



国外机械类优秀教材改编系列
Adapted Oversea Exellent Textbooks on Mechanical Engineering



制造工程与技术 第四版 改编版

Manufacturing Engineering and Technology Forth Edition

原著 Serope Kalpakjian Steven R.Schmid

改编 唐一平



高等教育出版社
Higher Education Press

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内容简介

本书是在 Serope Kalpakjian 等主编的 Manufacturing Engineering and Technology (Forth Edition) 教材的基础上改编而成的, 改编后的教材既保留了国外原版教材的风格, 又适合国内教学的需要, 是优秀的“双语”教学教材。

本书除绪论外共三篇 20 章, 第一篇为工程材料基础, 主要介绍的金属材料、非金属材料、复合材料的特性、选用方法及在工程中的实际应用, 并对纳米材料及高分子材料做了介绍。第二篇为材料成形技术, 本篇不仅介绍了传统的铸锻工艺、精密锻造以及粉末冶金、塑料和复合材料的成形技术, 还介绍了快速原型和快速模具技术; 第三篇为机械加工技术, 除了对传统的各种机加工工艺进行了介绍外, 还介绍了高速切削加工、现代加工中心、先进刀具和磨削材料、非传统加工技术(化学、电火花、超声、等离子、激光加工等)以及正在逐渐成为现代制造领域的一个重要发展方向的纳米制造和微细加工等先进制造技术。

为了便于读者阅读, 本教材在每一章后面都附有中文注释和主要的专业术语, 而且在书末还附有按字母顺序排列的中英文对照词汇表。

本书可作为机械设计制造及其自动化专业以及机电类其他相关专业的本科生或研究生的英文教材, 也可供相关的工程技术人员参考。

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出版说明

为进一步适应高等教育教学改革发展的趋势,加速培养具有国际竞争力的高素质优秀人才,教育部在《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)中提出:“本科教育要创造条件使用英语等外语进行公共基础课和专业课教学。”目前,按照教育部教高[2001]4号文件的精神,我国各类高校都以不同的形式全面展开“双语”教学,教师们在“双语”教学实践中积累了一些经验,同时也对双语教学提出了不同的意见与看法。教材是教学内容与教学方法的知识载体,是教师教学、学生学习的基本工具,也是深化教学改革、提高教学质量的重要保证。因此,一本优秀的“双语”教学教材无疑将对高校开展“双语”教学产生积极的推动作用。许多老师在实践中体会到,没有国外原版教材,“双语”教学犹如无本之木、无源之水,而直接使用国外教材作为“双语”教学的教材在实际授课中也存在诸多弊病。尤其是在机械类课程的教学中,不仅存在着工程标准不同的问题,而且存在着课程内容与课程体系的差异。许多教师在授课过程中采用不同的教材作参考,根据授课的需要将所需的资料拼凑到一起,以解决上述教学中存在的矛盾。因此,由于缺乏合适的“双语”教材,使“双语”教学缺乏进入机械类课程课堂教学的基础。

我社在发展壮大过程中积极实施国际化的战略,从世界范围内发掘优秀教育资源服务于我国高校的教育教学与人才培养,为我国高等教育的可持续发展提供精工细作的食粮。针对我国高校开展“双语”教学的现状,我社积极开展与 Pearson Education, John Wiley & Sons, McGraw-Hill 以及 Thomson Learning 等国外大型教育出版集团合作,以不同的方式将国外优秀教材输送到我国高等教育的第一线。针对机械类课程的特点及我国高校机械类课程开展“双语”教学存在的问题,我社积极组织国内外专家,进行了改编国外优秀教材,为我国机械类课程“双语”教学量体裁衣的尝试。

首先,精选教材。在广泛了解我国高校机械课程开展“双语”教学的情况,了解广大高校在开展“双语”教学的过程中对教材的需求后,我们与多家国外出版公司进行了广泛接触,经推荐并在国内专家的协助下,精选了涉及机械、材料、能源动力等专业领域的优秀教材几十种之多。我们聘请了国内高校一线教师、专家学者参与这些原版教材的评介工作,从中遴选出了一批可供改编的优秀教材。

