21世纪高等院校教材

Advanced Manufacturing Technology

先进制造技术

（英文版）

唐一平 主编

科学出版社

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内 容 简 介

本英文版教材是从近年内出版的二十多本原著中摘录、筛选后编辑而成. 全书共分三章. 第一章介绍了制造业中的计算机辅助生产与控制系统，并对因特网的诞生、历史沿革和组织结构作了初步介绍；第二章主要介绍CAD/CAM、数控加工、柔性制造系统和计算机集成制造系统；第三章是本书的重点，系统介绍了近年来先进制造技术的几个主要内容：包括敏捷制造、快速原型制造、基于环境意识的设计与制造、纳米技术和微机械以及智能制造等. 为便于读者学习，在本书的每章后面对一些疑难句子作了注释，并在书后附有总词汇表.

本书可以作为机械制造及自动化、现代设计、工业工程与管理以及环境保护等专业的高年级本科生和研究生的选修教材，也可选作专业英语的教材.

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前　言

先进制造技术 AMT（Advanced Manufacturing Technology）这一概念是美国根据本国制造业面临来自世界各国，特别是亚洲国家的挑战，为增强制造业的竞争力，夺回美国制造工业的优势，促进国家经济的发展于 20 世纪 80 年代末提出来的．它是以提高制造企业综合效益为目的，以人为主体，以计算机技术为支柱，综合利用信息、材料、能源、环保等高新技术以及现代系统管理技术，对传统制造过程中与产品在整个寿命周期中的使用、维护、回收利用等有关环节进行研究并改造的所有适用技术的总称．AMT 这一全新概念一经提出，立即受到世界各国政府、企业界和学术界的高度重视并将其称之为面向 21 世纪的技术．因为先进制造技术的主要特征是强调实用性，它以提高企业综合经济效益为目的，所以被认为是提高制造业竞争能力的主要手段，对促进整个国民经济的发展有着不可估量的影响．

同先进工业国家相比，我国制造业技术水平还很低，面对世界市场的激烈竞争，我们只有认真实施"科教兴国"战略，采用以高新技术为支撑的先进制造技术，开展"知识创新"，才能在竞争中站稳脚跟，迎接 21 世纪制造业的严峻挑战．

到目前为止，全面系统地介绍先进制造技术的书籍尚不多见，这同当前正在形成的先进制造技术的研究和推广应用热潮很不相适应．为此，我们组织力量，花了两年多时间参考了 20 世纪 90 年代以后出版的 20 余本有关先进制造技术的英文原版专著与教材，并经过仔细筛选后编写出了这本英文版教材．我们直接采用英文原著，目的是为了使工科高年级学生和研究生能尽快熟悉本专业的技术词汇，尤其是在知识更新越来越快的信息时代能及时了解当前最新科研成果，鼓励他们广泛阅读反映本专业领域最新发展状况的外文原著（包括论文和专著）．香港和台湾高校用原版书教学对提高学生的外语水平有极大好处，故值得借鉴．

为了提高这本教材的教学效果，我们特意在每章后面附有一些疑难句子的注释，并在书后附有总词汇表（按章节和出现先后次序编排）．从书后的总词汇表可以看出，该书几乎包括了最近几年内涌现的涉及到计算机、自动控制、制造技术和信息产业等方面的大部分最新词汇（有少数词汇甚至在较大的英汉科技词典中都未来得及收录）．

本书作为选修课已经在高年级本科生中讲授了两遍，在听取有关专家的意见和建议的基础上对书中内容又作了一些删节与修改．

本书在编写过程中得到西安交通大学卢秉恒教授、吴序堂教授、重庆大学张根保教授和西北轻工业学院曹巨江教授的指导与帮助；在第二次修改定稿送出版社之前承蒙西安交通大学管理学院资深教授汪应洛先生审看了样稿，并向出版社郑重推荐出版该书；在原稿录入和编辑、配图过程中还得到了江云女士和胡德洲、张顺德两位博士的协助，在此一并致以衷心的感谢．

由于先进制造技术的概念提出的时间不长，还未形成完整的理论体系，尤其是编写这样一本以英文原著作为素材的面向中国学生的教材还仅仅是一种尝试，加之编者水平有限，缺点错误在所难免，敬请各位专家学者批评指教.

