普通高等教育"十二五"规划教材
PUTONG GAODENG JIAOYU "12·5" GUIHUA JIAOCAI

Bilingual Course of Material Forming Process

金属材料成形双语教程

余万华 编

冶金工业出版社
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内 容 提 要

本书是在 Serope Kalpakjian 教授等主编的《Manufacturing Engineering and Technology》及国外有关的优秀教材基础上，针对我国高校金属材料加工与控制专业学生的双语教学需要改编而成的。全书共分 8 章，包括：材料成形基础知识，金属结构特点和结构缺陷，合金相变和组织演变的基本特性等。在此基础上重点介绍了铸造、轧制、锻造、焊接等几种主要的金属成形方式、最新成形工艺和相应的质量缺陷及防治方法等。为了便于学生学习，每章章后附有思考题，书后列出了材料加工方面常用单词英汉对照。在内容组织和结构安排上，力求理论联系实际，注重学生专业能力的培养，突出实用性、先进性。

本书主要作为大专院校冶金和金属材料加工与控制专业双语教学用书，也可作为相关企业在职人员的培训教材，并可供从事金属材料研究、生产和应用方面的工程技术人员与管理人员参考。

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前　言

材料加工工程是现代工业体系中的一个重要环节，它是将机械、材料、信息及计算机控制等技术综合应用于产品的开发设计、制造等全过程。现代材料加工技术发展很快，它是衡量一个国家综合竞争力的重要标志。随着经济全球化发展，现代材料加工技术国际交流日益频繁，也越来越重要，在这方面学习的学生，不仅需要掌握本国的技术发展，还需要了解最新的国际动态，参与国际市场的交流与竞争。因此，现代教育不仅要培养学生学好专业知识，还要培养和教育学生掌握一定的外语表达、阅读和交流能力，以适应国际化发展需要。

本教材是针对金属材料加工与控制专业的学生编写的，目的是通过英语讲授金属材料加工方面的知识，既提高学生的英语听、写和交流能力，又深化学生专业知识，实现双语教学。本教材内容以金属材料加工为主，重点介绍了几种主要金属材料加工方法，如铸造、轧制、锻造及焊接工艺特点及可能产生的质量缺陷等。为了便于学生学习和思考，每章章前有本章要点，章后有思考题及中文注释，并且书后附有金属材料成形常用单词英汉对照。

本教材部分章节节选于美国 Serope Kalpakjian 教授编著的《Manufacturing Engineering and Technology》（Third Edition, by Addison – Wesley, 1995）和《Manufacturing Processes for Engineering Materials》（Second Edition, by Addison – Wesley, 1991），这些教材语言简洁，内容深入浅出，应用广泛。

本教材由北京科技大学余万华副教授编写，在对有关内容进行筛选和改编过程中，北京科技大学吴春京教授、韩静涛教授，华中科技大学王桂兰教授和河北联合大学郑申白教授均提出了许多宝贵的建设性意见，北京科技大学教务处和材料学院对该教材的出版提供了资助，在此表示衷心的感谢！

由于编者水平有限，书中不妥之处，敬请读者批评指正。

余万华

2012 年 6 月

Preface

Materials Processing Engineering is an important part in the modern industrial system, it is the whole process of the integration of machinery, materials, information and computer control technology used in product development and design, manufacturing, etc. Modern materials processing technology has developed rapidly, it is an important indicator of measuring a country's overall competitiveness. With the development of economic globalization and frequent international exchanges, students learning in this field not only need to master the technological development in the country, but also need to know the latest international developments. Therefore, the modern education is not only to train students to learn professional knowledge, but also to train and educate students to master skills in expression, reading and communication with foreign language, to adapt to the future development needs.

This textbook is written in English for students major in the material processing and control to improve student's English listening, writing and communication skills and deepen the student's professional knowledge. Textbook includes metal materials processing, and highlights several major metal processing methods, such as casting, rolling, forging and welding process characteristics and quality defects that may arise. In order to facilitate student's learning and thinking, each chapter provides Summary and Questions for review and chinese annotation, finally the book is attached with the main English – Chinese vocabulary in metal material forming.