这批教材普遍具有以下特点:(1)基本上是近几年出版的,在国际上被广泛使用,在同类教材中具有相当的权威性;(2)高版次,历经多年教学实践检验,内容翔实准确,反映时代要求;(3)各种教学资源配套整齐,为师生提供了极大的便利;(4)插图精美,图文密切配合;(5)语言简练、流畅,可读性强,比较适合非英语国家的学生阅读。

其次,慎选改编者。教材的优劣将直接影响到教学质量的高低,而一位学识渊博、治学严谨的作者是编写出高水平精品教材的前提。我们与国内众多高等院校的众多专家学者进行了广泛的接触和细致的协商,几经酝酿,最终确定下来改编者。大多数改编者是有国外留学背景的中青年学者,他们既有相当高的学术水平,又热爱教学,活跃在教学第一线。他们能够承担

此任,不单是因为他们了解引进版教材的知识结构、表达方式和写作方法,更重要的是他们有精力、有热情,愿意付出,有的甚至付出了比写一本新教材更多的劳动。

在努力降低引进教材售价方面,高等教育出版社做了大量和细致的工作。总之,这套引进改编的教材具有一定的权威性、系统性、先进性和经济性。

改编国外优秀教材,不仅引进了国外优秀教材所包含的先进的科技知识,而且引进了先进的教育理念、教学思想。我们希望这套教材能够为我国高校“双语”教学的教材建设带来启示,同时也对推进我国高校机械类课程“双语”教学有所裨益。

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前 言

随着科学技术的发展,制造技术已成为当今各国在经济上获得成功的关键技术,并逐渐发展形成制造科学体系。制造技术既是制造业赖以生存的主体技术,又是国民经济发展的主要支柱技术。先进制造技术是将机械、材料、信息以及现代管理技术等最新成果综合应用于产品开发与设计、制造以及管理等制造全过程,实现优质、高效、低耗、敏捷生产的前沿制造技术的总和。先进制造技术已成为提高制造业竞争力的主要手段,是增加综合国力和促进国民经济发展的基础。

目前,我国高校机械设计制造及其自动化专业普遍开设了制造科学与技术课程,该课程主要讲述工程材料、材料成形技术、机械加工技术等相关知识。为了加强在该课程上与国外高校的交流,引进国外先进的制造技术与教学思想,开阔我国高校师生的眼界,很多高校在该课程上进行了“双语”教学的尝试。许多老师在实践中体会到,没有国外原版教材,“双语”教学犹如无本之木、无源之水,而直接使用国外教材作为“双语”教学的教材在实际授课中也存在诸多弊病。对原版教材进行适当的删节与精选,使之与国内的教学实际相适应,成为了解决矛盾的有效方法。

由美国伊利诺伊理工学院 Serope Kalpakjian 教授等编著的、美国多所大学广为使用的 Manufacturing Engineering and Technology (Forth Edition) (《制造工程与技术》(第4版))教材,内容涵盖面宽,体系完善,涉及传统和现代的各种制造技术,尤其是对近年来出现的高速切削、快速原型制造和微制造技术也用一定篇幅作了介绍。改编后的教材既保留了国外原版的教材的风格,又适合国内教学的需要,是优秀的“双语”教学教材。本书结合我国制造业的实际发展与需求,将最有用的以及最能代表制造前沿技术的有关知识传授给学生。为了提高教学效果,本书添加了适量的中文注释和中英文对照词汇表。

本书由西安交通大学唐一平教授改编,在对原书内容进行筛选和改编过程中,西安交通大学卢秉恒教授、丁玉成教授、赵万华教授和苏秦教授提出了许多宝贵的建设性意见,在此致以衷心的感谢!

