAD systems permit the creation of drawings of both primitive and parametric objects using broken lines, points, circles and ellipses. Provision can be made to include special attributes related to the objects. With these systems it is possible to solve plane geometric tasks, work with texts, with libraries, carry out archiving and transformations such as shift, rotation and affinity.

The world trend is towards systems using UNIX as a base, because it permits simultaneous interactive execution of extensive tasks and also towards three-dimensional systems which permit the execution of calculations and plotting tasks as well as automation of plane and special geometric tasks by means of the volume-elements method.

An important component of CAD software is to handle data base management. In this regard, many complex software systems are being developed on the basis of the user's own CAD software. Such systems tend to be specialized for certain product areas. The systems have the advantage of being compact, but the disadvantage of incompatibility and narrow specialization.

Actually, the main efforts are being done in makir three-dimensional systems faster and cheaper, with special regards to the required hardware.

3.3.5. CAM tools

The CAM systems use construction and technological data to produce order-independent manufacturing documents. Production organization data are also elaborated on the basis of construction and technological requirements to provide order forms on the due date, specifications on material and manufacturing equipment at the proper time, as well as other documents required for the planning and disposition of parts.

The current development efforts are directed towards improving:

- The adaptability of CAM software to various computer and user environments;

- The capacity of software for the handling of operating data; and

- The structure and generation of centralized and distributed data base systems.

In the last few years, the interaction between CAD and CAM software received a lot of attention and there are a lot of products on the market which permit the direct generation of machine programs using design data. This kind of transducer is normally called a post-processor and it also allows the use of mechanical simulation moduls on the CAD specific hardware.

3.3.6. CAPP tools

There are two main approaches to the automation of process planning, the variant and the generative. The variant approach can be defined as the preparation of the process plan through the manipulation of a standard plan or a similar part of the plan. On the other hand, the generative approach is the logical creation of a process plan from information (rules) available in a manufacturing data base with little or no intervention by a planner. They require the use of a set of inferred and/or heuristic rules which, when applied on a factual data base, enable the solving of problems (expert knowledge systems). A combination of the generative and variant approaches may also be found.

The application of CAPP software can be divided into three principal areas:

- Production-process design, working either on the basis of type or group technology or on the principle of multi-level synthesis from elementary standard elements of technological processes.

- Programming of NC-machines using special languages for the technological rationalization of the production process with graphics to speed up the work and for simulation purposes.

- Automated design and technological preparation of the production of special manufacturing facilities, where practically all types of tools are designed by computer.

3.3.7. Data base managing tools

CIM is a concept that relies on a common manufacturing data base for production planners and schedulers, shop-floor workers, accountants, etc., and a clearly structured information system that effectively links all main functions of the factory, i.e. engineering design, manufacturing planning and control, and factory automation.

The data base is a central element within a CIM system. Different types of data (geometric, technological, organizational, etc.) used by different modules to solve given problems must be systematically classified and controlled.

The data base software controls long-term recording, management and handling (local and remote) of all data. Data transfer between the functional modules of the system is performed via the system interfaces. The result is the logic interlinking of communication modules and data files. These system interfaces are of particular importance for integration measures.

The actual trends are concentrated into the relational and object-oriented approach to data base management.

3.3.8. CAP tools

The traditional CAP method is to always calculate a goal schedule. This goal schedule is normally of high complexity and usually arrives at sub-optimal solutions requiring an enormous computational effort. This kind of method produces an inherent limitation in industry, meaning that the goal schedule will only be recalculated if the variation is very big.

Therefore the traditional system normally works at an "adapted" (inferior) level of a sub-optimal solution; this shows the necessity of new P&S structures.

Two types of scheduling may be defined long time scheduling (LTS) and short time scheduling (STS).

Long time scheduling: This kind of scheduling is usually based on the required work which the industry is aware of. This comes from the batch-style systems where the producer fixes the minimum time before an order must be solicited or else he works on stock.

There are a lot of different production planning systems that more or less allow an LTS. But one of the changes CIM must introduce is to drastically reduce the time periods involved. The unit of LTS must be reduced from years and months, to weeks and days.

Short time scheduling: This is the level where a fast reaction is needed when internal or external variables change or when even the model parameters change. The only way to reach the solution quickly is not to use all of the existing information in a centralized way, because the computational efforts will not suffice. In most cases the information that can be taken care of locally is very limited because it is not easy to find out how it affects other areas. A possible solution could be the use of expert systems. These allow a rapid search of an information structure and permit the distinction between fundamental variables that must be sent for a central analysis from those whose influence may be analysed using local heuristic knowledge in order to send an abstracted variable only to the central control. The expert systems also enable the early detection of failure causes (for example finding a degraded robot function, based on the power consumption of a motor), which enables a reduction in the number of errors tending to the ideal zero quality control.

An introductory idea to an STS system could be found in the article "The technology oriented approach to flexible assembly" (published in this Monitor).

3.4. Artificial intelligence

Artificial intelligence may be defined as the study of computer techniques to supplement the intellectual capabilities of humans in order to realize a more effective use of digital computers through improved programming methods. The following may also be said to relate of AI use: the ability of any machine or routine to learn and improve its performance as a result of the repetitive execution of a given activity or search for solutions to a given set of problems.

Conventional data processing techniques and AI techniques are complementary in the manufacturing field and they address different classes of problems. Nowadays it is known that any actual or future manufacturing facility would collapse without a high degree of support from conventional data processing. Possibly in a few years the same will be valid for AI techniques.

The initial purpose of developing a universal mechanism and theories of intelligence for problem solving has been postponed, at least temporarily, in favour of systems that function in narrowly defined areas with very restricted task specific knowledge.

As knowledge processing develops, artificial intelligence may be of help in overcoming some of the difficulties encountered in the organizational area, by building managerial decision support systems (DSS). Therefore the basic processes have to be understood and capabilities and conceptions have to be evaluated.

Many consultants today are being used as an excuse for not taking the responsibility in decision-making. There is a danger that automated systems could be used in the same way if the role of support of the DSS is not well understood. Taking the part of an expert in automation-aided consultations, they can only assist and advise the user in problem solving.

3.5. Expert systems

Professor E. Feigenbaum, a pioneer in the AI field, defines an expert systems as an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. A expert system (ES) basically consists of:

- A knowledge base or knowledge source of domain facts and heuristics associated with the problem;

- An inference procedure or control structure for utilizing the knowledge base in solving the problem; and

- A working memory or global data base for keeping track of the problem status, the input data for the particular problem and the relevant history of what has been done.

Expert systems are designed for automated problem solving in special applications where the applied knowledge of experts in a specific field is transferred to computing systems. Also, expert systems in the form of DSS, would free human experts from their routine jobs and allow them to concentrate on the more difficult ones, while at the same time expanding their expertise. They could also provide the possibility of preserving the know-how of a human expert, making it available at all times.

Based on the fact that knowledge acquisition is very difficult, time-consuming and expensive, the main efforts are directed towards the study and development of various methods for knowledge acquisition, including induction by observation or analogy, discovery by construction and the reading of text from highly specialized sources of knowledge.

In the industrial sector, ES for diagnosis have emerged as the most common area of application. Process control, CAD and CAM comprise a significant percentage of industrial applications.

While some commercial ES offer real-time capabilities, the AI community in general lacks experience with sensor interfacing, data interpretation, real-time control and other manufacturing specific areas. For real-time ES with a large number of rules, current processing speeds may also be too slow. An approach to reducing the model complexity and computational time can be found in the article "The technology approach to flexible assembly" (published in this Monitor).

3.6. Decision support systems

The sequencing/scheduling problem can be solved by searching the mathematical space of possible solutions in the factory, and only when the search space is large enough does a decision support system become important.

An automatic control is not always the most optimal. Automatic control always has boundary conditions, giving it a certain rigidity. For example, let us suppose that an industry receives an express order which exceeds the disposable resources. It is possible that the system is working JIT and so does not have the possibility of including another order in a new schedule. But it is also possible that some factor (i.e. economic or strategic) makes it convenient for the industry to pay the penalities for finishing other works later in order to schedule the new, more profitable, express order. In conjunction with the management, the "frontiers of automatic decision" must be determined, i.e. identifying those boundary conditions which could be changed automatically and those which have to be asked for. The definition of priority levels for job characteristics would be very helpful.

A user-friendly environment is necessary to give the management an easy comparison of alternative possibilities and also give them an easy change of all the parameters that they may change. This allowance established by the system manager permits a hierarchical structure of decisions.

In order to allow a correct analysis of the individual possibilities of the system, it would be helpful to have a simulation module to make an analysis of the utilization of resource possibilities as well as their economics.

Interdisciplinary work to try to combine existing techniques in a novel way and, if needed, to develop new ones, is a necessary prerequisite for a good DSS.

An introduction to this principle can be found in the article "The technology approach to flexible assembly" (published in this Monitor).

PART 4

4. Communication

Each time digital control for a machine or process is installed, a so-called "automation island" is created. During normal operations, the control systems of an industry have to receive a lot of digitized information (starting from the level of sensors up to the level of complete data sheets). This data flow must be multi-directional, providing the whole company (from the senior management through the departments of sales and distribution, handling, warehousing, material purchasing, product design and development, and so on down to the machine operator on the shop floor), with the necessary information and all needed parts, tools and materials, at the appropriate place and at the appropriate time.

4.1. Computer Esperanto

The first approach to a CIM oriented communication systems is intended to normalize factory data communications so that information can be networked rapidly and reliably within a shop floor environment. It tries to make compatible all languages and protocols used for the industry, by using bridges, gates and converters, amalgamating them all into something like "computer Esperanto".

As a result of this approach, a lot of new "computer Esperanto" systems have been developed, but as no official protocol exist, none of them could communicate. Before continuing with the idea of trying to combine all these systems into a "universal normalized computer Esperanto", it is important to point out that such a solution would involve a lot of overheads by turning the system more or less into a batch system and therefore inappropiate for real time communication.

4.2. Standardization

4.2.1. The ISO/OSI model

The idea of establishing a universal communication protocol began to be a reality with the publishing of the Open System Interconnecting (OSI) model by the International Standards Organization (ISO) in 1978.

This ISO-OSI model has been almost universally accepted as a pattern for local area network (LAN) developments in both the factory and the office and so the first steps in the direction of standardization of the communication language have been made.

4.2.2. MAP and TOP

The second step was completed in 1980, when the Institute of Electrical and Electronic Engineers of the USA (IEEE), created the project 802 Committee to start work on LAN standards while the General Motors Technical Center established an internal task force with representatives from seven divisions in order to develop a communications standard enabling communications between devices from different manufacturers. The objectives of this task force were to develop a communications standard from existing standards and procedures for diverse, intelligent devices and to encourage vendors to adopt the standard. The first results were the development of a specification based on the existing ISO-OSI seven-layer model as a framework for many established and emerging networking standards: this development was called Manufacturing Automation Protocol (MAP). At this early stage General Motors recognized the need for other companies to support the MAP specification.

In 1982 General Motors formally adopted MAP as a communication standard for all its plants and requested that equipment suppliers follow the MAP standards for interconnecting. In 1985 the company implemented the first pilot MAP installation at the Detroit-Hamtranck plant, and together with Boeing and their Technical Office Protocol (TOP) they co-sponsored a major demonstration at the Autofact show in Detroit. The resulting MAP/TOP network demonstrated the feasibility of a multivendor, computer integrated manufacturing facility. But a problem appeared at this stage that the Version 2.0 of MAP was not compatible with the Version 1.0 and so a lot of developed products were no longer usable. When the new Version 2.1 appeared and for a second time the upwards compatibility was not guaranteed, some of the participating companies left the project, resulting in some specialized magazines writing articles with titles like "MAP is DEAD".

This problem did not stop the efforts of the MAP/TOP users group, and they prepared a Version 3.0 which gave a new impulse to the standard. At the same time a working group in Europe began to develop the CNMA protocol which differs only by a few points from the MAP/TOP ideas.

A possible conceptual description of MAP would be to say that it is an enabling technology which only specifies standard protocols to facilitate the connection between equipment from many different vendors on a network and without the need for customer developed communications hardware and software. This situation gives the manufacturers a choice of the appropriate manufacturing equipment vendors, without having to be concerned with compatibility.

4.2.2.1. MAP-EPA and MINIMAP

For time-critical communication tasks, two additional standards have been developed: MiniMAP and Enhanced Performance Architecture MAP-EPA. These two standards bypass some of the layers and therefore some important limitations, not only from the compatibility side but also from the technical features (e.g. message size, guaranteed message delivery), are introduced. The idea is to reduce overheads and give a faster performance in situations where speed is critical and full MAP features are not required (e.g. in situations where operations do not need to communicate with a wide variety of other devices).

The MiniMAP standard is not a MAP node because it is not ISO-OSI compatible and can only communicate outside its own sector with a gateway. The intent of this standard is to allow non-compatible equipment to co-exist in a MAP environment at the early stages, but it is expected to be phased out in the future.

4.2.3. The actual situation

The actual situation shows that the MAP/TOP standard proposed by General Motors and Boeing is being accepted by leading United States firms and some European firms such as Siemens. Although not all of the functions of the protocol are defined, it is developing into a de-facto standard for all manufacturing industries. In 1988 IBM gave a new impulse to this standard by announcing a PC-Card and a PS2-Card which allows the PC to communicate at the MAP protocol.

The MAP/TOP Task group standardization work allows a multivendor communication between different hardware elements, but it does not represent a complete solution. A lot of work has to be done at the higher levels, where the application communicates with one another. It is very important to have a normalized communication so that one application software can communicate with another and exchange information at the program level, and not only through a "file transfer management system". Using the idea of the computer Esperanto, the actual state is that the required words have already been determined and also how they will be transmitted: however the information on how to construct a sentence and transmit an idea has not yet been defined.

PART 5

5. CIM and the world

From the middle of this century the demand for mass-produced manufacturing goods began to decline and many manufacturing industries were obliged to produce customized products. The new market demand was for medium to small batch series of products, which mean a flexible production.

With the introduction of the microprocessor, the situation changed considerably and the bulk of interest focused on developments in software and communication aspects. The logical follow-up of the manufacturing process will be the use of computerized tools from the moment of the concept of production according to market information, to its delivery to the customer.

In contrast to traditional automation, the new automation technologies are flexible and applicable to a wide range of machine building operations.

Until now the development of industrial automation was fairly fast and rather chaotic. Automation requires a "system idea", beginning at the single production task and ending with the global concept of the plant layout.

The key to the successful implementation of CIM is to understand relationships between production objectives, technical components and the organizational structure of the factory.

The introduction of CIM issues, like most new developments, was mostly done in such a way that none of the expected results were reached while new problems have arisen.

The fast expansion of the area and the many general information articles representing CIM as "The Panacea", or "The solution to all your problems", or "The factory of the future", and the marketing statements of industries (which always involve the main idea of selling their own products), have developed a lot of "wrong concepts".

Some of these are:

- The concept is CIM and not CIAM (Computer Integrated Automated Manufacturing).

- It would be better and more realistic to refer to CHIM (Computer and Human Integrated Manufacturing) and not to CIM.

- CIM is a concept, its applications are different in each enterprise.

- The first effect in introducing CIM is always an increase in the production cost for a short time.

- Two steps must be taken into account on the introduction of CIM technologies:

  1. The first step must always be a thorough study of the industry's structure and

enterprises. This study must be made from the top downwards, beginning at the management level and ending on the shop floor;

2. The second step should be the acquisition of a decision support software at the management and intermediate levels which will be responsible for the information flow inside the industry, and for support for the medium- and long-term production planning.

Unfortunately, in most cases the first step was the introduction of automation elements at the lower level, without consideration of future development and the need for communicating with a central system or, in cases where this communication exists, without consideration of the compatibility of the different elements. This always leads to very expensive especially developed solutions such as protocol adaptors, post-processors, etc.

5.1. CIM and industrialized countries

Manufacturing as a technology and as an industry is undergoing substantial and significant changes in industrialized countries. These changes must be viewed as both a logical extension of the trends and innovations in manufacturing since the industrial revolution, resulting in a new style of manufacturing operations and a new role for manufacturing as a competitive weapon (especially against developing countries) and an integral component of the business strategy. There are today far-reaching changes taking place in the global marketplace which will result in the requirement for CIM-based flexibility for many enterprises.

5.1.1. CIM-components in industry

The basic CIM-concept of an enterprise is determined by its organizational structure, the product-mix, manufacturing organization and technical presuppositions. Thus no standardized CIM-solution can be developed or analysed. Its degree of realization in an enterprise will be determined by the number of connections between different CIM-levels. Accordingly, two development stages of CIM-systems may be classified:

(a) Implementation of CIM-components: concerning the realization of main components as CAD, CAM, NC-programming or CAQ, most of the investigated small and medium-sized enterprises may be allocated to the first stage of CIM. At their plants CAD, NC-programming and machining centres are realized, while production planning and scheduling systems and CAP are only realized to some extent. As points of mayor effort, the areas of calculation, scheduling, planning of machine capacities and definition of machining sequences may be determined. DNC-systems with direct connections between NC-programming and machine tools are not realized to a degree worth mentioning.

A second CIM-stage differs from the first by the employment of FMCs, automated stores and automated transport systems and also by the extension of planning systems. This planning comprises areas such as job accounting, material management, calculation and work load planning. The coupling of measuring systems with CAD is still a future objective.

(b) Interrelationship of CIM-components: Referring to table 1, some aspects of data relations between CIM-components should be outlined. As far as isolated solutions are concerned, most enterprises have so far only realized the integration of CAD-NC systems. Data transmission from CAD to production planning and scheduling systems is done manually, i.e. data from piece lists, orders or work plans are transmitted to the planning systems by the production engineer. At some enterprises, technology data bases are used, mainly relating to machining data (turning, milling, etc.). By means of the installation of DNC-systems, operational data (machine data, order data or personnel data) can be collected economically. In many cases the integration of these systems is realized via order release, work-load planning and scheduling.

Table 1: Degree of CIM-realizations, based on connections between CIM components*

		Degree
CAD-NC	geometry-data for NC-programming	xxx
CAD-CAPP	geometry data for work plan generation	xx
CAD-CAQ	geometry data for measuring system	x
CAD-CAP	piece list	x
CAPP-NC	tools and technology data	xx
CAPP-CAQ	workplan for integrated test cycles	x
CAPP-CAP	workplan management	xx
CAP-CAM	order-release, availability, capacity	xxx
CAP-CAQ	control data of in-process measuring	x
CAM-NC	DNC: program release and transfer	xx
CAQ-NC	NC-test program for CNC-gauging machine	x

* (F. Liu and A. Mootz, 1988, Federal Republic of Germany).

5.1.2. CIM centres

Contrary to the industry situation, some CIM realizations with a high degree of integration do exist, but these are in most cases confined to prototypes installed at so-called CIM centres. As an example for such an installation, a CIM centre in Sweden is outlined below:

A number of Swedish companies co-operate in this CIM project (called CIMFUTURA). Its aim is to provide the means of linking together information and production systems to create efficient factories. A unique contact network of companies has been developed through co-operation in the CIMFUTURA project. New software has been produced that can handle the difficult interfaces between the various systems. The software is entirely application-oriented and independent of equipment performing the machining, transporting and so on. Testing procedures that bring CIM installations into service by stages have also been developed. CIMFUTURA's first reference installation has been set up at the IBM plant in Sweden.

It has been integrated into the factory flow and manufactured parts for IBM printer feeders. Currently four different parts are being manufactured and information flow has been integrated between orders, planning, design, preparation, manufacturing and delivery.

At the start of the system, material is manually loaded onto pallets which are identified by bar codes. Information from the planning system directs an industrial robot, mounted on an 11-metre track, to load the correct billet into the fixture of a machining centre. After debarring and washing at another station the finished part is transferred to the magazine store. Parts are called-on from the store as required and loaded into an assembly station which incorporates a SCARA-robot (it is also possible for parts to pass directly from machining to assembly, by-passing the store). The sub-assembly is then marked and forwarded to another factory for final assembly.

In this project, design and manufacture are integrated by means of an MRP-type system, based on a relational data base for flexible data access with a simplified adaptation for new information needs. It works with finite capacity loading and order/operation network scheduling. However, an operator can interject into the system with an express order. The system would then be rapidly emptied to make way for the new on-demand schedule.

The CAD-system can produce NC programming functions and simulate robot motions as well as generate a parts list (parametric designs are easily created). The CAM-system of the project is a so-called FME type (Flexibility, Modularity and Economy), which is claimed to be a major advance on normal CAM. It undertakes information processing on the shop floor and is said to be a new engineering philosophy which can electronically describe manufacturing processes such as operator instructions, NC-machining or automated materials handling. It is a toolkit of PC-based program modules for communicating between the cell computer and the manufacturing engineer, design and planning. CIMFUTURA has already created functions, interfaces and communication protocols for a variety of devices, including robots, automated stores and machining centres.

The Swedish CIM-project can be regarded as one of the most integrative approaches in this field. Its most important achievement has been to give other (Swedish) companies the knowledge and motivation to carry through their own projects.

5.2. CIM and developing countries

Considerable gains in efficiency could be obtained by the adoption of contemporary methods for factory organization, planning and scheduling and production control, as well as appropriate subcontracting policy.

In the last few years, the developed countries have been involved in correcting mistakes in the chaotic introduction of automation. Actually, most of the industries in developing countries are still involved in this correction

This is the reason why it is the best moment now to try to learn from these errors and perhaps through technical counselling not only avoid the widening of the technological gap, but reduce it.

The key will be to optimize or change the organizational structure of the industry, trying on the one side to stimulate the introduction of co-operative systems and avoid hierarchical structures and on the other to understand the industry as an entire and complex model, where the bottlenecks and possible deadlocks have to be determined.

5.2.1. Some ideas on the introduction of organizational changes and automation technologies in developing countries

With the above-mentioned concepts in mind, some important elements to be avoided at the preparation phase are listed below, together with some necessary previous studies and project steps (the points outlined here only represent a general direction because every country has to carry out these actions according to their own socio-cultural context):

To avoid:

(a) Do not simplify the problem by a "machine purchase", this will never be a solution but will only present a bigger problem. If one introduces a computer into a chaotic system, one obtains a "computerized chaos". If one automates the production of a bad product, one obtains a fast production of a bad product.

(b) Do not believe that all the increases in productivity are caused by automation - most of them originate from a change in the organizational structure required for the introduction of a flexible automation.

(c) Avoid a confrontation between capital and labour by creating awareness programmes with trade-union leaders, progressive entrepreneurs and governmental politicians.

(d) Avoid bad reactions caused by the use of wrong terminology. Most of the correct expressions such as CIM, automation, structural change, etc., are charged with a negative connotation.

(e) Avoid short-term programs that will bring "spureos" competitiveness based on factors such as low interest loans, tax benefits and so on. The program must be based on technological changes and better working conditions through a better distribution of the resources.

To study:

Analyse the production market in order to select specific areas and try to:

(a) Assure a "cascade" effect in production;

(b) Introduce advances that could act as a pull-up or motor for the industrial system;

(c) Maximize the direct and indirect benefits in local society;

(d) Promote a local technology development through selected imports.

To do:

(a) Encourage bilateral transfer and communication between industries and universities;

(b) Generate industry clubs to support local technology transfer centres which may be implemented as external institutes of the universities;

(c) Develop training programmes at all levels;

(d) Use practical demonstrations of new technologies (video, PC);

(e) Encourage inter-disciplinary teams;

(f) Create a regional information system to enable better contacts between the existing institutions and projects.

Industry club:

Some of the characteristics of such an "industry club" should be:

(a) Independence of the product, i.e. the system must be capable of adapting itself to the manufacture of different types of products with very small modifications;

(b) Independence of the hardware and software being used: The system should be independent from software and hardware elements with which it interacts. This means that at the system level only resources with determined economic and temporary characteristics and not determined elements will exist. This requires a definition of clear interfaces enough simple to be able to communicate with elements from different suppliers without too much extra effort;

(c) Practically demonstrable: The system must be in a position to manufacture some kind of product. After studying the specific needs of the market, a product must be selected which is flexible enough to be easily produced in different types and different variations of this types;

(d) Flexible software: The software must be easily expandable to allow for a step-by-step introduction into the industry. Its design must therefore be modular;

(e) Flexible hardware: The system to be controlled must be easily expandable.

III. CONCLUSIONS

A number of potential fields of conflict exist (mainly socio-cultural ones) in connection with the introduction of modern information technologies. The adoption of CIM could be a major hindrance in building up an economy if it is not based on the special needs and peculiarities of a country. But CIM must not be regarded as the "ingenious solution for production" - this is still a slogan originating in the massive interests of CIM components suppliers, to establish new markets for their products.

Much has been said and written about the "workplace killing" effect of organizational changes and modern automation technologies in industry. In my opinion, the main problem must not only be in how to protect the work place, but more importantly on how to increase the "quality of life".

I like to use a model of mankind's future, showing a man walking along a road scattered with stones he has to avoid. Referring to this model, I interpret the "scientific spirit" as follows: Our responsibility lies in supporting all activities which could help smooth the road so that the man can walk without problems and raise his head.

The developing countries specially have to be active in this process, then this "smoothing procedure" will appear sooner or later all over the world, with or without their help. But if this occurs too fast, without allowing the man to adapt himself to the new environment by making a gradual step-by-step development, he may possibly not be able to walk at all. Moreover, not being prepared for such smoothness, the "developing country man" may only walk with difficulty or even fall down.

Similar to the industrial system, the human system is dynamic and so it is impossible to have a unique, permanently valid description of what this "head raising" means. But this is not really so important, because in "dynamic human systems" the only solution is the continuous search for new solutions to increase the "Productivity of Life" for every single person in the world and not of every single person in the world.

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2. IMPLEMENTING INTEGRATED TECHNOLOGY

1. The potential of computer-integrated manufacturing

There is widespread agreement that advanced computer-based systems have considerable potential for improving manufacturing operations. Rates of diffusion of technologies such as computer-aided design (CAD), flexible manufacturing systems (FMS) and computer-aided production management (CAPM) systems although still slow, are beginning to accelerate as firms recognize the benefits that can be obtained in terms of reduced inventories, shorter lead times, tighter production control, higher quality and overall improved responsiveness to the market. Table 1 which draws on the INSEAD manufacturing future survey of European manufacturing executives indicates the range of typical manufacturing concerns and sets those against the contributions which computer-based technologies can offer (see page 27).

The trend in the application of computer-based systems is towards computer-integrated manufacturing (CIM). That is, the convergence of the various systems associated with different aspects of manufacturing around a single data base and shared communications. Such convergence continues a trend established for some time within the manufacturing process where there has been growing integration, first within and then between tasks. A good example is the case of machine tools, where the various individual operations which used to be carried out by different machines and operators have gradually converged into single sophisticated machining centres and where much of the original craft skill of the operator can be embodied in the control program of a CNC device. Such machines can also be combined with robot manipulators, computer-controlled tool management and parts handling, and linked together with other machines capable of different types of operation, such as cutting, drilling or grinding. This has made it possible to create an integrated manufacturing cell, under some form of direct numerical control (DNC) by computer, and behaving in many ways as a single complex machine. Figure 1 illustrates this convergence (see page 28).

The present stage of convergence is for integration between these operations and the overall production planning and scheduling systems in a flexible manufacturing system. CIM takes the process a step further, by offering potential linkage with all elements of the manufacturing process: design, co-ordination and production. It is also worth noting that the pattern of integration does not need to stop at the boundaries of the firm: linkages between firms - on design, purchasing, distribution, etc. - are also possible via similar computer communication networks. Digital Equipment, for example, in a recent report describing their Clonmel CIM facility in Eire point out that through the use of the company's world-wide computer/communication network the plan can access up to 15,000 computer systems. For a task like design this means that a vast resource of specialized knowledge - distributed geographically throughout the world - can be brought to bear on the problems of a particular plant through a single computer terminal and appropriate communications software. Figure 2 illustrates this extension of integration (see page 28).

2. Problems with computer-integrated manufacturing

From this it appears as if CIM represents a "golden key" with which manufacturers will be able to unlock their productivity and quality problems. And at first glance the diffusion of advanced automation technology appears to support this view, with market growth rates in particular sectors often in excess of 20 per cent per year. But in practice, although there has been considerable publicity and strong market pressure from the supply side, a growing mood of disenchantment with CIM amongst users can be detected, with many reducing their investment intentions and seeking simpler solutions to their manufacturing problems.

A report for the British Institute of Management makes the point that although firms have made investments in AMT these have not always been successful. In one sample of 64 plants which had invested in some form of FMS over two thirds had so far only achieved low payback, whilst others using CAD also felt that they were not getting the best out of them (see table 2 on page 27). Inevitably this has led firms to revise their investment intentions downwards and in particular away from the more complex systems technologies.