This textbook excerpted from 《Manufacturing Engineering and Technology》(Third Edition, by Addison – Wesley, 1995) and 《Manufacturing Processes for Engineering Materials》(Second Edition, by Addison – Wesley, 1991) compiled by Professor Serope Kalpakjian, whose textbook language is concise, easy to understand, a wide range of applications.

The book was complied by Dr. Yu Wanhua, Beijing University of Science and Technology, in the process of filter and adaptation, Prof. Wu Chunjing, Prof. Han Jingtao (Beijing University of Science and Technology), Prof. Wang Guilan (Huazhong University of Science and Technology), and Prof. Zheng Shenbai (Hebei Union University) have put forward many valuable and constructive comments on the book, USTB Office of Academic Affairs and Department of Materials Science have provided funding for publication, Dr. Yu want to express sincere thanks for these helps here!

Due to time limited, the book is inevitable to have some errors, your comment and suggestion are welcomed.

Wanhua Yu
2012. 6

Contents

1 General Introduction

本章要点 本章简要介绍了制造工程在现代工业生产中的必要性，它是衡量一个国家工业化水平的重要标志，涉及到现代生活的各个方面，如环保、紧密敏捷设计和制造、公司组织构架等。材料成形是制造工程的重要组成部分，其最终目的是以低成本、高质量的产品满足用户的需求。在制造工程中，要注意避免过分设计导致不必要的浪费。计算机技术已在材料成形中广泛应用，涉及到各个方面，极大地推动了材料成形的技术进步。质量管理也很重要，它是确保产品质量稳定的必不可少的手段。

1.1 What are Material Forming and Manufacturing?

As you begin to read this Introduction, take a few moments and inspect the different objects around you: your watch, chair, stapler, pencil, calculator, telephone, and light fixtures. You will soon realize that all these objects have different shapes at one time. You could not find them in nature as they appear in your room. They have been transformed from various raw materials and assembled into the shapes that you now see.

Some objects are made of one part, such as nails, bolts, wire or plastic coat hangers, metal brackets, and forks. However, most objects aircraft engines, ballpoint pens, toasters, bicycles, computers, and thousands more are made of a combination of several parts made from a variety of materials. A typical automobile for example, consists of about 15, 000 parts, a C-5A transport plane is made of more than 4 million parts, and a Boeing 747-400 is made of 6 million parts. All are made by various processes that we call manufacturing. Manufacturing, in its broadest sense, is the process of converting raw materials into products. It encompasses the design and manufacturing of goods, using various production methods and techniques.

Manufacturing is the backbone of any industrialized nation. Its importance is emphasized by the fact that, as an economic activity, it comprises approximately 22 to 30 percent of the value of all goods and services produced in industrialized nations.

The level of manufacturing activity is directly related to the economic health of a country. Generally, the higher the level of manufacturing activity in a country, the higher is the standard of living of its people.

Manufacturing also involves activities in which the manufactured product is itself used to make other products. Examples are large presses to form sheet metal for car bodies, metalworking machinery used to make parts for other products, and sewing machines for making clothing. An equally important aspect of manufacturing activities is servicing and maintaining this machinery during its useful life.

The word manufacturing is derived from the Latin manu factus, meaning made by hand. The word manufacture first appeared in 1567, and the word manufacturing appeared in 1683. In the modern sense, manufacturing involves making products from raw materials by various processes, machinery, and operations, following a well organized plan for each activity required[1]. The word product means something that is produced, and the words product and production first appeared sometime during the fifteenth century. The word production is often used interchangeably with the word manufacturing. Whereas manufacturing engineering is the term used widely in the United States to describe this area of industrial activity, the equivalent term in Europe and Japan is production engineering.

Because a manufactured item has undergone a number of changes in which a piece of raw material has become an useful product, it has a value defined as monetary worth or marketable price. For example, as the raw material for ceramics, clay has a certain value as mined. When the clay is used to make a ceramic dinner plate, cutting tool, or electrical insulator, value is added to the clay. Similarly, a wire coat hanger or a nail has a value over and above the cost of a piece of wire. Thus manufacturing has the important function of adding value[2].