国外原版教材的引进与精选是一项艰苦而细致的工作,将其改编成面向中国学生的合适教材还仅仅是初步尝试。由于改编者水平有限,疏漏之外在所难免,敬请各位专家学者不吝赐教。

改编者

2004 年 12 月

CONTENTS

General Introduction	1
1. What Is Manufacturing?	1
2. The Design Process and Concurrent Engineering	6
3. Selecting Materials	11
4. Selecting Manufacturing Processes	13
5. Computer-Integrated Manufacturing	18
6. Global Competitiveness and Manufacturing Costs	21
7. Lean Production and Agile Manufacturing	22
8. Environmentally Conscious Design and Manufacturing	23

PART I Fundamentals of Materials; Their Behavior and Manufacturing Properties

1 The Structure of Metals	29
1.1 Introduction	29
1.2 The Crystal Structure of Metals	30
1.3 Cold-, Warm-, and Hot-Working	31
1.4 Work Hardening (Strain Hardening)	32
1.5 Plastic Deformation of Polycrystalline Metals	32
2 Mechanical Behavior, Testing, and Manufacturing Properties of Materials	37
2.1 Introduction	37
2.2 Tension	38
2.3 Compression	42
2.4 Torsion	43
2.5 Bending(Flexure)	44
2.6 Hardness	45
3 Physical Properties of Materials	51
3.1 Introduction	51
3.2 Density	51
3.3 Melting Point	55
3.4 Specific Heat	55
3.5 Thermal Conductivity	55
3.6 Thermal Expansion	56

3.7	Electrical, Magnetic, and Optical Properties	57
3.8	Corrosion Resistance	58
4	Metal Alloys Structure and Cast Irons	63
4.1	Introduction	63
4.2	Structure of Alloys	64
4.3	The Iron-Carbon System	67
4.4	Cast Irons	69
5	Ferrous Metals and Alloys	75
5.1	Introduction	75
5.2	Production of Iron and Steel	76
5.3	Carbon and Alloy Steels	79
5.4	Tool and Die Steels	82
6	Nonferrous Metals and Alloys	85
6.1	Introduction	85
6.2	Aluminum and Aluminum Alloys	87
6.3	Magnesium and Magnesium Alloys	88
6.4	Copper and Copper Alloys	90
6.5	Superalloys	91
6.6	Titanium and Titanium Alloys	92
6.7	Low-Melting Alloys	93
6.8	Precious Metals	96
6.9	Shape-Memory Alloys	96
6.10	Amorphous Alloys (Metallic Glasses)	97
6.11	Nanomaterials	97
7	Polymers: Structure, General Properties, and Applications	101
7.1	Introduction	101
7.2	The Structure of Polymers	103
7.3	Thermoplastics	108
7.4	Thermosetting Plastics	109
7.5	Additives In Plastics	110
7.6	General Properties and Applications of Thermoplastics	111
7.7	General Properties and Applications of Thermosetting Plastics	114
7.8	Biodegradable Plastics	115
7.9	Elastomers (Rubbers)	117
8	Composite Materials: Structure, General Properties, and Applications	121
8.1	Introduction	121
8.2	The Structure of Reinforced Plastics	122

8.3	Properties of Reinforced Plastics	126
8.4	Applications of Reinforced Plastics	127
8.5	Metal-Matrix Composites (MMC)	130
8.6	Ceramic-Matrix Composites (CMC)	131
8.7	Other Composites	131

PART II Forming and Shaping Processes and Equipment

9	Fundamentals of Metal-Casting	135
9.1	Introduction	135
9.2	Solidification of Metals	137
9.3	Metal-Casting Processes	140
10	Forging of Metals	157
10.1	Introduction	157
10.2	Open-Die Forging	159
10.3	Impression-Die and Closen-Die Forging	161
10.4	Extrusion and Drawing	164
11	Processing of Powder Metallurgy	169
11.1	Introduction	169
11.2	Production of Metal Powders	171
11.3	Compaction of Metal Powders	176
11.4	Sintering	177
11.5	Process Capabilities	180
11.6	Economics of Powder Metallurgy	181
12	Forming and Shaping Plastics and Composite Materials	183
12.1	Introduction	183
12.2	Injection Molding	184
12.3	Blow Molding	187
13	Rapid-Prototyping Operations	191
13.1	Introduction	191
13.2	Additive Processes	192
13.3	Applications of Rapid-Prototyping Technology	200

