

PEARSON

时代教育·国外高校优秀教材精选

制造工程与技术 ——热加工

(英文版·原书第6版)

MANUFACTURING ENGINEERING AND TECHNOLOGY
— HOT PROCESSE

(美) Serope Kalpakjian

(美) Steven R. Schmid

著

SI Conversion by

(美) Hamidon Musa

王先逵

改编



机械工业出版社
CHINA MACHINE PRESS



时代教育·国外高校优秀教材精选

制造工程与技术——热加工

(英文版·原书第6版)

MANUFACTURING ENGINEERING AND TECHNOLOGY (Hot Processe)

(美) Serope Kalpakjian
Illinois Institute of Technology
(美) Steven R. Schmid
The University of Notre Dame 著
SI Conversion by
(美) Hamidon Musa
Universiti Teknologi Malaysia

王先逵 改编
清华大学精密仪器与机械学系



机械工业出版社

影印改编版序

制造技术是一个永恒的主题，是实现设想、概念、科学技术物质化的基础和手段。其涉及面非常广泛，是所有工业的支柱，是国家经济与国防实力的体现。制造技术在不同的历史时期有不同的发展重点，但需要重视和发展制造技术是永恒的。现代制造技术是当前世界各国研究和发展的主题，是提高生产力，经济竞争，产品革新的重要手段，所有的国家，特别是工业强国，都在寻求获得、开发和利用它，历史证实，它是现代国家经济上获得成功的关键因素。

现代制造工艺技术是先进制造技术的重要组成部分，是其最有活力的部分，也是生产中最活跃的因素，工艺是设计和制造的桥梁，设计的可行性往往会受到工艺的制约，工艺往往会成为设计的“瓶颈”。因此，工艺是制造技术的灵魂、核心和关键。

20 世纪 50 年代，我国在原苏联的援助下，开展了大规模的机械工业建设，教育战线上，同样得到原苏联专家的帮助，在高等学校里开办了机械制造专业，开设了“机械制造工艺学”、“金属切削原理与刀具”、“机床概论与设计”等课程，其后在我国学者的努力下，出版了自己编写的相应教材。改革开放以来，出现了机械制造系统、计算机辅助设计和计算机辅助制造等先进制造技术，形成了机械制造工程与科学，对我国社会主义建设和人才培养发挥了重要作用。

虽然欧美国家在教育制度、教学计划、课程设置、教学方式以及教材等方面与我国有所不同，但具有较强的参考性。摆在我们面前的《制造工程与技术》一书就是美国大学里机械工程学科的教材，本书全面论述了机械制造中的材料、成形加工、计量和发展趋势等工程与技术，涵盖了我国机械制造专业的金属工艺学、公差与技术测量、材料、铸造、锻压、切削原理与刀具、机械制造工艺学、机床概论和设计等多门课程内容，

本书第 4 版、第 5 版和第 6 版分别于 2001、2006 和 2010 年由美国培生教育出版股份有限公司出版发行，作者为美国卡尔帕基安教授和施密德教授，深受美国大学生的欢迎。我国已多次引进这本书的版权，由此可见本书水平之高，影响之大。

本影印改编版具有以下一些特点：

1. 内容丰富全面

主要内容有材料、成形加工、机械加工、微制造和微电子装备制造、表面技术、计量技术和竞争环境下的制造技术等，包含我国机械工程专业的大多数专业课和专业选修课的内容。

2. 体系先进新颖

增加了许多先进制造技术的新内容，如绿色设计与制造、快速原型制造、机械电子装备制造和系统、微制造和微电子装置、纳米尺度制造，以及制造工程的发展趋势等，具有很强的先进性。