编　者

2000 年 7 月于西安交通大学

CONTENTS

CHAPTER 1
Computers in Manufacturing

1.1 Computer-aided Production and Control Systems (CAPACS)

Manufacturing technology has been around for many years.[1] Over these years, it has gone through many changes, ranging from the simple to the complex. The driving forces behind the changes were people's desires to improve basic needs such as food, clothing, shelter, and recreation. To meet these desires, methods have been developed from producing simple devices such as weapons for obtaining food to today's modern manufacturing systems, which use computers to produce such items as televisions and space vehicles.

Computers are being given an increasingly important role in manufacturing systems. A computer's ability to receive and handle large amounts of data, coupled with their fast processing time, makes a system approach indispensable. The use of computers in manufacturing is now coming of age. Computer application in manufacturing production controls the physical process and is typically referred to as computer-aided manufacturing (CAM). It is built on the foundation of such systems as NC, AC, robotics, automated guided vehicle system (AGVS), automated storage/retrieval system (AS/RS), and flexible manufacturing system (FMS). Some of the new uses are briefly discussed below. More detailed discussions are presented in subsequent chapters.

Many interrelated manufacturing activities are grouped together to form a special application system that may be referred to as a production and control system (PACS). The grouping of manufacturing activities into PACS varies from one manufacturing environment to another. A PACS is defined as a subsystem in a global manufacturing environment. It may be a single subsystem, or it may be a complex set of subsystems. An illustration of PACS working in a global manufacturing system is shown in Fig. 1.1. For PACS to meet their designed functional requirements, they should be designed to function independently of other PACS. Also, PACS should be able to work collectively with other PACS in a to-

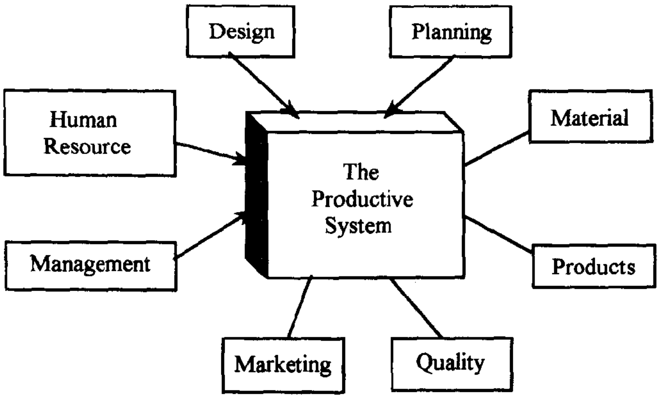

Fig. 1. 1 Interaction of PACS in a Manufacturing System

tal integrated manufacturing environment. Each PACS in the total system can have an effect on the other PACS in the total system, and a systems planning approach must be taken for the following reasons:

- To prevent duplication of effort
- To enable vital information to pass efficiently through the system
- To allow each PACS to know its relation to the others and how it affects the others
- To make the whole manufacturing system function more efficiently and productively

Computers are by far the most powerful single approach used in integrating and manipulating the series of interrelated manufacturing PACS and activities.

They have brought manufacturing technology into the era of "smart" machines. The advances in technical production have brought about a computer technology and manufacturing technology that has enhanced manufacturing technology development. This marriage is the basis for computer-aided production and control systems (CAPACS), which are computer-driven CAPACS. Thus, CAPACS have increased the roles of smart machines in production and control functions. The increased roles of smart machines have demanded a more intimate communication and interaction between such functions as design, financial accounting, production, personnel, and marketing. The ways in which production operations are conceptualized, formalized, discharged, and performed are being changed by CAPACS.

Typical CAPACS in manufacturing are as follows:

- CAD Computer-aided design

- CAIN Computer-aided inspection
- CAM Computer-aided manufacturing
- CAPP Computer-aided process planning
- CAQC Computer-aided quality control
- CIPM Computer-integrated production management
- DNC Direct numerical control
- GT Group technology

Fig. 1. 2 gives an overview of interrelated functions of CAPACS working from an integrated data base system. The design data, generated by the interaction between CAPACS, are a single collection of all the information that describes the product and related operations. It is the hub of the manufacturing wheel. The CAD system is the principal tool used by engineering in carrying out its responsibility.