PART III Material-Removal Processes and Machines

14	Fundamentals of Cutting	211
14.1	Introduction	211

14.2	The Mechanics of Chip Formation	214
14.3	The Types of Chips Produced In Metal-Cutting	216
14.4	Cutting Forces and Power	218
14.5	Tool Life; Wear and Failure	222
14.6	Surface Finish and Surface Integrity	225
14.7	Machinability	227
15	Cutting-Tool Materials and Cutting Fluids	235
15.1	Introduction	235
15.2	Carbon and Medium-Alloy Steels	239
15.3	High-Speed Steels	239
15.4	Cast-Cobalt Alloys	240
15.5	Carbides	240
15.6	Coated Tools	245
15.7	Alumina-Based Ceramics	246
15.8	Cubic Boron Nitride	247
15.9	Silicon-Nitride Based Ceramics	248
15.10	Diamond	248
15.11	Whisker-Reinforced and Nanocrystalline Tool Materials	249
16	Machining Processes Used to Produce Round Shapes	253
16.1	Introduction	253
16.2	Turning Parameters	256
16.3	Lathes and Lathe Operations	259
16.4	High-Speed Machining, Ultraprecision Machining, and Hard Turning	267
16.5	Boring and Boring Machines	270
16.6	Drilling and Drills	272
17	Machining Processes Used to Produce Various Shapes	279
17.1	Introduction	279
17.2	Milling Operations	280
17.3	Milling Machines	289
17.4	Planing and Shaping	292
18	Machining and Turning Centers	295
18.1	Introduction	295
18.2	Machining and Turning Centers	295
18.3	Machining Economics	303
19	Abrasive Machining and Finishing Operations	309
19.1	Introduction	309
19.2	Abrasives	311

19.3	Bonded Abrasives (Grinding Wheels)	313
19.4	Honing	317
19.5	Lapping	318
19.6	Polishing	318
19.7	Electropolishing	319
19.8	Polishing Processes Using Magnetic Fields	319
19.9	Buffing	320
20	Advanced Machining Processes and Nanofabrication	323
20.1	Introduction	323
20.2	Chemical Machining	325
20.3	Electrical-Discharge Machining	327
20.4	Wire EDM	330
20.5	Laser-Beam Machining	331
20.6	Electron-Beam Machining and Plasma-Arc Cutting	334
20.7	Nanofabrication	335
20.8	Micromachining	337
20.9	Economics of Advanced Machining Processes	338
	中英文对照词汇表	343

General Introduction

1. What Is Manufacturing?
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4. Selecting Manufacturing Processes
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6. Global Competitiveness and Manufacturing Costs
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1. WHAT IS MANUFACTURING?

As you begin to read this Introduction, take a few moments and inspect various objects around you: your pen, watch, calculator, telephone, chair, and light fixtures. You will soon realize that all these objects had a different shape 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.

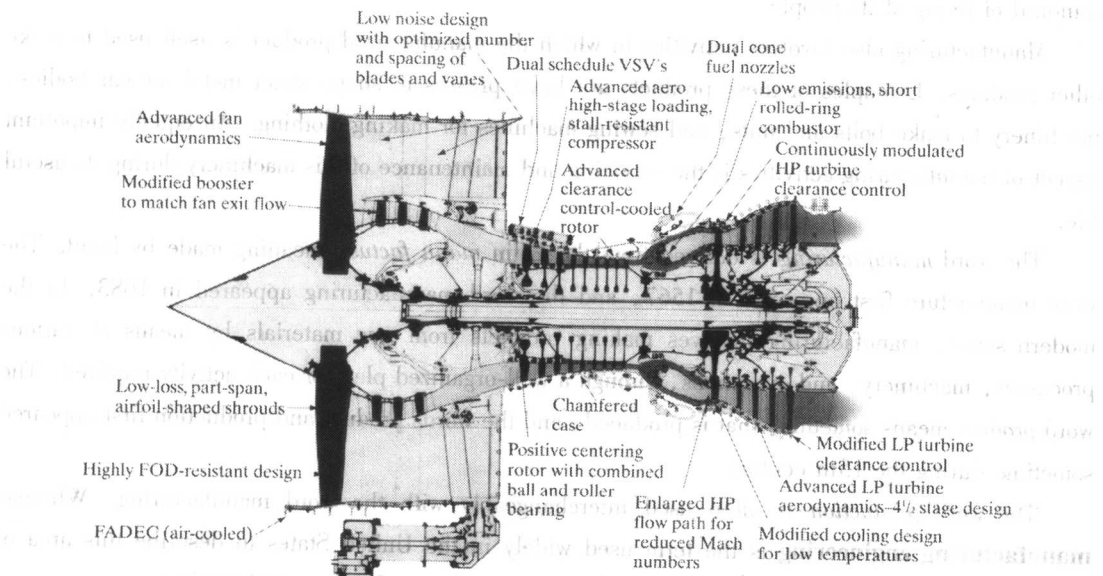


FIGURE 1 Cross-sectional view of a jet engine, showing various components. Many of the materials used in this engine must maintain their strength and resist oxidation at high temperatures. *Source:* Courtesy of General Electric Company.