3. 自学特色突出

每章之前均有该章的要点和重要内容说明，以及目录和案例名称；每章最后有小结、关

关键词、参考文献、思考题、定性分析类习题、定量分析类习题和综合作业，论述深入浅出，问题及习题数量和类型多，具有较大的可选择性，特别适合学生自学。

为了提高学生的学习兴题，在内容上还涉及网球拍、高尔夫球杆、管乐器中“瓣”的摩擦焊、去毛刺机器人、半固态铸造等的介绍。

4. 联系工业实际

实例分析、工程应用案例比较多，有些章节论述中，用一辆汽车或一台汽车发动机作为引例，讲述该章内容的工程实际背景，生动有趣。

5. 印刷质量上乘

印刷质量好，采用双色印刷，重点内容、实例分析内容显现突出。编排上使图或表尽量在同一页，便于阅读。

本书可作为我国高等院校机械工程专业本科生的“金属工艺学”、“机械制造工程基础”、“机械制造工艺学”、“切削原理和刀具”等课程的英语教科书和专业英语教材，也可供教师、研究生和广大工程技术人员作为参考书，具有较高的参考价值。

6. 适合国内教学

针对国内教学课程设置，将原书内容改编为机加工和热加工两册，并分别出版，方便学校选用。为保持书籍内容体系，方便读者查找和了解原书全貌，特别在两册中保留完整的改编目录。

本书可作为我国高等院校机械工程专业本科生的“金属工艺学”、“机械制造工程基础”、“机械制造工艺学”、“切削原理和刀具”等课程的英语教科书和专业英语教材，也可供教师、研究生和广大工程技术人员作为参考书，具有较高的参考价值。

清华大学精密仪器与机械学系制造工程研究所

王光造

制造工程与技术——热加工

英文版·原书第6版

(王先逵 改编)

读者信息反馈表

尊敬的老师:

您好!感谢您多年来对机械工业出版社的支持和厚爱!为了进一步提高我社教材的出版质量,更好地为我国高等教育发展服务,欢迎您对我社的教材多提宝贵意见和建议。另外,如果您在教学中选用了本书,欢迎您对本书提出修改建议和意见。

机械工业出版社教材服务网网址: <http://www.cmpedu.com>

一、基本信息

姓名: _____ 性别: _____ 职称: _____ 职务: _____

邮编: _____ 地址: _____

任教课程: _____ 电话: _____ — _____ (H) _____ (O)

电子邮件: _____ 手机: _____

二、您对本书的意见和建议

(欢迎您指出本书的疏误之处)

三、您对我们的其他意见和建议

请与我们联系:

100037 机械工业出版社·高等教育分社 余 皞 收

Tel: 88379730, 68994030 (Fax)

E-mail: yuhaohust@qq.com

Contents



制造工程与技术——热加工

影印改编版序

General Introduction 1

- I.1 What Is Manufacturing? 1
- I.2 Product Design and Concurrent Engineering 8
- I.3 Design for Manufacture, Assembly, Disassembly, and Service 11
- I.4 Green Design and Manufacturing 13
- I.5 Selection of Materials 15
- I.6 Selection of Manufacturing Processes 18
- I.7 Computer-integrated Manufacturing 26
- I.8 Quality Assurance and Total Quality Management 29
- I.9 Lean Production and Agile Manufacturing 32
- I.10 Manufacturing Costs and Global Competition 32
- I.11 General Trends in Manufacturing 34

Metal-Casting Processes and Equipment 37

1 Fundamentals of Metal Casting 39

- 1.1 Introduction 39
- 1.2 Solidification of Metals 40
- 1.3 Fluid Flow 45
- 1.4 Fluidity of Molten Metal 47
- 1.5 Heat Transfer 49
- 1.6 Defects 51

Summary 55 *Key Terms* 56 *Bibliography* 56

Review Questions 56 *Qualitative Problems* 57

Quantitative Problems 57 *Synthesis, Design, and Projects* 58

2 Metal-Casting Processes and Equipment 60

- 2.1 Introduction 60
- 2.2 Expendable-mold, Permanent-pattern Casting Processes 64
- 2.3 Expendable-mold, Expendable-pattern Casting Processes 72
- 2.4 Permanent-mold Casting Processes 79
- 2.5 Casting Techniques for Single-crystal Components 87