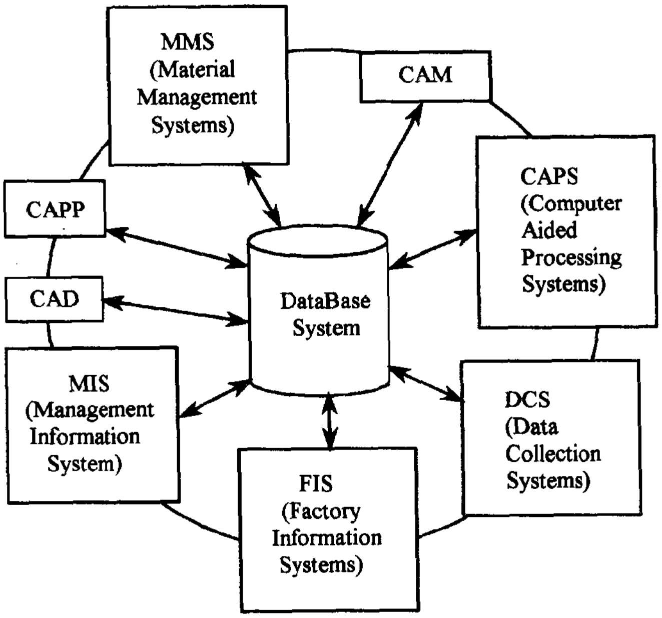

Fig. 1. 2 Interaction of CAPACS in a Manufacturing System

The spokes of the wheel are made from various kinds of CAPACS involved in the activity. Each CAPACS has a communication link to the controlled database so that it will capture the data to form its own distributed database. Values are added the distributed database to meet the needs and requirements of its expected users. The application of CAPACS to the manufacturing process enables the total system to increase productivity, reduce waste, and produce things it would not otherwise be able to make. As a result, new technologies, demands for products of higher quality and lower production costs, and the needs for improved technology in a competitive society have caused extensive use of CAPACS.

1.1.1 Automation Concepts

Automation may be defined as a system that is relatively self-operating. Such a system includes complex mechanical and electronic devices and computer-based system that take the place of observation, effort, and decision by a human operator. It is a system that exhibits properties of human beings by following predetermined operations or responding to encoded instructions.

1.1.2 Computer Process Control

Process control involves the control of variables in a manufacturing process, where one or any combination of materials and equipment produces or modifies a product to make it more useful and hence more valuable. In process control systems, the computer serves as the control mechanism that automatically controls continuous operations. Two kinds of control systems are the open loop and the closed loop. In an open-loop control system, the computer does not itself automate the process. That is, there is no self-correction. The process remains under the direct control of human operators, who read from various sources of information such as instruments, set calibrated dials for process regulation, and change the controlling medium.

Closed-loop control systems use computers to automate the process. The computer is directly in charge of the process. It adjusts all controls from the information provided by sensing devices in the system to keep the process to the desired specifications, a technique that uses a feedback mechanism. Feedback is the action of measuring the difference between the actual result and the desired result and using that difference to drive the actual result toward the desired result. The term feedback comes from a measured sample of the output of the process (production) function that becomes the input of the control function. That is, the output of the control function, meeting special designed requirements is the input to the control system. Thus, the signal begins at the output of the controlled production function and ends at the input to the production.

Typical functions of process control systems are monitoring, data logging, quality control, maximizing output, maximizing profit for a given output, supervisory control, and factory information systems (FIS). Benefits of computer process control systems are increased productivity, improved product quality, and enhanced efficiency, safety, comfort, and convenience.

1.1.3 Management Information Systems (MIS)

Management information systems are designed to aid in the performance of management functions. These systems are generated by computer systems and are developed to provide executives with up-to-the-minute information about the operations of the enterprise. When required, information systems are used to aid management in the decision-making functions of the enterprise. Viewing CIM (Computer Integrated Manufacturing) as an information system for the enterprise for decision-making, CAPACS must be information interconnected. As a result, there are many software packages associated with the CAPACS in Fig. 1.2. Typical of these are CAPP, DCS, FIS and CAD.