Manufacturing may produce discrete products, meaning individual parts or part pieces, or continuous products. Nails, gears, steel balls, beverage cans, and engine blocks are examples of discrete parts, even though they are mass produced at high rates. On the other hand, a spool of wire, metal or plastic sheet, tubes, hose, and pipe are continuous products, which may be cut into individual pieces and thus become discrete parts.

Manufacturing is generally a complex activity, involving people who have a broad range of disciplines and skills and a wide variety of machinery, equipment, and tooling with various levels of automation, including computers, robots, and material handling equipment. Manufacturing activities must be responsive to several demands and trends:

(1) A product must fully meet design requirements and specifications.

(2) A product must be manufactured by the most economical methods in order to minimize costs.

(3) Quality must be built into the product at each stage, from design to assembly, rather than relying on quality testing after the product is made.

(4) In a highly competitive environment, production methods must be sufficiently flexible so as to respond to changing market demands, types of products, production rates, production quantities, and on time delivery to the customer.

(5) New developments in materials, production methods, and computer integration of both technological and managerial activities in a manufacturing organization must constantly be evaluated with a view to their timely and economic implementation.

(6) Manufacturing activities must be viewed as a large system, each part of which is interrelated to others. Such systems can be modeled in order to study the effect of factors such as

changes in market demands, product design, material and various other costs, and production methods on product quality and cost.

(7) The manufacturing organization must constantly strive for higher productivity, defined as the optimum use of all its resources: materials, machines, energy, capital, labor, and technology. Output per employee per hour in all phases must be maximized.

1.2 Examples of Manufactured Products

In this section we review briefly the thought processes and procedures involved in designing and manufacturing some common products. Our purpose is to identify the important factors involved and, with specific examples, to show you how intimately design and manufacturing are and should be interrelated.

1.2.1 Paper clips

Assume that you are asked to design and produce ordinary paper clips. What type of material would you choose to make this product? Does it have to be metallic or can it be nonmetallic, such as plastic? If you choose metal, what kind of metal? If the material that you start with is wire, what should be its diameter? Should it even be round or should it have some other cross section? Is the wire's surface finish important and, if so, what should be its roughness? How would you shape a piece of wire into a paper clip? Would you shape it by hand on a simple fixture and if not, what kind of machine would you design or purchase to make paper clips? If, as the owner of a company, you were given an order of 100 clips versus a million clips, would your approach to this manufacturing problem be different?

The paper clip must meet its basic functional requirement: to hold pieces of paper together with sufficient clamping force so that the papers do not slip away from each other. It must be designed properly, including its shape and size. The design process is based partly on our knowledge of strength of materials and mechanics of solids, dealing with the stresses and strains involved in the manufacturing and normal use of the clip[1].

The material selected for a paper clip must have certain stiffness and strength. For example, if the stiffness (a measure of how much it deflects under a given force) is too high, a great deal of force may be required to open the clip, just as a stiff spring requires a greater force to stretch or compress it than does a softer spring. If the material is not sufficiently stiff, the clip will not exert enough clamping force on the papers. Also, if the yield stress of the material (the stress required to cause permanent deformation) is too low, the clip will bend permanently during its normal use and will be difficult to reuse. These factors also depend on the diameter of the wire and the design of the clip.

Included in the design process are considerations such as style, appearance, and surface finish or texture of the clip. Note, for example, that some clips have serrated surfaces for better clamping. After finalizing the design, a suitable material has to be selected. Material selection requires knowledge of the function and service requirements of the product and the materials that, preferably, are available commercially to fulfill these requirements at the lowest possible cost. The selection of the material also involves considerations of its corrosion resistance, since the clip is handled often and is subjected to moisture and other environmental attack. Note, for example, the rust marks left by paper clips on documents stored in files for a long period of time.

Many questions concerning production of the clips must be asked. Will the material selected be able to undergo bending during manufacturing without cracking or breaking? Can the wire be easily cut from a long piece without causing excessive wear on the tooling? Will the cutting process produce a smooth edge on the wire, or will it leave a burr (a sharp edge)? A burr is undesirable in the use of paper clips since it may tear the paper or even cut the user's finger. Finally, what is the most economical method of manufacturing this part at the desired production rate, so that it can be competitive in the national and international marketplace and the manufacturer can make a profit? A suitable manufacturing method, tools, machinery, and related equipment must then be selected to shape the wire into a paper clip.