2.6	Rapid Solidification	88
2.7	Inspection of Castings	89
2.8	Melting Practice and Furnaces	89
2.9	Foundries and Foundry Automation	91
<i>Summary</i> 91 <i>Key Terms</i> 92 <i>Bibliography</i> 92		
<i>Review Questions</i> 93 <i>Qualitative Problems</i> 93		
<i>Quantitative Problems</i> 94 <i>Synthesis, Design, and Projects</i> 94		

3 Metal Casting: Design, Materials, and Economics 96

3.1	Introduction	96
3.2	Design Considerations in Casting	96
3.3	Casting Alloys	104
3.4	Economics of Casting	109
<i>Summary</i> 110 <i>Key Terms</i> 111 <i>Bibliography</i> 111		
<i>Review Questions</i> 111 <i>Qualitative Problems</i> 111		
<i>Quantitative Problems</i> 112 <i>Synthesis, Design, and Projects</i> 112		

Forming and Shaping Processes and Equipment 115

4 Metal-Rolling Processes and Equipment 118

4.1	Introduction	118
4.2	The Flat-rolling Process	120
4.3	Flat-rolling Practice	124
4.4	Rolling Mills	127
4.5	Various Rolling Processes and Mills	129
<i>Summary</i> 134 <i>Key Terms</i> 135 <i>Bibliography</i> 135		
<i>Review Questions</i> 135 <i>Qualitative Problems</i> 135		
<i>Quantitative Problems</i> 136 <i>Synthesis, Design, and Projects</i> 136		

5 Metal-Forging Processes and Equipment 137

5.1	Introduction	137
5.2	Open-die Forging	139
5.3	Impression-die and Closed-die Forging	141
5.4	Various Forging Operations	145
5.5	Forgeability of Metals; Forging Defects	150
5.6	Die Design, Die Materials, and Lubrication	151
5.7	Die-manufacturing Methods and Die Failures	153
5.8	Forging Machines	155
5.9	Economics of Forging	157
<i>Summary</i> 159 <i>Key Terms</i> 160 <i>Bibliography</i> 160		

<i>Review Questions</i>	160	<i>Qualitative Problems</i>	160
<i>Quantitative Problems</i>	161	<i>Synthesis, Design, and Projects</i>	161

6 Metal Extrusion and Drawing Processes and Equipment 162

6.1	Introduction	162
6.2	The Extrusion Process	164
6.3	Hot Extrusion	166
6.4	Cold Extrusion	170
6.5	Extrusion Defects	173
6.6	Extrusion Equipment	175
6.7	The Drawing Process	175
6.8	Drawing Practice	177
6.9	Drawing Defects and Residual Stresses	179
6.10	Drawing Equipment	179

<i>Summary</i>	180	<i>Key Terms</i>	180	<i>Bibliography</i>	181
<i>Review Questions</i>	181	<i>Qualitative Problems</i>	181		
<i>Quantitative Problems</i>	182	<i>Synthesis, Design, and Projects</i>	182		

7 Sheet-Metal Forming Processes and Equipment 183

7.1	Introduction	183
7.2	Shearing	184
7.3	Sheet-metal Characteristics and Formability	194
7.4	Formability Tests for Sheet Metals	196
7.5	Bending Sheets, Plates, and Tubes	199
7.6	Miscellaneous Bending and Related Operations	203
7.7	Deep Drawing	209
7.8	Rubber Forming and Hydroforming	215
7.9	Spinning	219
7.10	Superplastic Forming	222
7.11	Specialized Forming Processes	223
7.12	Manufacturing of Metal Honeycomb Structures	228
7.13	Design Considerations in Sheet-metal Forming	230
7.14	Equipment for Sheet-metal Forming	232
7.15	Economics of Sheet-forming Operations	233

<i>Summary</i>	234	<i>Key Terms</i>	235	<i>Bibliography</i>	235
<i>Review Questions</i>	236	<i>Qualitative Problems</i>	236		
<i>Quantitative Problems</i>	237	<i>Synthesis, Design, and Projects</i>	237		