Too much should not be read into figures of this kind, but they do demonstrate that moving to integrated configurations of technology raises a number of questions. Despite optimistic market forecasts and the promise of considerable benefits, a growing mood of caution is clearly developing amongst potential users. This emerges in the apparent slow-down in investment, in comments in the trade press and in a growing cynicism about much of the supply industry. It reflects, above all, a disenchantment with AMT's ability to deliver the benefits promised and there are several examples of costly failures or of systems that are only working at a fraction of their true potential.

Even where systems do work it may take several years to learn to use them well enough to exploit the sort of gains the suppliers suggested were possible.

Although there are clearly several major technological problems to be overcome in achieving full integration, it is becoming clear from closer analysis of the experience of firms which have implemented partially integrated solutions (such as CAD/CAM or FMS) that considerable organizational change is also needed in order to achieve the expected benefits. Indeed, in several cases firms report that the majority of benefits achieved derived from these organizational changes rather than the technology in which they had invested.

An illustration of this can be found in the experience of Digital in implementing a major CIM facility in Clonmel, Eire. Although this was planned as a technological innovation and, five years on, is generally regarded as having made a significant contribution to improved performance at the plant across a range of indicators, such as productivity growth, stock turn, inventory reduction, lead time reduction and quality improvement, the plant director views the major benefits as having come from organizational learning. He identifies several key lessons which the company learned including the need to

"... simplify ways of doing things before automating. Most people who get into difficulties with investments do not realize their potential because they try to automate their existing operations."

It is useful to consider how far the organizational response to technology can influence its success or failure. CAPM systems have been around for some time but the experience is still, as indicated above, that many of them are being poorly used. Although such systems appear logical and relatively simple in concept, there have been significant problems in their use since the 1960s when basic MRP (materials requirements planning) systems were first introduced. Early systems suffered from a number of problems which had more to do with organizational and human factors than technological; these included:

- Poor-quality input data (because of lack of commitment or even deliberate action), rendering the information generated by the system ineffective or wrong;

- Poor implementation: many systems remained the province of data-processing experts and were often imposed upon the rest of the organization;

- Lack of commitment from senior management;

- Slow operation (runs could take several hours) and unresponsive to changes;

- Lack of feedback provision to take account of changes in capacity, order levels, lead times, etc.;

- Often seen as the responsibility of one department (usually DP or stock control) rather than an organization-wide responsibility;

- Weak links to other aspects of the production process such as quality control.

As a result, MRP systems worked best for those firms making with little basic variety in product range and with relatively stable patterns of orders and supply. More advanced systems, such as MRPII (manufacturing resource planning) were developed in the late 1970s to maintain the basic principles but also to improve the practicalities. However, although many elements, such as improved feedback and responsiveness to change, are designed into the system, much still depends on the way in which it is implemented within the organizational context.

3. Dimensions of organizational change

The need for some degree of organizational adaptation to get the best out of technology has long been recognized; indeed, it forms the basis of the well-known "experience curve" effect identified during the 1940s. That is, that organizations learn to produce more efficiently as volume and familiarity with the process increases. Such learning involves several components including patterns of work organization, of plant layout, of process routing, plant loading, and so on.

Where this effect applies to a single new machine or a well-established process, it represents something which the firm can assimilate in incremental fashion. However, it can be argued that the novel, highly complex and integrated characteristics of present manufacturing systems make this at best a long learning curve and one which requires considerable adaptation along the above-mentioned dimensions. In particular, the requirement appears to be for much higher levels of integration within the organization, to match those emerging in the technology.

An example of this can be found in the skills area. As industry moves towards more integrated forms of manufacturing so it becomes clear that some new skills will be needed, such as programming, systems analysis and electronics maintenance. In addition to these there is a need for increasing breadth in the portfolio of existing skills and for increased flexibility in their deployment. Finally, there is a need to blend new skills with long-term "tacit" knowledge and experience of the processes involved and the materials being used and worked on.

Combining these elements in response to the demands being posed by increasing technological integration has led to the emergence of new breeds of personnel at a variety of levels in the business. For example, the concept of "manufacturing systems engineers" - that is, engineers with a breadth of knowledge across production systems and technologies rather than the somewhat narrower traditional single-discipline graduates - are increasingly to be found in the United Kingdom, whilst the Federal Republic of Germany's demand for the Wirtschaftsingenieur is growing.

In the design area the traditional draughtsman is being replaced by a composite designer/draughtsman/CAD technician with close links into and experience of the actual manufacturing process. In the maintenance area the multidisciplinary/multi-trade maintenance fitter is becoming essential to support items such as robots which involve several different technologies such as hydraulics, pneumatics, electronics and mechanical engineering.

Multiple skills are an important requirement in this connection, bringing together different engineering disciplines (hardware/software, electronics with applications, manufacturing systems engineering, etc.) and different craft skills (for example, in maintenance). Further, with the decreasing importance and involvement of direct workers, those who remain need to be flexible and highly trained in first-line maintenance, diagnostics, etc., whilst the increasing number of indirect support staff need to be broadly skilled and able to respond in flexible fashion to a wide variety of problems right across an integrated facility.

In essence this is a process of skill convergence to match that of technological convergence in the moves towards the computer integrated factory. Nor is it confined to production-related skills alone. Similar patterns can be found in other application areas, such as in the case of flexible manufacturing systems. In one Scandinavian example that we examined, the level of delegation to the shop floor was such that even purchasing decisions regarding the castings to be machined and the overall relationships with the supplier foundries were handled by the highly skilled system operators. In other cases skilled operators were trained to undertake aspects of the maintenance and quality management and to contribute to the overall scheduling and planning within flexible manufacturing cells.

The move to FMS and other integrated automation technologies also poses questions about organizational structures and particularly about the traditional pattern of functional specialization. For example, there is the need - itself facilitated by moves towards CAD/CAM linkages within firms - for the design and production departments to work closely together to develop products which are suitable for manufacture on an FMS. Such a "design for manufacture" philosophy is of particular significance in the flexible assembly automation field where small modifications to the design of an item can eliminate the need for complex manipulation or operations within an automated system.

In one FMS case that we examined, for example, the redesign of the product led to a reduction in the number of operations (handling and machining, from 47 to 15, with significant implications for cost and lead time savings). As one manager put it,

> "FMS is going to drive the shop, but it is also going to drive the people who design the product and the production engineering ... those parts have got to be made if we are to justify this investment."

The essence of such functional integration is not to eliminate specialist skills but to bring them to bear in a co-ordinated fashion on the problems of designing, producing and selling products: creating a single system view of the process rather than one with many parochial boundaries and little interchange across them. Another good example of this can be found in the area of financial appraisal of FMS, where the integrated and strategic nature of the technology is forcing a major rethink about the traditional role and perspective amongst management accountants.

In the same way that integrating technologies require closer functional integration, so they imply shorter hierarchies and greater vertical integration in the organization's structure. In order to exploit the full benefits of a rapidly responsive and flexible system it is necessary to create a managerial decision-making structure which is closely involved with the shop floor and which has a high degree of delegated autonomy. In this connection it is clear that the pattern of devolution in the use of FMS and in the wider factory context is much more developed in Sweden than in the United Kingdom with few levels in the operational and decision-making hierarchy and with considerable responsibility passed through to the operators themselves.

Integration also has significant implications for the pattern of work organization. With greater reliance on a small group of workers and managers comes the need to look for models of production organization which have less to do with task fragmentation, division of labour and control by external regulatory systems of sanctions and rewards and to evolve alternatives based on small autonomous working groups, with high flexibility and internal control. These moves (which, it should be stressed, were not observed in all the plants visited) can be seen as attempts to move towards a more appropriate form of manufacturing organization to support highly integrated technology. Whereas "traditional" production organization often stresses factors such as functional specialization, division of labour, procedural control and other components called "mechanistic" organization, it can be argued that more "organic" forms that stress integration and more flexible controls will increasingly be required.

4. New forms of organization and management?

The prescription for CIM appears to require the presence of an integrated organization. It is important to recognize that this challenges many of the basic assumptions about the way in which manufacturing is organized and managed. At the time they were working their approach - based on the principles of scientific management - was highly effective. It is instructive to remember, in these days of discussion about lead time reduction and just-in-time production, that Ford's plants were able to produce a complete Model T from raw iron ore in five days.

The basic pattern is summarized in table 3 (see page 27), in which the Ford/Taylor approach is contrasted with the kinds of model which may be more appropriate for supporting CIM.

5. Mechanisms whereby integration can be achieved

As we can see from table 3, CIM cuts across traditionally recognized and accepted functional and hierarchical organizational divides. Thus in order to gain successful results from CIM applications, some corresponding integration of the organization needs to take place. For example, in a recent survey of CAD/CAM users, Voss found that those organizations achieving either business or systems success had undergone some form of organizational integration.

There are a number of potential alternative mechanisms, whereby integration of the technology, strategy and structures of organizations can be achieved. Inevitably there is no one "best" solution for how to integrate an organization, since each one has its own history and set of characteristics that shape the choices and constraints influencing its integration strategy.

Structural reorganization is often seen as an essential key to the success of an integrated system. Various methods for integrating the organizational structure have been developed by both organizational development consultants and academics. One such form of organizational integration is that of matrix management. In a matrix structure, representatives from different functional disciplines are grouped together on a team basis, usually to tackle a specific project. The physical integration of the group, i.e., the combination of different functions such as engineers, designers and marketing people, combined with its geographical integration (usually in the same location), fosters team spirit. That the group is also directed to achieving one agreed goal, appears to pay off in terms of tangible benefits, such as reduced lead times, design for manufacture, etc., although usually a short-term, project-specific approach a matrix structure can be a permanent arrangement, enabling multi-functional teams to work together.

To paint a glowing picture of the matrix management structure, however, may be misleading. Certainly it does have advantages in terms of maximizing communication between functions on specific projects, but it also has drawbacks. One problem often confronted is what might be termed, the "servant of two masters" issue, i.e., where an individual is part of a project team but also part of a functional department. Potential conflict exists, for example, where commitment to a project may be seen to detract from career progression within the functional department. It is therefore essential to ensure clearly defined authority lines and maintenance of professional links, such as through frequent meetings or circulation of professional magazines.

Although a matrix approach can be seen as a way of integrating the organization, the structure means that the original functional labels are maintained. Thus the extent to which radical integration using this form of organization can take place is questionable. It can be argued that matrix management in fact only represents partial integration, whereas integrating technologies are revolutionary and therefore demand more radical functional change, which confronts from the accepted wisdom of set format.

Restructuring the organization in such a radical way may work within a small, organic organization; for larger, relatively mechanistic organizations such a change, or simplification of structure may not be as easy to achieve.

In several cases it had led to the design functions being hived off allowing a simplification of the structure enabling the function to respond more effectively to the demands of the new system. This may also be seen as a way of defusing the political resistance to integration.

The emphasis of these studies is that integrated technologies require a simplification of structure along horizontal levels, i.e., between functions, to enable fuller integration. The need for similar simplification of the organizational structure on the vertical axis is given weight in a study undertaken by Haywood and Bessant of Swedish firms successfully employing FMS. It was noted that the organizational structures in Sweden are considerably flatter than their equivalent in the United Kingdom (3-4 levels in Sweden compared with 6-10 levels in the United Kingdom). Haywood and Bessant assert that this structural organization has significant implications, increasing communication and enabling managers within the organization to have a greater overall knowledge of the business as a whole. This increase in integration appears to reduce the progress-chasing role of middle management, although it represents a potential threat, in some cases by making this level of management redundant.

Research evidence also suggests that organizations may have to undertake changes in organizational roles and skills in order to achieve further integration. In a study currently being undertaken by Winstanley et al. the introduction of new integrative technology for CAD users has implications for the role of the draughtsperson. This task can now be undertaken by a design engineer, but this implies a change from the multi-functional engineer who might operate within a matrix structure, to the multidisciplinary engineer. Thus the engineer, instead of being a development engineer or a designer, may carry out both tasks and perhaps work directly on a CAD system.

Interestingly, Haywood also quotes Swedish managers who suggest that the traditional delineation between blue-collar and white-collar staff may be weakening. Computer-driven companies may cause white-collar staff to become more involved with shop-floor work and conversely the new integrated technologies may cause shop-floor workers to do more indirect work.

"We would rather get the person with the machine or manufacturing knowledge to acquire computer or electronic skills rather than get the academically more qualified to acquire machining knowledge, since it generally takes much longer to acquire machining skills."

We have already indicated the need for higher levels and greater breadth of skills required by organizations implementing CIM applications. For example, Swedish companies adopting FMS increased their graduate level from 3 per cent in 1981 to 10 per cent in 1986. Moreover, these graduates were spread across functions in the organization rather than being in the traditionally accepted positions such as R&D or production engineering.

With the increased use of CNC machines, for example, the emphasis changes for the operator from the manufacturing task to tasks associated with programming and maintaining equipment. Workers without relevant skills can cause expensive downtime and repairs. Integrated technology is requiring employees to move beyond narrow job definitions and functional barriers with the implication that each worker will be responsible for more jobs/machines. The advantages to the organization are that it should increase integration, more people will know what is going on, and delays in the downtime of machinery will be reduced.

Such shifts in the skill profile of firms will require extensive investment in a programme of training and retraining for its employees. However, this shift in training emphasis may prove difficult to achieve in the current climate of retrenchment, where training needs have been increasingly undertaken by consultancies, or have been sold as part of the package for a manufacturer's explanation of how the machine works. In future, internal training may well become a key mechanism for ensuring full organizational integration.

Further integrating strategies for the implementation of the technologies may come from new methods of working such as just-in-time and total quality control. For example there is growing appreciation of the capability of such approaches within CIM systems. Such approaches enable the worker to become more conscious of his/her own work and to understand the whole system of organization and production and his/her own part within it. Thus the system is philosophically a more integrative one, although in practice it needs to be combined with the removal of restrictive practices.

So far we have discussed various strategies which potentially could be employed for increasing integration throughout the organization. In addition we have to consider the ways in which an organization can best introduce new technologies and work practices. The importance of implementation strategies and the subsequent approach taken by management to the installation of CIM systems has been an area of considerable interest. It would appear that where participation in the introduction and implementation of the system has been evident at each stage, issues of organizational change have been anticipated and, consequently, ownership of the system has been spread across the organization allowing for a smooth implementation. This is consistent with the "participative design approach".

It would appear vital when implementing integrated technologies of any form that the organization has an understanding of the process and reasons behind the integration thrust. This understanding will perhaps more readily allow organizations to adapt their structure create an atmosphere of functional change and skill change, which should in turn lead to better use being made of the systems employed by the organization.

6. Conclusion

Technical integration in the form of a CIM system is highly complex. As technology allows tasks to be increasingly combined and functional barriers to be blurred, its success appears to depend upon a correspondingly integrated organization. Therefore, organizations have to undergo an extensive period of organizational learning and adaptation to enable them to exploit the full potential of these systems. Successful organizational implementation strategies appear to involve a recognition of the need to change through an initial simplification of the organization's present operations. In addition there is a change in the skills requirements, with the need for increasing breadth of skills and consequent flexibility of deployment of labour. Such skills changes occur at all levels of the organization from shop-floor through to highly skilled "professional" occupations. The combining of skills and integration of functions in turn can lead to a flatter organizational structure.

Various methods by which this organizational integration can be achieved have been examined. The setting-up of new structural arrangements such as matrix management can be seen to have positive effects. However, it is recognized that treating the issue of structure in isolation is limited in its help in understanding the process of integration. Further research needs to examine the relationships and impact of the different variables that make up the process.

In addition, the question is raised of how far an integrated technological system demands integration in the form of centralization. Paradoxically one of the key features contributing to greater flexibility is the decentralized operation which CIM makes possible. One reconciliation of this apparent contradiction may lie in some form of organizational networking, mirroring the distributed patterns present in modern computer systems.

In the final analysis it is instructive to remind ourselves that technology refers not only to physical equipment and computer software but also to the various organizational components - such as skill, structure and culture - which go to make the "useful arts of manufacture". With this perspective it is easier to see that a successful systems change such as the move to CIM will only be possible if there is simultaneous technological and organizational innovation.

TABLE 1 CIM – a solution for the manufacturing problems of the 1990s?

Main problem issues as seen by senior manufacturing executives in Europe	Potential contributions offered by CIM
Producing to high quality standards	Improvements in overall quality via automated inspection and testing, better production information and more accurate control of processes
High and rising overhead costs	Improvements in production information and shorter lead times, smoother flow less need for supervision and progress chasing
High and rising material costs	Reduces inventories of raw materials, work in progress and finished goods
Introducing new products on schedule	CAD CAM shortens design lead time. Tighter control and flexible manufacturing smooths flow through plant and cuts door to door time
Poor sales forecasts	More responsive system can react quicker to information fluctuations. Longer term integrated systems improve forecasting
Inability to deliver on time	Smoother and more predictable flow through design and possible accurate delivery
Long production lead times	Flexible manufacturing techniques reduce set up times and other interruptions so that products flow smoothly and faster through plant

Source: Derived from INSEAD [1]

TABLE 2 Payoffs from advanced manufacturing technology (base 250 firms)

Technology	Zero to low payoff (%)	Moderate to high payoff (%)
CAD	46	54
CAM	46	54
MRP	19	81
FMS	67	33
Robots	76	24

TABLE 3 The Ford Taylor approach and the CIM approach

Ford Taylor	CIM
Production of large volume, standardized products	Production of small batch, customer specific products
Dedicated production process	Flexible production process
High division between skill levels leading to a *tall* vertical organizational structure	Increasing integration between skill levels, leading to a flatter vertical structure
Individual repetitious task emphasizing horizontal differentiation	Increased integration horizontally, with semi autonomous work groups
Reward structure based on individual performance	Reward structure based on group performance
Tight supervision	Supervisor viewed as a resource

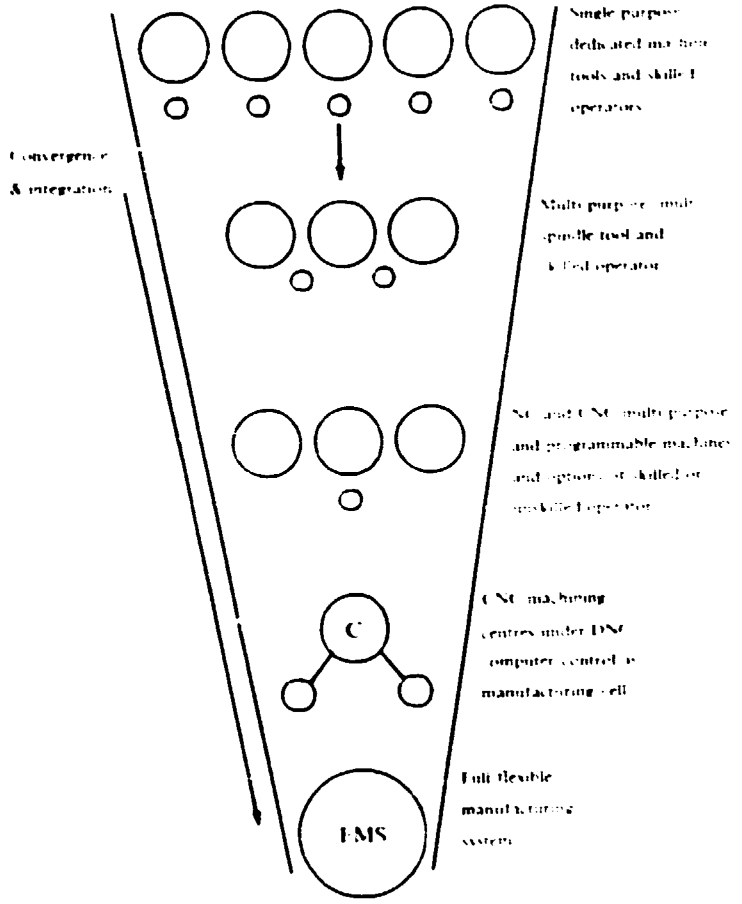

Fig. 1 The trend towards integration in metalworking.

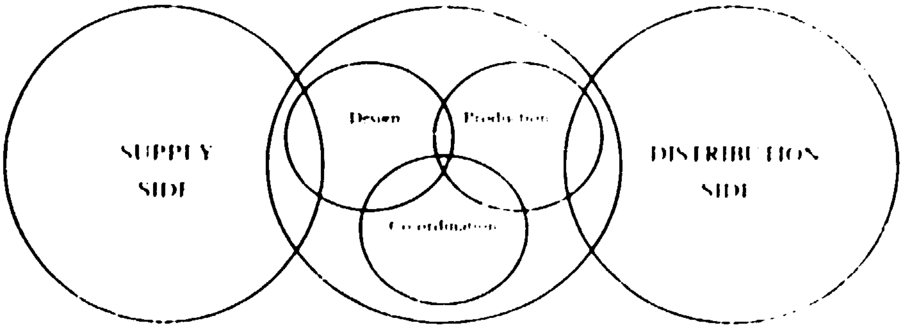

Fig. 2 Integration within and beyond the firm

(Source: Extracted from Technovation, 9 (1989), article written by John Bessant and Joanna Buckingham, Centre for Business Research, Brighton Polytechnic (UK))

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3. THE TECHNOLOGY APPROACH TO FLEXIBLE ASSEMBLY

A flexible assembly cell test bed has been installed at the Austrian Research Centre in Seibersdorf. Work is progressing to solve cell control and cost accounting problems.

(F. Spinadel [also the Technical University of Vienna and Buenos Aires] and E. Fugger, Austrian Research Centre, Seibersdorf)

Today, market requirements demand higher flexibility in the production process, especially assembly. Modern industrial elements like robots, transportation systems and monitoring systems can already be used individually in a highly flexible way. A further increase in the flexibility of these elements does not promise better results, but it is crucial to utilize their high flexibility within a production or assembly system. Better "co-operation" between elements could be the way to increase total flexibility. In the following a method is described indicating how this objective can be reached by changing: the physical configuration of a system/cell and the organization of the work flow. The "Technology Oriented Station" concept (TOS) has been developed for the former, and the "DYnamic Control Optimization" mechanism (DYCO) for the latter.

These new aproaches in the field of flexible assembly are closely related to the EUREKA project EU72 "FAMOS" at the Austrian Research Centre, Seibersdorf, where a pilot assembly cell was built for the practical application and test of TOS-DYCO (figure 1 shows the layout of the cell) (see page 32). To achieve high flexibility for the total assembly cell (not just for the individual units), two main criteria had to be considered:

- The physical configuration of the cell;
- Work-flow organization and control.

Consequently, in this cell, assembly technologies are arranged in single stations which can be operated independently (TOS) and assembly sequences, paths and durations of assembly cycles are controlled on-line and optimized by means of the DYCO mechanism.

Assembly assumes a central position in production if it has to cope with small batch size and rapid changes of product types or variants, with a high degree of efficiency being required at the same time. To achieve this high efficiency, the cell configuration is to be oriented according to the following rules:

- Assembly components are situated in such a way that assembly sequence can be performed independent of their location within the cell;
- The layout of the cell is to allow certain assembly technologies/techniques to be concentrated within its operating range, provided they can be utilized in a flexible way;
- Assembly components are to be operated and controlled independently from other cell-components and are linked by means of a flexible transport system.

The TOS-method was developed according to these rules. It operates in conjunction with a dynamic control system (DYCO) for optimization of the assembly process.

An assembly cell with technology-oriented stations allows the user to manufacture new product variants or new product types not known at the planning stage. The flexibility of the cell permits the rapid adaptation of assembly to specific customer requirements, without having to solve problems of small batch sizes and alterations in product design.

TOS-method

The principal function of the TOS-method is explained with reference to figures 2 and 3 (see page 33). Figure 2 shows, in a simplified way, the arrangement of assembly stations in a "rigid" assembly line. The individual assembly tasks are accomplished in certain predetermined sequences and cycles. The stations are arranged one after another and repeated: where necessary, three screwing stations or three glueing stations. Moreover, the stations have to be planned in a way so that they can be synchronized according to the cycle time. Minor alterations of the product or the process necessitate numerous adjustments of the assembly components.

In contrast to this example, figure 3 shows, also in a simplified way, the function of an assembly cell with technology-oriented stations. Several stations are connected by a flexible transport system. The arrangement of the stations is decisive for the functioning of the cell: stations are "docked" to the transport system in a double ring arrangement. The result is a flexible cell which can assemble different products in independently working stations. The components are conveyed to the stations on part carriers. Certain assembly technologies/techniques (such as glueing or measuring) are concentrated in each station. They are constructed and controlled in such a way as to allow high versatility of the assembly process to cover a wide range of products/variants.

Part carriers are conveyed to a station as frequently as the specific technology installed there is applied to assemble the product. The path within the cell is not predetermined in advance: it depends on parameters like product type, circulation times or external priorities. Every part carrier is equipped with a dot memory storage, so that every part circulating in the cell "carries" all the information required for the assembly process - type, stage of assembly, quality data and so on.

As a result, the TOS-method, supported by the dynamic control optimization system, allows different products to be manufactured simultaneously, starting with a batch-of-one. The sequence of parts fed into the cell is irrelevant to the operation of the assembly process.

Accounting

Cost accounting methods applied today cannot address the special economic questions of flexible assembly, such as how can the structure of a production programme be adapted to existing capacities or bottlenecks, or what additional costs will arise for the production of certain "exotic" parts? To gain optimal results of the assembly planning process, cost accounting instruments have to be applied in a modified way, with respect to costing objectives and computing results.

Based on the overall goal of a company to make profits (and not to save expenditures), the assembly cell as a means of production has to be utilized in a way that permits high profitability. By means of a modified direct costing method, not only the criteria of profitability, but also special requirements of flexible assembly can be taken into account simultaneously. A pre-supposition for its application is the data exchange with the control computer of the cell. The characteristic feature of the planning process (for products to be assembled) is not only the technically optimal utilization of the assembly cell, but also the consideration of cost accounting criteria during this planning process.

In integrating these criteria into TOS-DYCO by means of direct costing, products to be assembled within a certain period are listed hierarchically, according to sales prospects. The resulting objective function is contrasted with the objective function of the DYCO-module (figure 4) (see page 31) with regard to the available capacities of single technology-oriented stations (representing groups of resources) of the cell. The production process is simulated by means of DYCO and, as a result, bottlenecks and free capacities can be determined. In approximating the two objective functions – the technical one of DYCO, which is based on the production possibilities of the assembly cell and the economic one representing market requirements – an optimal grouping of products to be assembled is computed. Direct costing used in this form allows optimization of medium-term planning, whereas DYCO per se is an instrument for short-term planning (controlling) of the assembly process. In this way the assembly cell can be utilized economically, guaranteeing high profitability.

The concept of flexibility is usually associated with the capacity of a production system to adapt correctly and quickly to alternative situations. 1/ Within this concept, two types of flexibility can be distinguished: dynamic flexibility, which determines principally "how quick", and static flexibility, mainly responsible for "correctness". A production system can adapt itself to several product variants by means of the control system. The greater the number of different variants, the greater the chance will be for the system to achieve economic solutions for new products. Thus, flexibility can be regarded as a dimension of different variants co-existing in a production system.

According to control theory, the complexity of a system and thus the time necessary for the computation of a new solution increases exponentially with the number of alternatives. This means that the complexity of a software structure, used for achieving the dynamic optimal solution, increases exponentially with flexibility. Although the system could actually be guided to a dynamic optimal solution with traditional methods (as the system flexibility increases), software control structures become more and more the key to the optimal functioning of the system. Interdisciplinary work trying to combine existing techniques in a new way and, if needed, to develop new ones, is a necessary prerequisite.

DYCO

The requirements for DYCO can be outlined in a short description of the configuration of the user interface for a flexible assembly cell. Referring to figure 5 (see page 34), the DYCO environment can be divided into two "worlds": a real one and a possible one. In the "real world" there exists status information like work-in-process, statistical information, work plans, or networks in use. These are the structures actually used for upstream and downstream resource relationships, product flow, but also including specified information like: "average costs for product type A, variant 2 during the last two days and its relation to planned costs." In the "possible world" different product potentials could be analysed; the system could search its data bases, looking for relevant data. If this search shows that the product is a new one, the feasibility of its production could be tested and a preliminary cost analysis be made to arrive at a decision. If the search shows that product data already exists in the data base, the control and decision support module can start working. This module can also "turn active" if the development and testing phase of a new product is finished.

It is also the task of this module to make a guided intelligent search of possible insertion places for assembly products within an already planned working queue. This analysis shows when the product could be finished and which costs, side-effects and consequences could result. This analysis could give the operator information, like "the required product could be ready in two hours at costs C_a and side-effects E_a, or tomorrow afternoon at costs C_b and side-effects E_b, in one week at costs C_c without any side-effects".

This module will also be used for medium-term planning of assembly by an analysis of a proposed grouping of products, to be assembled within a certain period. Figure 4 shows the integration of a direct costing interface to the DYCO-environment.

At the present development stage, some of the described functions are done manually; thus it could be said that a CHIM (Computer and Human Integrated Manufacturing) structure and not a CIM one was built.

