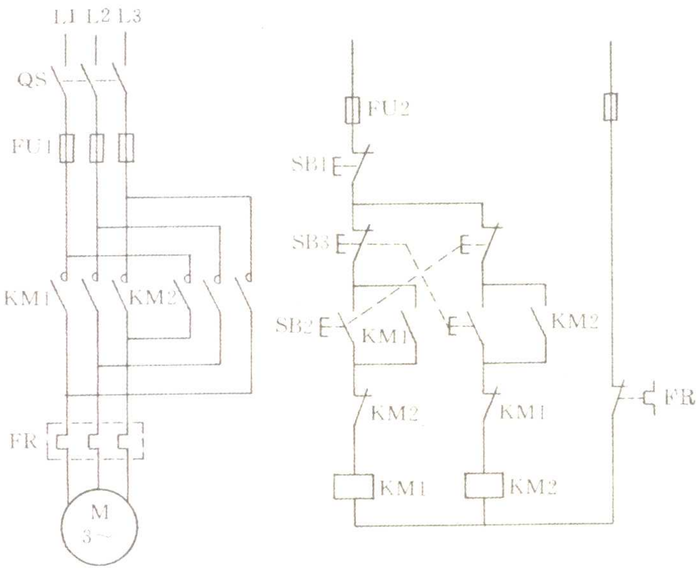
建筑识图系列教材



建筑电气识图教材

（第二版）

JIANZHU DIANQI SHITU JIAOCAI

陆文华 编著

上海科学技术出版社 SHANGHAI SCIENTIFIC & TECHNICAL PUBLISHERS

教育部高等教育面向21世纪课程教材

Numerical Control Technology

（数 控 技 术）

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Wuhan University of Technology Press

武汉理工大学出版社

ABSTRACT

Main techniques encountered in selecting, using and developing of NC machine tools are introduced in this book, which including: features of NC machine tools, NC machining programming, controlling principle and CNC unit of machine tools, position measurement devices, and servo systems of spindle and feed. The developing trend of CNC technology is brief introduced at the end of the book. Some exercises are given at each chapter for self-study of readers.

This book can be used for textbook of bilingual teaching of numerical technology for the students of mechanical engineering major, and refernce for engineers in using and developing of CNC machine tools.

图书在版编目(CIP)数据

数控技术/胡占齐，董长双，常兴主编. —武汉：武汉理工大学出版社，2004.5

ISBN 7-5629-2062-1

Ⅰ. 数…

Ⅱ. ① 胡… ② 董… ③ 常…

Ⅲ. 数控机床-高等学校-教材-汉、英

Ⅳ. TG659

中国版本图书馆 CIP 数据核字(2004)第 107052 号

出版发行：武汉理工大学出版社

武汉市武昌珞狮路 122 号　邮编：430070

http://www.techbook.com.cn

E-mail：liuyj@mail.whut.edu.cn

印 刷 者：武汉理工大印刷厂

经 销 者：各地新华书店

开　本：787×1092　1/16

印　张：17

字　数：424 千字

版　次：2004 年 5 月第 1 版

印　次：2004 年 5 月第 1 次印刷

印　数：1～3000 册

定　价：32.00 元

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普通高等学校机械工程类专业双语系列教材
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出版说明

随着经济全球化的发展，中国的经济必然要与世界接轨。由于近年来中国经济的快速增长，各发达国家的装备制造业纷纷向中国转移，中国将会成为世界制造业的中心。大力发展装备制造业是我国经济发展的一个重要方向，机电产品将是出口创汇的主要来源之一。中国的企业和产品必须面向世界市场，参与国际竞争。与此相适应，高等学校培养出来的人才，不管是到国外的企业(包括合资企业)工作，还是在国内的企业就业，用外语进行交流的机会将逐渐增多。因此，能熟练使用外语的学生在人才市场的竞争中将会具有更大的优势。