8 Powder-Metal Processing and Equipment 239

8.1	Introduction	239
8.2	Production of Metal Powders	240

8.3	Compaction of Metal Powders	246
8.4	Sintering	254
8.5	Secondary and Finishing Operations	258
8.6	Design Considerations	259
8.7	Process Capabilities	261
8.8	Economics of Powder Metallurgy	262
<i>Summary</i> 264 <i>Key Terms</i> 264 <i>Bibliography</i> 265		
<i>Review Questions</i> 265 <i>Qualitative Problems</i> 265		
<i>Quantitative Problems</i> 266 <i>Synthesis, Design, and Projects</i> 266		

9 Rapid-Prototyping Processes and Operations 267

9.1	Introduction	267
9.2	Subtractive Processes	270
9.3	Additive Processes	272
9.4	Virtual Prototyping	283
9.5	Direct Manufacturing and Rapid Tooling	284
<i>Summary</i> 291 <i>Key Terms</i> 291 <i>Bibliography</i> 291		
<i>Review Questions</i> 292 <i>Qualitative Problems</i> 292		
<i>Quantitative Problems</i> 292 <i>Synthesis, Design, and Projects</i> 293		

Joining Processes and Equipment 295

10 Fusion-Welding Processes 299

10.1	Introduction	299
10.2	Oxyfuel-gas Welding	300
10.3	Arc-welding Processes: Nonconsumable Electrode	303
10.4	Arc-welding Processes: Consumable Electrode	307
10.5	Electrodes for Arc Welding	313
10.6	Electron-beam Welding	314
10.7	Laser-beam Welding	314
10.8	Cutting	316
10.9	The Weld Joint, Quality, and Testing	318
10.10	Joint Design and Process Selection	327
<i>Summary</i> 327 <i>Key Terms</i> 327 <i>Bibliography</i> 332		
<i>Review Questions</i> 332 <i>Qualitative Problems</i> 332		
<i>Quantitative Problems</i> 333 <i>Synthesis, Design, and Projects</i> 333		

11 Solid-State Welding Processes 334

11.1	Introduction	334
------	--------------	-----

11.2	Cold Welding and Roll Bonding	335
11.3	Ultrasonic Welding	336
11.4	Friction Welding	337
11.5	Resistance Welding	339
11.6	Explosion Welding	347
11.7	Diffusion Bonding	348
11.8	Economics of Welding Operations	350
<i>Summary</i> 352 <i>Key Terms</i> 353 <i>Bibliography</i> 353		
<i>Review Questions</i> 353 <i>Qualitative Problems</i> 353		
<i>Quantitative Problems</i> 354 <i>Synthesis, Design, and Projects</i> 354		

12 Brazing, Soldering, Adhesive-Bonding, and Mechanical-Fastening Processes 355

12.1	Introduction	355
12.2	Brazing	356
12.3	Soldering	360
12.4	Adhesive Bonding	365
12.5	Mechanical Fastening	373
12.6	Joining Plastics, Ceramics, and Glasses	376
12.7	Economics of Joining Operations	379
<i>Summary</i> 380 <i>Key Terms</i> 381 <i>Bibliography</i> 381		
<i>Review Questions</i> 381 <i>Qualitative Problems</i> 382		
<i>Quantitative Problems</i> 382 <i>Synthesis, Design, and Projects</i> 382		

制造工程与技术——机加工

影印改编版序

Machining Processes and Machine Tools 1

13 Fundamentals of Machining 4

13.1	Introduction	4
13.2	Mechanics of Cutting	6
13.3	Cutting Forces and Power	16
13.4	Temperatures in Cutting	19
13.5	Tool Life: Wear and Failure	22
13.6	Surface Finish and Integrity	29
13.7	Machinability	31
<i>Summary</i> 35 <i>Key Terms</i> 36 <i>Bibliography</i> 36		
<i>Review Questions</i> 36 <i>Qualitative Problems</i> 37		
<i>Quantitative Problems</i> 37 <i>Synthesis, Design, and Projects</i> 38		