Combined with the sequencing/scheduling problem it is a critical point to determine not just a feasible sequence, but the time-optimal one. 2/ So the main task is the reduction of the time needed to reach an optimal solution in a dynamic way. Two approaches could be used to reduce the computational effort: the reduction of the analytical model complexity, and the use of new mathematical methods.

Reducing model complexity. Given a set of variables and the relations between them, the objective of a mathematical model is to obtain a set of values, which could be defined as solutions or responses. Taking into account the proposed solutions and model reactions, it is possible to recalculate a set of variables that generate a new set of solutions and start the cycle again. Not all variables are influenced by internal changes – some of them are determined in a static or dynamic way by elements external to the model. This basic model satisfies the prerequisite necessary for the so-called automatic state of the system (that is, for a static system, where only process elements change). In any other work-mode of the system, different from the automatic one, it is necessary to create a variation of the model. This variation does not refer to internal variables of the system - they represent the successive temporary states of elements processed in the model - but rather to the parameters which relate the individual variables.

To analyse the influence of degraded system complexity on each of the parameters (and also its temporary variation to permit the return to the automatic state in an optimal way), not only are special algorithms for translating the actual system reality to the mathematical model needed, but also heuristic knowledge and data structures to get the best possible return. This new feedback could be identified as a model feedback.

It will allow only the definition of a basic model of the cell and to represent its variations with the help of flexible parameters, changed in this way. It will permit the use of net-theory without reaching complexity levels which cannot be analysed.

Reducing analysis time. The sequencing/scheduling problem must be solved by searching the space of possible solutions. When the search space is large, a decision support system becomes important. 2/ Recently, many researchers have used a special kind of net for modelling and representing the search space of production systems. Most of these nets are based on the PETRI-concept. PETRI-nets can be regarded as a combination of Pert and state/transition diagrams. Some important features of extended PETRI-nets (EPN) are parallelism, concurrence and sequentiality.

A model of flexible assembly cell could be built using an EPN concept. Referring to figure 4 (see page ..), concentrating on a part of this structure, an intelligent transition can be seen, which combines element-in-work tokens, waiting at place WE, with resource tokens waiting at place R. Matching the element-in-work tokens with the resource token queue is the key to system optimization. It was proposed to solve the matching in "real-time", using a dynamic priority equation and evolution strategy for solving the queueing/matching problem. But this is not sufficient, because the optimization of this priority equation, which could have as much as 50 terms or more in some cases, needs an enormous computational effort.

The Flexible Automation group at the Austrian Research Centre at Seibersdorf is investigating this priority equation using several practical cases and particularly investigating the question, is the optimization of all parameters (each time a change occurs in the system) really needed? It is assumed that only a few terms have to be changed, but in a dynamic way. If this assumption can be verified, a complete analysis of the priority equation will have to be made only once, at the process start, in a static way. The actual part being developed at this project stage is the data structure of a group of assembly products. This is important for the reduction of computational efforts as well as for the re-utilization of knowledge.

The pilot assembly cell (figure 1) installed at the robotics laboratory at Seibersdorf is being used for application, tests and optimization of developments in the field of assembly automation. The cell was configured according to criteria, deduced from the TOS-method. It allows this method to be demonstrated and the dynamic control optimization mechanism to be applied. The following main-components (elements) have been installed in the cell:

- Industrial robots (ASEA IRb 60, Bosch SR 800, Berger Lahr cartesian R.), sensor-controlled gripper, gripper changing devices;
- Vision system (to be installed in 1989/90), measuring units (colour and distance recognition), bar-code readers, dot memory data carriers (8 kB);
- Sensor-controlled press, flexible conveyer system, flexible feeding system, automatic storage (to be installed in 1989/90);
- Host computer and PCs.

The assembly cell consists of four stations, which are in a position to accomplish assembly operations independently, combined with feeding systems. For the transport of assembly parts to and from remote areas, such as pallets and magazines from an automatic storage, automated guided vehicles will be used. Examples of operations, concentrated in technology stations:

- Station 1 - glueing, coating, screwing, pick-and-place;
- Station 2 - sensor-controlled press (pre assembly);
- Station 3 - measuring systems (quality checking).

The product to be assembled, a precision gearbox, is being regarded as a pilot-product, for testing the cell and demonstrating its operation. The product itself is not the central point, the assembly method is. Gearboxes have been chosen because they are particularly suitable for developing new assembly methods and control systems as well as for demonstrating results. The gearbox manufactured at the plant in Seibersdorf is assembled with 18 variants, including the following:

- Gear wheels - 3 transmission ratios,
- Shafts - 3 diameters/ends,
- Bushes - 2 materials,
- Flanges - 2 forms,
- Electromotors - 2 types.

Out of these different components (together with standard parts such as screws, pins, ball-bearings and so on), the different variants of the gearbox can be assembled automatically (independent of batch size and sequence) by applying the method of Technology-Oriented Stations.

The interdisciplinary nature of the project, outlined in this paper, is more or less the key for the development of generally valid solutions. Special knowledge of three disciplines - mechanical engineering, cybernetics and production economy - was brought together and concentrated on the complex field of assembly automation. The results which have been achieved with TOS-DYCO up to now are promising. They should contribute to a better understanding of this field, both for academic research and potential industrial users of the method.

The next project phase will concentrate on implementing the DYCO-mechanism, further integration of sensor-guided systems and the development of a cost accounting model, based on TOS-DYCO.

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An extended version of this paper was presented at the 10th International Conference on Assembly Automation, Kanazawa, Japan, 23-25 October 1989, and is published in the proceedings available from IFS Conferences.

(This article from Assembly Automation, November 1989, was given to us by Prof. P. Spinadel.)

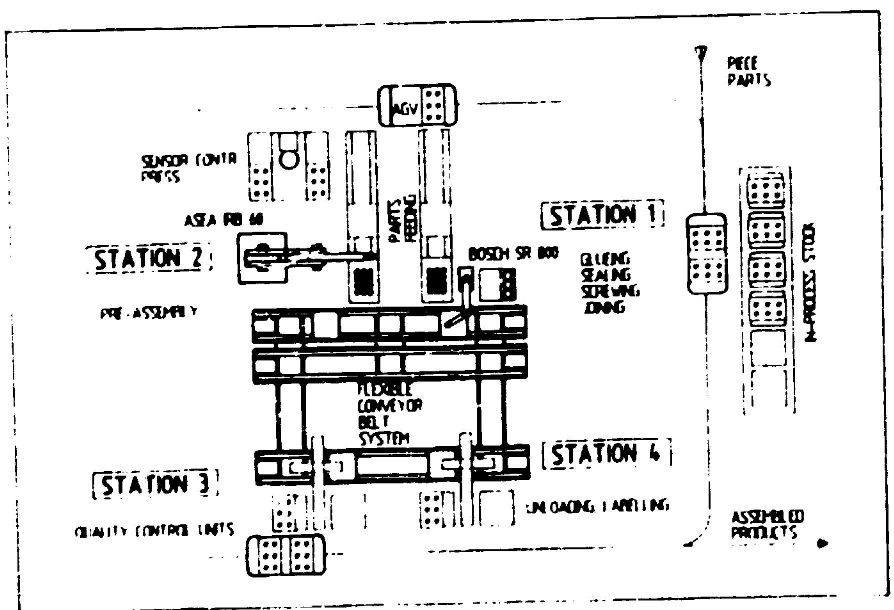

Fig. 1. Layout of assembly cell

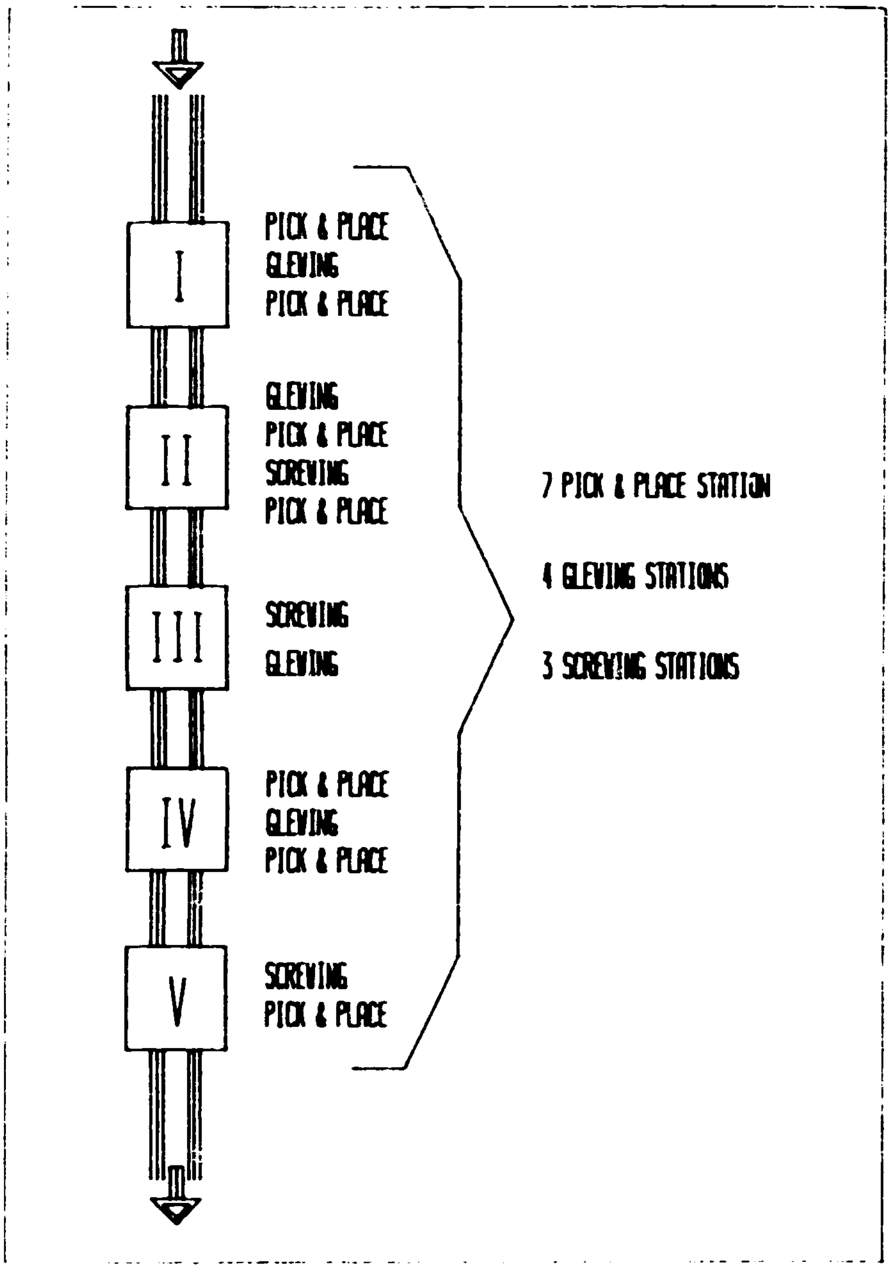

Fig. 2 Rigid assembly structure

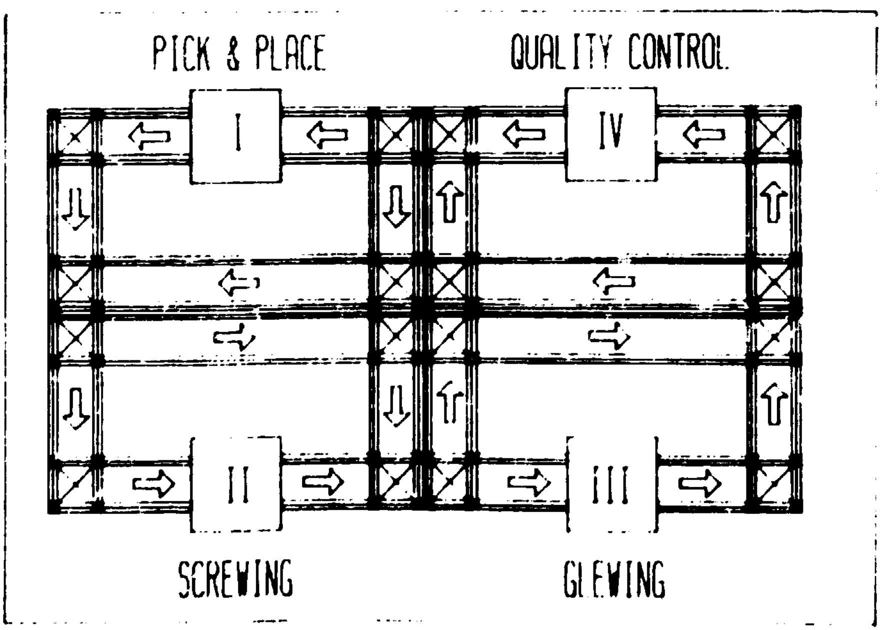

Fig. 3 Technology oriented station structure

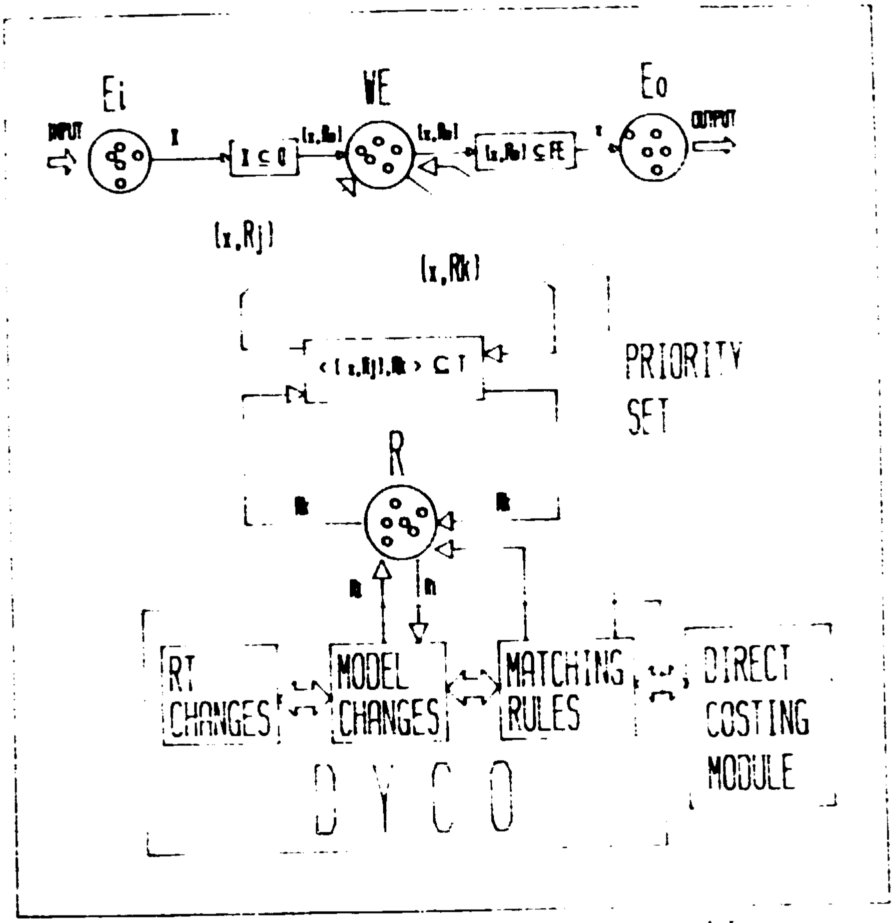

Fig. 4 Comparing the DYCO module with the direct costing module

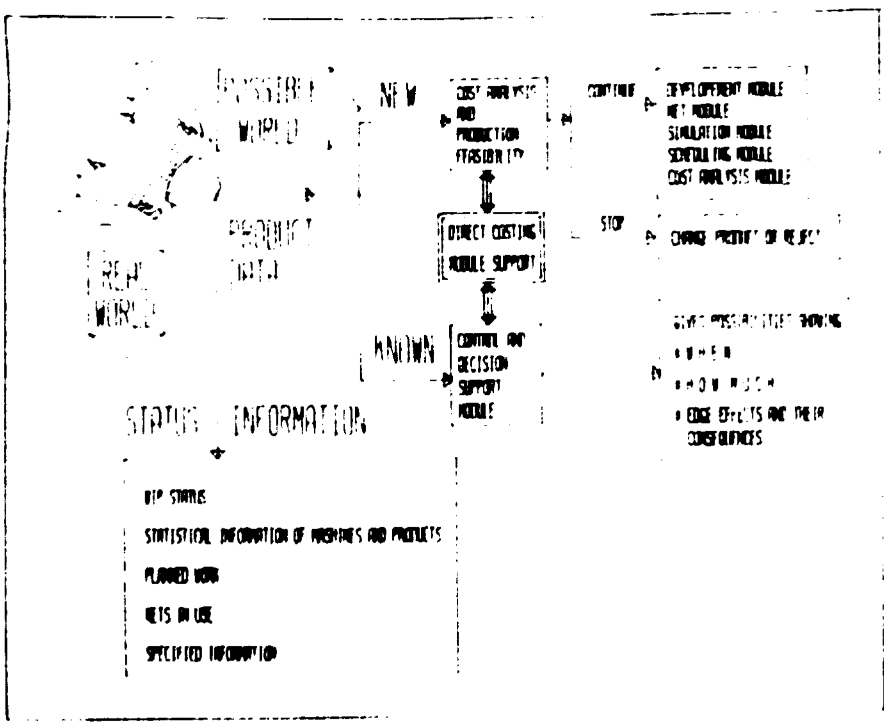

Fig. 5 User's view of the system

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4. COMPUTERS INTEGRATE DESIGN AND PRODUCTION

A recent 242-page study "Computer Integrated Manufacturing: a Strategic Manufacturing Impact Report" from international business and industrial analysts Frost & Sullivan, states that robots, machine vision systems, automatic identification, and other devices must be viewed elements of a broader strategy, that of Computer Integrated Manufacturing (CIM).

It observes that it is not only engineers, but also accountants, who must broaden their view if CIM is to be accurately evaluated and effectively deployed. Traditional cost accounting methods based on internal rates of return tend to inhibit this adoption of new technologies, whereas CIM can lower the cost of inventory, labour, and prototype design and construction, besides reducing plant consumption of energy and raw materials, while eliminating data re-entry and processing duplication. Some of its most important advantages relate to enhanced quality, flexibility of design, product mix and production, speed of new product launching, and one-time delivery.

The above view is largely supported by Bull HN Information Systems, which observes that manufacturers are now settling for a less immediately ambitious but more practical approach to full CIM. Rather than all-in-one solutions, they are now seeking to link their overall business systems including MRP II to specific shop-floor elements such as CNC devices, robots and workcell controllers. Systems to provide these connections, hitherto the "missing link" in manufacturing automation, are now becoming available from leading suppliers, Bull for example having launched its new AMIPS (Advanced Manufacturing Integration Products) library of software packages earlier this year, to offer manufacturers a structured approach to integration.

The increasing adoption of JIT (Just-in-Time) techniques is producing an emphasis on "Supply Chain Management" with manufacturers now looking beyond the bounds of their own production facilities to link key suppliers into the manufacturing information system. This has increased emphasis both on Electronic Data Interchange (EDI) and on those MRP II systems which support JIT.

JIT and MRP II have sometimes been presented as opposing techniques, but leading-edge manufacturers now accept that MRP II should form the basis for JIT provided the MRP II system is able to give "instant updating" of all information, i.e. a Perpetual MRP facility - and one of the options within Bu 's HDRMS package.

Automate now

More and more companies now have both the time and finance to embark on major manufacturing automation projects, Bull believes, with industry no longer so preoccupied with industrial relations and the problems of recession. Instead, it is freer to concentrate on raising standards, and on winning new markets rather than simply holding on to existing ones. This growing interest in automation is accompanied by a more cautious approach to supplier selection with stronger emphasis on visits to reference sites and suppliers' demonstration centres. Although a more calculated and in-depth appraisal which may lengthen the selection process, it produces systems which are a surer fit for the user and provides a strong contribution to his business from day one.

The basis of CIM, namely computer-aided design and computer-aided manufacture (CAD/CAM) has of course now been with us for a long time, but there is still continuing innovation in this area. Typical is the work done by Schlumberger's CAD/CAM Division whose new Bravo3 NC system, the result of years of mathematical research and the company's extensive graphics and machining experience, is claimed to set improved industry standards for ease of learning and usability in complex surface machining.

Engineers have been fed a diet of CAD/CAM for so long, says Schlumberger, that it is tempting to assume that parts designed on computers are always machined easily from a common data base. Attractive examples have even been presented of automatic NC programming which could release companies from their dependence on part programmers, who are often in short supply.

But research shows the reality of the situation is far different - there is still a technology gap between CAD and CAM. Graphic interfaces have superficially changed NC programming software but the underlying software - Automatically Programmed Tool (APT) is nearly 30 years old!

APT systems allow users to develop NC programs for complex surfaces but only one surface at a time; their use is time-consuming and prone to error as the programmer has to continually interact with the system to define surfaces.

Concluding that APT technology with its inherent drawbacks and difficulties in learning and use has reached its limit, Schlumberger decided on a fundamentally different approach.

The result is Bravo NC. The user has to identify all surfaces of the part to be machined, then with this information and the tool description, Bravo NC calculates a surface, or set-up surfaces, called a lattice representing all possible tool positions relative to the part surface. The software then examines the tool path and tool geometry, eliminating all invalid positions from the lattice to reveal all acceptable tool positions on the surface; no tool motion is created until the correct lattice has been calculated.

With the final lattice complete, tool positions are calculated. I ol direction is indicated on the lattice, the soft are calculating the end-points of the projected motion. Any direction can be specified so there are no limitations on computing single motions over single surfaces, and the programmer is no longer confined to cutting along surface flow-lines used in defining the part; even spiral or lace cuts may be calculated.

The lattice being a single item offset from the entire part, multiple surfaces and gouge-checking are no longer a problem, and are handled automatically by the software rather than the programmer.

Enhancements and refinements to existing systems continue to be developed and launched. For example, Mannesmann Information Systems' new CAD package with the 4110 personal workstation, a heavy duty system based on an advanced 386 workstation, incorporates Conception 3D (C3D) which holds 40 per cent of the French micro-CAD market. C3D includes facilities for 2D draughting and design, 3D visualization, data base and parts lists, parametrics and macros. It also allows for data exchange with any other CAD software supporting DEF, DXF or IGES interfaces, with facilities available for connection to any CAD program, to offer a full CAD/CAM solution. Available in both UNIX and MS-DOS versions, a typical single system configuration including an A1 vector plotter will cost around £18,500.

According to MD Phil Claydon the CAD market is polarized, with high-cost systems at one end of the spectrum, and under-powered packages at the other. "C3D is aimed fairly and squarely at the underserved middle sector".

New software is also announced by Matra Datavision (UK), whereby any user of its Euclid IS CAD/CAM system can access and modify designs faster on several workstations at once, greatly shortening lead time from initial design to completion.

The EDMF (Euclid IS Data Management Facilities) module is the first to be developed under the CMP/DOS Co-operative Marketing Programme agreed with Digital Equipment Corporation, to provide for joint development of systems and sale by either party. Euclid IS being DEC's preferred solid-modelling software.

With EDMF, a design can be prepared for validation and the model placed under control of Digital's new EDCS II for sharing with other departments. Engineers at different workstations are automatically notified that designs are ready for scrutiny; modifications are advised by passing the model and instructions back to the design environment.

Widening its PC hardware platform, MCS has launched its ANVIL-5000 version 2.0 which extends the capabilities of the ANVIL 3D CADD and CAM software modules beyond the area of workstations, superminis, mainframes and 80386-based PCs to over 100 different personal computer systems such as IBM, Compaq and RH Machine. The subset has been restructured to integrate easily with most operating systems including MS-DOS, UNIX and VMS to further MCS policy of hardware independence.

The software features a double precision data base with all functions fully integrated, and modules including 3D design and draughting, surface modelling, Omnisolids, Omnifem, 2 1/2D NC machining, 3-axis NC machining, Graphl-IV, the graphics applications programming language, and Extended Graphl-IV. Version 2.0 is available with special interfaces and applications packages for a wide variety of requirements. Also, third party software developers are now writing specialized applications, with MCS support, using Graphl-IV.

Taking on ANVIL for total solutions, Symonds DMS, a division of RH Symonds engineering group, has combined ANVIL-50000 PC 3D software on to its own DMS (Design Manufacturing Systems) to tackle the most complex CAD and CAM problems for NC and DNC applications. The combination covers the entire spectrum from initial design and draughting to final manufacturing, including machine tool programming, and results from a joint MCS/Symonds marketing agreement.

A versatile software package is offered by Renishaw - MAE Ltd., whose newly launched Papillon is a fully integrated CAD/CAM system developed in collaboration with SERVI of France.

Off-line programming

Based on the British company's MAECAM 4, a versatile, flexible and expandable CAM/Inspection package, and SERVI's Conception 3D, a powerful 3D CAD system, Papillon is claimed to be potentially one of the most powerful CAD/CAM tools yet.

A new specialized software program specifically for sheet metal-working equipment accepting IBM-compatible off-line programming, is announced by Copypress Machinery, sole UK agents for Nisshinbo punch presses.

Initially, the job parameters are set out in the program, the first task being to work out the material utilization to determine optimum sheet size required. The program's sheet library of various gauges enables the operator to choose sheet sizes and different materials, and either the operator or the computer can make the selection. The computer then permutates the operations required to achieve the workpiece shape, before calculating the percentage utilization of the sheet selected. The geometry of the job is then computed, the existing tooking is overlaid and the existing machinery entered in the program which is then created by the computer. The most cost-effective method of manufacturing the part is calculated before the job begins.

The software can change variables and can create any shape of tooling to execute any job with optimum efficiency. A violation code warns the operator of going out of range, particularly useful when inspection checks need to be made before each operation.

Claiming a new concept in product support and as an invaluable aid to the design engineer, is Kosma Pneumatic Products, a division of Drallim Controls.

No longer will the designer have to laboriously reproduce each pneumatic part onto his CAD system, says Kosma. Selection from the extensive library of disks will place any of its range of actuators directly onto the basic machine design.

An example of the potential huge savings in time, the company claims, is a typical sub-assembly compiled from three main standard items, namely an AHS single-axis robot unit, a pneumatic slide table, and twin rod cylinder.

By using the CAD library system, this could be accomplished in ten minutes. Drawn line-by-line, says Kosma, it could take up to three days!

Manufacturing companies installing shop-floor data capture systems can now extend the work of the terminals, to link to CNC machines, for example, or to given instantaneous validation of data, says Source Computers. Its latest terminals incorporate new features providing the intelligence and flexibility to adapt to such future trends. And in so doing, the company claims its new 800 Series bridges the gap between the conventional terminal, PLCs and PCs.

They can be programmed in high-level language such as "C" and Pascal, and the programs written on a PC and downloaded to the terminals for ease of updating. They have networking capability, integrated bar-code readers, a full range of RS232 serial communications and digital input and output facilities and other advanced features. At £1,878, their price/performance ratio is said to be twice that of products with comparable facilities and flexibility.

The latest link in the Pathrace CAD/CAM chain is Pathway, a new industrial networking and DNC system. It is aimed at enhancing shop-floor communications and management information.

Linking up

Historically, linking computers with machine tools has created difficulties in terms of overall integration, but Pathrace claims to have overcome the problems with a DNC controller and industrial network. It not only provides effective links between different machine tool controls and CAM terminals but can also provide access into other networks.

It is suitable for a spread of applications from a single machine link-up to systems with 100 controllers. In its most basic form, it comprises a small rugged industrial terminal sited adjacent to the machine control, from which cabling in twisted pair, co-axial or fibre-optic, connects the terminal to the CAM system, enabling DNC with capacity to store and edit long NC programs.

For more comprehensive arrangements, a slightly larger, more intelligent terminal is used but with the same simple installation and operation. In this instance, Pathway forms what is really Distributed Numerical Control, with text and graphics displayed on the shop floor. It also allows tool presetting and the easy integration of other systems. And, although it is less expensive, it can integrate with other powerful networks like Ethernet, SNA and MAP.

Indeed, the UK market for DNC is expected to grow to around £35 million over the next ten years, says David Welsh, general manager of Symonds DMS which markets and supports a range of CAD/CAM and DNC systems - with the DNC business growing by far the fastest. "the growth of DNC is undoubtedly the future in UK manufacturing", he observes, "as many companies have already invested in stand-alone CAD/CAM systems but are frustrated by the automation gap between these and their shop-floor machine tools".

With its "D Net" DNC system, the company is moving fast and already has installations throughout UK manufacturing industry including Rolls-Royce, Lucas Aerospace, and GEC. It is a fully integrated system based on the Ethernet protocol which can be interfaced with all popular CAD/CAM and parts programming systems for direct machine tools control at shop-floor level.

The system focuses on a central PC-based program library and shop-floor-based "network stations" interfaced to the various machine tools controls, a program library allowing machine tool programs to be loaded or down-loaded at will. Continuous monitoring is another facility enabling larger users to monitor their machine shop efficiency and whether machines are actually running.