为了提高我国高等教育的国际竞争能力，教育部于2001年8月印发了《关于加强高等学校本科教学工作提高教学质量的若干意见》的通知(教高[2001]4号)，文件强调，“按照‘教育面向现代化、面向世界、面向未来’的要求，为适应经济全球化和科技革命的挑战，本科教育要创造条件使用英语等外语进行公共课和专业课教学。……力争三年内，外语教学课程达到所开课程的5%～10%。暂不具备直接用外语讲授条件的学校、专业，可以对部分课程先实行外语教材，中文授课，分步到位。”该文件还大力提倡编写、引进和使用先进教材。高等学校要结合学科的调整，加快教材的更新换代，鼓励有条件的高等学校编写具有特色的高水平教材。

双语教学(使用母语和英语等外语进行教学)对于提高学生的外语水平非常有利。因此，有计划地逐步推进双语教学，扩大双语教学的课程门数，提高双语教学的质量，是今后一个时期内高等学校必须重视的工作之一。机械工程类专业招生人数最多、就业面最广，而且随着我国装备制造业的发展，今后对能够熟练使用外语(主要是英语)的机械工程类人才的需求会越来越大。因此，在机械工程类专业中实施双语教学，具有更加现实的意义。

教材是教学的基础，对于双语教学来说尤其如此。要搞好机械工程类专业的双语教学工作，必须要有相应的英文教材，而机械工业类专业的原版英文教材与我国的教学大纲及教学体系差异较大，不太适合我国高校阶段的教学状况。此外，我国大学生现阶段的英语水平参差不齐，大多数学生的英语水平还不足以很好地理解英文原版教材的体系和内容，故英文原版教材现在还不可能在我国一般的高等院校大面积地推广。

许多高等学校的机械工业类专业，在开展双语教学的试点工作中，除了采用少量英文原版教材之外，还编写了部分英文讲义，经过试用后有的已经出版。但迄

今为止，各校出版的零星英文教材，还没有形成系列，还远远不能满足日益发展的双语教学的需要。为此，武汉理工大学出版社经过广泛、深入的调研，组织编写了这套面向全国普通高等学校机械工程类专业双语教学的系列教材。

本套教材集中了国内十多所大学从事过双语教学的专家、教授和有过留学经历的中青年骨干教师，承担教材编写和审校的任务；并且组织了以全国高校机械工程类专业教学指导委员会主任杨叔子院士为首的编审委员会，负责整套教材的策划和指导工作。

本套教材以机械工程类专业的学科基础课为主要对象，选择相应的优秀中文教材作为蓝本，同时广泛收集国外优秀的同类英文教材作为参考。各门课程都按照我国通用教学大纲的要求，用英文编写，并附有适当的中文注释和说明，在文字上力求规范、通俗易懂、繁简得当。本套教材分两批编写、出版，并逐步配齐相应的电子课件，以满足双语教学的需要。我们衷心希望广大读者多提宝贵意见，共同将这套教材建设成为机械工程类专业双语教学的精品。

武汉理工大学出版社

2004.3

前　言

数控技术是20世纪机械工程领域的重大成就之一，是一个综合了计算机技术、自动控制技术、信息技术、检测技术和机械加工技术的交叉和综合技术领域。数控技术以及以数控技术为基础的先进制造技术正在推动、并将继续推动着机械工程技术的飞速发展，数控技术已经成为机械工程类专业学生的重要技术基础课程之一。中国加入世贸组织后，发达国家的制造业将大量向中国转移，大批先进技术装备也会进入中国。这对于中国的制造业来说，既是机遇也是挑战。时代对机械工程类专业学生的专业知识和外语水平都提出了更高的要求。为了适应这样的形势，国内高校机械工程类专业普遍开展了专业课的双语教学。在普通高校机械工程类专业双语教材编委会的组织和指导下，我们编写了这本教材，以满足机械工程类专业数控技术双语教学的需要。