Some objects are made of a single part, such as nails, bolts, wire or plastic coat hangers, metal brackets, and forks. However, most objects, such as aircraft jet engines (invented in 1939; Fig. 1), ball-point pens (1938), toasters (1926), washing machines (1910), air conditioners (1928), refrigerators (1931), photocopiers (1949), all types of machines, and thousands of other products are constructed by the assembly of a number of parts made from a variety of materials, as the following list indicates. All of the products mentioned are made by various processes that we call manufacturing.

Product	Number of parts
Rotary lawn mower	300
Grand piano	12,000
Automobile	15,000
C-5A transport plane	>4,000,000
Boeing 747—400	>6,000,000

Manufacturing, in its broadest sense, is the process of converting raw materials into products. It encompasses (1) the design of the product, (2) the selection of raw materials, and (3) the sequence of processes through which the product will be manufactured.

Manufacturing is the backbone of any industrialized nation. Its importance is emphasized by the fact that, as an economic activity, it comprises approximately 20% to 30% of the value of all goods and services produced. A country's level of manufacturing activity is directly related to its economic health. Generally, the higher the level of manufacturing activity in a country, the higher the standard of living of its people.

Manufacturing also involves activities in which the manufactured product is itself used to make other products. Examples of these products are large presses to shape sheet metal for car bodies, machinery to make bolts and nuts, and sewing machines for making clothing. An equally important aspect of manufacturing activities is the servicing and maintenance of 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 means of various processes, machinery, and operations, through a well-organized plan for each activity required. The word *product* means something that is produced, and the words *product* and *production* first appeared sometime during the 15th 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 other countries is **production engineering**.

Because a manufactured item has undergone a number of processes in which pieces of raw material have been turned into a 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 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 the piece of wire from which it is made. Thus manufacturing has the important function of *adding value*.

Manufacturing may produce **discrete products**, meaning individual parts, or **continuous products**. Nails, gears, balls for bearings, beverage cans, and engine blocks are examples of discrete parts, even though they are mass produced at high production rates. On the other hand, a spool of wire, a sheet of metal or plastic, and lengths of tubing, hose, and pipe are continuous products, which may be cut into individual pieces and thus become discrete parts.^①

Manufacturing is generally a complex activity involving a wide variety of resources and activities, such as the following:

- | | | |
|-------------------------|----------------------|--------------------|
| • Product design | • Purchasing | • Marketing |
| • Machinery and tooling | • Manufacturing | • Sales |
| • Process planning | • Production control | • Shipping |
| • Materials | • Support services | • Customer service |

Manufacturing activities must be responsive to several demands and trends:

1. A product must fully meet **design requirements** and **product specifications** and **standards**.
2. A product must be manufactured by the most **environmentally friendly** and **economical** methods.
3. **Quality** must be *built* into the product at each stage, from design to assembly, rather than tested in after the product is made. Furthermore, the level of quality should be appropriate to the product's use.
4. In a highly competitive environment, production methods must be **flexible** enough to respond to changes in market demands, types of products, production rates, production quantities, and on-time delivery requirements.
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 appropriate, timely, and economical implementation.
6. Manufacturing activities must be viewed as a large **system**, the parts of which are interrelated. Such systems can now be modeled, in order to study the effect of factors such as changes in market demands, product design, and materials. Various other factors and production methods affect product quality and cost.
7. A manufacturing organization must constantly strive for higher levels of **quality** and **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. Zero-based part rejection (and consequent reduction of waste) are also an integral aspect of productivity.

Although it is difficult to be more precise, manufacturing dates back to about 5000—4000 B.