For RWT also, DNC is the largest growth market and the company is concentrating on shop-floor systems integration from simple, two-way entry-level DNC through to full FMS control packages for groups or cells of machine tools.

Products range from basic systems based on PC equipment through the 6000 series incorporating Machine Data Capture (MDC) and Shop Floor Data Capture (SFDC) up to the full screen system with abilities to transmit graphic files from CAD systems to the shop floor directly. Also in the products inventory and integrated with the DNC is Manufacturing Manager, a finite scheduling software system which can be configured to accept input from any MRP-type system and outputs finite schedules for immediate shop-floor use using real-time data collected from the SFDC systems. User interaction via a graphics interface makes it ideal for today's implementation requirement.

From Tetra Business Systems, Chameleon in Manufacturing is a fully integrated software system incorporating manufacturing control, distribution and accounting modules for operation in a wide diversity of industries. Production modes supported include "make to stock", "assemble to order", and jobbing environments and handling every stage from forecasting and planning, through procurement, production and completion to dispatch and invoicing.

Contemporary features like automatic backflushing, bar-coded electronic data capture and bottleneck analysis ensure the system's capability to operate JIT and Optimized Product Technology techniques as well as the more traditional MRP and Master Production Scheduling.

Claiming to make CIM affordable for companies wishing to implement manufacturing cells with few resources other than their own production engineers, is CIMPICS, a computer-based control system based on a single common data base, from Reflex Manufacturing Systems.

Configurable to suit any level of factory automation, it is claimed to make CIM economically effective no matter what the scale of operations, whether batch or series manufacturing for individual cells or complex machining areas. Unco-ordinated manufacturing processes can result in Work-in-Progress (WIP) items spending considerable time idly waiting, but the Reflex Area/Cell control ensures that all the short-cycle benefits of the JIT approach can be applied within an overall MRP II plan to cut WIP time to a minimum, reducing order completion times and unit costs and yielding a real advantage from more effective use of resources.

Maintenance is a previously somewhat neglected area now being recognized at last as an essential element in the production support area. It therefore needs effective control to obtain the best return on investment, and specially developed for the purpose in MAINPAC from Cruickshank Management Resources.

A menu-driven computerized maintenance management system controlled by multiple level passwords, it incorporates the conventional features of Plant Register, PM Schedules, Work Orders plus Inventory Management, Condition Monitoring, Shutdown Planning and a range of separate utilities embracing downtime analysis to export of data. The user can schedule maintenance based on calendar or runtime. Breakdown, repair and modification work as well as planned maintenance can be controlled, giving a complete picture of the work requirement at any time and a full job history. The Kit List and Plant Spares facility integrates the maintenance aspect with the Inventory Management module, which as well as stock control incorporates purchasing including automatic generation of purchase requisitions.

The Condition Monitoring module for predicting likely breakdowns automatically generates work orders within the maintenance module when an alarm condition is reached. Data can be readily transferred to other associated systems, for example production planning, so that time for maintenance can be allocated within the production plan.

Comprising seven integrated modules which combine to handle all the maintenance requirements for sites as varied as manufacturing plants, petrochemical complexes and electrical and gas utilities, MAXIMO, PSDI's computerized plant and facilities management system, provides preventive and corrective maintenance.

Easy integration

Running on IBVM PCs and compatibles and operating on local area networks (LAN), it includes data base configurations, screen editing, communication utilities, security systems, inventory controls, automatic work order tracking and equipment history. It easily integrates with many other automated applications and software packages.

Comac Systems (Europe) claims to be the first UK company to develop maintenance management systems for PCs.

Its Delta provides for work scheduling and control, resources control, defect analysis and stores and purchasing. It also includes a limitless asset of structure for detailed preventive maintenance planning and a menu-driven report writer that allows instant access to any information in any format. Alpha, designed using the same powerful data base, gives the smaller maintenance function the tools necessary to get started.

Liaisons with other factory floor systems have resulted in interfaces with condition monitoring and plant monitoring systems and hand-held data collection devices.

Several major British companies have invested in the specialist information technology of Osprey's MAP (Maintenance Administration and Planning) package for IBM mid-range equipment. For example, British Aerospace at Filton, one of the first to adopt the system, have found an increase, from 45 per cent to 81 per cent in completed planned maintenance, covering almost 100,000 hours of maintenance in the year, double that previously controlled by the department, with clerical work reduced by 50 per cent.

A computer-based system for monitoring machine tool performance adds little to the cost of a typical installation, says Clover Computer Systems, but has significant impact on its value if one puts a price on the customer's peace of mind! Its Infact system, already proven in applications from tank level monitoring to energy management, is now enhanced with a new version developed specifically for the machine tools sector.

Clover believes it has big potential as a service/maintenance aid through its ability to monitor remotely. The system comprises various essential elements - an IBM AT compatible PC, running modular software and supporting LAN to control microprocessor-based outstations. It is within these that its main intelligence is located, providing a capacity which, it is claimed, has so far only been available on systems dependent on much larger computers.

Its configuration allows response to a breakdown very quickly, says Clover, sometimes even before the user has realized a fault exists! Also its data-log function for analysis of previous readings of analog values, counts and times, can track a sequence of events leading to a breakdown.

Designed for maintenance departments which often have little or no computer expertise, Mercia Software has launched its Mainsaver/DEC and Mainsaver/400 computerized maintenance management systems for the DEC/VAX and IBM AS/400.

Described as truly turnkey solutions in the minicomputer range, they are menu-driven with easy access to a relational data base, require minimum set-up time, and have their own electronic service and support to minimize user staff requirement.

Six basic modules cover Work Order, Budget, Maintenance History, Inventory, Purchase Order and Preventive Maintenance, each operating as part of an integrated system and created to cover specific problems of maintenance in cost reduction, control and cost avoidance. Monthly reports covering statistics, graphs and costs for the maintenance manager are also provided.

Said to be the first system to be developed for all project managers, whether for small, simple projects or large complex ones, PLANTRAC II from Computerline is claimed as the most versatile project management package available. It incorporates over 20 years' experience in project management software across a wide diversity of industries.

Three levels

Three levels of operation - Easyplan, Guide, and Direct - provide a comprehensive operational style to suit a variety of industry conditions, management style and expertise.

Distributorship for Nucleus Software Systems' specialist supervisory control and monitoring software package, Dexterity, has been awarded to Supervisory & Industrial Process Control. Suitable for a range of industrial environments such as process control, automation, materials handling and production line control, Dexterity is a configurable system with proven communications protocol between PLCs and computers from the Commodore/Amiga to DEC/VAX, plus communications with S & IPC's Micon range of process controllers.

A total solution which includes a GA computer, shop-floor data collection terminals and PM Plus software, is General Automation's production monitoring system. Modules include machine monitoring, labour tracking, job tracking, material usage analysis and quality analysis.

A wide range of intelligent machine status terminals for different manufacturing processes are available. Linked either by cabling or fibre-optics, depending on shop-floor conditions, to the GA computer, they enable instant analysis of current job status, shop-floor problems and conditions, facilitating machine allocation planning and job scheduling, and data on production rates, cycle times fault analysis and work-in-progress.

Local area networks (LAN) have already been mentioned, and Softklone UK has just launched its Mirror LAN version of the Mirror III communications package.

With the program, users can access local or remote mainframe or minicomputers, View-data and messaging services, electronic mail and many other on-line services without the need for a dedicated modem and telephone line for each workstation.

As a guide, prices start at £695 for an eight-workstation version, but individual customer requirements can be priced either by port or workstation configuration.

As to the future, Peter Morris, director, Manufacturing Automation Group, Bull HN Information Systems, forecasts that with the demand for Open Systems accelerating, it seems likely to become a universal requirement in the 1990s. Key concepts within this approach will continue to be the OSI model for computer communications and the UNIX operating, two key areas where Bull has a long-standing major commitment.

The need to link MRP II systems to the shop floor will give a further boost to Open Systems over the next five years, with sites such as Cummins Engines, for example where Bull software is linking an IBM host to shop-floor robotics based on Siemens and other suppliers' equipment, becoming common. Also, today's manufacturing systems demand far less in computer skills than those systems of just five years ago, and by the mid-1990s even less data processing expertise will be needed, partly due to intensive work to create user-friendly interfaces by the computer industry, and partly because a greater processing power at all levels will promote/enable user-friendly software without draining processor resources.

Morris also foresees a growing number of manufacturing data base management systems incorporating core functions such as MRP but with many applications, e.g. purchasing, scheduling, hived-off into satellite environments as with Bull's mini-computer-based HDMS MRP II system where the management module runs on a PC linked into the main system but supplies such classic PC facilities as spreadsheet and graphics. He also believes that re-usable code will prove vital in lowering development costs for bespoke projects, and Bull in fact claims a significant advance in this area.

Of similar importance in keeping costs down is the concept of increased modularity, Bull's new AMIPS set of modular packages for example, offering users the ability to build what is, in effect, a bespoke solution.

Increasing resistance to the high cost of customized projects looks set to force such developments over the next five years. (Source: Metalworking Production, November 1989)

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5. HOW TO SUCCEED AT CIM

Less than ten years ago, computers were thought to be the cure-all for lagging production and other shortcomings of US industry. Overseas competition was rapidly eroding our manufacturing superiority, and we were scrambling to regain lost momentum. To reverse this trend and keep the US competitive in a global economy, a few bold industry leaders attempted to meld computer technology with manufacturing technology. The result is a new approach to the factory called computer-integrated manufacturing, or CIM.

Though hardware systems were easy to construct and software systems were easy to write, serious interface problems often arose when the two were integrated and applied to a real plant. Despite difficulties, some companies managed to assemble successful manufacturing cells, while a few others achieved total company-wide CIM. Significant progress has been made over the past two years in the technology and in understanding requirements to achieve successful CIM installations.

What is CIM?

In its broadest interpretation, CIM is a totally new way of doing business that changes the way people work. More than a technology, CIM combines every element of a company's business sytem with the production process in a special way. From order entry, through design and manufacturing, to the shipping dock, the transition from factory automation (islands of automation) to CIM is a change from the control of machines to the manipulation of information and data.

Major goals of CIM include maximizing automated product design and assembly, task reduction, 100 per cent uptime of production machinery and processes, and minimum product handling. Additional goals are reduced inventory, just-in-time shipments, high-quality products, and a paperless factory.

A great deal of experimentation and heavy investments in manpower and facilities have been undertaken by several companies to bring industry to the present state. The 1980s was the decade of discovery and enlightenment, and CIM projects produced a wide range of results. Some manufacturers achieved large cost reductions and higher profits and throughput, while others got little improvement, or worse, lost money.

In many cases, successful companies enjoyed benefits that exceeded initial goals. For example, experts report that product lead times frequently dropped by nearly 50 per cent, product delivery improved from 50 to 90 per cent, and inventories shrank more than 40 per cent.

The difference between success and failure (or modest benefit) did not depend on company size and resources, but on the approach taken to plan and implement CIM. Over time, several key factors and guidelines have evolved that must be observed when considering a CIM installation.

For a truly successful integrated CIM system, one vendor cannot do the entire job. A profitable CIM installation requires a team of vendors, each expert in some area such as controls, system integration, computers, and third-party application software. All vendors need to work together to make the customer successful.

Sometimes an outside company will assemble the team and assume total responsibility for the installation. This takes pressure off the customer to ensure that the four or five different vendors are interfacing without problems. Finger-pointing is eliminated if one or more of the vendors do not get their part in mesh. The team works together under the group leader for the benefit of the customer.

Setting up a CIM system

Experts claim at least four major steps are involved in the strategic planning process to install CIM. Such planning is no small job and must be done by top management. Management must realistically address major aspects of the business such as product cost, margin, quality, size of product family, and similar issues.

The first step requires establishing long-term goals. Heavy investment is needed in the technology to carry off a CIM program. Return on investment (ROI) computed from short-term goals cannot be justified in traditional ways as was done with machines. Long-term goals are essential for some companies just to ensure they will remain in business and be competitive over the next five to ten years.

The second step requires an action plan. Both short- and long-term goals are managed over a time frame that will not seriously disrupt established day-to-day business. The people needed to help create the functional specification that determines how the plant is run can be reassigned within the company, or outside consultants can be used. It is frequently difficult to reassign personnel to the planning phase (or even implementation phase) when they are needed to run the daily business. Thus, consultants can be used with the added benefit that they may be more objective in carrying out the tasks than the full-time employees.

The third step involves selecting the data system architecture. One of the most important elements of CIM is the system's ability to collect and distribute information and data through the entire company. A completely synchronized communications system depends on standard rules to ensure compatibility among the various automated operations, and hardware from different vendors. An example of such a standard is the Manufacturing Automation Protocol (MAP).

The fourth step is to inform the entire technical and management staff of the strategic plan. Their commitment and support are essential if the plan is to succeed.

Task levels

CIM can be viewed as the integration of several levels of activity taking place in a single plant. Each level provides a unique function that in some way depends on another level.

There are many ways to describe the different levels and the relationships among them. Allen-Bradley, for example, uses a systems approach that combines five operating levels into a single, seamless automation system. A standard communication network ties all levels together, from the mainframe computer to the lowest level controller at the factory floor.

The highest level in the hierarchy is the plant level. Its function is to handle overall strategic planning and execution of the plans using the mainframe computer. Two-way broadband communications link the mainframe with all lower levels using internationally accepted standards such as MAP.

Next is the centre level where integration takes place between industrial controls and management computers. Here, production is scheduled, and management is provided with information from lower levels, such as cell controllers. Management computers also monitor and supervise lower levels, analyse data, and report to higher level computers.

The cell or supervisory level connects data processing with plant-floor control. Again, with the help of computers, production flow is co-ordinated among the various stations. Hardware at this level includes cell-control systems, programmable logic controllers, graphics systems, and digital numerical-control (DNC) systems.

Fourth is the station level where computers continuously monitor the machinery/process level and change outputs according to commands from higher levels. Station-level devices control and monitor production while reporting to the next level. Programmable controllers, vision systems, intelligent motion controllers, and drive systems are among the components found here.

The fifth level, the machinery/process level, is where the end product is actually made. Sensors such as limit switches, pressure and temperature controls, and encoders respond to upper level commands. Logic controls and indicators include pushbuttons, modular automation controllers, and intelligent panel systems.

Elements of the plan

Experts observe that a profitable CIM system is comprised of at least five major ingredients: people, information, processes, machinery, and computers. The order does not necessarily imply rank, nor is the list universally accepted. And each of the major elements contains subsets that are recognized in one form or another as tasks or functions in the organization.

People: Most experts agree that the most important element in making CIM work is the uncompromising involvement and commitment of top management. This is essential to provide new paths between departments, cut unnecessary paper work, expedite tasks, approve budgets, and reassign personnel. These managers are responsible and accountable for the entire project.

A task force with a strong leader is also needed. This is a group of people who are single-mindedly dedicated to the CIM project. They are drawn from within the organization and are skilled in the disciplines needed to assist the team of vendors. It is important that these people remain separated from the mainstream of everyday problems, even if it requires moving their office or workplace to a new location.

Information: The next element, information, is the key resource in the automated factory, ranging from input/output (I/O) signals to complete schedules and process plans. This information also includes the traditional management information system (MIS) and the data base management system (DBMS).

MIS and DBMS should be made available to all functional departments within the company. Exceptions, of course, are certain personnel records and payroll data that can be easily restricted to those with a need to know. Setting guidelines and providing means to integrate departments, gradually at first, allow easy transition to integration of machines and computers. The entire system can then be networked with electronic data highways to provide real-time information to any department that requires it.

Processes: A CIM manufacturing environment contains four key functional entities that feed the production process: computer-aided design drafting (CADD), computer-aided manufacturing (CAM), material review procedures (MRP), and data base management systems. The way these technologies are combined, however, is unique to the company and depends on both the product and the volume. For example, a manufacturer of printed-circuit boards will have a different configuration than a company that manufactures gear pumps.

A wide variety of CAD packages is available today. The job of selecting the right one requires a careful analysis of individual needs. CAD software prices range from several hundred dollars to $1 million, and vary just as much in capability. Some CAD packages, for example, have special features and other programs such as finite-element analysis that make them a powerful tool.

CAD systems are not necessarily faster than pencil and paper, but their value lies more in forcing the designer to adhere to a set of standards. The standards are usually part of the data base and free the designer from always starting with a blank sheet of paper, often spending time drawing a nonstandard part that must be reworked. Perhaps the most important feature is being able to download drawings to the CIM system for manufacturing without the need for paper at all.

MRP software is available in standard packages, or it can be custom designed for an operation. For an MRP system to be successful in a CIM installation, it must first be successful in the present business. If material flow is a bottleneck now, a computer will not straighten it out or handle it any better.

The factory floor must be thoughtfully organized, standard procedures must be followed by everyone, and the data base must be up to date. Though this may sound obvious, these basic requisites are overlooked or ignored all too frequently in factories that have grown in modular fashion over the years. Manufacturing processes must be completely reliable in the way they are done manually before they can be automated.

Almost the same can be said of the DBMS. Some DBMSs have been useful while others have caused additional expense. The data base must contain reliable and accurate data. Information and data must be immediately available to the user, and they must be continuously and automatically on line for the CIM system.

The CAM system must be flexible because demands, products, and resources will change, and product life cycles will shorten. All these needs must quickly adapt to the manufacturing system.

The amount of flexibility depends on the nature of the manufactured product. For example, a line set up to manufacture as many as 375 different printed-circuit boards with an average lot size of 25 will be different from one that produces 10,000 parts of only three different configurations. However, both lines need flexibility.

Machinery: Analysts have found that a workpiece spends only about 5 per cent of its production time in a machine tool. Also, most machine tools are used only about 6 per cent of the time. Furthermore, 95 per cent of production time is spent just moving parts and raw material through the factory and waiting. Thus, there is great incentive to increase machine uptime. Experience has shown that an integrated system that ties into the MIS can increase machine uptime, reduce inventory to nearly zero, and meet just-in-time manufacturing needs simultaneously.

Computer: Computers used in a CIM installation are placed at all levels of the manufacturing operation. Embedded microprocessors are found at the factory level in intelligent drives. PLCs are used at the station level, and PC systems are managed at the cell or supervisory level. The mainframe computer at the centre level integrates planning and scheduling from the plant level with information and data from control and management computers. However, intelligent controls, PLCs, and PCs of various complexities can be found at almost all of the lower three levels.

These computers monitor processes and trends, manage alarms and data, and generate reports. Process variables are monitored continuously, compared to set-points, and set off alarms if limits are exceeded. Application programs make appropriate adjustments, or alert operators or maintenance to correct malfunctions. (Source: Machine Design, 26 October 1989)

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6. RESEARCH AND DEVELOPMENT

Implications for developing countries

CIM technology offers a powerful weapon for tackling the range of challenges facing manufacturers. Firms in developing countries (and in many developed countries) have to overcome significant difficulties in moving away from discrete applications of programmable automation and towards integrated solutions. These include problems of high cost, lack of skills, lack of suitable technology (or, often, suitably configured and packaged technology) and a supply market that is still maturing.

For this reason, it is argued that firms with limited resources and experience - such as are likely to be found in developing countries - should concentrate at the technological level on well-proven programmable automation applications (such as CNC machinery, low-cost computer-aided design, low-cost production management aids and basic microprocessor controls for process operations) and use these to enhance flexibility, quality and productivity.

In some cases, the technologies will prove important in removing several production bottlenecks, in saving scarce natural and energy resources and in making up for specific skills shortages. In the long term, it is likely to prove essential that firms in a wide range of developing countries adopt some of the technologies. First, the technologies would help firms advance along the learning curve. Second, the technologies would help develop local capabilities in determining the most appropriate applications, thus contributing towards the development of national technological capabilities.

The adoption of such technologies may, however, carry social costs. Job control, job boundaries, skill requirements and employment levels are altered. Adoption of technology in any context must take into account both the market requirements and the social costs.

At the same time, attention should be paid to the range of organizational innovations which may be more appropriate to the constrained circumstances of many developing country manufacturers. The contribution of such innovations - which require primarily investment in training and reorganization rather than in new technology - can be significant, especially in dealing with some of the fundamental problems confronting developing country manufacturers. The following table indicates how just-in-time and total quality control approaches might address many of these problems.

Table 1. Potential contribution of organizational innovation

Problem	Just-in-Time and Total Quality Control Improvements
Under-utilization of workers and equipment	Multi-function workers take responsibility for several machines and move to where the work is. When demand is slack, workers can carry out maintenance or quality improvement projects.
Inferior quality	TQC programmes aim to improve all aspects of quality. The low inventories in JIT production mean that quality becomes visible and problems are picked up at an early stage.
Unreliable and long times	Multi-function workers and short set-up times smooth flow and reduce lead times. TQC means fewer stoppages for quality-related problems.
High scrap rates	TQC and working in small batches minimize scrap production.
Poor and inadequate maintenance	Multi-function workers include maintenance as part of their task. Planning allows for some production time to be spent on preventive maintenance.
Shortages of raw materials	Scrap minimization helps conserve these.
Shortages of skilled workers	Simpler machinery, quality and production management reduce demand for high-level skills. In addition, multi-function workers will acquire different skills through training.
Lack of appropriate supervision	Less supervision is required with smoother flow and smaller batches. In addition, responsibility for production management, quality, etc. is devolved to multi-function workers.
Poor quality control	Small batches expose quality problems; TQC tackles all aspects of these problems.
Low productivity	Better use of resources (space, inventory, labour, etc.) together with stable or higher output and less scrap, results in higher productivity.

The key then here is that in each area of manufacturing activity there is now a range of choice of improvement opportunities. These range from predominantly organizational changes - where the investment is in human capital, via training and support - to different levels of automation and computer support.

For example, an activity like maintenance can be improved by:

(a) Reorganization of production and training of individual operators to carry out basic preventive maintenance (as in the just-in-time approach).

(b) Investments in maintenance craft training to develop and augment skills.

(c) Use of a simple computer system (PC-based) to improve maintenance record-keeping and support a targetted preventive maintenance programme.

(d) Install computer-based monitoring equipment to record information about machinery status, performance and utilization to improve the maintenance data base.

(e) Integrate real-time condition monitoring of key parameters (such as tool wear) with machine and process control systems. Implicit in this approach is a gradual increase in cost, complexity and integration but with a corresponding increase in the level of control over the activity.

Similar choices exist, for example, in energy management. Here the stages might include:

(a) Use of simple microelectronics-based monitoring equipment to record energy consumption on various items of plant and equipment.

(b) Use of computer control systems to respond more accurately to varying energy demand and optimize their use through accurate and fast control of plant and equipment.

(c) Distribution of monitoring system across the entire manufacturing facilities, to provide a total picture of energy consumption. Use of computer-based analysis can calculate where loads can be more evenly balanced, allowing overall reductions in costs.

(d) Integrated energy management systems which use a central computer linked to such a monitoring and analysis network and which calculate control instructions for individual plant controllers so as to optimize energy use.

Once again, the pattern is of a step-by-step approach to the problem using a combination of hardware, software and organizational change - in this case, in the way information is collected and used.

The same approach can be applied throughout the manufacturing facilities and in all areas. For example:

(a) In machining, where the progression might be from retro-fitting microelectronic controls to existing machines, then investment in CNC, then into linked DNC systems and finally flexible manufacturing and robotics.

(b) In process control, where it might involve retro-fitting electronic monitoring, then retro-fitted controls on key parameters, then new plant with integrated monitoring and control loops and finally integrated network control across the entire facilities.

(c) In production management, where basic reorganization and rethinking could be followed by information support systems based on low-cost computers (for example, in stock control) and leading gradually to integrated modular systems such as MRP.

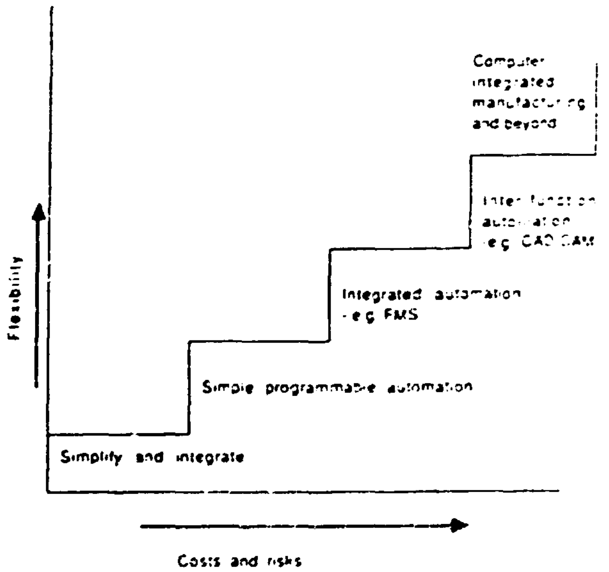
In each case the principle is one of step-by-step progress within an overall strategic framework. Each increment of change is important not only in providing direct benefits but in establishing the foundations (organizational learning, information availability, skills and experience, etc.) for the next.

This is not to suggest that developing countries should not be aiming for full CIM in their strategic planning. Rather, such strategies should be based on an incremental progression from organizational integration with relatively little emphasis on technology, towards more advanced and integrated technological solutions. The degree of CIM required will depend upon the markets in which the firm is attempting to sell, the competitive pressures and the trade-off with factor prices and social costs.

This prescription is similar to that advocated in the industrial countries. The message of "simplify, integrate, then computer-integrate" retains its validity although it might be slightly altered to "simplify, integrate then, if necessary or if advantageous - computer-integrate". The advice given by early users of advanced and integrated systems, stressing evolution rather than revolution, certainly has much to commend it.

This recommendation is borne out in the following figure which derives from the experience gained in implementing many advanced and integrated manufacturing technologies. It illustrates that the degree of risk, cost and possibility of failure increases considerably as firms move towards integrated configuration. The message is again to adopt an incremental approach, building upon organizational improvements and proven discrete applications of programmable automation and gradually building towards full CIM. One advantage of such an approach, if successful, is that the savings generated by each stage in the programme can be used to fund the investments necessary in the next.

Figure 1. Stepwise approach to advanced integrated manufacturing



(Extracted from a UNIDO document [IPCT.70, 13 October 1988] "Integrated Manufacturing" written by John Bessant and Howard Rush from the Centre for Business Research, Brighton Business School, UK)

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UNIDO report

Benefits of CIM

At first sight, the experience of early users of even partially integrated systems - islands of CIM - appear to confirm the promise of substantial benefits.

Consider the following examples:

(a) In research on flexible manufacturing systems (combining production and co-ordination spheres in the metalworking engineering sector), a study of more than 50 cases covering a wide size range highlight major benefits for all users, as Table 1 indicates.

Table 1. Benefits of FMS use by company size

Size of firm (No. of employees)	Lead time	Work-in progress (WIP)	Machine utilization
	(Percentage)		
1-500	-66	-66	+45
501-1,000	-76	-63	+50
1,000+	-86	-70	+55
Average	-74	-68	+52

(b) In the Rolls-Royce Advanced Integrated Manufacturing System (AIMS) project for the manufacture of turbine blades, benefits included a reduction in lead time from 26 weeks to 6, a reduction in overall inventory of £4.6 million and an increase in labour productivity. The whole system cost £4 million and was paid for out of the inventory savings achieved in the first year of operation.

(c) One large manufacturer of men's shirts in the United States reported total savings of more than $10 million in seven years as a result of introducing CAD/CAM for grading, marking and cutting. Nearly a third of these savings came from a reduction in direct labour, another third was a result of the increased utilization of piece goods and the remaining third came from a combination of reductions in indirect labour, transportation, idle space utilization and various supply items. In general, it was found that firms in the clothing industry that had introduced CAD/CAM experienced between 25 and 40 per cent direct labour reduction, 1-2 per cent savings on fabric, 90 per cent reduction in training time and throughput savings of 50 per cent. Significant downstream savings in assembly time were also reported as a result of more accurate cutting.

It is also important to recognize that other benefits accrue from investments in AMT which may be intangible but which still make an important contribution to competitiveness. For one user of a large integrated system, these included:

(a) Improved control and reduced disruption upstream and downstream of the FMS;

(b) Ability to react quickly to required modifications or product changes;

(c) Ability to handle pre-production (R and D) batches under production conditions;

(d) Improved control over materials handling;

(e) Improved company image;

(f) Enabled introduction of multi-skilled working.

However, a number of problems make these benefits difficult to achieve and their incidence rises with the level of integration attempted. As has been seen, this pushes firms towards strategies looking towards investments in discrete rather than integrated systems, at least in the short term. A recent report for the British Institute of Management makes the point that although firms have made investments in AMT, these have not always been successful. In one sample of 64 plants that had invested in some form of FMS, more than two thirds had so far only achieved low payback, while others using CAD also felt that they were not getting the best out of them. Table 2 presents some of the data from this study.