本书是根据国内大学数控技术教学大纲编写，力求吸收国内外最新技术成果，符合国内工科大学的教学需求。

本书第1、7章由董长双编写，第2章由常兴编写，第3章由李文斌编写，第4章由王洪海编写，第5章由杨莉编写，第6章由胡占齐编写，全书由胡占齐统稿。燕山大学臧怀泉教授和英国Bradford大学于洪年教授担任本书的主审。燕山大学王益群教授对于本书的出版给予了宝贵的支持，研究生宋树军、武琳璞也参加了本书的校对工作，对于他们付出的劳动，一并表示感谢。

编写双语教材是一次全新的尝试。尽管我们尽了很大的努力，但由于作者水平所限，仍然可能存在错误和疏漏之处。我们期待着读者的批评指正。

编　者

2003年9月

PREFACE

Numerical Control is one of the most important achievements in mechanical engineering field in 20 century. It is a crossing and integrating technology comprising of computer technology, automatic control technology, information technology, sense technology, and machining technology. Numerical control technology and advanced manufacturing technology based on numerical control technology have promoted and will promote mechanical engineering technology and make it develop rapidly. Numerical control technology has become one of the important technical basic classes of the students of mechanical engineering specialty. After China join to the WTO, the manufacturing industry will transfer from advanced countries to China, and great amounts of advanced equipment will enter to China. This is not only challenge but also opportunity for the manufacturing industry of China. The age has brought forward the higher requirements of special technique and foreign language to the students of mechanical engineering major. In response to these requirements, many universities and colleges have developed double language teaching. Under the guide and organizing of committee of double language textbooks of general university, we write the textbook, to meet the requirement of mechanical engineering speciality for bilingual textbook.

This book is written on the base of teaching précis of numerical control technology of universities in our country. We strive to add the most current advantages of numerical control technology from abroad and our country, to meet the requirements of China's university.

The chapter 1 and 7 of the book are written by Dong Changshuang, the chapter 2 is written by Chang Xing, the chapter 3 written by Li Wenbin, the chapter 4 written by Wang Honghai, the chapter 5 written by Yang Li, and the chapter 6 written by Hu Zhanqi. The total book is arranged by Hu Zhanqi. Zang Huaiquan, Professor of Yanshan University, and Yu Hongnian, Professor of Bradford University England, are retained as the chief umpire of the book. Wang Yiqun, Professor of Yanshan university, gives greate support to the publishing of the book, Song Shujun and Wu Linpu, the graduated students of Yanshan University, take part in the proofreading of the book. We are grateful to them for their contributions to this book.

It is a very new attempt to write bilingual textbook. Because of the limits of the writer's ability, There may be some mistakes and careless omissions in the book, although we have tried our best. We hope to get the criticizing from readers.

Authors

2003.9

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CHAPTER 1

INTRODUCTION TO NUMERICAL CONTROL

1.1 FUNDAMENTALS OF NC TECHNOLOGY

1.1.1 Development History of NC

The concept for NC dates from the late 1940s. The development of NC owes much to the United States Air Force and the early aerospace industry. The first development work in the area of NC is attributed to John Parsons and his associate Frank Stulen at Parsons Corporation in Traverse City, Michigan. Parsons was a contractor for Air Force during the 1940s and had experimented with the concept of using coordinate position data contained on punched cards to define and machine the surface contours of airfoil shape. He had named his system the Cardamatic milling machine, since the numerical data was stored on the punched cards.