14 Cutting-Tool Materials and Cutting Fluids 39

- 14.1 Introduction 39
- 14.2 High-speed Steels 43
- 14.3 Cast-cobalt Alloys 44
- 14.4 Carbides 44
- 14.5 Coated Tools 48
- 14.6 Alumina-based Ceramics 52
- 14.7 Cubic Boron Nitride 53
- 14.8 Silicon-nitride-based Ceramics 53
- 14.9 Diamond 53
- 14.10 Whisker-reinforced Materials and Nanomaterials 54
- 14.11 Tool Costs and Reconditioning of Tools 55
- 14.12 Cutting Fluids 55
- Summary* 60 *Key Terms* 60 *Bibliography* 61
- Review Questions* 61 *Qualitative Problems* 61
- Quantitative Problems* 62 *Synthesis, Design, and Projects* 62

15 Machining Processes: Turning and Hole Making 63

- 15.1 Introduction 63
- 15.2 The Turning Process 66
- 15.3 Lathes and Lathe Operations 74
- 15.4 Boring and Boring Machines 89
- 15.5 Drilling, Drills, and Drilling Machines 91
- 15.6 Reaming and Reamers 100
- 15.7 Tapping and Taps 101
- Summary* 103 *Key Terms* 104 *Bibliography* 104
- Review Questions* 104 *Qualitative Problems* 105
- Quantitative Problems* 105 *Synthesis, Design, and Projects* 106

16 Machining Processes: Milling, Broaching, Sawing, Filing, and Gear Manufacturing 107

- 16.1 Introduction 107
- 16.2 Milling and Milling Machines 108
- 16.3 Planing and Shaping 122
- 16.4 Broaching and Broaching Machines 123
- 16.5 Sawing 126
- 16.6 Filing 129
- 16.7 Gear Manufacturing by Machining 129
- Summary* 137 *Key Terms* 138 *Bibliography* 138
- Review Questions* 138 *Qualitative Problems* 139
- Quantitative Problems* 139 *Synthesis, Design, and Projects* 140

17 Machining Centers, Machine-Tool Structures, and Machining Economics 141

- 17.1 Introduction 141
- 17.2 Machining Centers 142
- 17.3 Machine-tool Structures 150
- 17.4 Vibration and Chatter in Machining Operations 154
- 17.5 High-speed Machining 157
- 17.6 Hard Machining 159
- 17.7 Ultraprecision Machining 159
- 17.8 Machining Economics 161
- Summary* 165 *Key Terms* 165 *Bibliography* 165
- Review Questions* 165 *Qualitative Problems* 166
- Quantitative Problems* 166 *Synthesis, Design, and Projects* 166

18 Abrasive Machining and Finishing Operations 167

- 18.1 Introduction 167
- 18.2 Abrasives and Bonded Abrasives 169
- 18.3 The Grinding Process 175
- 18.4 Grinding Operations and Machines 184
- 18.5 Design Considerations for Grinding 192
- 18.6 Ultrasonic Machining 192
- 18.7 Finishing Operations 194
- 18.8 Deburring Operations 198
- 18.9 Economics of Abrasive Machining and Finishing Operations 201
- Summary* 202 *Key Terms* 203 *Bibliography* 203
- Review Questions* 204 *Qualitative Problems* 204
- Quantitative Problems* 205 *Synthesis, Design, and Projects* 205

19 Advanced Machining Processes 257

- 19.1 Introduction 207
- 19.2 Chemical Machining 209
- 19.3 Electrochemical Machining 213
- 19.4 Electrochemical Grinding 216
- 19.5 Electrical-discharge Machining 217
- 19.6 Laser-beam Machining 222
- 19.7 Electron-beam Machining 225
- 19.8 Water-jet Machining 226
- 19.9 Abrasive-jet Machining 227
- 19.10 Hybrid Machining Systems 228
- 19.11 Economics of Advanced Machining Processes 229
- Summary* 232 *Key Terms* 232 *Bibliography* 232
- Review Questions* 233 *Qualitative Problems* 233
- Quantitative Problems* 233 *Synthesis, Design, and Projects* 234