Table 2. Payoffs from advanced manufacturing technology (Base: 250 firms)

Technology	Zero to low payoff	Moderate to high
	(Percentage)	
CAD	46	54
CAM	46	54
MRP	19	81
FMS	67	33
Robots	76	24

(Source: British Institute of Management, Cranfield, 1986)

Inevitably, this has led firms to revise their investment intentions downwards and away from the more complex systems technologies. Too much should not be read into figures of this kind, but they do demonstrate that moving to integrated configurations of technology raises a number of questions. Despite optimistic market forecasts and the promise of considerable benefits, a growing mood of caution is clearly developing among potential users. This emerges in the apparent slowdown in investment, in comments in the trade press and in a growing cynicism about much of the supply industry. It reflects, above all, a disenchantment with AMT's ability to deliver the benefits promised. There are several examples of costly failures and of systems working at a fraction of their true potential.

Although firms would rather not publicize their failures, it is instructive to consider them since they confirm the view that realizing the potential benefits offered by advanced automation is not always a simple matter of making the decision to invest.

Examples of major projects gone wrong are:

(a) The GM Saturn project, where performance expectations have been dramatically revised downwards despite massive investment in technologies and the acquisition of a key systems house to provide the necessary software support;

(b) The Computer-Aided Production Management facilities of the bicycle manufacturer TI-Raleigh, where the changes in computer control systems not only failed to produce improvements but caused a serious loss of production efficiency.

Even where systems do work, it may take several years to learn to use them well enough to exploit the sort of gains the suppliers suggested were possible. For example, in research on CAD, it was found that it took firms an average of two years to achieve "best practice" productivity gains. In another study on 44 robotics projects, half were abandoned before completion. A study of CAPM in the UK pointed out that "even advanced CAPM users have difficulty in understanding how best to use the numerous CAPM control variables (especially in combination) ... thus, they are not getting full benefit from CAPM systems".

These appear to be symptoms of a negative reaction to the massive injection of AMT, which was supposed to make the manufacturing "patient" better. One of the most significant points now beginning to emerge is that technology alone will not solve many of the fundamental problems present in factories. It is argued strongly that there is no point in putting in sophisticated computer-based systems into factories that still operate inefficiently. As one interviewee on CAPM put it, "When you put a computer into a chaotic factory the only thing you get is computerized chaos!"

To add to this criticism, the evidence from those firms that have implemented organizational innovations such as Just-in-Time has been that they not only improve performance in areas like inventory reduction and quality management but they also help reorganize and simplify the overall operation. Careful analysis of the root problems and the key areas for improvement have shifted attention away from traditional targets like direct labour costs towards materials management and overhead reduction. It is argued - by users and consultants alike - that on the back of such simplification and organizational improvement, advanced technology stands a much better chance of succeeding.

An illustration of this can be found in the experience of the Digital Equipment Corporation in implementing a major CIM facility in Clonmel, Ireland. Although this was planned as a technological innovation and, five years on, is generally regarded as having made a significant contribution to improved performance at the plant across a range of indicators (such as productivity growth, stock turn, inventory reductions, lead time reductions and quality improvement), the plant director views the major benefits as having come from organizational learning. He identifies several key lessons which the company learned including the need to "simplify before automating. Most people who get into difficulties with investments that do not realize their potential do so because they try to automate their existing operations. Information technology and automation permit new and simpler ways of doing things". (Extracted from a UNIDO document [IPCT.70, 13 October 1988] "Integrated Manufacturing" written by John Bessont and Howard Rush from the Centre for Business Research, Brighton Business School, U.K.)

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ESPRIT's news on CIM

ESPRIT (European Strategic Progress for Research and Development in Information Technology), the largest research and development programme sponsored by the European Community, has achieved a reasonable degree of success in its first five years. ESPRIT II, which follows immediately, will place more emphasis on the development aspect in order to help the industry get products for the market in the 1990s. The funding for ESPRIT II is 3.2 billion ECU for the five years - a little more than double that for ESPRIT I. The programme is likely to achieve significant results.

One of the main areas of concentration for ESPRIT II is summarized below:

Computer integrated manufacturing (CIM)

CIM is a potentially large market area for IT not yet dominated by overseas suppliers. CIM represents a challenging and complex test bed for IT in that systems must operate in real time, cope with hostile environments, and operate for long periods with minimal manning.

Activities include advance design and modelling techniques, unified strategies and implementations of both logistical and physical control of manufacturing processes, robotics, and other shop floor systems, and the communications systems for the shop floor and process plant environments. Key targets such as flexible automatic assembly and the high throughput, fail-safe operation of modern process plants will provide test beds for these activities.

The tendency for new projects to cluster around successful ESPRIT I projects is encouraging and is an early indication that vertical mass is building up.

The CNMA Project (2617), with its parallel action on test tool development (2292), will allow communication vendors to move into a leading position in factory and plant communications, as well as fueling the provision of future conformance testing services in Europe.

Project 2277, led by the German systems house Actis, offers a promising approach to the problem of direct factory-to-factory communication in multi-supplier operations.

The area of product design and analysis has evolved rapidly in recent years as minicomputers have become viable possibilities for CAD workstations. Project 2590, led by MATRA, is an initiative to strengthen the European position in the CAD/CAE field in product and production modeling. The partners involved represent the strongest European CAD-vendor team. They will develop a new generation of CAD systems to allow the integration of modeling functions which are at present separate and sequential. Thus the current overheads for manufacturers which include high costs, long lead times, and complex organization structures can be reduced. This is a project which could build market share where there is now a gap and bring direct benefits to users.

A parallel project in the same area (2165), led by Krupp Atlas Datensysteme, brings together an impressive team which will apply the results of the ASF group from the German and Norwegian national programmes.

Mobile robots and process industry topics are among the new items in the work programme. Mobile robots have many potential applications including forestry, agriculture, mineral extraction, plant maintenance, space operations and defence. For manufacturing, availability of mobile robots would lead to new concepts in factory layout and the ability to solve the problems of manoeuvering in unstructured environments.

Project 2483 covers this area. The team will develop an advanced perception and navigation system for mobile robots, applied first to the forestry domain. The Finnish partners will develop the prototype with Community companies targeting the component market for this and other types of mobile robot.

Robots and other types of material transport systems are already well developed. As methods and tools for integration improve, the demand for flexibility is becoming stronger. Hence, there is an increasing move towards greater sophistication in shop-floor devices, and the emergence of new types of device. This provides many opportunities for Community vendors.

The automated crane is an alternative to the automated guidance vehicle as a form of transport on the shop floor. The topic is addressed by project 2280, led by AEG. The approach could open a large new market in manufacturing, construction, shipbuilding, and haulage environments.

In the process industry, ESPRIT Project 2671 attacks a similar problem by using knowledge-based systems to gather sensor information. ICI, one of the main users in the process industry, is involved, thus assuring that knowledge of the process will be provided for the prototype. The IT market in process control is largely dominated by foreign competitors. This proposal is a first step towards opening the market for European vendors. (Extracted from European Science Notes Information Bulletin, 89/3)

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Lithography CIM cell drives reworks down, feedback in less time

An integrated photolithography cell at Hewlett Packard (HP), Corvallis, Oregon, USA, addresses the philosophy of computer integrated manufacturing (CIM) as much as automated semiconductor manufacturing.

At the International Semiconductor Manufacturing Science Symposium, it was stated that the photolithography cell allows one operator to execute all operations - from resist coat through inspection - at a single terminal. SPC real-time reporting gives early warning of problems, and interactive analysis tools helps a user learn more about the process.

The workcell uses 5:1 stepping projection aligners, in-line track equipment, and is heavily dependent on automation software. It is an interchangeable 0.8, 1.0 and 1.3 micron CMOS process with one resist chemistry.

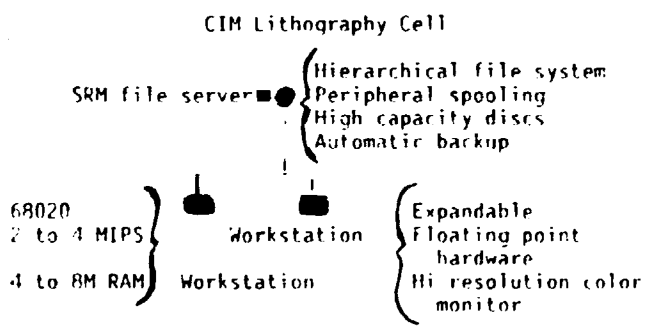
A key benefit is the environment in which a single operator has ownership - and all the tools required to be successful - for all aspects of the photolithographic process. Briefly described, the ESP 2 CIM system uses a 68020-based HP 300 Series workstation. Workstations connect to a shared resource manager that is a LAN-based file server with peripheral sharing services. Each station runs in the Rocky Mountain Basic environment, which among other advantages enables clean handling of multiple interfaces.

It was decided early that the cell must have a central user interface or workcell controller that replaces the original equipment interfaces. This makes the linked system appear as a single machine during setup, simplifies operation and minimizes error.

This HP workcell has reduced rework rate from 11 per cent to less than 2 per cent, has improved the feedback time on lots from 8 hours to 15 minutes, and has reduced the average active time of work in progress in the photolithography area from 24 hours to 8 hours.

Reportedly, this CIM system focuses on the basics and provides a high-quality, low-cost, generic solution to help engineers and operators to be more productive.

Giving general advice on CIM development, these HP engineers state that CIM engineers should expect change and a successful approach to CIM must be able to deal with it cost-effectively. This requires choosing the correct environment for software development and producing reusable code.



Hewlett Packard's CIM lithography cell, in use at the Northwest IC Division in Corvallis, Oregon, is based on HP 300 workstations. (Source: Semiconductor International, September 1989)

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CIM in Clonmel

A collaborative project involving Digital Equipment International BV, Clonmel and University College Galway has put Ireland on the map as a centre of excellence in Computer Integrated Manufacturing (CIM).

Researchers at Digital's Clonmel facility recently conducted a pilot implementation of a novel production control system which was developed as part of the European Commission's ESPRIT programme. The Production Activity Control (PAC) system is designed to provide planning and control of work cells and devices on the factory floor, and communicates production and material requirements from high-level Manufacturing Resource Planning (MRP) systems.

A modular architecture of PAC was proposed by the project team. This is based on five distinct building blocks where it was intended that the architecture would be generic and applicable to most discrete parts manufacturing industries. During the project, sophisticated application software was written to support the PAC architecture and the inter-module communication. A simulation tool was also developed to enable the verification of the prototype systems in target manufacturing sites.

The Clonmel pilot project took place during March 1989 and was successfully reviewed by a European panel of CIM experts and officials from the European Commission. (Source: Advanced Manufacturing Technology, August/September 1989)

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Mazak unveils new CIM-based plant

Mazak Corp (Florence, Kentucky, USA) gave press and customer tours of the machining systems portion of its impressive $50+-million plant expansion. Expansion of the machining lines included the complete replacing of an FMS that was only six years old with three completely new FMS/cells for machining medium-size prismatic, large prismatic, and cylindrical parts. Shortly the entire plant will be a true CIM-plant, controlled by Digital 3500 Vax computers. Those computers will schedule the machines and material, control the inventory of the automatic storage and retrieval system, and deliver six-Sigma quality parts via automatic guided vehicle to the machine assembly area. Total Mazak investment in its US facilities will be close to $110 million when the present expansions are completed. And another phase of expansion is in the planning stage. (Excerpted from American Machinist, February 1990)

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CIM interface provided via HyperLab

Software engineers at the Centre for Integrated Systems, Standford University, have developed a prototype interface for semiconductor computer integrated manufacturing (CIM) called HyperLab. HyperLab provides access to a CIM system via active text and graphics for writing process specifications, facility control and monitoring, and documentation.

HyperLab runs on an Apple Macintosh computer using HyperCard. The system couples, through RS-232 links, to an existing data base server on a DEC VAX-3600 running Unix. This data base supports the existing CIM system. The engineers developing HyperLab are considering an Ethernet link and will add it when the necessary software becomes available.

Reporting at the recent general meeting of the Electrochemical Society in Hollywood, Florida, USA, Ernest Wood explained, "The system is a prototype for testing the use of hypermedia concepts in accessing a CIM data base supporting our research laboratory."

In use for writing a process specification, for example, the interface closely couples the process steps in a specification with the physical facility required and all of its associated control and support functions. To keep a user oriented with the system hierarchy, HyperLab uses equipment and facility graphics and careful selection of commands and menus.

Wood said, "The goal of this project was to develop a conceptually simple, powerful, fast and flexible user-interface that is easy to learn and use by laboratory technicians. There is no functional capability, such as scheduling, relational data base and equipment control, in HyperLab; the external server, which links HyperLab and the CIM system, supplies these components.

According to Wood, a negative aspect brought out in this work is the difficulty of connecting the Macintosh environment to the Unix operating system. "A future possibility is to transfer the essential hypermedia components of the interface to an advanced X-Windows toolkit, thus making the entire system more portable," he said. (Source: Semiconductor International, November 1989)

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7. TRENDS

Current and future manufacturing industry

Manufacturing refers to a broad concept covering marketing, research and development, production and sales. In the period between the 1960s and the 1970s, the manufacturing industry placed its main emphasis on production with the aim of reducing the cost of production through the development of the automated mass-production systems. Now, the manufacturing industry is entering a new stage where an integrated effort is required for marketing and flexible production on a global basis, and computer integrated manufacturing (CIM) has come out as an efficient tool to be employed in the current and future manufacturing industry.

1. Traditional manufacturing industry

(1) Mass production versus new production systems

With extensive efforts directed towards the development of mass-production systems based on robotics and automation, the manufacturing industry has undergone a remarkable expansion during the period between the 1960s and the 1970s. The manufacturing industry has benefited much from the introduction of the mass-production system. Some of the important accomplishments include: high-speed production, high accuracy in production process, less cost, and uniform and high quality of finished products.

The concept of mass-production was hardware as well as manufacturer-oriented. Customers were satisfied with standardized products thus supplied under mass-production systems, as long as the products met their requirements for quality and prices.

In the latter part of the 1970s, the manufacturing industry underwent a change in character from mass-production to producing a wider variety of products in small lots, mainly to cope with the increased diversification of customers' needs. Technologies were also rapidly advancing as illustrated by the appearance of semiconductor and microelectronics technology. Such a rapid change in technologies has made the life-cycle of a product short. The mass-production also involved a risk of over-production.

"The just-in-time production system" developed by Toyota Motors presents a typical example of the production process of producing a wide variety of products in small quantities. The basic concept of the "just-in-time production system" was to avoid all possible "wastes" generated during the production process such as:

1. Over-production;
2. Waste time spent at the machine;
3. Waste involved in the shipment of units and parts;
4. Waste in processing;
5. Waste in taking inventory;
6. Waste of motion;
7. Waste in the form of defective units.

Further improvements have since been made in the "just-in-time production system", leading to the establishment of a "product system without loss". The basic concept of a this system was to achieve the following in production processes: no defective products, no machine failure, no need for the transport of parts, complete synchronization of line speed and machine cycles, and full-automation to permit a 24-hour unmanned operation.

Both the "just-in-time production system" and the "production system without loss" were market, customer-oriented and software-oriented, as against the mass-production system which was manufacturer-oriented and hardware-oriented.

(2) Conventional technologies versus science-based technologies

Technologies can be classified into the following two categories according to their natures:

(a) Conventional technologies whose mechanism and performance are well established. Examples include conventional mechanical engineering, chemical engineering, and electrical engineering;

(b) Modern high technologies which are based on science and are in the stage of constant advancement. Examples include high-temperature superconductivity, semiconductors, micro-electronics, DNA recombination, new materials and artificial intelligence.

Recently developed high technologies are all based on science. In some technologies, both mechanism and theory are not fully clarified. These technologies are featured by the need for highly sophisticated production equipment and facilities. Often super-clean laboratories are needed. They also are highly capital-intensive, and a large amount of investment is required for equipment and facilities.

(3) External elements

During the period of mass-production, the manufacturing industry acted based on the following traditional assumptions: resource is infinite, energy supply is infinite, production-related space is infinite, market expansion is infinite, consumption is infinite, and people's desire is infinite.

These assumptions, however, have lost their legitimacy for the current manufacturing industry. Recent developments indicate that there will be shortage of resources and energy supply, space is limited, market expansion will not last forever, consumption will also be saturated, and people's desire is also limited and is getting increasingly specific.

To cope with the new situations, the manufacturing industry has been taking measures in place of the old assumptions. Some of the measures are: high functional performance for a limited supply of resources; energy conservation and savings, and development of alternative energy sources for a limited energy supply; compact design, miniaturization and high density for a space problem; flexible production for a limited market expansion; consumption-oriented production for limitation in consumption; and development of products which customers want for their specific needs.

In addition, there are also some external elements which stand in the way of the linear expansion of the manufacturing industry. These external elements arose in relation to limited capacity for waste treatment and disposal, environmental pollution problems, and safety of new products or new technologies. Processing and disposal of industrial wastes present a serious problem in the industrialized nations, as the amount of waste exceeds the capacity for disposal. Environmental pollution has come up as a serious problem, as the manufacturing industry expanded its production and consumption by humans increased.

Typical examples of such environmental pollution are the destruction of ozone layer by fluorocarbon compounds, and the greenhouse effect by carbon dioxide. Safety of new technologies and products also presents a problem for public acceptance. It requires long-term effort to prove reliability and safety of new technologies.

2. Global business operation

(1) Vertical operation versus horizontal operation

The manufacturing industry is now going into global operation and there are four main elements responsible for the manufacturing industry to go into global operation.

1. Political element as represented by trade frictions;

2. Marketing element such as diversified customers' needs;

3. Formation of regional economic blocs;

4. Technological element which includes needs for scientific research, sophisticated software, and co-operative development projects.

With regard to the marketing element, there is recently a trend in which products are being produced within or near the marketplace because of diversified customers' needs. The technological aspect is also an important element to be considered for the global operation. Because of sophisticated nature of recently-developed high technologies, no single country can fulfil all necessary R&Ds ranging from science to software. It has now become necessary for the manufacturing industry to seek technological expertise and skills on the world-wide basis.

In the 1960s and part of the 1970s, all functions of manufacturing industry including marketing, R&D and production were performed in one country and finished products were exported to world markets through overseas sales offices. Offshore production was carried out mainly for economic reasons such as modest labour cost. Only standardized products with established production processes and market needs were transferred to offshore production. Later, production technology and some R&D work were transferred to offshore operations. The manufacturing industry was operated on the vertically intergrated scheme.

Marketing
R & D) Country A
Production

Offshore production Country B

Offshore production Country C

Now that the manufacturing industry is operated on a global basis, all the necessary functions are scattered world-wide with equal participation of each function in the business operation.

R & D ⟷ Design ⟷ Software ⟷ Production

Country A Country B Country C Country D

Present global business operation is based on the horizontal scheme. The manufacturing industry in short has shifted its operation from a vertically integrated scheme to a horizontally integrated scheme.

(2) Technology sharing

Taking a close look at the history of science and technology, one can observe that there is a sort of technology sharing among countries.

European countries and the United States have been playing a leading role in the field of scientific research. Many new technologies based on science were first developed in Europe and brought to the level of engineering in the US. The US effort has been featured by the development of super-high technologies and ultra-large scale engineering projects, while Japan has been active in improving newly-developed technologies and production processes. Japan also devotes a large amount of its efforts to applying new technologies to the consumer-oriented products.

(3) US versus Japanese technologies

Technologies in the US and Japan present two extremes. There are reports comparing characteristics of the US and Japanese technologies. Following is a comparison of characteristics of technologies in the two countries.

US	Japan
Basic research	Applied research and development
Breakthroughs and inventions	Incremental improvements
Defence applications	Commercial applications
New product design	Production technology
Systems integration	Components and parts
Software	Hardware
New architectural design	Miniaturization
Custom-made oriented	Standardized, mass volume

Recently-published reports point out the US engineers and scientists think in terms of defence applications first, while the Japanese counterparts think in terms of consumer applications. For example, in the United States, a large amount of carbon fibre was consumed by aircraft and defense industries, whereas in Japan they were extensively applied to sporting goods.

(4) Product innovation

There was a belief that markets for conventional consumer products were already saturated with no more or little possibility for expansion. Markets for refrigerators, washing machines and cameras were believed saturated. This belief, however, proved incorrect when a refrigerator with a new door-opening mechanism, a quiet washing machine and a disposable camera have contributed to generating marked demands for them. This indicates that there still remains possibility for future innovations in the conventional durable consumer goods.

3. Current and future manufacturing industry

(1) Changes in market and technology, and measures taken

It is important to review once again changes in market trends and technologies. In the 1960s, the manufacturer-oriented approach was practised in manufacturing industry and standardized products were mass-produced for mass sales by employing conventional technologies such as mechanical engineering, electrical engineering and chemical engineering. In the 1970s, needs in the market had begun to diversify and newly developed technologies had come to be adopted extensively, resulting in further diversification of market needs in the 1980s, along with customers' tastes directed towards luxury goods. Newly-developed science-based or software-based technologies such as new materials and artificial intelligence have begun to be applied to the consumer markets.

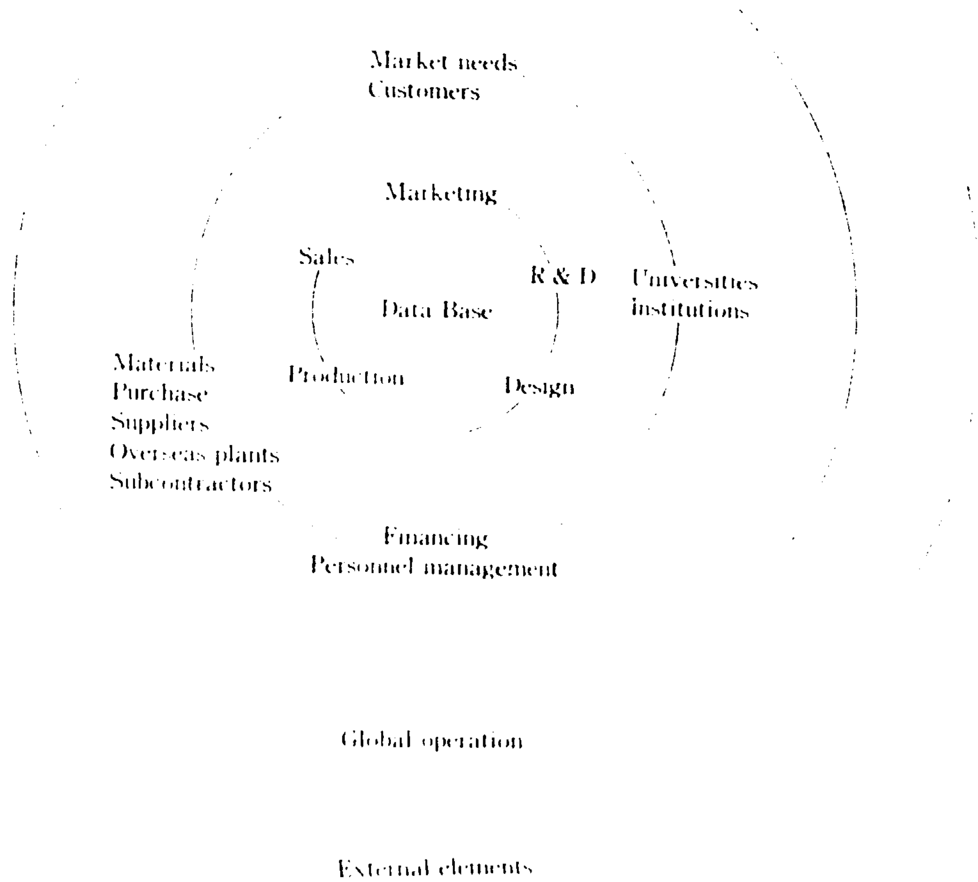
To meet such changes in market trends and customers' tastes as well as to cope with rapidly advancing technologies, the manufacturing industry has been taking a series of measures which call for operations on the global basis. Table 1 shows the summary of measures taken by the manufacturing industry.

Table 1.

	1960	1970	1980
Market trend	Manufacturer oriented approach	• Diversified market needs	• Needs for luxury products
Products	Standardised product with simplified function	• Product with multiple function	• System product for individual taste
Technologies	Conventional technologies	• Semiconductors Micro electronics	• Science based technologies Software based technologies
Mersures taken			
Production system	Mass production	• Production of varieties of products in small lots	• Highly flexible production
Delivery	Long term delivery Long life cycle of products		• Short term delivery Short life cycle of products
Production line	Automation NC machine	• Flexible manufacturing system (FMS)	• Marketing information + Computer integrated manufacturing (CIM)
Operation scheme	Operation on the national basis Vertically integrated scheme		• Global operation Horizontally integrated scheme

(2) Computer integrated manufacturing

Computer integrated manufacturing (CIM) is defined as an integrated system of marketing, production and delivery to meet highly diversified customers' specific needs. As marketing, R&D, production and sales are performed on a global basis, CIM is considered to serve as the most powerful tool for global operation. Today's manufacturing industry requires world-wide efforts not only for marketing, R&D and production, but also for purchase of materials, employment of sub-contractors, financing and recruitment of personnel. The whole CIM operation is based on data base. In purusing computer integrated manufacturing, a careful step must be taken. First, production CIM must be completed, followed by the establishment of factory CIM. The last step in CIM operation is the establishment of company CIM. The following figure shows a schematic diagram of the CIM, with the data base at the centre.



Summary

The manufacturing industry was once labour- and equipment-intensive with mass-production and mass-sales as its major objectives. And its globalization advanced on this mass-production/mass-sales concept.

Now the time has changed: market needs have diversified, technologies have become highly sophisticated and formation of regional economic blocs is under way. Current globalisation is going on due to these political, economic, marketing and technological elements.

The manufacturing industry has thus become information-intensive. Computer integrated manufacturing (CIM) serves as a tool for the operation of the manufacturing industry on a global basis. Future manufacturing industry will become knowledge-intensive. Future CIM will require highly integrated intelligent planning and automation. (Source: Management Japan, Vol. 23, No. 1, Spring 1990)

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Computer integrated manufacturing

Automation and industrial computing are paving the way towards a twofold change: a marked increase in production capacity, and a broader variety of products. They are based on numercial control machines, industrial robots, computer-assisted design and manufacturing systems and visual tactile recognition devices. In short, they are vital for the future of industry and structural adjustment of the economy.

The number of programmes using these technological developments reflects this trend: the Japanese JUPITER programme, the United States ICAM (Integrated Computer-Aided Manufacturing) under the Defence Department of the MAP project (launched by General Motors), the German programme Fertigungstechnik, completed in 1987, various sub-projects under EUREKA, BRITE and ESPRIT, and so on. Most of these aim to improve the diffusion of new applications while developing a specific national asset. The technological lead of the United States and Japan is being matched by the European strategy of alliances and groupings with a view to preventing technological dependence. In most European countries (Germany, France and the United Kingdom in particular) research is being supplemented by programmes aimed at promoting the diffusion of the new technology. (Extracted from The OECD Observer 159, August-September 1989)

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Manufacturing

A major shift in responsibilities from manufacturing companies to vendor industries is envisaged in the 1990s. Major manufacturing companies in the automotive and aerospace industries are changing their way of doing business with vendors to become more profitable and to overcome the shortage of experienced process engineers. The process-design function of the total manufacturing process must assume greater importance in establishing lasting relationships between vendors companies (suppliers of materials, components, and technical services) and their customers (manufacturers of goods for the global market). World-wide opportunities will be great for vendors who can respond quickly to the demands of potential customers in terms of quality products, delivered on time, and at a competitive cost (QDC).

In many instances, suppliers are being asked to contribute heavily or to take full responsibility for product and process design and engineering. This trend is related in part to the significant reductions in manpower that manufacturers have experienced during the 1980s.

Because many vendors have not responded well to change during the 1980s, developing significant product and process design capabilities may be difficult. For example, many vendors have been slow to adopt information technology, which is a necessity in all businesses today. Dramatic changes in computer-based information technology is leading to obsolescence of all computer systems currently in use, which will challenge materials vendors who seek to capitalize on the opportunities to broaden their business base in the world market.

Senior managers of these companies have not responded well to today's technical and business opportunities, many of which are related to changes in materials, manufacturing processes, as well as changes in personnel (their skills and career expectations). In many instances, managers do not understand the science of manufacturing, and the design functions are almost entirely ignored in the company. A study by Harvard Business Review shows that 83 per cent of senior managers believe the problem of global competitiveness is getting worse, due primarily to poor management practices.

Another serious challenge to materials suppliers will be to attract an adequate supply of qualified, college-educated people, particularly in science and technology. Current trends in the education system in the US, both undergraduate and graduate levels, indicate fewer "well-prepared" candidates will be available. Well-educated engineers who are aware of and understand the complexity of doing business in the global market will be required for companies who want to be competitive in the 1990s.

To become an effective integrated manufacturer of high-quality products in the 1990s, materials and component suppliers must train their workforce to become more proficient in the use of computers and related manufacturing tools and concepts such as Taguchi methods, just-in-time (JIT), computer-integrated manufacturing (CIM), statistical process control (SPC), and advanced process modeling (APM). Few office or factory workers will escape the requirement of using a computer, if they have not already been introduced to computer use in the 1980s.