1.2.2 Incandescent light bulbs

The first incandescent lamp was made by T. A. Edison and lit in 1879. Many improvements have since been made in the materials and manufacturing methods for making bulbs. The components of a typical light bulb are shown in Fig. 1.1. The light emitting part is the filament which, through electrical resistance, is heated to incandescence, that is, to temperatures between 2200℃ and 3000℃. Edison's first successful lamp had a carbon filament, although he and others had also tried various materials such as carbonized paper, osmium, iridium, and tantalum. However, none of those materials has the high temperature resistance, strength, and long life of tungsten, which is now the most commonly used filament material.

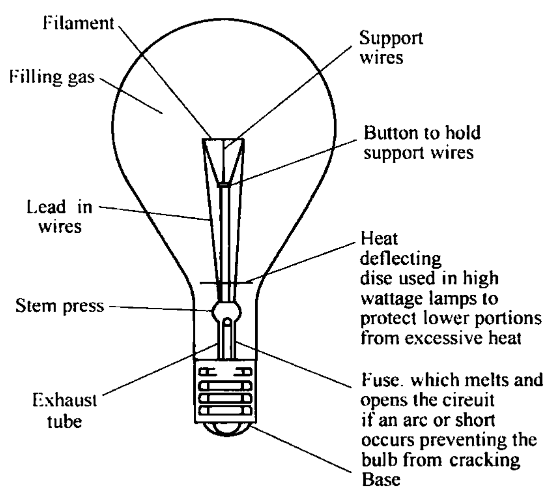

Fig. 1.1 Components of a typical light bulb

The first step in manufacturing a light bulb is making the glass stem which supports the lead in wires and the filament and connects them to the base of the bulb (Fig. 1.2). These parts are positioned, assembled, and sealed while the glass is heated by gas flames. The filament is then attached to the lead in wires. These and other operations in making bulbs are performed on highly automated machines.

The completed stem assembly, called the mount, is then transferred to a machine that lowers a glass bulb over it. Gas flames are used to seal the rim of the mount to the neck of the bulb. The air in the bulb is exhausted through the exhaust tube (an integral part of the glass stem), and the

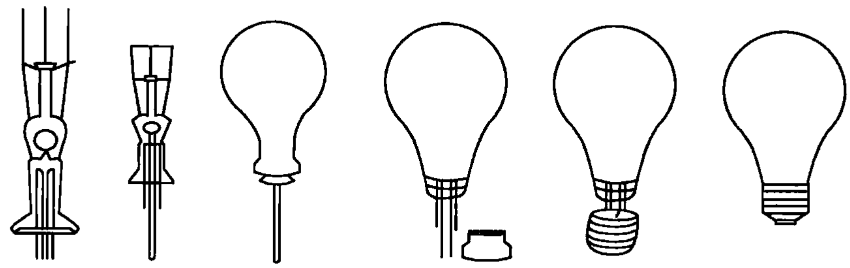

Fig. 1.2 Manufacturing process of a light bulb

bulb is either evacuated or filled with inert gas. For bulbs of 40 watts and above, the gas is typically a mixture of nitrogen and argon. The filling gas should be pure; otherwise the inside surfaces of the bulb will blacken. For example, just one drop of water in the gas used for half a million lamps causes blackening in all of them. The exhaust tube is then sealed off. The last production step consists of attaching the base to the bulb, using a special cement. The machine that does the attaching also solders or welds the lead in wires to the metal base for electrical connection.

The filament is made by first pressing tungsten powder into ingots and sintering it (heating without melting). The ingot is then shaped into round rods by swaging, and the rods are drawn through a die in a number of steps into thin wire. The wire is coiled to increase the light producing capacity of the filament. The wire diameter for a 60watt, 120volt lamp is 0.045mm and must be controlled very accurately. If the wire diameter is only 1 percent less than that specified, the life of the lamp may be reduced by as much as 25 percent. Spacing between coils must also be very accurate to prevent heat concentration at one point and possible shorting.