The first NC machine was developed in 1952. Under contract to the U. S Air Force, the Parsons Corporation undertook the development of a flexible, dynamic manufacturing system, designed to maximize productivity by emphasizing details required to achieve desired accuracies①. This system would allow design changes without costly modifications to tooling and fixturing, and it would fit into a modern, productive manufacturing management for small-to-medium sized production runs. The Parsons Corporation subcontracted the development of the control system to the Massachusetts Institute of Technology (MIT) in 1951. A control, which could be applicable to a wide variety of machine tools, would drive a slide lead screw through an interface, instructed by the output of a computer. MIT met the challenge successfully, and in 1952 demonstrated a Cincinnati Hydrotel milling machine equipped with the new technology, which was named Numerical control (NC) and used a prepunched tape as the input media. Since 1952, practically every machine tool manufacturer in the Western world has converted part or its entire product to NC.

The first NC machines used vacuum tubes, electrical relays, and complicated machine-control interfaces (1952). The second generation of machines utilized improved miniature electronic tubes (1959), and later small scale integrated circuits (1965).

As computer technology improved, NC underwent one of the most rapid changes known in history. The fourth generation used much improved integrated circuit (1970s). Computer hardware became progressive less expensive and more reliable and NC control builders introduced for the first time Read Only Memory (ROM) technology. ROM was typically used for program storage in special-purpose applications, leading to the appearance of the computer numerical control (CNC) system. CNC was successfully introduced to practically every manufacturing process.

The fifth generation is microprocessor CNC. Since the introduction of NC in 1952, there have been dramatic advances in digital computer technology. The physical size and cost of a digital computer have been substantially reduced at the same time that its computational capabilities have been substantially increased. It was logical for the makers of NC equipment to incorporate these advances in computer technology into their products, starting first with microcomputer in the 1980s. Among the strengths of the fifth generation microprocessor CNC (MCNC) are added part program memory storage, reduction of printed circuit boards, programmable interface, faster memory access, parametric subroutines, and macro capabilities.

1.1.2 Concept of NC and CNC

Numerical control (NC) is a form of programmable automation in which the mechanical actions of a machine tool or other equipment are controlled by a program containing coded alphanumeric data. The alphanumerical data represent relative positions between a workhead and a workpart as well as other instructions needed to operate the machine. The workhead is a cutting tool or other processing apparatus, and the workpart is the object being processed. When the current job is completed, the program of instructions can be changed to process a new job. The capability to change the program makes NC suitable for low and medium production. It is much easier to write new programs than to make major alterations of the processing equipment.

Numerically controlled (NC) machine tools were developed to fulfill the contour machining requirements of complex aircraft parts and forming dies. The first-generation numerically controlled units used digital electronic circuits and did not contain any actual central processing unit; thereby they were called NC or hardwired NC machine tools. In 1970s, computer numerically controlled (CNC) machine tools were developed with minicomputers used as control units. With the advances in electronics and computer technology, current CNC systems employed several high-performance microprocessors and programmable logical controllers that work in a parallel and coordinated fashion. Current CNC systems allow simultaneous servo position and velocity control of all the axis, monitoring of controller and machine tool performance, online part programming with graphical assistance, in-process cutting process monitoring, and in-process part gauging for completely unmanned machining operations[②]. Manufacturers offer most of these features asoptions. Today, virtually all the new machine control units are based on computer technology; hence, when we refer to NC in chapter and elsewhere, we mean CNC.

1.1.3 Basic Components of NC Machine Tools

The control system of a numerically controlled machine tool can handle many tasks commonly done by the operator of a conventional machine. For this, the numerical control system must 'know' when and in what sequence it should issue commands to change tools, at what speeds and feeds the machine tool should operate, and how to work a part to the required size. The system gains the ability to perform the control functions through the numerical input information that is the control program, also called the part program.

The work process of NC is show in Figure 1.1. The part programmer should study the part drawing and the process chart and then prepare the control program on a standard form in the specified format. It contains all the necessary control information. A computer-assisted NC part program for NC machining method is also available, in which the computer considerably facilitates the work of the programmer and generate a set of NC instructions. Next the part program is transferred into the control computer; the wide accepted method is that the worker types the part program into the computer from the keyboard of the computer numerical control front panel. The computer converts each command into the signal that the servo-drive unit needs. The servo-drive unit drives the machine tool to manufacture the finished part.