The concept of an MIS is a design objective, its goal being to get the correct information to the appropriate manager at the right time. As a result, MIS implementation varies considerably among manufacturing enterprises because of each organization's function, type of production, information resources available, and organizational commitment to MIS.

1.1.4 Engineering

Computers are used extensively in most engineering functions. Engineering is a profession in which a knowledge of the natural sciences is applied with judgment to develop ways of using the materials and forces of nature. Typical engineering functions using CAPACS are design, process planning, analysis and optimization, synthesis, evaluation and documentation, simulation, modeling, and quality control planning. Using CAPACS in engineering increases the productivity of engineers and improves the quality of designs.

For example, the application of computers to an engineering design process is performed by a CAD system Engineers can design and thoroughly test concepts quickly and simply from one workstation. Computers permit engineers to take a concept from its original design through testing to numerical control (NC) output, or a combination of steps in between. They perform complex scientific and engineering computations rapidly with high accuracy, calculate physical properties before actual parts are made and provide a fast, easy method to create models of even the most complex parts.

The computer has influenced the way products are designed, documented and released for production. As technology develops, engineering operations are becoming more and more automated and are relieving the engineer of many tedious manual calculations.

1. Production

Applications of computers to the production process encompass such functions as computer monitoring, supervisory computer control, direct digital control (DDC), material handling, and product fabrication, assembly and test/inspection operations. New ideas and technology developments are gaining acceptance on the factory floor. More important, the integration of more computers into the production process increases automation on the factory floor.

Computer automation helps to organize, access, and provide vital information in a common data base system for use by all manufacturing operations. Computer automation helps to control and to schedule machines and processes, and to control raw materials and parts. A computer automated system concept is shown in Fig. 1. 3. Each function in manufacturing has its own area controller under the control of a host computer in order to share information with other operations.

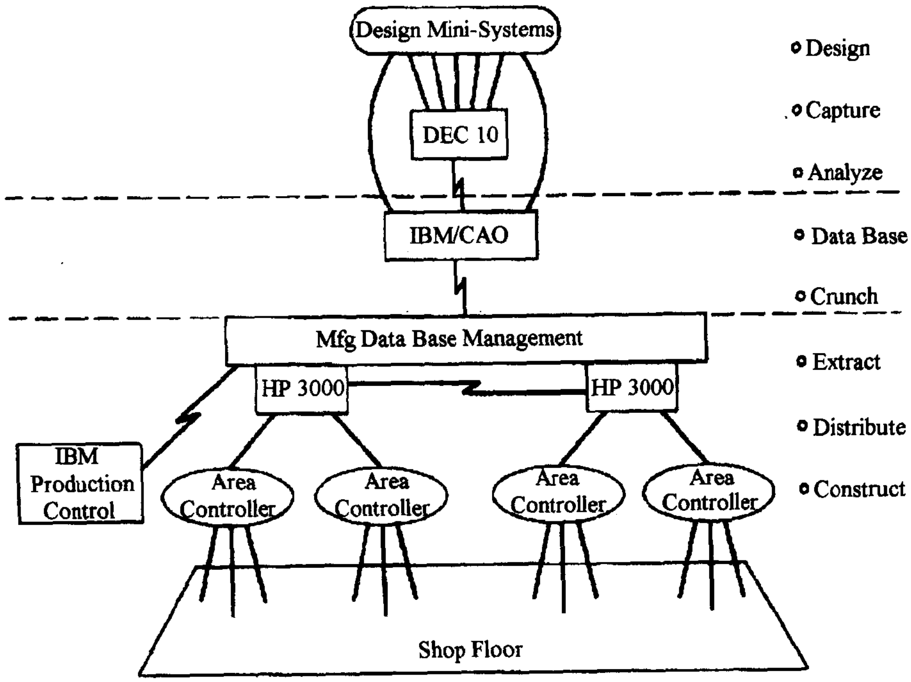

Fig. 1. 3 Conceptual Computer Automated Factory

2. Computer-aided Engineering and Production

The production cycle (CAD/CAM cycle) highlights four distinct phases[2] in the manufacturing of a product, as shown in Fig. 1. 4. These phases are product definition, translation, construction, and support.