Lead in wires are usually made of nickel, copper, or molybdenum, and the support wires are made of molybdenum. The portion of the lead in wire embedded in the stem is made of an alloy of iron and nickel, coated with copper, and has essentially the same thermal expansion as the glass. In this way, thermal stresses that otherwise might cause the stem to crack are not developed. The base is generally made from aluminum, specially lubricated to permit easy insertion into the socket. In the past the base was made from brass, which is both more expensive than aluminum and not as good an electrical conductor.

The glass bulbs are commonly made by blowing molten glass into a mold. Automated machinery can make bulbs at rates of 1000 a minute or higher. Several types of glasses are used depending on the kind of bulb desired. The inside of the bulb is either plain or frosted to reduce glare and diffuse the light better.

1.3 The Design Process and Concurrent Engineering

The design process for a product first requires a clear understanding of the functions and the performance expected of that product (Fig. 1.3). The product may be new, or it may be a revised version of an existing product. We all have observed, for example, how the design and style of radios, toasters, watches, automobiles, and washing machines have changed. The market for a product and its anticipated uses must be defined clearly, with the assistance of sales personnel, market analysts, and others in the organization. Product design is a critical activity because it has been estimated that 70 to 80 percent of the cost of product development and manufacture is determined at the initial design stages.

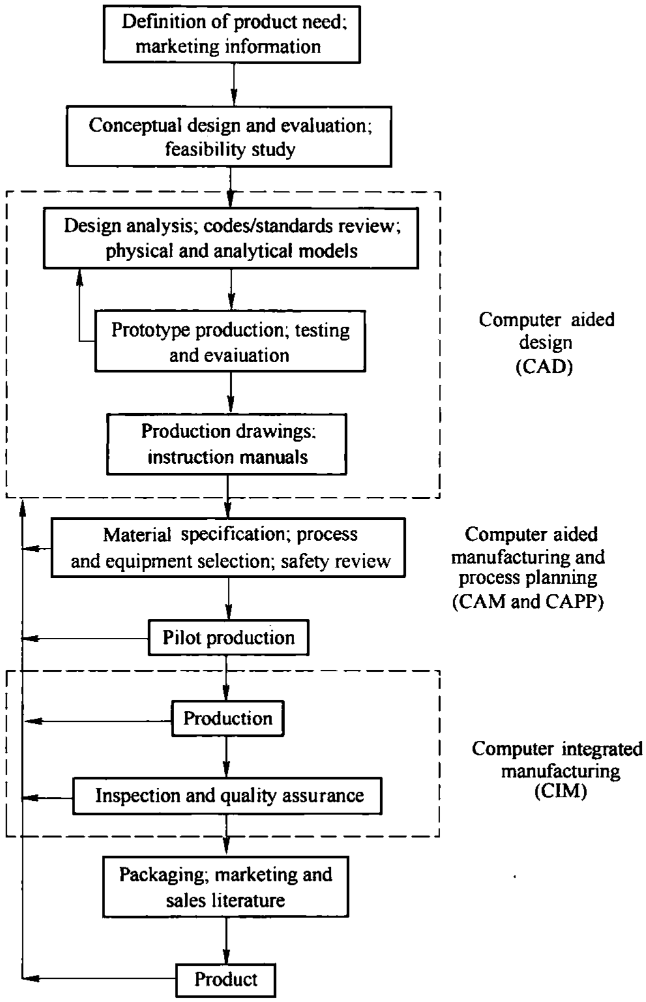

Fig. 1.3 Chart showing various steps involved in designing and manufacturing a product. Depending on the complexity of the product and the type of materials used, the time span between the original concept and marketing a product may range from a few months to many years. Concurrent engineering combines these stages to reduce the time span and improve efficiency and productivity

Traditionally, design and manufacturing activities have taken place sequentially rather than concurrently or simultaneously. Manufacturing engineers were given the detailed drawings and specifications of the product and were asked to make them. They often encountered difficulties because the design or product engineers did not anticipate the production problems which could occur. This situation has been improved greatly by the use of concurrent engineering (CE) or simultaneous engineering.