Being computer literate will be absolutely essential in the 1990s, because manufacturing involves not only the transformation of data into useful information, but also the need to create, sort, trasmit, and analyse data. Manufacturing data are both textural (alpha-numeric data - numbers and letters) and geometrical. These data forms must be electronically integrated so they are available from product and process design, to manufacturing, to field service, as well as between customers and materials and parts suppliers.

Process design by computer simulation of unit-manufacturing processes will become more important in the 1990s for efficient inventory control as a result of the concept of JIT manufacturing introduced in the 1980s. JIT however, means more than simply inventory control. It requires that materials suppliers have a complete understanding of material behaviour under manufacturing conditions, and that more be known about each unit process than was previously known.

It will be necessary for US materials and component suppliers to "front-load" process development to be competitive in the world market during the 1990s. Instead of passing the design from one department to another in serial fashion, a new structured design process called global-design methodology will have to be used. Global design is the crux of concurrent engineering: an integrated approach to engineering, manufacturing, and support processes. Global design applied to the entire manufacturing process: i.e., a communication system between various functional tasks required to produce a quality product having the required characteristics.

All manufacturing departments must work together as a team from the beginning in concurrent engineering. Although European and Japanese manufacturing teams typically take a longer time to complete their product-development and design functions than their US counterparts, the total product/process development cycle is almost always shorter using the structured concurrent-engineering approach. For example, Japanese automakers can introduce a new model in three years or less, but US automakers frequentl, require five or more years to introduce a new model. Whereas a prototype model is built to validate a design when concurrent engineering is used, a prototype is used to discover problems in the instance of limited front-end design.

Computer simulation already is state-of-the-art technology for a wide range of industrial processes. Most computer-aided tools available can be used to implement process design, offering a potentially competitive advantage for US suppliers in the 1990s.

Several large US foundries, for example, have begun to use computer simulation methods to design precision castings for the automotive and aerospace industries. Experience to date indicates that millions of dollars can be saved annually in high-volume production of a single casting due to increased casting yield alone. (Source: Advanced Materials and Processes, January 1990)

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CIM technology centres in the Federal Republic of Germany

Technology transfer supported by Federal Ministry for Research and Technology: CIM landscape completed; after completion of the northern network, computer-aided manufacturing will now be demonstrated under conditions approximating actual use in 16 locations.

One of the objectives of the recent founding serving as an interface between the university and the regional economy is to help the latter choice to be the solution of the abbreviation. To satisfy this claim and to provide support where it is needed for companies in the introduction and implementation of new technologies, the CIM Technology Transfer Centre will provide information regarding the introduction of CIM as a solution strategy and will qualify and advise users.

The University initially equipped the CIM laboratory in the Bremen Innovation and Technology Centre (Bitz). From milling aluminium to turning steel, nibbling and reshaping aluminium, welding, cutting of thick sheet metal, up to and including robot assembly and stereolithography, all manufacturing methods applicable for the region of Bremen are already represented here in the work process with CAD, MRP and CAP links. Stereolithography intends to produce a three-dimensional actual-sized solid object without expensive intermediate steps. The CAD model of a product to be manufactured is used as the initial basis.

Manufacturing is based on suitable polymers that are cured selectively and predominantly in layers along calculated geometric contours by means of numerically controlled energy beams. In contrast to machining methods, this new production process has the advantage that it operates with a single tool - the energy beam - virtually without any forces in a purely liquid raw material. This eliminates the long-term, expensive production of tools and fixtures that must be available before the control information can be produced for the CNC machines from the CAD data. Following the just completed set-up period of the CIM Technology Transfer Centre, the additional phases of development will connect the individual manufacturing processes to a data network and finally integrate material flow so that computer-aided planning and design, manufacture and assembly can be demonstrated in a single process.

CIM is a technology that allows factories to adopt to changing requirements. However, one cannot buy CIM "off the rack", but rather one needs solutions tailored to the factory. These solutions must consider the entire manufacturing process of a factory. This makes the orientation advice that the CIM centres are to provide all the more important. Today, one still has the chance of designing CIM oneself. The people who participate now do not need to have a foreign CIM concept forced down their throats later. Each of the 16 CIM Technology Transfer Centres focuses on a different technical area. "CIM in single-series manufacturing and assembly" is the blanket theme of the Bremen CIM Technology Transfer Centre. This theme is particularly important in the region of Bremen because the production of single-series is very important here in plant, ship and aircraft construction. The College Group on Manufacturing Engineering (today: Scientific Society for Production Technology) provided the impetus. Starting from the potential in employees and equipment already available at the many colleges, CIM Technology Transfer agencies have been constructed at 16 locations, distributed over the entire Federal Republic, since the beginning of the programme. The newest location is the CIM Technology Transfer Centre at the Kiel Institute of Technology. Kiel is the only Institute of Technology in the series of locations. The Kiel Transfer Centre provides the facilities to represent all factory operations from order confirmation with the customer to delivery of parts manufactured on CNC (Computer Numercial Control) production machines from start to finish. When designing the CIM components, it was important that, in addition to a comprehensive linking as a CIM total system, functional partial solutions or interfaces can be demonstrated.

"This applies in particular to the transfer of data from the CAD system all the way to the machine tools", says Professor Martin Storm, leader of the Institute for CAD/CAM Applications, the agency responsible for the Transfer Centre. On account of historical development, the CAD area is particularly broad in Kiel. An additional focal point was created in the areas of computer-aided planning (CAP) and computer-aided manufacturing (CAM). This work area includes information integration on the shop floor. In training courses, particular importance was attached to the total exploitation of the rationalization potential of an operative level, designed to be transparent due to shop information systems, in conjunction with appropriate MRP instrumentation.

The CIM Centre in Kiel will also demonstrate start-to-finish initial solutions within the framework of its events. Above and beyond this, however, a particular focal point is the thematic conceptualization of conversion difficulties on the path to CIM. Because of this, the seminars mainly deal with individual CIM components and the appropriate interfaces to adjacent elements. In accordance with the project plan of the Federal Ministry for Research and Technology, the CIM-TT of Kiel is active in three areas: demonstration of the various CIM modules, provision of basic and special training, orientation information.

CIM Technology Transfer Centres and their areas of emphasis

Shop-floor information systems in the CIM network (Kiel): MRP-centered interfacing of CIM modules (Hamburg): data bases for CIM (Berlin); analysis and rearrangement of factories (Hanover): CAQ-centrerd interfacing of CIM modules (Brunswick); assembly planning in CIM (Erlangen); CAD/CAM-centred interfacing of CIM modules (Munich); personnel development and qualification; networks, communications technology (Stuttgart); expert systems in CIM (Kaiserslautern); interfaces (Karlsruhe); procedures for CIM planning and introduction (Darmstadat); CIM strategy as a part of the company strategy (Saarbrucken); simulation in CIM (Aachen); CIM manufacturing islands (Bochum); CIM definitions and CIM basic modules (Dortmund); CIM in single-series production and assembly (Bremen). (Extracted from VDI Nachrichten, 5 January 1990)

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Switzerland to step up CIM R&D programmes

Professor Michel Pochet of the Ecole Polytechnique Féderal de Lausanne, Switzerland, has urged the country to offer totally integrated solutions to manufacturing problems and productivity. Otherwise, he says, Switzerland will have purely a service industry, importing components and software. However, the Swiss Government has announced its intention to spend millions of Swiss francs to promote computer-integrated manufacturing (CIM). The initiative follows four successful "impulsion" programmes promoting management- information systems, CAD/CAM, sensors and building technology.

The decision follows recommendations by the so-called "Cimex" commission of experts created in 1987. This reported in 1988 that Switzerland was falling behind its main trading partners in CIM R&D, technical applications and the training of specialists.

The Cimex programme earmarks SFr 80 million of the total for the creation of six regional CIM centres as "pillars of progress" in this field. Where possible, each centre would interact with a local university or polytechnic. Each will be responsible for applied R&D, CIM training schemes, and technology transfer to small and medium companies in its region. To the federal and private funding will be added subsidies from the cantons. At the end of the six-year period the CIM centres will pass to cantonal control. (Excerpt from FINTECH-Advanced Manufacturing, 29 January 1990)

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IUCCIM Vienna - A New Inter-university Centre for Computer-integrated Manaufacturing in Vienna, Austria

Vienna University of Technology and Vienna University of Economics are co-operatively establishing a centre for CIM (IUCCIM). About ten different divisions of the two universities are joining the centre covering all sectors of a virtual model enterprise. The endeavour is supported by Digital, IBM and Siemens as main sponsors contributing hard- and software and academic staff in an amount of about 100 million Austrian schillings.

The main objectives of IUCCIM are: Postgraduate and continuing education as well as research and development and consultancy for industry and small and medium-sized enterprises.

The most important and ambitious first activity is a two year/16 week inter-university sandwich course in CIM starting 7 January 1991. The main target groups of the course are graduates of engineering or economics and managers from industry with respective professional experience. The course contains in introductory modules fundamentals of engineering and industrial management. A comprehensive coverage of CAx-components form the core of the course followed by modules on techno-organizational integration as well as marketing, PPS accounting and controlling. Project management, assessment of investments and - last not least - human resource management are further essential course modules. To train the participants in "real life situations" projects and case studies are integral parts of the course.

The involvement of the two universities brings IUCCIM in the position to offer to industry holistic solutions covering all ranges from order to delivery and from development to production. IUCCIM combines the technological aspects of CIM with all the necessary industrial management and organization perspectives. The heart of the newly established centre will be situated at a new site of the Department of Mechanical Engineering of Vienna University of Technology. All divisions of the two universities forming co-operating parts of the centre are elements in an electronic network linking the locations in different parts of Vienna.

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8. APPLICATIONS

CIM for headliner production

In order to improve quality and reduce the cost of manufacturing headliners (the lining on the inside roof of a car), Ford Motor Co.'s Utica Trim Plant (Utica, Mich.) is developing a CIM approach that ties individual flexible manufacturing cells, automatic-guided vehicles (AGVs) and overhead flow systems, factory-management computers, and a communication network into a totally automated scheme that begins with the customer order request and ends with final shipment. The system will be two to three years in development and cost is estimated to be in the $8-10 million range with a three-year ROI expected.

The CIM-design scheme will control each component in process, know its exact location, and record and react to SPC data. Accuracy will be maintained through the control of computers directing the mechanical components of the system, thus eliminating manual and human decision-making. Hardware consists of four primary components. (1) Four line-process control and diagnostic systems performing SPC and providing production, build-schedule, and process-procedure information. (2) Two cell controllers that co-ordinate and supervise line control, co-ordinate the line with material-handling, download and store robot programs, collect and manipulate data, distribute build schedule and projections, and act as a diagnostic system backup. (3) One factory-management-computer system that collects and supports information of the manufacturing-knowledge data base and performs shop-floor scheduling, inventory control, quality control, production analysis, engineering analysis, maintenance management, and overall supervision of production operations and assembly-plant data. (4) One communication network that ties all of the automation components, assembly-plant data base, and computer workstations together. How it all works was described by Jim Gould, Senior Process Engineer at the Utica plant, during the February Society of Automotive Engineers (Warrendale, Penn.) Conference in Detroit.

The process begins when the factory-management system receives a customer order (schedule) and forwards it to all suppliers for the required material (either fibre-glass-, polyurethane- or styrene-base substrates; bodycloth with foam backing coverstock, and hot-melts and latex adhesives).

Upon arrival, stock gets an item number and passes through a bar-code scanner which alerts the factory-management computer to register the stock and pass the information along to accounts payable.

Stock is then transferred to a holding area and once again passes through bar-code scanners. This station serves as a checkpoint so if material registered at receiving does not enter the holding area it will be identified by the factory-management computer as "lost stock" and tagged as a "red" item for material-handling departmental investigation

AGVs remove stock from the holding area and deliver it to the manufacturing area. Each manufacturing area has a stock warehouse, and the AGVs will load material here in the off shift for next-day production. During actual production, AGVs transfer stock from the warehouse to the cell and remove finished stock from the cell and deliver it to a finished-stock warehouse.

The manufacturing area contains individual production lines or cells. Each cell is an individual entity and incorporates a flexibility to change to a desired style, colour, mix, and quantity required by the controller.

Also, each cell answers to the same factory computer.

As the substrate enters the cell via power conveyor, it is again scanned by a bar-code reader to alert the cell controller to index appropriate tooling and program pre-set parameters. The material enters an unload envelope where a robot locates it to an overhead pick-and-carry system for delivery to an adhesive-spray station.

At the next station, the substrate will either be pre-cut by a robotic water-jet cutting system or indexed to a bottom pick-and-carry system for passage through a curing oven.

The substrate is then transferred to an overhead pick-and-carry system for transport to the cover-stock load station where it is married to the cover stock. The cover stock racks, with the scheduled cover materials, are placed on power conveyor and fed to a sheeter. The material is then cut to the size of the substrate as determined by the factory-management computer schedule. The tackiness of the adhesive will retain the cover stock until it reaches the lamination station.

Two laminating presses await the covered substrate from the bottom pick-and-carry system. The use of two presses allows the system to make carline and model changes without interruption in the flow of stock. The press not being used will have a tool positioned for the next model, scheduled by the cell controller, to be run on that line, and each press will include an automatic die-change and die-preparation station to facilitate quick die changes to minimize downtime.

After lamination, the headliner is indexed out of the press to an index-holding station where an overhead pick-and-carry system will transport the headliner to edgefold.

At the edgefold station, a robot dispenses a bead of hot-melt adhesive to the backside of the pre-cut substrate and turns the cover material over, folding it to the backside of the substrate. Grippers hold the substrate in position during edgefold to avoid any misalignments or movement of part during the operation. Once this operation is completed, the headliner will be indexed back on to the bottom pick-and-carry system for transport to the final-trim station.

Finally, a gantry-type robotic water-jet cutter, knowing which part is being cut through feedback from the cell controller, trims the part as programmed. The headliner is then placed in a pack-out container (actually the same specially designed shipping container) and moved through another bar-code station situated along the power conveyor line. The stock will be registered with the cell controller, and this information will also be forwarded to the factory-management system for inventory, shipping, and billing purposes. After completion of bar-coding, the power conveyor will move the packed container to the end of the conveyor and position it for AGV pick-up.

The AGV will transfer the packed stock and transfer it to either the finish-stock warehouse for future shipments or directly to the outgoing stock-holding area for final shipment. In either case, the stock is entered into inventory and location is identified.

The CIM design utilizes distributive control and modular design approaches which allow for flexibility. Future CIM expansion capabilities include maintenance dispatching, decision support, make/buy cost analysis, and supplier quality tracking. The factory-management-computer system could potentially support shop-floor scheduling and inventory-control functions for other areas of the plant, and in combination with the automated lines and the material-handling system, increased production, reduced labour, scrap, and engineering cost can be achieved. (Source: American Machinist, April 1990)

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Using CIM in engine repair facility

At the Sochata repair plant, computers organize everything - estimates, supplying of parts, and more - from the moment the jet engines arrive.

The CIM (computer-integrated manufacturing) concept was formerly reserved to mass-production plants. Now the repair sector is in on the fun. Sochata, a SNECMA subsidiary, has just inaugurated a brand new facility in Saint-Quentin-en-Yvelines for repairing airplane engines in which computers are ubiquitous.

The facility already has 150 consoles that communicate with each other in a network; there will be 200 between now and the end of the year. Two computers, one of which is a Bull DPS 7040, supervise the whole operation, working in parallel with computers of the other Sochata factory, in Chatellerault, if needed. A specific program, christened Booster, was developed to manage all the tasks. The inspectors use it as soon as the engines arrive in the inspection shop, when they enter, via the terminals, the list of repairs to be made and the reference numbers of the parts. The computer immediately figures the cost of the different operations and chooses between repair and replacement of the defective components. This will optimize estimates. If a part is needed, the warehouse, which automatically manages 2,800 stock boxes, is informed the very next minute.

Besides being fast, this set-up, which is linked to the GPAO (computer-assisted production management), eliminates all paperwork. With just this in mind, Sochata is preparing, together with CFM International, to do away with the some 3.6 million pages that make up the technical documentation of CFM 56 engines. They will make way for six numerical optical disks. The latter will be able to be consulted via screens placed throughout the different shop floors, which also make extensive use of data-processing; the washing and pickling line, for example, is operated by a loading robot that automatically lifts the parts from box to box.

This ultimate in computerization will substantially reduce the amount of time engines will be out of service. (Source: L'Usine Nouvelle Technologies, March 1990)

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The "Cimple" approach to CIM

Experts at General Electric, Fanuc Automation Div., claim that there are two major reasons why the factory automation market has not grown faster in the last few years: the perceived high cost of integrating systems and the fear of failure. But based on more than 15 years of experience working on large and small automation projects, GE Fanuc has built a cache of systems know-how that provided the basis for their Cimplicity systems for factory automation.

Modular hardware allows initial systems cost to be minimized by using only those modules that satisfied immediate requirements. Then, the Cimplicity architecture can be expanded to include new functions by adding modules to the existing bus.

In addition to modular hardware, GE Fanuc has introduced application-specific software modules that link factory-floor controllers to DEC and IBM-compatible industrial computers. GE claims that they provide the advantages of customized systems without the high cost associated with customization.

Two IBM-based products include the System 3000 Model I and the Cimstar I/386. Model I is a monitoring and control system for small to medium factory-floor applications; Cimstar I/386 is for larger factory-floor applications at both the cell and area levels.

Model I consists of the Cimstar I/286 IBM PC/AT-compatible industrial computer and Cimplicity application software. It communicates with factory-floor controllers for monitoring, alarm processing, and data management. It also controls individual manufacturing lines, cells, and areas. Process variables are monitored continuously and displayed on colour graphic terminals. The Model I system includes an 80286 processor, a 1-Mbyte RAM, a 50-Mbyte hard disk, and a 1.4-Mbyte 3.5 in. disk drive.

The Cimstar I/386 contains a 32-bit 80386 processor operating at 16 MHz with zero wait states. An 80837 math co-processor can be added for extensive floating-point applications. RAM memory available ranges from 1 to 16-Mbytes. This architecture handles data acquisition, process-variable monitoring, and high-speed graphics. It is fully compatible with a wide variety of IBM PC/AT hardware and software.

The processor board contains a Centronics parallel printer port and two serial ports configured as RS-232 or RS-422. Options include an optically isolated RS-422 port, message light, game port, overtemperature sensor, powerfail detector, and a software-readable key-switch. The base unit contains a 50-Mbyte hard disk drive with 28 ms average access time, and a second optional 50-Mbyte drive that fits the same housing.

The Cimstar DX is the DEC-based industrial computer for factory-floor automation. Four processor options are available: MicroVAX, Real-time VAX, PDP-11/83 and PDP-11/53. Applications software includes MicroVMS, Ultrix, and VaxeIn that are available to systems integrators or users who need these special features. Standard software modules available are statistical process control, tool management, and maintenance management. Other solutions include DNC, monitoring and alarm, and cell control.

Cimstar DX computers interact with programmable controllers, DNC, and other intelligent controllers on the factory floor. Serial links include RS-232, RS-423, or RS-422. Two local-area network options include DECnet/Ethernet and the MAP standard with either broadband or carrier-band modems. Mass storage available for the DX computer is either a 42 or 71-Mbyte hard drive, and a 1.2-Mbyte floppy disk drive. [See figure on p. 61] (Source: Machine Design, 26 October 1989)

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From CIM to IMS spelled success at 3M

As part of its efforts in the life sciences sector, 3M operates a plant in Brookings, South Dakota, USA, to supply products to the health care industry. This plant employs 700 people, has 13 acres under roof, and contributes significantly to 3M Health Care's $1 billion in global sales.

Brookings' principal products are surgical tapes and drapes, masks, post-operative tapes and related products designed to save expensive hospital labour costs, speed healing or improve patient welfare. The plant manufactures about 1,000 different products, with perhaps 100 in production at any one time.

Common to all product lines is batch process manufacturing, as opposed to discrete assembly. Brookings converts bulk raw materials to bulk rolled goods and then converts again to individual packages, such as rolls of tape or operating room drapes.

Keeping up with the competitive pressures in the industry requires a constant flow of new products. Product lifetime is now down to two years on some items. Management cannot be sure what the product mix will be in three or four years. The implication for management, however, is clear: flexibility at every level of the operation is mandatory.

From CIM to IMS

In the early 1980s, the Brookings plant, already automated at the process operation level, began investigating approaches to computer integrated manufacturing (CIM). Just-in-Time (JIT) and Total Quality Control (TQC) were implemented at about that time, and a feasibility study for a CIM approach was undertaken. At this point, the project was still focused on the engineering side of plant information processing, essentially a higher form of process control.

Around 1986, management widened the horizons of the project to encompass the total integration of all the information technology in the plant. At that time, "CIM" ceased to be sufficiently descriptive of the activities management had in mind; the project received a new name - Integrated Manufacturing Systems (IMS).

To justify the expanded scope of IMS, every possible area of savings that could be drawn from it was identified. Opportunities appeared particularly promising in the areas of waste reduction, increased machine utilization, inventory reduction, clarification of the manufacturing process, improved cost accounting, better lot tracking, and faster installation of new manufacturing systems. Significant productivity improvements were also projected for both hourly and salaried labour.

Payback projections were presented to corporate management and approved, and, in 1987, the specifications were put before potential system vendors for bids. Implementation began in 1988 and, with enhancements, is now an ongoing process.

Implementing IMS

Among the system priorities, first and foremost was single-source data entry. The data that drives the business, technical and administrative systems at Brookings overlaps by 80-90 per cent; therefore, no data should ever need to be entered more than once, and all data should be available across all applications.

Other priorities included a similar "look and feel" for all applications; "user seductive" interfaces to make the operators want to use the system in spite of competing responsibilities; and on-line education, so an operator in the middle of a process operation does not find him/herself at a loss as to what to do next.

To simplify project management and support, a single hardware vendor was sought: one who was strong in the area of industry-standard communications and who was capable of integrating/connecting with other vendors' instruments and systems in use within and beyond the confines of the plant.

The software vendor had to provide off-the-shelf packages rather than development assistance for turn-key applications. The most important attribute of those packages would be their ability to be modified easily, their configurability. If 3M was to have the ability to modify its plant systems to meet constantly changing competitive environments, the software had to be instantly reconfigurable to reflect the new conditions.

Other software vendor selection criteria included packages that were easy to use, with tools instead of applications that would enable in-house people to build what they needed as they went along.

Given its remote location, project management wanted complete ownership after system acceptance. They thus decided to assign in-plant people to maintain both the hardware and the software after implementation. For that reason, technology transfer became a critically important issue with management.

Following a capabilities demonstration and a thorough review of the products and personnel involved, the Brookings team selected Hewlett-Packard and Hilco Technology of St. Louis as joint hardware/software suppliers and integrators. HP addressed the business and administrative areas of IMS using its MM/PM 3000 products (Manufacturing Management and Production Management, respectively, running on the HP 3000 minicomputer) for the foundation. Hilco concentrated on the technical areas with its Monitrol product, an application development package running on HP 9000 Series 300 and 800 computers.

Monitrol has some particularly apt characteristics for 3M's needs. It is a fourth-generation, menu-driven, user-configurable software tool that can be used by plant personnel from operators to managers. It downloads process information, setpoints and specifications to the plant floor and provides for closed-loop control and automated statistical process control (SPC). It allows process graphics to be created and altered easily. It accesses desired data, manipulates it as necessary and displays it in a variety of desired formats - all without the need for programming.

Beyond configurability, Monitrol enabled 3M to integrate the Brookings process lines with the business and administrative systems, through the use of several key industry standards, including UnixR, X-Window version 11, SQL, and IEEE 802.3 communication protocols. Monitrol also provided fully distributed data base and processing capabilities.

IMS - Beyond functional boundaries

Very few companies even consider tying their administrative systems into their CIM structures. Typically, CIM projects involve engineers, production planners and inventory control people. At Brookings, however, IMS allows the plant manager, the human resource manager, the cost accountant, and anyone else with the appropriate clearance to access the information they need.

In many CIM environments, maintenance is not included in the system. At Brookings, equipment to be taken out of service is planned out in the context of production scheduling, moved on-line, and performed to the greatest extent possible by the operators themselves. The result is a significant improvement in machine utilization.

In the manufacturing area, recipes can now be downloaded automatically, eliminating the errors previously caused when operators loaded the wrong tapes into the PLCs, a source of waste in the past.

Training and education is now an on-line function at Brookings, so management knows which people are trained on which equipment and to what level.

Distributed processing

It is important to note that applications running on one computer may actually be using a data base residing on another. In other words, all Monitrol applications are fully distributed. In addition, personnel can interact with an application running on the administrative computer in a window (X-Window) while simultaneously monitoring another application on a process computer. This means greater flexibility in extending and integrating the manufacturing environment.

The analysis of data/information at any time during the process and afterwards is easily accomplished from any terminal or PC on the network. The X-Window terminals and Unix-based devices also offer the most comprehensive capabilities for graphics and data manipulation, permitting multiple applications to be viewed and active simultaneously. There are over 250 terminals, PCs and engineering workstations currently on the network, and each one has full office systems functions (electronic mail, word processing, etc.) which further complement the analysis capabilities of the system.

At the Brookings plant, IMS is a process which continues indefinitely rather than a project with a beginning and an end. Brookings people continually add new enhancements, and the introduction of new products constantly drives the addition of new capabilities to the system. Thus, the technology transfer that management initially insisted upon has indeed taken place.

Because it was installed in modular fashion, benefits became apparent early on in the implementation. For example, Brookings has already attained a 48 per cent reduction in rejects on the first of the plant's three principal process machines.

In addition, management originally estimated that the IMS system would pay for itself one year after implementation was complete. However, the system had already begun to pay back within a year of time implementation was initiated, with about 30 per cent of the annualized projected savings showing up at that time.

Management also points out that the process of implementing the IMS has brought about critical insights into the manufacturing process. These insights lead to improvements which, while not directly related to the management system itself, might never otherwise have come about. (Extracted from Industrial Engineering, February 1990)

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Software for CIM project investment

A software package called AutoMan allows investors to include non-financial and even non-quantitative criteria in their analysis. For this reason it is expected to be helpful in evaluating major investments for automated manufacturing where such factors as throughput, lead time, quality, and flexibility are part of the picture but do not fit in conventional investment analysis.

AutoMan was developed by the National Institute of Standards & Technology Center for Computing and Applied Mathematics, under sponsorship of the AMRF, and with MANTECH support. The Navy, CAM-I, and a consortium of manufacturing firms were also involved in the development.

It uses four steps to measure the impact of potential investments: (1) define the decision model by identifying the impact criteria; (2) establish weights for the categories and criteria through pairwise comparisons; (3) rate investment alternatives with respect to each criterion; and (4) compute a weighted average rating for each investment alternative. There can be up to seven categories of impacts and seven criteria per category.

For additional information, contact Dr. Stephen F. Weber, AMRF Project, Building 101, Room A-415, NIST, Gaithersburg, MD 20899, USA. (Source: American Machinist, November 1989)

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Unmanned CIM moulding shop supplies parts just in time

An eight-machine injection moulding production cell devised by Klöckner Ferromatik Desma (KFD) for domestic appliance manufacturer AEG's plant at Rothenburg, Federal Republic of Germany, will begin producing parts on a just-in-time basis for AEG's vacuum cleaner assembly operation, located on the same site. The system is designed to operate unmanned around the clock. Automatic control of all functions, including changing of materials, moulds, and plasticating units, is fully integrated within a computer network.

Control systems for the equipment are linked via a bitbus to a Hewlett Packard cell supervision computer, which is integrated through a local area network (LAN) into AEG's existing Ethernet computer network. The computer-integrated manufacturing (CIM) concept was chosen by AEG for its ability to cut required manufacturing capacity, material losses, stock levels, and labour requirements, and to increase operation flexibility, while delivering higher quality parts on a just-in-time basis.

Cell computer handles data

The cell computer is responsible for supervision and control of all functions in the production cell. It enables the cell to operate as part of AEG's CIM system, or fully independently. Access to the computer is gained through five terminals which are located at key points in the factory.

Information on how many parts of a particular type and a particular colour are required is regularly downloaded into the cell computer from AEG's central computer. The cell computer decides which machines should be used, on the basis of the urgency of the requirement, availability of machines and moulds, lowest changeover time, and lowest materials loss. When a changeover is required, the cell computer downloads data on the new mould or plasticating unit to the relevant moulding machine and robot, and to the preheating station. It issues travel commands to the tool-change wagon, and it provides instructions on predrying and delivery of material to the materials handling system.

The cell computer collects and stores processing data (processing parameters, number of parts made in a run, material usage, downtime, and reason) from each element in the production cell. Any adjustments made to machines by operators are fully logged according to time, and number of parts made. Using this data, the computer calculates operating protocols for any period from the current shift to a full year.