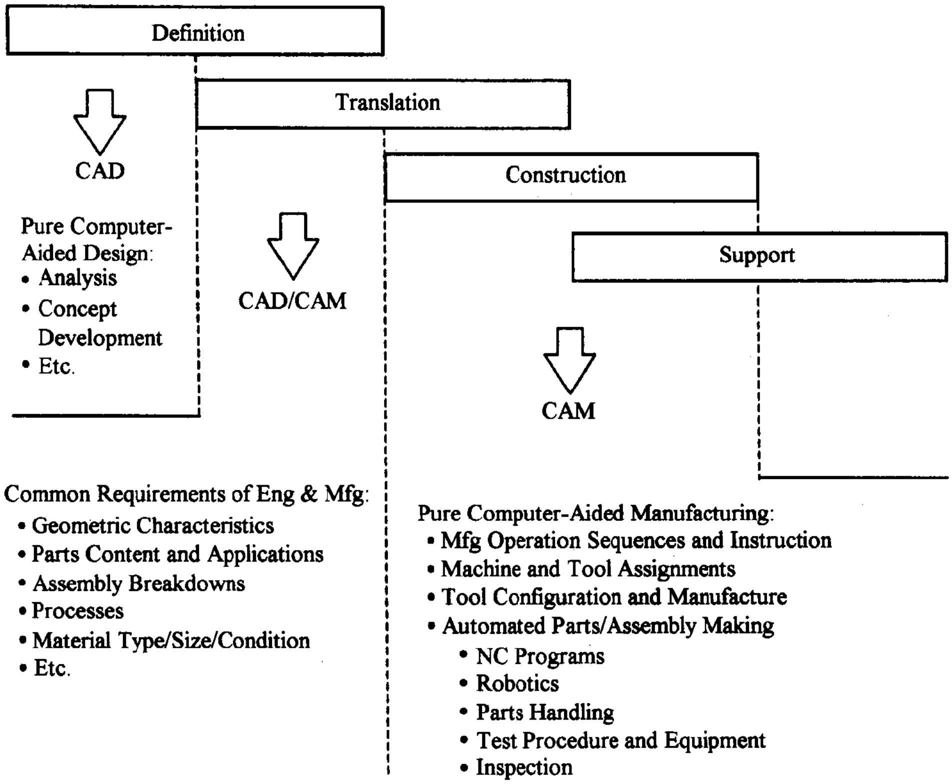

Fig. 1. 4 CAD/CAM Systems in Manufacturing

Definition is the engineering design process. Translation is the manufacturing engineering that provides the initiating actions for the manufacturing processes, including tool orders for the production tools to accomplish fabrication and assembly. Construction (production) consists of the physical actions of fabrication and assembly of the product. Support is the preparation of maintenance manuals, parts catalogs, and spares, together with field support of the customer. These basic phases are bound together by management control systems that provide scheduling, budgets, job tracking, shop loading and control, order writing, procurement and inventory control, and so on.

The use of computers in automating and integrating engineering and production systems adds a new dimension to the manufacturing process. A typical commercial integrated system is Control Data's "Integrated Engineering and Manufacturing" (IEM) system, which ties together the procedures required to take products from concept to production line. This system permits all functions involved—from design to manufacturing—to share data. Integrated computer-aided engineering and production systems (CAD/CAM systems) streamline[3] a firm's operation. They reduce design time, accurately create test conditions, and directly link them to production, all of which reduce production costs and time, thus making the price and availability of the end product more competitive.

Most integrated CAD/CAM systems perform the following key manufacturing functions:

- Preliminary and detailed designs and drafting
- Solid geometric modeling
- Testing and analyzing models
- Finite element modeling
- Generating cutter-line output files for NC machines
- Process planning and group technology

Through computer-integrated CAD/CAM systems, factory automation, process control, design engineering, facilities engineering, and the design of material handling systems and quality control systems are integrated through a common data base system. As a result, the production cycle is shortened and better managed, and the time from product design to product shipment is greatly reduced.