C. It is older than recorded history, because primitive cave or rock markings and drawings were dependent on some form of brush or marker using a "paint," or a means of notching the rock; appropriate tools had to be made for these applications. Manufacturing of products for various uses began with the production of articles made of wood, ceramic, stone, and metal (Table 1). The materials and processes first used to shape products by casting and hammering have been gradually developed over the centuries, using new materials and more complex operations, at increasing rates of production and at higher levels of quality.

TABLE 1 Historical Development of Materials and Manufacturing Processes

	Period	Casting processes	Forming processes
Egypt: ~3100 B.C. to ~300 B.C. Greece: ~1100 B.C. to ~146 B.C. Roman empire: ~500 B.C. to ~476 A.D. Middle ages: ~476 to 1492 Renaissance: 14th to 16th centuries	Before 4000 B.C.	Gold, copper, meteoritic iron	Hammering
	4000–3000 B.C.	Copper casting, stone and metal molds, lost wax process, silver, lead, tin, bronze	Stamping, jewelry
	3000–2000 B.C.	Bronze casting	Wire by cutting sheet and drawing; gold leaf
	2000–1000 B.C.	Wrought iron, brass	
	1000–1 B.C.	Cast iron, cast steel	Stamping of coins
	1–1000 A.D.	Zinc, steel	Armor, coining, forging, steel swords
	1000–1500	Blast furnace, type metals, casting of bells, pewter	Wire drawing, gold and silver smith work
	1500–1600	Cast iron cannon, tinplate	Water power for metalworking, rolling mill for coinage strips
	1600–1700	Permanent mold castings, brass from copper and metallic zinc	Rolling (lead, gold, silver), shape rolling (lead)
	1700–1800	Malleable cast iron, crucible steel	Extrusion (lead pipe), deep drawing, rolling (iron bars and rods)
Industrial revolution: ~1750 to 1850	1800–1900	Centrifugal casting, Bessemer process, electrolytic aluminum, nickel steels, babbit, galvanized steel, powder metallurgy, tungsten steel, open-hearth steel	Steam hammer, steel rolling, seamless tube piercing, steel rail rolling, continuous rolling, electroplating
	1900–1920		Tube rolling, hot extrusion
	1920–1940	Die casting	Tungsten wire from powder
	1940–1950	Lost wax for engineering parts	Extrusion (steel), swaging, powder metals for engineering parts
WWI	1950–1960	Ceramic mold, nodular iron, semiconductors, continuous casting	Cold extrusion (steel), explosive forming, thermomechanical treatment
	1960–1970	Squeeze casting, single crystal turbine blades	Hydrostatic extrusion; electroforming
	1970–2000	Compacted graphite, vacuum casting, organically bonded sand, automation of molding and pouring, rapid solidification technology, metal-matrix composites, semisolid metalworking, rheocasting	Precision forging, isothermal forging, superplastic forming, dies made by computer-aided design and manufacturing, rapid prototyping, net-shape forming
Space age			
WWII			

Source: After J. A. Schey, C.S. Smith, R.F. Tylecote, T.K. Derry, T.I. Williams, and S. Kalpakjian.

The first materials used for making household utensils and ornamental objects included metals such as gold, copper, and iron, followed by silver, lead, tin, bronze, and brass. The production of steel in about 600–800 A. D. was a major development. Since then, a wide variety of ferrous and nonferrous metals have been developed. Today, the materials used in advanced products such as computers and supersonic aircraft include engineered or tailor-made materials with unique

properties, such as ceramics, reinforced plastics, composite materials, and specially alloyed metals.

Until the Industrial Revolution, which began in England in the 1750s, goods had been produced in batches, with much reliance on manual labor in all aspects of production. Modern mechanization began in England and Europe with the development of textile machinery and of machine tools for cutting metals. This technology soon moved to the United States, where it was developed further, including the important advance of designing, making, and using **interchangeable parts**. Prior to the introduction of interchangeable parts, a great deal of hand-fitting was necessary, because no two parts were made exactly alike. By contrast, we now take for granted that we can replace a broken bolt of a certain size with an identical one purchased years later from a local hardware store.