Automation of the mould and plasticating unit changeovers enables a massive reduction in product changeover times. Product changeover of all eight moulding machines can be achieved in one 8-hour shift - a considerable saving over manual changeover systems. The significant reduction in downtime that this provides has enabled AEG to reduce the number of moulding machines it needs from nine to eight.

The production cell comprises two 5500-kN injection moulding machines, and six 8000-kN units, in two parallel lines of four. All units are equipped with robotic part removal devices that load on to an overhead conveyor system running between the two rows. At ground level, an automatic wagon on rails transports moulds and plasticating units between a storage unit, a preheating station, and the moulding machines.

Peripheral equipment integration

The materials handling system, supplied by Colortronic Reinhard, Friedrichsdorf, Fed. Rep. of Germany, incorporates a series of centralized silos, feeding twin hoppers on each machine via a vacuum line (AEG processes around seven standard colours, and a higher number of low-run "special" colours). The moulds and plasticating units are fitted with Stäubli (Bayreuth, Fed. Rep. of Germany) multicoupling systems for electrics, water and hydraulics.

The robots, supplied by Remak, a subsidiary of KFD, are servo-driven, and have an advanced teach-in facility and movement control: the operator enters co-ordinates for each of the three axes, but only one velocity, relating to the resolved direction of motion of the robot. This contrasts with systems in which velocity has to be resolved along each of the axes of movement. Equally, the robot moves simultaneously along three axes, reducing time taken to achieve a given movement by up to 40 per cent.

Robots remove the sprues from the moulded parts. Three parallel conveyor belts run between the machines. The robots place the parts on any one of the three. A series of sensors prevent the robots from placing parts on top of one another.

One wagon running on a track between the two rows of machines changes both moulds and plasticating units. It has a maximum load-bearing capacity of 6 t, and can hold two moulds, which enables it to change moulds at the machine without having to return to the storage bay half way through the process. However, it accepts only one plasticating unit at a time.

All moulds and plasticating units have electronic identity tags that are read by an induction unit on the wagon. The data on the tag is cross-checked with the data in the production program to confirm that the wagon is picking up the correct unit. Changeable grippers for the robots, stored above the moulding machines, are similarly coded.

The wagon has two speeds - a normal running speed and a slower, approach speed. Safety features include infrared sensors that trigger a power cut-out if factory personnel inadvertently come within a set distance of the wagon. Further safety features include touch-sensitive bumpers, also connected to the cut-out facility, and emergency stop buttons on each corner of the wagon. If the wagon stops through a triggering of any of these alarms, the program stored in the wagon is not lost.

During normal running, the wagon is in a rest position, connected to the prewarming station. The cell computer downloads instructions on tool changeovers to the wagon via the prewarming station. As a safety measure, the wagon repeats back to the computer the information it receives. Then, at a time calculated by the cell computer, the wagon fetches a tool from the storage area, and loads it into the preheating station in readiness for the production change. The preheating phase is calculated to run so that the tool is ready to be inserted into the machine just as the machine finishes its current job.

The wagon loads and unloads moulds directly at their storage positions. AEG has around 21 moulds for use in the cell - most for various models of vacuum cleaner, plus a limited number of moulds for ovens and other AEG products - but only 14 positions are directly accessible to the wagon; tools held in remote areas are brought alongside the track in advance on a tool-change table. For the plasticating units, there are four storage places. The plasticating units are taken from the wagon and put into storage by crane, since space constraints do not permit an automatic racking system.

Retaining a human element

Although the system is the most highly automated yet devised by KFD, the human element is still indispensable. All parts are checked by eye for surface imperfections, before they are sent to assembly. The quality control personnel have individual terminals into which they report on each item inspected. Data is fed into the CIM system.

Automatic and manual quality control measures are used. If the moulding machine registers a part that is out of specification - owing to processing parameters falling outside set limits - the part is automatically diverted to a scrap bin. The details of the incident are automatically logged in the cell computer. And at the manual packing station, personnel enter data on rejects through individual terminals. Regular quality control reports are entered by the QC staff. (Klöckner Ferromatik Desma GmbH, Riegeler Strasse 4, D-7831 Malterdingen, Fed. Rep. of Germany) (Source: Modern Plastics International, April 1990)

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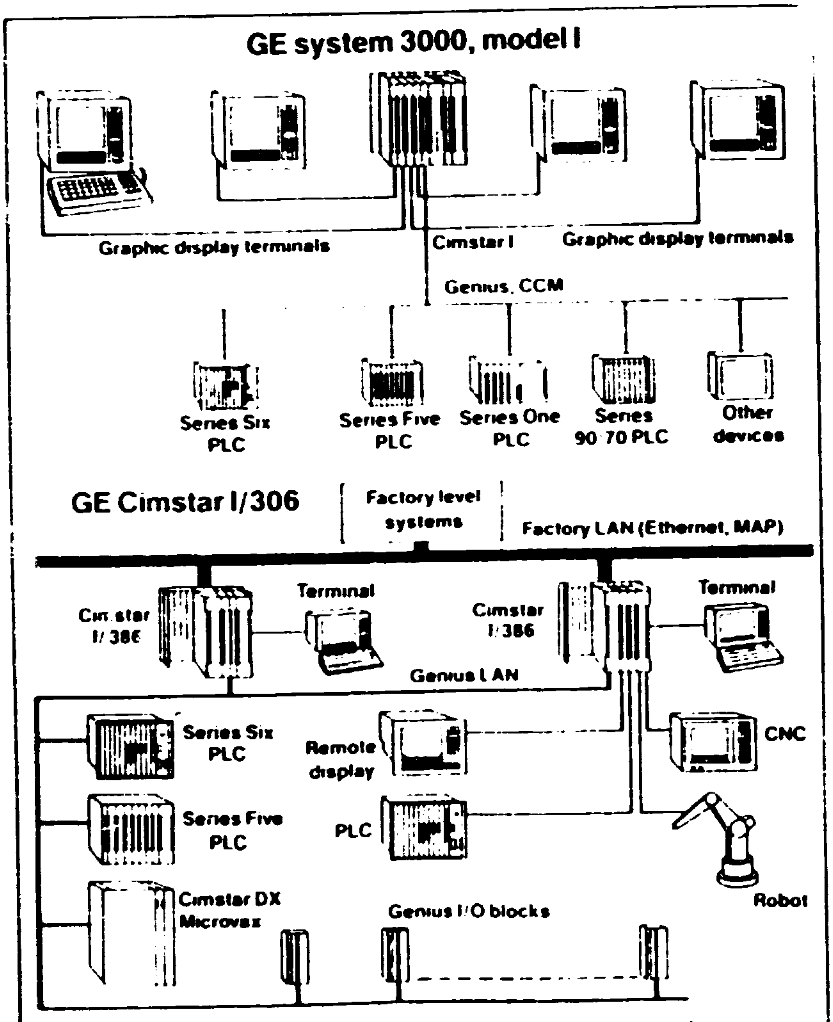

Cimstar I/386 provides cell or area level control. It has the speed and capacity to handle multiple tasks in real time. It communicates with other controllers at lower levels of the information hierarchy, and with higher level supervisory computers

(Source: Machine Design, 26 October 1989)

9. MARKETING

CIM system integrates factory

Work Cell Manager provides real-time operating information from production equipment on equipment status, accept and reject rates, production counts, and quality measurements. Factory managers can access an overview of the entire factory and zoom in on a particular machine or operation. Machine operators can access real-time statistical process-control (SPC) functions and are notified when a problem occurs or is about to occur. Work Cell Manager communicates directly with programmable logic controllers and other third-party devices and connects with other plant computers via LANs. The CIM system consists of one or more MicroVAX computers, a software core, and up to 12 optional standard software modules, and is available as a stand-alone product or part of a turnkey package. Work Cell Manager prices start at $US 35,000; turnkey system prices range from $US 200,000 to $US 400,000. (Northern Research and Engineering Corp., 39 Olympia Ave., Woburn, MA 01801, USA). (Source: Machine Design, 22 February 1990)

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CAD pathway to CIM

A new version of the CIMCAD design and drafting software package provides a low-cost approach to full CIM. Costing less than £3,000, it is available under Unix on the full range of Sun, Hewlett Packard and Solbourne workstations. The manufacturer's pricing policy enables CAD buyers to look beyond basic PC-based systems to a comparably priced CIMCAD package which can be expanded, with growing applications, to CAM, intelligent documentation production and full CIM. (Source: Metalworking Production, mid-March 1990)

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Integrated bench-top machines aimed at low-cost CIM training

Boxford's new flexible manufacturing system for training applications is claimed to give full facilities for introducing computer-integrated manufacturing with bench-top machine units, at a starting cost of £21,000.

The Boxford 160 TCL CNC slant bed lathe, 190 VMC vertical machining centre and a six-axis robot which make up the system can be operated with central control or used independently. (Source: Machinery and Production Engineering, 2 February 1990)

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Reynard Racing Cars is investing in a computer-integrated manufacturing system from CIMLINC. As a first stage, three Sun Sparc 4/110 workstations, running CIMCAD and CIMCAM software have been installed and eventually there will be links to computer systems throughout the factory. (Source: Machinery and Production Engineering, 2 February 1990)

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10. PUBLICATIONS

UNIDO

Republic of Korea. Report of training in computer aided design techniques

Soerensen, M., Vienna, 1986. 58 pp., graphs, diagrams. UNIDO publication. Expert report on training programmes in computer-aided design held in Republic of Korea - covers (1) lectures and training given at a technological institute (KAIST) concerning: use of acquired software package; expert systems; feature technology; an integrated graphic exchange system (IGES); CAD and CAM modeling techniques; (2) computer integrated manufacturing functions. Recommendations, diagrams, list of documents. Additional references: computer programs, computer-aided manufacture, models.

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ENERCONSULT, BRESCIA, ITALY

Manufacturing systems engineering programme at the Asian Institute of Technology (AIT), Bangkok, Thailand. Final report.

Vienna, 1988. 36 pp., tables, diagram. Assistance to a technological institute in Thailand in setting up a programme for engineering design with special reference to computer-aided manufacture - covers (1) project objectives and implications for regional development; (2) evolution of the industrial engineering discipline; computer-integrated manufacturing systems (CIMS); (3) factory automation and industrial engineers; (4) the institutional framework; project activities and outputs; (5) project inputs. Job descriptions, diagram, budget tables, annexes.

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Future IIASA publications

Volume I: CIM - Revolution in Progress. R.U. Ayres.

Volume II: CIM - Technology Survey and Forecast. R.U. Ayres, M.E. Merchant, and J. Ranta, eds.

Volume III: CIM - Adoption and Diffusion. R.U. Ayres, W. Haywood, and I. Tchijov, eds.

Volume IV: CIM - Economic and Social Implications. R.U. Ayres, P. Dobrinsky, W. Haywood, K. Uno and E. Zuscovitch, eds.

(Publication plans for Volume V: CIM: Managerial and Organizational Implications. J. Bessant, J.E. Ettlie, R. Jaikumar, Z. Kozar and J. Ranta, eds., are yet to be established.)

The IIASA project on computer-integrated manufacturing will have been ongoing for four years at the time of the July 1990 conference. During this time researchers from around the world have investigated all aspects of the problems and potentialities of the concept.

The project has been truly international, covering countries from both East and West, with a particular emphasis on countries with fairly well-developed industrial economies. It is hoped that future work at IIASA will also include an analysis of how CIM is affecting, or is likely to affect, developing or less-developed countries. (Published by Chapman & Hall, London.)

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Trends and impacts of computer-integrated manufacturing

J. Ranta, Editor, January 1989, WP-89-1. Proceedings of the "2nd IIASA Annual Workshop on CIM: Future Trends and Impacts", 18-20 July 1988, Stuttgart, Federal Republic of Germany and "The IIASA Workshop on Technological Factors in the diffusion of CIM Technologies", 24-27 May 1988, Prague, CSFR.

International Institute for Applied Systems Analysis (IIASA), A-2361 Laxemburg, Austria
Fax: (02236) 71313, Telex: 079137 iiasa a

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PCs for engineering

Simulation and analysis tools, electrical CAE/CAD software, plotters and digitizers, data-acquisition and control devices, and software development tools are among the featured products in this comprehensive 52-page catalogue. Instrumentation, signal-processing and analysis devices, data-communications boards, voice synthesizers, graphics and mathematics software, and project-management systems also are shown. Listings give in-depth application data, selection guidelines, and prices. PERX, 1730 S. Amphlett Blvd., San Mateo, CA 94402, USA.

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PC share source

A 12-page brochure describes several shareware products available for PC-XT and PS/2 systems. Introduction explains shareware concept of trial runs and low registration fees. Listings give brief descriptions and operating requirements for CAD, drawing, curve digitizing, modeling, data base, spreadsheeting and word processing programs. Mathematics, statistics, financial programming, communications, and utilities also are covered. Professional Shareware Source, Box 2287, East Peoria, IL 61611.

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CIM products guide

"CIMPLE, because CIM should make things simple" presents 113 books, courses, videotapes, seminars, and conferences related to computer-integrated manufacturing. Introduction package, management group, and planning sections offer specialized information at a glance. Other sections detail CAD/CAM/CAE, factory-floor computers, networking, JIT, and other pertinent topics. Society of Manufacturing Engineers, Box 930, Dearborn, MI 48121, USA.

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Computer-integrated testing

Edited by Allen Buckroyd. NY: Wiley, 1989. 394 pp., US$54.95. 670.42'7 TS155.6 89-30990. ISBN 0-471-50486-6

Contents: Introduction to CIT. Computer-aided design. Case studies. Miscellany of extras. Index.

Note: Computer-integrated testing (CIT) is viewed as an essential aspect to computer-integrated manufacture (CIM). Papers are intended to aid senior engineering staff involved with CIT to maximize benefits of implementation. Chapter references included. Appropriate for academic and research-level engineering collections.

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Software and CIM module

Set of brochures on application software for users of IBM midrange computers includes information on business planning and control system (BPCS), a completely integrated MRP II software system that performs manufacturing, financial, data collection, distribution, and decision functions. Also covered is SSA's CIMPath support module that allows BPCS application software to be tied directly to machinery on the plant floor via CAD/CAM equipment. System Software Associates Inc., 500 W. Madison, Chicago, IL 60606, USA.

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Intelligent design ideas

Systems for design, engineering, and manufacturing integrate the product cycle and are said to save time and money. A colourful 20-page brochure concentrates on information management, specifically through integrated automation, mechanical design functions, drafting options, testing without prototypes, and analysis modes. Factory-floor automation, factory planning, and CIM integration also are stressed. Integraph Corp., 1 Madison Industrial Park, Huntsville, AL 35807, USA.

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Computer-integrated manufacturing handbook

Hunt, V. Daniel, NY: Chapman & Hall, 1988. 322 pp., US$57.50. 670.42'7 TS155.6 88-2575. ISBN 0-412-01651-6

Contents, abridged: The need for computer-integrated manufacturing. Description of CIM system elements. Application of CIM. Planning for CIM implementation. Operation of CIM. Computer-integrated manufacturing technology assessment. Projected trends in CIM technology. US industry performance. Assessment of world-class competition. Index.

Note: Provides an overview of the field of computer-integrated manufacturing in an accessible fashion. Organized in four parts, discussing system fundamentals, CIM application, technology assessment, and world-wide competitiveness. Includes a glossary of terms, names and addresses of CIM/CAD/CAM organizations, bibliography, and list of acronyms and abbreviations. Appropriate for public and academic libraries.

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Computer and information sciences - 3: proceedings

Edited by E. Gelenbe, E. Orhun and E. Basar. Commack: Nova Sci Pubs, 1989. 732 pp. $125. 004 QA75.5 89-16390. ISBN 0-941743-63-2

Contents, abridged: Computer networks. Modelling and simulation. Artificial intelligence. Computer applications. Data base systems. Robotics. Computer architecture. CAD/CAM. Indices.

Note: Contains papers from around the world on a variety of current issues in computer and information science. The primary focus is the application of computers in education and the "application of artificial intelligence techniques ... to build knowledge-based systems" in areas as diverse as medicine, education, image processing, pattern recognition, decision support and simulation. Includes numerous graphs, charts and diagrams. For special and research libraries.

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AutoCAD: the complete reference

Johnson, Nelson, Berkeley: Osborne McGraw. 1989. 837 pp. $39.95 620. T385 89-151120. ISBN 0-07-881463-4

Contents, abridged: Drawing. Editing. Text and fonts. Working with menus. Introduction to AutoLISP. Programs in AutoLISP. AutoLISP function reference. AutoCAD command reference. Index.

Note: A comprehensive guide to AutoCAD (Release 10), Autodesk Inc.'s computer-aided design software. Covers fundamentals such as installing AutoCAD and learning program basics. Also explores advanced features like writing your own programs in AutoLISP and customizing AutoCAD for individual applications. Appendix A includes a complete list of AutoCAD commands for easy reference. For academic and public libraries with collections in computer science and for individual users of AutoCAD.

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Putting expert systems into practice

Bowerman, Robert G. and David E. Glover. NY: Van Nos Reinhold, 1988. 402 pp. $39.95. 006.3'3 QA76.76 87-13296. ISBN 0-442-20842-1

Contents: Understanding expert systems: technology and capabilities. Why AI expert systems do not have intelligence. Recognizing knowledge in order to select an application. Strategies for selecting expert systems tools: features and other requirements. Expert system shell tools - product analysis by feature. Specialized hardware and programming environments for expert systems. Knowledge capture and codification. Integrating expert systems into MIS and CIM environments. People roles in creating the production expert system. Conclusions and future trends. Index.

Note: Goal is to provide practical guidance for the implementation of expert systems in two types of corporate environments: management information systems and computer-integrated manufacturing. Stresses strategic design and planning rather than academic programming or reviewing current implementation methods. Concentrates on general features of production application of expert systems to enable readers to apply principles to new material. Discusses development of expert systems chapter by chapter. Written for executives, project managers, and software engineers. Prerequisites are background in commercial or industrial computing and some theoretical knowledge of expert systems. Includes bibliography. For research level collections.

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CIM - The Data Management Strategy (in 4 parts)

Olin H. Bray. Pulished by Digital Press in the US, and distributed in the UK by John Wiley and Sons, 1 Oldlands Way, Bognor Regis, West Sussex PO22 9SA. £42.50.

Part one examines the importance of CIM in a comprehensive manufacturing strategy; part two addresses data management technology; part three, the core of the book, describes individual CIM functions and builds a generic information model to support each function; and part four discusses some key integration issues.

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Computer aided design in composite material technology

Edited by C.A. Brebbia, W.P. de Wilde and W.R. Blain. NY: Springer-Verlag, 1988. 560 pp. US$138. 620.1'18'0285. TA418.9 88-70183. ISBN 0-387-19024-4.

Contents: Laminated analysis and design. Software for composite material technology. Computer simulation of filament winding and other processes. Thermal analysis. Structural behaviour and identification. Manufacturing processes and quality control. Impact and wave propagation problems. Numerical methods.

Note: Publishes 38 of the papers, edited and with references, presented at the 1st International Conference on Computer Aided Design in Composite Material Technology, April 1988, Southhampton, UK. Main theme the application of computers to the analysis, design and manufacture of composites and structures. For research level collections.

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Computer-integrated manufacturing: current status and challenges

NATO Advanced Study Institute on Computer-Integrated Manufacturing: Current Status and Challenges (1987: Istanbul, Turkey)

Edited by I. Burhan Turksen. NY: Springer-Verlag, 1988. 568 pp. $101.50 (NATO ASI Series. Series F, Computer and Systems Sciences; Vol. 49). 670.42'7 TS155.6 88-28161. ISBN 0-387-50220-3.

Contents: Current status. New directions. Management of uncertainty. Models toward integration. Indices.

Note: Publishes 21 papers that review the current status of CIM (Computer-Integrated Manufacturing). Specific topics considered include computer-aided design (CAD) robotics, artificial intelligence applications in industry, aggregate production planning, fuzzy set and fuzzy logic methodologies, and flexible manufacturing systems (FMS). For graduate and research level collections in manufacturing engineering.

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CIM - Technologie im Maschinenbau - Stand und Perspektiven der betrieblichen Integration. Expert Verlag, Ehningen bei Böblingen, 1989.

(Book written in German dealing with the "Factory of the Future" whereby the emphasis is being put on CIM).

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Research Centres Directory 1990

14th Edition, Peter D. Dresser and Karen Hill, Eds.

A guide to more than 11,700 university-related and other nonprofit research organizations with continuing research programmes in the sciences, medicine, humanities or technology.

Indexed by research area and title. Gale, 1990, 2 volumes, 2,062 pp., hardcover, $390.00.

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The GEC research laboratories 1919-1984

Clayton, Sir Robert, and Joan Algar, Piscataway: IEE, 1989. 438 pp. $80. (Distributed by PPL Dept/IEEE) (IEE History of Technology Series; 10). 621.31'042. ISBN 0-86341-146-0

Contents, abridged: Origins, philosophy and organization. Six decades of research. Lighting. Communications and electronics. Semiconductor materials and devices. Engineering and technology. Heating. Glass and refractories. Metallurgy. Chemistry and materials characterization. The 1939-1945 war. Statistics and quality control. Indices.

Note: After the first world war, determining that British industry should never again be dependent on German science, a group of British industrialists set up the GEC Hirst Research Laboratories. Originally established to do research on lamps and glass, programmes gradually expanded to cover electrical applicances, electronics, and telecommunications. An institutional history for libraries supporting programmes in the history of technology.

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The McGraw-Hill electrical engineering materials reference guide

Edited by H. Wayne Beaty. NY: McGraw, 1990. Various pagination. $38.50. 621.3 TK453 89-12554. ISBN 0-07-004196-2

Contents, abridged: Materials research. Carbon and graphite. General properties of insulating materials. Insulated conductors. Insulated gases. Mica and mica products. Plastics. Insulating varnishes. Coating powders. Wood products. Index.

Note: Definitions, formulas, physical properties of conductor, magnetic, insulating and structural materials from the new interdisciplinary field of materials science. Information drawn from McGraw-Hill Standard Handbook for Electrical Engineers. For working electrical engineers.

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Electronics research centres: a world directory of organizations and programmes

2nd edition. Essex: Longman, 1989. 523 pp. $325 (Distributed in the USA and Canada by Gale Research Company). 621.381'072 TK7855
ISBN 0-582-03604-6

Second edition lists approximately 3,000 research and technology laboratories in over 75 countries. Includes industrial centres, official and university laboratories which conduct research in such areas as electronic engineering, telecommunications, and computer science. Listings arranged by country provide name of research centre, address, telephone, director, activities, and publications. A subject index as well as a titles of establishments index provide access to listings. For science and technology oriented collections.

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Materials research centres: a world directory of organizations and programmes

3rd edition. Essex: Longman, 1989. 790 pp. $325 (Distributed in the USA and Canada by Gale Research). 620.1'1'072 TA404.2
ISBN 0-582-03682-8

Contents: Argentina through Zimbabwe. Titles of establishments index. Subject index.

Note: Provides details for over 5,000 research and technology laboratories in 80 countries. Profiles industrial centres, official laboratories, and major university and technical college laboratories involved in research in industrial chemistry and chemical process engineering, hydrocarbon processing, refining technology, metallurgy, synthetic materials and fibres, composite materials, and fine chemicals. Arrangement is alphabetical by country and alphabetical by organization within country. Entries give title in original language and English, address, telephone number, telex address, facsimile number, product range, affiliation or parent organization, name of research director, departments and division and respective heads, number of graduate research staff, annual expenditure, scope of activities, publications, and liaisons. Indexes are provided for organization name and subject. Intended as a source for administrators, scientists and engineers, technical consultants, market researchers, and others. Appropriate for research level collections and special libraries.

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Ferrous physical metallurgy

Sinha, Anil Kumar. Boston: Butterworth, 1989. 818 pp. $95. 669'.1 TN693 88-19167.
ISBN 0-409-90139-3

Contents, abridged: Iron - carbon alloys. Recovery, recrystallization, and grain growth. Pearlite and proeutectoid phases. Bainite. Isothermal and continuous cooling transformation diagrams. Hardening and hardenability. Thermomechanical treatment. Defects in heat-treated parts. Index.

Note: A monograph focusing on theoretical aspects of physical metallurgy, with in-depth coverage of ferrous alloys (nonferrous alloys are given less emphasis). Aims to introduce "the study of the interrelationships among phase diagram, free-energy-composition diagram, kinetics of phase transformation, microstructure, property, and processing for better understanding the behaviour of metallic materials". Assumes an introductory level knowledge of materials science, metallography, crystallography and physics. Intended audience includes practicing engineers, designers, researchers, upper level undergraduates and beginning graduate students studying ferrous physical metallurgy, phase transformations in solids, or heat treatment of ferrous alloys. Comprehensive chapter reference lists and detailed subject index enhance usefulness. For academic and research level engineering collections.

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The beginning of the use of metals and alloys: papers

International Conference on the Beginning of the Use of Metals and Alloys (2nd: 1986: Cheng-chou shih, China)

Edited by Robert Maddin. Cambridge: MIT Pr. 1988. 393 pp. $55. 669'.009 TN16 87-29391
ISBN 0-262-13232-X

Contents, abridged: Early metallurgy in Mesopotamia. Early copper metallurgy in Oman. Tell Edh-Dhiba'i and the southern Near Eastern metalworking tradition. Early metallurgy in Sardinia. Early nonferrous metallurgy in Sweden. Prehistoric metallurgy in South-East Asia: some new information from the excavation of Ban Na Di. Archaeological investigations into prehistoric copper production: the Thailand Archaeometallurgy Project 1984-1986. Early East Asian metallurgy: the southern tradition. Science and magic in African technology: traditional iron smelting in Malawi. The metallurgy of the iron bloomery in Africa. Characteristics of casting revealed by the study of ancient Chinese bronzes. metallurgy of ancient west Mexico. Traditions and styles in central Andean metalworking. Index.

Note: A fascinating review of metallurgical history from its earliest beginnings, 8500-7000 BC, focusing on a number of areas of the world including Eastern and Western Europe, the Middle East, South-East Asia, China, Japan, Mexico and the Andes. Interesting interdisciplinary mix of scientists, engineers, archaeologists and historians present papers on such topics as ore deposits and mining, the beginning of metallurgy, ancient alloys and alloy development, the development of early iron and steel and archaeometric techniques. Reference bibliographies and interesting tables and photos of artifacts and excavations. University and research levels.

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Metals handbook Vol. 16: Machining

Prepared under the direction of the ASM International Handbook Committee. 9th edition. Metals Park: ASM, 1989. 99 pp. $111. 669 TA459 78-14934. ISBN 0-87170-022-0

Contents: Fundamentals of the machining process. Cutting tool materials. Cutting fluids. Traditional machining processes. Grinding, honing, and lapping. Nontraditional machining processes. High-productivity machining. Machine controls and computer applications in machining. Machining of specific metals and alloys. Metric conversion guide. Abbreviations and symbols. Index.

Note: Updates the 8th edition (1967) with comprehensive information on current machining technology. Also provides a comprehensive description of the evolution of machining technology. Seventy-eight articles, of which 30 are new to the present edition, cover all aspects of material removal. Heavily illustrated and including a detailed subject index. An essential reference for all manufacturing collections.

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Cast reinforced metal composites

International Symposium on Advances in Cast Reinforced Metal Composites (1988: Chicago, ILL.).

Edited by S.G. Fishman and A.K. Dhingra. Metals Park: ASM, 1988. 413 pp. $85. 669 TA481 88-071717. ISBN 0-87170-339-4

Contents: Fundamentals of cast composites. Squeeze casting of metal composites. Micro-structure/property relationships of cast composites. Mechanical/thermal behaviour of cast composites. Tribology, damping, corrosion and erosion of cast composites.

Note: Publishes 58 referenced papers presented at the Symposium. Researchers and technicians from academe and industry discuss cast composites. The initial overview article reviews historical interest in metal composites. For research level collections.

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Proceedings

International Symposium on Advances in Refractories for the Metallurgical Industries (1st: 1987: Winnipeg, Manitoba)

Edited by M.A.J. Rigaud. NY: Pergamon, 1988. 327 pp. $60. (Proceedings of the Metallurgical Society of the Canadian Institute of Mining and Metallurgy; Vol. 4). 669'.82 TN677.5 87-32788. ISBN 0-08-035879-9

Contents, abridged: Steel industry refractories ... what next. Comparative thermal conductivities of silicon carbide refractories. The use of basic refractories in modern steelmaking practices. The application of dolomite refractories in ladle refining furnaces. Refractory selection for non-ferrous smelting applications. Refractories testing: the usefulness of the rotary slag test. Development of monolithic steel ladle at Gary works. The development of the rotary valve tundish flow control system. Indices.

Note: Publishes 23 of the 25 papers presented at the first international symposium on the subject. Five main themes are covered: refractories for iron and steelmaking; basic refractories and ladle refractories; non-ferrous smelting refractories; refractory concretes and testing; ladle and tunish refractories. For research and level collections in metallurgy.