Micromanufacturing and Fabrication of Microelectronic Devices 235

20 Fabrication of Microelectronic Devices 238

- 20.1 Introduction 238
- 20.2 Clean Rooms 241
- 20.3 Semiconductors and Silicon 242
- 20.4 Crystal Growing and Wafer Preparation 243
- 20.5 Film Deposition 246
- 20.6 Oxidation 247
- 20.7 Lithography 248
- 20.8 Etching 256
- 20.9 Diffusion and Ion Implantation 264
- 20.10 Metallization and Testing 266
- 20.11 Wire Bonding and Packaging 268
- 20.12 Yield and Reliability 273
- 20.13 Printed Circuit Boards 274
- Summary* 275 *Key Terms* 276 *Bibliography* 276
- Review Questions* 277 *Qualitative Problems* 277
- Quantitative Problems* 278 *Synthesis, Design, and Projects* 278

21 Fabrication of Microelectromechanical Devices and Systems and Nanoscale Manufacturing 279

- 21.1 Introduction 279
- 21.2 Micromachining of MEMS Devices 281
- 21.3 The LIGA Microfabrication Process 292
- 21.4 Solid Free-form Fabrication of Devices 298
- 21.5 Nanoscale Manufacturing 303
- Summary* 306 *Key Terms* 306 *Bibliography* 306
- Review Questions* 307 *Qualitative Problems* 307
- Quantitative Problems* 308 *Synthesis, Design, and Projects* 308

Surface Technology 309

22 Surface Roughness and Measurement; Friction, Wear, and Lubrication 311

- 22.1 Introduction 311
- 22.2 Surface Structure and Integrity 312
- 22.3 Surface Texture and Roughness 313
- 22.4 Friction 317
- 22.5 Wear 321

- 22.6 Lubrication 324
- 22.7 Metalworking Fluids and Their Selection 326
- Summary* 330 *Key Terms* 330 *Bibliography* 331
- Review Questions* 331 *Qualitative Problems* 331
- Quantitative Problems* 332 *Synthesis, Design, and Projects* 332

23 Surface Treatments, Coatings, and Cleaning 333

- 23.1 Introduction 333
- 23.2 Mechanical Surface Treatments 334
- 23.3 Mechanical Plating and Cladding 336
- 23.4 Case Hardening and Hard Facing 336
- 23.5 Thermal Spraying 337
- 23.6 Vapor Deposition 339
- 23.7 Ion Implantation and Diffusion Coating 342
- 23.8 Laser Treatments 342
- 23.9 Electroplating, Electroless Plating, and Electroforming 343
- 23.10 Conversion Coatings 346
- 23.11 Hot Dipping 347
- 23.12 Porcelain Enameling; Ceramic and Organic Coatings 348
- 23.13 Diamond Coating and Diamondlike Carbon 349
- 23.14 Surface Texturing 350
- 23.15 Painting 350
- 23.16 Cleaning of Surfaces 351
- Summary* 353 *Key Terms* 353 *Bibliography* 353
- Review Questions* 354 *Qualitative Problems* 354
- Quantitative Problems* 354 *Synthesis, Design, and Projects* 355

Manufacturing in a Competitive Environment 357

24 Automation of Manufacturing Processes 359

- 24.1 Introduction 359
- 24.2 Automation 361
- 24.3 Numerical Control 368
- 24.4 Adaptive Control 374
- 24.5 Material Handling and Movement 376
- 24.6 Industrial Robots 379
- 24.7 Sensor Technology 385
- 24.8 Flexible Fixturing 389
- 24.9 Assembly Systems 391
- 24.10 Design Considerations for Fixturing, Assembly, Disassembly,
and Servicing 394
- 24.11 Economic Considerations 397

<i>Summary</i>	397	<i>Key Terms</i>	398	<i>Bibliography</i>	398
<i>Review Questions</i>	399	<i>Qualitative Problems</i>	399		
<i>Quantitative Problems</i>	400	<i>Synthesis, Design, and Projects</i>	400		