Further developments soon followed, resulting in numerous products that we cannot imagine being without, because they are so common. Since the early 1940s, major milestones have been reached in all aspects of manufacturing. For example, note from Table 1 the progress made during

Joining processes	Tools, machining, and manufacturing systems	Nonmetallic materials and composites
	Tools of stone, flint, wood, bone, ivory, composite tools Corundum	Earthenware, glazing, natural fibers
Soldering (Cu-Au, Cu-Pb, Pb-Sn)		
Riveting, brazing	Hoe making, hammered axes, tools for ironmaking and carpentry	Glass beads, potter's wheel, glass vessels
Forge welding of iron and steel, gluing	Improved chisels, saws, files, woodworking lathes	Glass pressing and blowing
	Etching of armor	Venetian glass
	Sandpaper, windmill-driven saw	Crystal glass
	Hand lathe (wood)	Cast plate glass, flint glass
	Boring, turning, screw cutting lathe, drill press	Porcelain
	Shaping, milling, copying lathe for gunstocks; turret lathe; universal milling machine; vitrified grinding wheel	Window glass from slit cylinder, light bulb, vulcanization; rubber processing, polyester, styrene, celluloid, rubber extrusion, molding
Oxyacetylene; arc, electrical resistance, and Thermit welding	Gear lathe, automatic screw machine, hobbing, high-speed steel tools, aluminum oxide and silicon carbide (synthetic)	Automatic bottle making, Bakelite, borosilicate glass
Coated electrodes	Tungsten carbide, mass production, transfer machines	Development of plastics, casting, molding, PVC, cellulose acetate, polyethylene, glass fibers
Submerged arc welding		Acrylics, synthetic, rubber, epoxies, photosensitive glass
Gas metal—arc, gas tungsten—arc, and electroslag welding; explosive welding	Electrical and chemical machining, automatic control	ABS, silicones, fluorocarbons, polyurethane, float glass, tempered glass, glass ceramics
Plasma arc and electron beam, adhesive bonding	Titanium carbide, synthetic diamond, numerical control	Acetals, polycarbonates, cold forming of plastics, reinforced plastics, filament winding
Laser beam; diffusion bonding (also combined with superplastic forming)	Cubic boron nitride, coated tools, diamond turning, ultraprecision machining, computer integrated manufacturing, industrial robots, flexible manufacturing systems, untended factory	Adhesives, composite materials, optical fibers, structural ceramics, ceramic components for automotive and aerospace engines, ceramic-matrix composites

the past 100 years, and especially during the last two decades with the advent of the computer age, as compared to that during the long period from 4000 B.C. to 1 B.C.

Although the Romans had factories for mass-producing glassware, manufacturing methods were at first very primitive and generally very slow, with much manpower involved in handling parts and running the machinery. Today, with the help of **computer-integrated manufacturing** systems, production methods have been advanced to such an extent that, for example, holes in sheet metal are punched at rates of 800 per minute and aluminum beverage cans are manufactured at rates of 500 per minute. ⁽²⁾

2. 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. 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% of the cost of product development and manufacture is determined by the decisions made in the initial design stages.

Traditionally, design and manufacturing activities have taken place sequentially rather than concurrently or simultaneously (Fig. 2a). Designers would spend considerable effort and time in analyzing components and preparing detailed part drawings; these drawings would then be forwarded to other departments in the organization, such as materials departments, where, for example, particular alloys and vendor sources would be identified.

The specifications would then be sent to a manufacturing department, where the detailed drawings would be reviewed and processes selected for efficient production. While this approach seems logical and straightforward in theory, it has been found in practice to be extremely wasteful of resources.

In theory, a product can flow from one department in an organization to another and then directly to the marketplace, but in practice there are usually difficulties encountered. For example, a manufacturing engineer may wish to taper the flange on a part to improve its castability or may decide that a different alloy is desirable; such changes necessitate a repeat of the design analysis stage, in order to ensure that the product will still function satisfactorily. These iterations, also shown in Fig. 2a, certainly waste resources, but, more importantly, they waste time.

There is a great desire, originally driven by the consumer electronics industry, to bring products to market as quickly as possible. The rationale is that products introduced early enjoy a greater percentage of the market and hence greater profits, and that they have a longer life before obsolescence (clearly a concern with consumer electronics). For these reasons, **concurrent engineering**, also called **simultaneous engineering**, has come to the fore.