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Metal forming and the finite-element method

Kobayashi, Shiro, Soo-Ik Oh and Taylan Altan NY: Oxford U Pr, 1989. 377 pp. $65. (Oxford Series on Advanced Manufacturing; 4). 671'.072'4 TS213 88-11995. ISBN 0-19-504402-9

Contents, abridged: Metal-forming processes. Plasticity and viscoplasticity. The finite-element method - Part I. Plane-strain problems. Sheet-metal forming. Compaction and forging of porous metals. Three-dimensional problems. Index.

Note: Fills a gap in the body of literature on metal forming by focusing on the application of the finite-element method (FEM) to model forming processes. Emphasizes applications based on flow formulation (as opposed to solid formulation). Intended for use by graduate students and researchers. Will also be helpful to practicing engineers with a background in FEM who wish to apply it to the analysis of metal deformation processes. Chapter references. For academic libraries.

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Strength of metals and alloys (ICSMA 8)

International Conference on the Strength of Metals and Alloys (8th: 1988: Tampere, Finland)

Edited by P.O. Kettunen, T.K. Lepisto and M.E. Lehtonen. NY: Pergamon, 1989. 1503 pp. $400 (set). 620.1'6 TA460 88-17862. ISBN 0-08-034804-1

Three-volume set publishing 230 papers presented at the conference. Technical in nature, the discussions cover dislocations, plastic deformation, strengthening mechanisms, cyclic deformations and fatigue, plastic deformation at high temperatures, fracture, modern strengthening methods in steels, and boundaries and interfaces. References included. For research level collections.

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Handbook of polymer science and technology Vol. 1: Synthesis and properties. Vol. 2: Performance properties of plastics and elastomers. Vol. 3: Applications and processing operations. Vol. 4: Composites and specialty applications

Edited by Nicholas P. Cheremisinoff. NY: Dekker, 1989. 783 pp. 742 pp. 664 pp. 680 pp. respectively. $185 each. 668.9 QD388 89-7961. ISBN 0-8247-8173-2, ISBN 0-8247-8174-0, ISBN 0-8247-8004-3, ISBN 0-8247-8021-3, respectively

A four-volume comprehensive and authoritative source that unifies the theory of polymer science and practical manufacturing concepts. Polymerization kinetics, reactor design, and analytical methods used to study and characterize polymer molecular/chemical structures are discussed in volume 1. Physical, structural and compositional properties of elastomeric materials and plastics are emphasized in volume 2. The 14 chapters of volume 3 consider end-use processing operations employed in the handling and manufacturing of rubber and plastic articles used in consumer-oriented applications. The final volume is devoted to end-use properties and applications of engineering plastics, polymer blends and alloys, and polymer composites. For science and engineering collections at the university and research levels.

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Functional polymers

Edited by David E. Bergbreiter and Charles R. Martin. NY: Plenum Pub. 1989. 216 pp. $59.50. 668.9 TP1081 89-3932. ISBN 0-306-43203-X

Contents: Control of phase structure in polymer blends. Functional uses of styrenic block copolymer. Electrochemically controlled release of ions from polymers. Recent advances in self-doped conducting polymers and arylenevinylenes. Functional polymers. Functionalized poly(alkyl/arlphosphazenes). Synthesis of gold containing functionalized polymers. Acid-base chemistry at polymer-solution interfaces. Index.

Note: Represents the proceedings of the Sixth Annual Texas A & M Industry-University Co-operative Chemistry Program Symposium on Functional Polymers held on 22-24 March 1988. The macromolecules under discussion have properties significantly dependent on the functional group substituents. The papers reflect new developments in the field and the potential for industrial applications. Photo-responsive polymers, polymer blends, electronically conductive polymers, and biomedical polymers are among topics considered. For university level collections.

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Mechanical behaviour of materials-V: proceedings of the Fifth International Conference, Beijing, China, 3-6 June 1987

2 vols. Edited by M.G. Yan, S.H. Zhang and Z.M. Zheng. 1st edition. NY: Pergamon, 1988. 1451 pp. $415 (set). 620.1'1 TA417.6 87-7021. ISBN 0-08-034912-9

Publishes papers presented at a forum intended "to bring together continuum mechanics specialists, material scientists and engineers to discuss current engineering problems, thereby gaining a mutual understanding and promoting and enhancing international co-operation." Five themes are: material aspects of fracture in engineering practice; fatigue criteria and material characterization; environmental effects on fracture and fatigue; high-temperature deformation and failure; mechanical properties and engineering applications of composite and non-metallic materials. For research level collections.

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11. PAST EVENTS AND FUTURE MEETINGS ON CIM AND OTHER MATERIALS

The Autofact '89 conference and exposition on computer-integrated manufacturing (CIM) (31 October - 2 November 1989 Detroit, USA). The event's newest attraction was "Partnership for Integration", a state-of-the-art multivendor exhibit featuring real factory production of a portion of a Deere lawn garden tractor. It takes the production process from engineering design through manufacturing, assembly, and inspection. Deere Tech Services, Moline, IL, acted as the systems integrator for Partnership. Team leaders included Digital Equipment Corp., Marlboro, MA; IBM, Boca Raton, FL; Prime Computer, Natick, MA; Sun Microsystems Inc., Mountain View, CA; and Texas Instruments Inc., Dallas, TX. Team members providing equipment and services for Partnership were AT&T, Bridgewater, NJ; Burr-Brown, Tucson AZ; C-COR Electronics, State College, PA; Cimlinc Inc., Elk Grove Village, IL; Comm/Scope Inc., Catawba, PA; Effective Management Solutions, Milwaukee, WI; General Instrument, Flemington, NJ; Intermec Corp., Lynnwood, WA; NCR, Wichita, KS; Octal Corp., Mountain View, CA; Optigraphics, San Diego, CA; and Fritsker Corp., Indianapolis, IN.

More than 300 companies displayed products in 380,000 sq. ft. of exhibit space at Autofact. An estimated 25,000 engineering professionals were expected to view the latest advances in computer-integrated manufacturing.

Conference scene: The Autofact '89 conference offered 61 sessions (including the Partnership presentations) that focused on integration for competitive advantage. For the first time, the sessions were segmented into six areas: manufacturing engineering, product engineering, high technology, computer systems, management and finance, and soft technology. Thirty-three technical programs covered topics from workstations to manufacturing-resource planning (MRP) to sensors, machine vision, and robotics. Twenty-five tutorials with practical suggestions delved into topics such as artificial intelligence, simulation, networking, solid modelling, change, and just-in-time (JIT). Three forums on government, global competitiveness, and the Partnerhsip exhibit gave attendees additional insight into using CIM.

The conference was sponsored by the Society of Manufacturing Engineers (SME) and the Computer and Automated Systems Association of SME (CASA/SME).

Planning ahead: SME will broaden the scope of Autofact in 1990. The Robots 14 Conference and Vision '90 Conference will join Autofact when it convenes 12-15 November 1990, at Detroit's Cobo Conference/Exhibition Centre.

Additional information on the exhibitions and all conference activities at Autofact is available from SME, Box 930, Dearborn, MI 48121 (313-271-1500). (Extracted from Machine Design, 26 October 1989)

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Fisher Controls International and the CIMCenter of Washington University conducted a Computer Integrated Manufacturing (CIM) Conference 22-24 May 1990 in St. Louis, USA. The programme discussed automating and integrating the manufacturing process, linking factory floor operations to a company's strategic planning, marketing, finance, distribution, and purchasing functions. For details, contact the CIMCenter at Washington University in St. Louis at (314) 726-4444.

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CIM: Revolution in Progress, 1-4 July 1990, Laxenburg, Austria. (Organized by: IIASA - International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria. Tel: (02236) 715210. Fax: (02236) 71313. Telex: 079137 iiasa a).

This conference was the culmination of a four-year research programme studying four elements of the current industrial revolution. These changes have been carried forward by rapid developments in microelectronics, computers and software, with concomitant changes in managerial philosophies.

The research has examined the impacts of CIM in the following areas:

(1) Technological developments;
(2) The diffusion process;
(3) Managerial and organizational issues;
(4) The economic and social implications.

The work within IIASA was primarily funded by the National Science Foundation of America, though individual research projects were carried out and funded by different organizations in 18 countries, from both East and West.

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CIM Education

IBM recently selected the Institute of Advanced Manufacturing Sciences (IAMS) and the University of Cincinnati's College of Applied Science as the Cincinnati CIM centre, one of IBM's Higher Education CIM Centres. IBM's CIM in Education involves a consortium of 48 colleges and universities, which are committed to CIM education and to restoring United States industrial competitiveness.

The University of Cincinnati's College of Applied Science will use the new computer hardware from IBM to offer CIM seminars and courses to the manufacturing community, while the College of Engineering will perform R&D activities. (Extracted from American Machinist, November 1989)

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Advanced production technologies in mechanical engineering

Short description: Flexible automation in manufacturing; managerial approaches to advanced technologies; physical planning and design of flexible manufacturing systems; modern manufacturing technologies and organization; education and training for professional personnel; new approaches to flexible maintenance in engineering. Commencing date: September 1990, 1991. Duration: 2 weeks. Qualifications:

Managers, engineers; master's degree, preferably in mechanical, electrical engineering, production economics; at least 5 years of experience. English.

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

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1990

20-22 June Amsterdam, the Netherlands	International Conference on Advanced Aluminium and Magnesium Alloys (organized by the ASM European Council and its Technical Committee, rue de l'Orme, 19 Olmstraat, B-1040 Brussels, Belgium)
25 June - 10 July Kharagpur, India	QUIP Short Term Course on Principles and Technology for Processing of Advanced Materials (organized by Materials Science Centre, Indian Institute of Technology, Kharagpur 721-302, India. Telex: 021-2760 IIKG IN)
20-23 August San Francisco, USA	Third Electronic Materials and Processing Congress (sponsored by The Electronic Materials and Processing Division of ASM INTERNATIONAL, Materials Park, Ohio 44073, USA)
24-26 August Sydney, Australia	1990 Australian Space Development Conference (National Space Society of Australia, Parrish Conference Organization Pty Ltd., P.O. Box 787, Potts Point NSW 2011, Australia)
16-19 September Montreal, Canada	International Conference on Fabrication of Particulates Reinforced Metal Composites (Sponsored by ASM INTERNATIONAL and the National Research Council of Canada)
18-20 September Vienna, Austria	EUROPA-SEMINAR - "Production with Precision" (yearly seminar organized by Dipl. Ing. G. Menzel, Europäisches Informations Institut für Fertigungstechnik und Automation in Wasserburg, FRG)
25-28 September Stuttgart, FRG	Eurocomposites and New Materials, exhibition. Contact: European Association for Composite Materials, 2 place de la Bourse, 33076 Bordeaux Cedex, France
27-28 September Zagreb, Yugoslavia	Conference, "Reactive production of polymeric goods". Contact: Hrvoje Marakovic, Society of Plastics and Rubber Engineers, Garicgradska 6, P.O. Box 119, 41001 Zagreb, Yugoslavia
26-29 September Stuttgart FRG	Eurocomposites '90, Exhibition of Advanced Composites and New Materials. Contact: Mr. Eckhard Schlecht, Stuttgarter Messe- und Kongressgesellschaft mbH, Am Kochenhof 16, 7000 Stuttgart 1, Federal Republic of Germany
2-4 October Stuttgart, FRG	Reliability of Advanced Materials: Design and Failure Analysis (Sponsored by ASM EUROPE and VDI-W)
3-4 October Kensington, London, UK	Conference, "Impact of Plastics Technology on Packaging". Contact: Dr. Brian Simmons, Research Manager, Packaging Division, Pira, Randalls Road, Leatherhead, Surrey KT22 7RU, UK
5-11 October Poliedro, Caracas, Venezuela	Aviplast '90, Plastics Exhibition. Contact: AVIPLA, Multicentro Macaracuay, Piso 7, Of. 9, 1060 Caracas, Venezuela.
3-9 October Palais des Congres, Brussels, Belgium	Compalloy Europe '90, Congress on compatibilizers and reactive polymer alloying. Contact: Schotland, Schotland Business Research, Inc., Conference Services, Princeton Corporate Center, Three Independence Way, Princeton, NJ 08540, USA
8-10 October Detroit, Michigan, USA	Near Net Shape Manufacturing for the Automotive Industry (Sponsored by the Materials Shaping Techn. Division of ASM INTERNATIONAL)
8-11 October Detroit, Michigan, USA	MATERIALS WEEK '90 (Sponsored by the Technical Division of ASM INTERNATIONAL)
8-11 October Detroit, Michigan, USA	Sixth Annual ASM/ESD Advanced Composites Conference and Exposition (Sponsored by ASM INTERNATIONAL and the Engineering Society of Detroit)
16-17 October Kongresshaus, Baden-Baden, FRG	Conference, "Liquid Crystal Polymers in Practice". Contact: VDI-Gesellschaft Kunststofftechnik, Postfach 1139, 4000 Düsseldorf 1, Federal Republic of Germany
17-18 October Brussels, Belgium	Conference, Aeroplas '90. Contact: Anne Weston, Corporate Development Consultants Ltd., 3 The Plain, Thornbury, Bristol BS12 2AG, UK
17-18 October White Haven, Pennsylvania,	"Plastic Waste Management - Recycling and its Alternatives". Contact: Robert Zeller, Akzo Engineering Plastics, Woodfern Road, P.O. Box 625, Neshanic Station, NJ 08853, USA
18-19 October Opatija, Yugoslavia	Conference, "Polymeric Materials of Reduced Flammability". Contact: Hrvoje Marakovic, Society of Plastics and Rubber Engineers, Garicgradska 6, P.O. Box 119, 41001 Zagreb, Yugoslavia
22-26 October Birmingham, UK	INTERCERAMEX '90. International Ceramic Plant, Machinery and Supplies Exhibition. INTERCERAMEX, P.O. Box 107, Broadstone, Dorset BH18 8LQ, UK
25-27 October Seattle, Washington, USA	43rd Pacific Coast Regional Meeting of the American Ceramic Society (Department of Materials Science and Engineering, University of Washington, FB-10, Seattle, WA 98195. Fax: (206) 543-3100)
29-31 October Manchester, UK	COMPEX '90 - Seventh BPF Reinforced Reinforced Plastics Congress (Interbuild, 11 Manchester Square, London W1M 5AB, UK)
29 October - 3 November Sydney, Australia	AUSPLAS - Australia's International Exhibition for the Plastic and Rubber Industry (Exhibition House Pty. Ltd., 193 Rouse Str., Port Melbourne, VIC 3004 Australia)

29 October - 2 November Los Angeles, Calif. USA	ISTFA: International Symposium for Testing and Failure Analysis/ Exposition (Sponsored by ASM INTERNATIONAL)
November Paris, France	PRONIC - Trade Exhibition for Engineering and Materials of the Electronic Industry (SDSA, 65 av. Edouard-Vaillant, F-92100 Boulogne Billancourt, France)
4-9 November Barcelona, Spain	Equiplast '90, Plastics Exhibition Contact: Feria de Barcelona, Avda. Reina M.a Christina s/n, 08004 Barcelona, Spain
5-7 November Backbay Hilton, Boston, MA USA	Conference, "Injection moulding for the 1990s". Contact: Bob Nunn, University of Lowell, 1 University Avenue, Lowell, MA 01854, USA
5-9 November Sarajevo, Yugoslavia	International Plastics and Rubber Fair (Centre "Skenderija", Ul. Mire Sokolovia bb, YU-71000 Sarajevo, Yugoslavia)
12-17 November Birmingham, UK	INTERPLAS - International Plastics and Rubber Exhibition (Plastics & Rubber Institute, 11 Hobart Place, London SW1W 0HL, UK)
13-18 November Harumi Fair-ground, Tokyo Japan	JP90, 13th Plastics and Rubber Fair Contact: JP Fair Association, Ginza-Yamagishi Bldg., 2-10-6 Ginza, Chuo-ku, Tokyo 104, Japan
14-16 November Moscow, USSR	International Conference on Composite Materials. Contact: NIIGrafit 2, Electrodnaya St., Moscow 111524, USSR
19-22 November National Exhibition Centre, Birmingham, UK	Interplas '90, Plastics and Rubber Exhibition. Contact: Richard Duckett, Interplas '90, Sales Manager, Reed Exhibition Companies, Radcliffe House, Blenheim Court, Solihull, West Midlands B91 2BG, UK
20-23 November Singapore	MetalAsia - Asian International Machine Tool and Metalworking Show (Singapore Exhibition Services Pte. Ltd., 11 Dhoby Ghaut, 15-09 Cathay Building, Singapore 0922)
20-24 November Lyon, France	EXPOTHERM - International Exhibition of the Sciences and Techniques of Energy (SEPEL, EUREXPO, B.P. 87, F-69683 Chassieu Cedex, France)
26-29 November Nagoya, Japan	Third International Polymer Conference (IPC Secretariat, Society of Polymer Science, 5-12-8 Ginza, Chuo-ku, Tokyo 104, Japan)
27-30 November Strasbourg, France	1990 Strasbourg Fall Meeting of (E-MRS; European Materials Research Society - C.R.N. B.P. 20, F-67037, Strasbourg-Cedex, France)
28 November - 3 December Beijing, P.R. of China	CHINAPLAS - International Exhibition for the Rubber and Plastic Industry (Adsale Exhibition Services, 21/Fl TungWay Commercial Building, 109-111 Gloucester Road, Wanchai, Hong Kong)
1-9 December Brussels, Belgium	EUREKA - International Fair for Innovations, Research and Industrial Renovation (Foire Internationale de Bruxelles A.S.B.L., Parc des Expositions, B-1020 Brussels, Belgium)

1991

3-16 January Kharagpur India	Winter school on "Electronic Materials Technology" (organized by Materials Science Centre Indian Inst. of Technology) Kharagpur, 721 302 India
30-31 January Birmingham, UK	Conference, "Is Plastics Packaging Rubbish?" Contact: Kay Royle, Rapra Technology Ltd., Shawbury, Shrewsbury, Shropshire SY4 4NR, UK
6-10 February Istanbul, Turkey	Plastics-Turkey, Exhibition. Contact: Philip McKean, Overseas Exhibition Services Ltd., 11 Manchester Square, London W1M 5AB, UK
20-21 February Brussels, Belgium	Compounding '91, "Polypropylene - New Directions in Compounding for the 1990s". Contact: Anne Weston, Corporate Development Consultants Ltd., 3 The Plain, Thornbury, Bristol BS12 2AG, UK
6-10 March Manila, Philippines	Asian Ceramics. Ceramics Association of the Philippines, 2/F Standard Bld., 151 Paseo de Roxas, Makati Metro, Manila, Philippines
12-13 March Zürich, Switzerland	Bonding and Repair of Composites (RAPRA Tech. Ltd., Shawbury, Shrewsbury, Shropshire SY4 4NR UK)
13-14 March London, UK	Conference, "Plastics Recycling - Meeting the Challenge". Contact: Mrs. Sian Tanner, Conference Dept., The Plastics and Rubber Institute, 11 Hobart Place, London SW1W 0HL, UK
27-30 March Wanchai, Hong Kong	Exhibition, Interplas Asia '91 Contact: Cahners Exhibitions (HK) Ltd., 2808 Office Tower, Convention Plaza, 1 Harbour Road, Wanchai, Hong Kong
30 April - 1 May London, UK	High Temperature Intermetallics (Institute of Metals, 1 Carlton House Terrace, London SW1Y 5DB)
1-2 May Ann Arbor, MI, USA	18th Annual Automotive Materials Symposium by the Materials Society (Metallurgy Dept. GM Research Lab., 30500 Mound Rd., Warren, MI 48090 USA)
6-11 May Milan, Italy	Plast '91, Plastics and Rubber Exhibition. Contact: Enfiplast, P.O. Box 24, 20090 Assago MI, Italy
29 May - 4 June Düsseldorf, FRG	PaPro '91, International Packaging Trade Fair. Contact: NOWEA, Postfach 32 02 03, Stockumer Kirchstrasse 61, 4000 Düsseldorf 30, Federal Republic of Germany
4-7 June Montpellier, France	Second European Technical Symposium on Polyimides and High-temperature Polymers, CORUM. Contact: Pf. Marc J.M. Abadie - LEMP/MAO - University of Montpellier II, 34095 Montpellier Cedex 2, France

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Report on Performance and Results of the Science and Technology Workshop (EADI)

This is an excerpt of a report based on the animated discussion that took place in Oslo, Norway on 27-30 June 1990 at the Sixth General Conference of the European Association of Development Research and Training Institutes. The subject chosen by the convener was: ADVANCED MATERIALS, THE RESTRUCTURING OF EUROPEAN INDUSTRY AND DEVELOPING ECONOMIES. Official participation came from the European Communities, UNCTAD, UNIDO, OECD, ACP group of States and other institutions.

Participants tried to examine how the new technologies can be transferred, adapted, originated and learned in a developing economy milieu. Skill/knowledge and investment barriers have been noted perhaps as two crucial impediments barring developing economies from entering successfully the general race in new technology development. Wider issues of cultural - cognitive resistance and political social barriers inhibit the possibilities of originating or diffusing new technologies. Successes and failures in the acquisition of new technologies by developing economies are the ways of building further knowledge in this area.

The main objective of the workshop is to achieve an understanding of the impact of new advanced materials on industrial development. The sessions dealt with the following issues: (1) the material revolution; (2) the extent of influence of this revolution on the restructuring of European industry; (3) the impact of the material revolution on the economies of developing countries and (4) specific policy recommendations linking, if possible, the first three topics.

The material revolution

A critical threshold of new advanced materials is considered as a crucial enabling technology in the competitive wish of nations to stay ahead of other nations. A related objective is the desire by the leading industrialized countries such as members of the European Communities, Japan and the U.S.A. to reduce their dependence on "strategic" raw materials. A study by the IMF has shown that since 1900 with the exception of the two world wars, the quantity of raw materials necessary to produce one unit of product has decreased on average by 1.25 per cent. In the case of Japan, for the same quantity of product, the necessary raw material input diminished by 60 per cent between 1973 and 1984.

The increasing importance of such an enabling technology as new advanced materials in the world of the 1990s is clear in terms of its putative advantage in costs, performance, innovative capability, competitiveness and a whole range of cultural and political advantages. In the workshop, there was no dispute on the significance of new advanced materials for economic growth and competition. There were different views regarding the classification of materials as new advanced materials (NAM). Which materials belong to NAM and which not? What is the taxonomy that would be useful in grouping certain materials as NAM? In what sense is the concept of the "material revolution" useful? Some stressed that microcircuitry, photonics and software engineering are the three distinct developments which have helped to bring about a material revolution. Others stressed metallic alloys, advanced ceramics, special polymers and composites - drawn from all of the others - to constitute or include the components/aspects of NAM. There was also discussion on whether or not the extent of the diffusion of NAM should not serve as a more accurate criteria than the novelty of the new materials themselves.

The other critical point which emerged in the discussion was the environmental constraint in developing new materials. Performance and quality should include passing an environmental test. Materials whose creation and use result in generating pollution should be regulated.

The restructuring of European industry

Mr. Lakis Kaoundes (University of Sussex, Brighton, UK) gave a broad overview of developments in new advanced materials (NAM) and its impact on European industry. In the 1970s and 1980s, European industry has been restructuring and shifting towards high-value added, knowledge-intensive production. At the same time, this restructuring process has been increasingly dominated by diffusion of micro-electronics based automation technologies across both new and traditional or declining manufacturing sectors. The materials revolution affecting as it does both traditional and monolithic materials and new advanced materials is coming to be recognized as a major new technology of critical importance to European industry in the world markets of the 1990s. New advanced materials (NAM) scientific and engineering capabilities can facilitate further technical changes in high-technology sectors such as micro-electronics, telecommunications and aerospace, confer competitive advantages in the global market place and influence the future path of employment, industrial growth, trade and balance of payments for national economies and the European economies as a whole.

Hence the issue of NAM and the strengthening of domestic materials scientific and processing capabilities is emerging as a central determinant of the competitive position of European vis-à-vis the Japanese and the United States economies and will underlie policies in the areas of transfer of technology, protectionism and trade unions. NAM will also have repercussions in the economic relations between developing economies and Europe.

Ms. H. Teulon (CERNA, Paris, France) attempted to link post-Fordism to the development of new advanced materials. The old dynamism was cost-cutting and price competition. The material revolution has given rise to a combination of flexibility and mass production and is characterized by contradictory developments in economies of scope and economies of scale. The movement from raw material - transformed material - part - product is accompanied by increasing economies of scope and decreasing economies of scale. Variety of functions of component parts improves quality. Volume and productivity gains remain as in the Fordist mass production system together with improved quality and functional variety and flexibility. In this case mass production itself becomes flexible.

Impact on developing economies

The primary objective of the science and technology workshop was to understand how developing economies can insert themselves in the product cycle of interrelated clusters of new advanced materials. Once the point of whether the developing economies should enter the advanced material revolution is accepted, the next crucial issue is to identify possible points of entry from the research phase of the material cycle to the product.

Mr. Mammo Muchie (School of Applied Sciences, London, UK) outlined the two basic scenarios on science, technology and advanced materials and development in the 1990s. The pessimists see no useful prospect for the developing economies to dabble in such high new technologies as NAM. They say that such technologies as photovoltaic conversion of light in the less developed countries might be easier and cheaper to install. The optimists affirm the necessity and desirability for developing economies to participate in the NAM revolution. The problem for them is not whether but how to identify the best point of entry.

As an enabling technology, NAM is useful in creating product differentiation, new products and niche markets. It enables the development of flexible sectors and creates demand for specialized goods. It also enables gains in product quality. There is a wisdom in advising developing countries to benefit from these technological developments.

Whether developing economies come to terms with it or not, NAM will lead to the increasing substitution of strategic commodities (e.g. cobalt, chromium). It could also reduce the intensity in use and the demand for raw materials (e.g. copper, aluminium). NAM will probably affect the foreign exchange earnings of many developing economies through the process of creeping dematerialization of the raw material commodities of these economies. Furthermore, NAM will affect the economic structure of these countries by processing and tampering with the quality of the inanimate and animate resources of the countries. This would, in turn, translate itself into further erosion of the social-institutional context. Thus the new technologies will impinge on the economies of developing countries directly and/or indirectly whether one likes it or not. There does not seem to be any alternative for developing economies except to prepare and upgrade their scientific and technological learning capabilities by building innovative institutions in order to try either to reap possible benefits and/or cope with the negative consequences of the NAM phenomenon.

Policy recommendations

The workshop reached a broad agreement on the UNIDO approach of helping and enabling developing countries to acquire theoretical and practical knowledge in new technologies in general and the field of new advanced materials in particular.

Publications: There should be information, documentation and publication of new advances in the area of advanced materials (e.g. ADVANCES IN MATERIALS TECHNOLOGY: MONITOR).

Centres of Excellence: To set up advanced materials centres in different regions of the world and to help increase national capabilities that may exist in different developing countries.

International Centre for Science and New Technologies: To establish a programme in new materials such as superconductivity, semiconductor superstructure, composite materials, photovoltaic conversion of light and so on in order to assist scientists and engineers from developing countries in obtaining experience and knowledge in the field.

Materials Assessment and Application Centre: This centre can carry out an in-depth analysis of trends in materials science and engineering, study the materials resources of developing countries, set up training programmes, build up-to-date data on new and improved materials relevant to developing economies and show the significance of going into new materials. In this context, the workshop deemed the establishment of UNIDO's International Materials Assessment and Application Centre (IMAAC) an important focus for gathering together network institutions, professional societies and experts from the developing world. This enables the cross-fertilization of ideas and practices among many countries in the materials field.

Conclusion

The workshop resolved that NAM would become increasingly critical for the economies of both developing and developed countries and is bound to influence policy issues and discussions in the 1990s. It also underscored the need to continue the "new technology and development" theme with the other new technologies such as biotechnology, information technology and photonics together with the environmental issues of the 1990s. It further decided to set up a network of researchers in the new technology and development areas.

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PREVIOUS ISSUES

Issue No. 1	Steel
Issue No. 2	New ceramics
Issue No. 3	Fibre optics
Issue No. 4	Powder metallurgy
Issue No. 5	Composites
Issue No. 6	Plastics
Issue No. 7	Aluminium alloys
Issue No. 8	Materials testing and quality control
Issue No. 9	Solar cells materials
Issue No. 10	Space-related materials
Issue No. 11	High-temperature superconductive materials
Issue No. 12	Materials for cutting tools
Issue No. 13	Materials for packaging, storage and transportation
Issue No. 14	Industrial sensors
Issue No. 15	Non-destructive testing
Issue No. 16	Materials developments in selected countries
Issue No. 17	Metal-matrix composites
Issue No. 18	Plastics recycling
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Reader's comments

We should appreciate it if readers could take the time to tell us in this space what they think of the 21st 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.