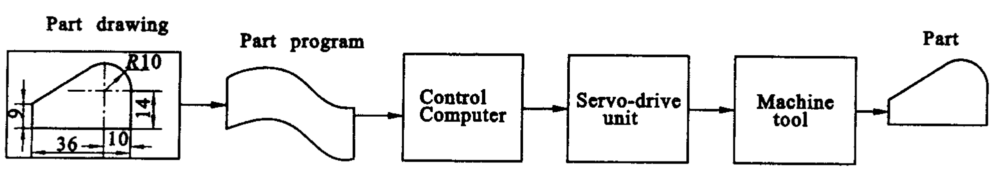

Figure 1.1 The work process of NC

A typical NC machine tool has five fundamental units: (1) the input media, (2) the machine control unit, (3) the servo-drive unit, (4) the feedback transducer, and (5) the mechanical machine tool unit. The general relationship among the five components is illustrated in Figure 1.2.

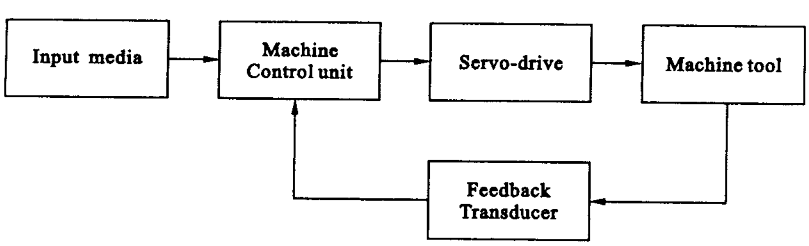

Figure 1.2 Basic components of a CNC machine tool

The input media contains the program of instructions, it is the detailed step-by-step commands that direct the actions of the machine tool; the program of instructions is called a part program. The individual commands refer to positions of a cutting tool relative to the worktable on which the workpart is fixtured. Additional instructions are usually included, such as spindle speed, feed rate, cutting tool selection, and other functions. The program is coded on a suitable medium for submission to the machine control unit. For many years, the common medium was 1-inch wide punched tape, using a standard format that could be interpreted by the machine control unit. Today, punched tape has largely been replaced by newer storage technologies in modern machine shops. These technologies include magnetic tape, diskette, and electronic transfer of part programs from a computer.

In modern CNC technology, the machine control unit (MCU) consists of a microcomputer and related control hardware that stores the program of instructions and executes it by converting each command into mechanical actions of machine tool, one command at a time. The MCU includes system software, calculation algorithm, and transition software to covert the NC parts program into a usable format for the MCU.

The third basic component of an NC system is the servo-drive unit; the drives in machine tools are classified as spindle and feed drive mechanisms. Spindle and feed drive motors and their servo-amplifiers are the components of the servo-drive unit. The MCU processes the data and generates discrete numerical position commands for each feed drive and velocity command for the spindle drive. The numerical commands are converted into signal voltage by the MUC unit and sent to servo-amplifiers, which process and amplify them to the high voltage levels required by the drive motors.

The forth basic component of an NC system is the feedback transducer. As the drives move, sensors measure their actual position. The difference between the required position and the actual position is detected by comparison circuit and the action is taken, within the servo, to minimize this difference.

The fifth basic component of an NC system is the machine tool that performs useful work. It accomplishes the processing steps to transform the starting workpiece into a completed part. Its operations are directed by the MCU, which in turn is driven by instructions contained in the part program. In the most common example of NC, machine tool consists of the worktable and spindle.

1.2 CLASSIFICATIONS OF NC MACHNINES

Numerical control machines are classified in different way: (1) the types of NC motion control system, (2) the type of servo-drive system, and (3) application of NC.

1.2.1 Types of NC Motion Control System

Some NC processes are performed at discrete locations on the workpart (e. g. , drilling,