1.1.5 Business

In today's manufacturing environment, computers are playing important roles in supporting various business functions. Typical of such key business functions in a manufacturing enterprise are production planning and control, finance and accounting, distribution management, maintenance scheduling and control, management information systems, data processing, and product planning. The applications of computers to assist or aid in performing various operations in these functions are referred to as computer-aided business (CAB).

Computers are influencing changes in the way manufacturing enterprises carry out their business operations and manage production functions. Computers aid in planning for the accomplishment of objectives through effective management. They assist in planning and establishing exactly where, how, and when various activities that are part of a long-term program are carried out. They help planners produce optimized schedules, improve production line efficiency, and use manufacturing resource planning (MRP II), which is a formal system for planning and managing a production function's resources.

The use of computers has gone beyond the calculation of payroll or the fancy electric typewriter that can produce reports by the tons of paper. Computers are now contributing to the relief of many labor-intensive tasks and, with intricate programs, assisting the design process and the automation of the factory.

Computer applications are appearing in all areas of manufacturing operations. Each application has programming that satisfies the unique needs of that particular function or organization. Little attention, if any, has been given to the overall impact. The growth of isolated micro- and minicomputer installations in stand-alone environments has created a hodgepodge of information across the business operation. Yet each element has been properly cost justified and will indeed cause savings to accrue over previous methods. However, the resultant effect is one of unrelated empires, and short range planning is the treatment of manufacturing symptoms and not the disease. The term Islands of automation is appropriate in such cases. The treatment of the disease is to work toward integrating the islands of automation.

Computers are changing the internal structure of manufacturing organizations, their methods of operations, and their external relationship to society. They assist in all manufacturing operations. In this scenario, all actions occur in engineering where new products are conceived and then presented to potential customers. The computer has a key role, and computer graphics is a core tool. It is normal practice in conceptual or preliminary design to make iteration after iteration to develop a product. Analysis and simulation methods also draw on the computer for support, A serviceable graphics software package provides these capabilities, or it interfaces to the programs that will provide these capabilities. When a concept is sold to a customer, program control develops master schedules and budgets for all functions of the project. Production design then puts the flesh on the skeletal concept. Manufacturing engineering prepares the tool plan and the process plan. Procurer orders material as defined on bills of material. Tool design prepares designs to fulfill the manufacturing plan and tool manufacturing builds the tools. Then production control issues fabrication and assembly orders to make sure that the proper tools are in the right place at the right time and that a product is created. Quality assurance inspects parts and assemblies in conformance with the engineering definition of the product, and delivery to the customer is accomplished.

Central to the whole process is the engineering design. All functions relate to it for their actions. The ability of the designer to communicate concepts is of paramount importance. Interpretive issues are kept at an absolute minimum. Each change affects every function; even if no action is necessary, each change is analyzed to make that determination. A good computer graphics system that is user-oriented eliminates or at least minimizes changes. It also provides a communication medium for the designer that is far better than any method previously available. A policy of computer accuracy, that is, no out-of-scale dimensions with squiggly lines, no line breaks, and no uncontrolled changes——significantly reduces interference fits in assembly. The computer model provides visibility that helps the designer avoid such problems. The design file locked but accessible to all downstream users, provides a single source of data to all functions in a read-only mode. This becomes the master drawing file, which no longer relies on vellums, and its proper protection is important. A daily redundant file spun off on tape should be vaulted, and weekly storage in an off-site location for disaster control must be provided.

Integration requires all the users of the engineering design, even engineering itself, to interface with the master drawing file for the extraction of data function in the chain of events leading to the end item. There are other assists in this process. Typical of such tools are NC Processors, graphic systems, engineering/scientific processors, CAD/CAM workstations, and finite element solver.

1.1.6 Computer Control of Manufacturing Systems

Computer-controlled manufacturing systems use computers as an integral part of their control. As a result, computer controls are used in modern manufacturing automation from product inception through product design, all operations between, and including product shipment and support. They control stand-alone systems such as robots welding, spray painting, processing planning, and processing. They provide optimal control over the use of resources to produce a salable product mix to satisfy sales forecasts and produce a profit for the firm. And they control complex systems such as automated storage/retrieval systems (AS/RS), automated guided vehicle system (AGVS), and flexible manufacturing systems (FMS). These concepts are discussed in later sections.