25 Computer-Aided Manufacturing 401

25.1	Introduction	401
25.2	Manufacturing Systems	402
25.3	Computer-integrated Manufacturing	402
25.4	Computer-aided Design and Engineering	405
25.5	Computer-aided Manufacturing	412
25.6	Computer-aided Process Planning	412
25.7	Computer Simulation of Manufacturing Processes and Systems	415
25.8	Group Technology	416
<i>Summary</i>	423	<i>Key Terms</i> 423 <i>Bibliography</i> 423
<i>Review Questions</i>	424	<i>Qualitative Problems</i> 424
<i>Synthesis, Design, and Projects</i>	424	

26 Computer-Integrated Manufacturing Systems 425

26.1	Introduction	425
26.2	Cellular Manufacturing	426
26.3	Flexible Manufacturing Systems	428
26.4	Holonic Manufacturing	430
26.5	Just-in-time Production	432
26.6	Lean Manufacturing	433
26.7	Communications Networks in Manufacturing	435
26.8	Artificial Intelligence	437
26.9	Economic Considerations	440
<i>Summary</i>	440	<i>Key Terms</i> 441 <i>Bibliography</i> 441
<i>Review Questions</i>	442	<i>Qualitative Problems</i> 442
<i>Synthesis, Design, and Projects</i>	442	

27 Product Design and Process Selection in a Competitive Environment 443

27.1	Introduction	443
27.2	Product Design	444
27.3	Product Quality and Life Expectancy	447
27.4	Life-cycle Assessment and Sustainable Manufacturing	448
27.5	Material Selection for Products	450
27.6	Material Substitution	454
27.7	Manufacturing Process Capabilities	456

27.8	Process Selection	460
27.9	Manufacturing Costs and Cost Reduction	464
<i>Summary</i>	469	<i>Key Terms</i> 469 <i>Bibliography</i> 470
<i>Review Questions</i>	470	<i>Qualitative Problems</i> 470
<i>Synthesis, Design, and Projects</i>	471	

General Introduction

.....

1.1 What Is Manufacturing?

.....

As you begin to read this chapter, take a few moments to inspect various objects around you: mechanical pencil, light fixture, chair, cell phone, and computer. You soon will note that all these objects, and their numerous individual components, are made from a variety of materials and have been produced and assembled into the items that you now see. You also will note that some objects, such as a paper clip, nail, spoon, and door key, are made of a single component. However, as shown in Table I.1, the vast majority of objects around us consist of numerous individual pieces that are built and assembled by a combination of processes called **manufacturing**.

The word *manufacture* first appeared in English in 1567 and is derived from the Latin *manu factus*, meaning “made by hand.” The word *manufacturing* first appeared in 1683, and the word *production*, which is often used interchangeably with the word *manufacturing*, first appeared sometime during the 15th century.

Manufacturing is concerned with making products. A manufactured product may itself be used to make other products, such as (a) a large press, to shape flat sheet metal into automobile bodies, (b) a drill, for producing holes, (c) industrial sawing machines, for making clothing at high rates, and (d) numerous pieces of machinery, to produce an endless variety of individual items, ranging from thin wire for guitars and electric motors to crankshafts and connecting rods for automotive engines (Fig. I.1).

Note that items such as bolts, nuts, and paper clips are *discrete products*, meaning individual items. By contrast, a roll of aluminum foil, a spool of wire, and metal or plastic tubing are *continuous products*, which are then cut into individual pieces of various lengths for specific purposes.

Because a manufactured item typically starts with raw materials, which are then subjected to a sequence of processes to make individual products, it has a certain *value*. For example, clay has some value as mined, but when it is made into a product such as cookware, pottery, an electrical insulator, or a cutting tool, value is *added* to the clay. Similarly, a nail has a value over and above the cost of the short piece of wire or rod from which it is made. Products such as computer chips, electric motors, and professional athletic shoes are known as *high-value-added* products.

A Brief History of Manufacturing. Manufacturing dates back to the period 5000–4000 B.C. (Table I.2), and thus, it is older than recorded history, the earliest forms of which were invented by the Sumerians around 3500 B.C. Primitive cave