



CONTENTS

 Content available in eBook

 Student solution available in interactive e-text

1 INTRODUCTION AND OVERVIEW OF MANUFACTURING 1

- 1.1 What Is Manufacturing? 2
- 1.2 Materials in Manufacturing 8
- 1.3 Manufacturing Processes 10
- 1.4 Production Systems 17
- 1.5 Manufacturing Economics 20

Part I Material Properties and Product Attributes 27

2 THE NATURE OF MATERIALS 27

- 2.1 Atomic Structure and the Elements 27
- 2.2 Bonding between Atoms and Molecules 30
- 2.3 Crystalline Structures 32
- 2.4 Noncrystalline (Amorphous) Structures 37
- 2.5 Engineering Materials 38

3 MECHANICAL PROPERTIES OF MATERIALS 40

- 3.1 Stress–Strain Relationships 40
- 3.2 Hardness 53
- 3.3 Effect of Temperature on Properties 57
- 3.4 Fluid Properties 59
- 3.5 Viscoelastic Behavior of Polymers 61

4 PHYSICAL PROPERTIES OF MATERIALS 64

- 4.1 Volumetric and Melting Properties 64
- 4.2 Thermal Properties 67
- 4.3 Mass Diffusion 69
- 4.4 Electrical Properties 71
- 4.5 Electrochemical Processes 73

5 DIMENSIONS, SURFACES, AND THEIR MEASUREMENT 75

- 5.1 Dimensions, Tolerances, and Related Attributes 75
- 5.2 Conventional Measuring Instruments and Gages 76
- 5.3 Surfaces 84
- 5.4 Measurement of Surfaces 88
- 5.5 Effect of Manufacturing Processes 90

Part II Engineering Materials 93

6 METALS 93

- 6.1 Alloys and Phase Diagrams 94
- 6.2 Ferrous Metals 98
- 6.3 Nonferrous Metals 114
- 6.4 Superalloys 124

7 CERAMICS 126

- 7.1 Structure and Properties of Ceramics 127
- 7.2 Traditional Ceramics 129
- 7.3 New Ceramics 131
- 7.4 Glass 134
- 7.5 Some Important Elements Related to Ceramics 138

8 POLYMERS 142

- 8.1 Fundamentals of Polymer Science and Technology 144
- 8.2 Thermoplastic Polymers 153
- 8.3 Thermosetting Polymers 157
- 8.4 Elastomers 160
- 8.5 Polymer Recycling and Biodegradability 166

- 9 COMPOSITE MATERIALS 169
- 9.1 Technology and Classification of Composite Materials 170
- 9.2 Metal Matrix Composites 177
- 9.3 Ceramic Matrix Composites 179
- 9.4 Polymer Matrix Composites 180
- Part III Solidification Processes 184**
- 10 FUNDAMENTALS OF METAL CASTING 184
- 10.1 Overview of Casting Technology 186
- 10.2 Heating and Pouring 188
- 10.3 Solidification and Cooling 192
- 11 METAL CASTING PROCESSES 200
- 11.1 Sand Casting 200
- 11.2 Other Expendable-Mold Casting Processes 204
- 11.3 Permanent-Mold Casting Processes 209
- 11.4 Foundry Practice 218
- 11.5 Casting Quality 222
- 11.6 Castability and Casting Economics 224
- 11.7 Product Design Considerations 229
- 12 GLASSWORKING 232
- 12.1 Raw Materials Preparation and Melting 232
- 12.2 Shaping Processes in Glassworking 233
- 12.3 Heat Treatment and Finishing 239
- 12.4 Product Design Considerations 240
- 13 SHAPING PROCESSES FOR PLASTICS 242
- 13.1 Properties of Polymer Melts 243
- 13.2 Extrusion 245
- 13.3 Production of Sheet and Film 257
- 13.4 Fiber and Filament Production (Spinning) 260
- 13.5 Coating Processes 261
- 13.6 Injection Molding 262
- 13.7 Compression and Transfer Molding 275
- 13.8 Blow Molding and Rotational Molding 277
- 13.9 Thermoforming 282
- 13.10 Casting 286
- 13.11 Polymer Foam Processing and Forming 287
- 13.12 Product Design Considerations 288
- 14 PROCESSING OF POLYMER MATRIX COMPOSITES AND RUBBER 291
- 14.1 Overview of PMC Processing 291
- 14.2 Open-Mold Processes 295
- 14.3 Closed-Mold Processes 299
- 14.4 Other PMC Shaping Processes 301
- 14.5 Rubber Processing and Shaping 305
- 14.6 Manufacture of Tires and Other Rubber Products 310
- Part IV Particulate Processing of Metals and Ceramics 315**
- 15 POWDER METALLURGY 315
- 15.1 Characterization of Engineering Powders 317
- 15.2 Production of Metallic Powders 321
- 15.3 Conventional Pressing and Sintering 323
- 15.4 Alternative Pressing and Sintering Techniques 329
- 15.5 Powder Metallurgy Materials and Economics 331
- 15.6 Product Design Considerations in Powder Metallurgy 334
- 16 PROCESSING OF CERAMICS AND CERMETS 338
- 16.1 Processing of Traditional Ceramics 338
- 16.2 Processing of New Ceramics 345
- 16.3 Processing of Cermets 348
- 16.4 Product Design Considerations 350
- Part V Metal Forming and Sheet Metalworking 352**
- 17 FUNDAMENTALS OF METAL FORMING 352
- 17.1 Overview of Metal Forming 352
- 17.2 Material Behavior in Metal Forming 355
- 17.3 Temperature in Metal Forming 356
- 17.4 Strain Rate Sensitivity 358
- 17.5 Friction and Lubrication in Metal Forming 360
- 18 BULK DEFORMATION PROCESSES IN METAL WORKING 362
- 18.1 Rolling 362
- 18.2 Forging 372
- 18.3 Extrusion 387
- 18.4 Wire and Bar Drawing 397
- 19 SHEET METALWORKING 405
- 19.1 Cutting Operations 406
- 19.2 Bending Operations 412
- 19.3 Drawing 416
- 19.4 Equipment and Economics for Sheet-Metal Pressworking 423
- 19.5 Other Sheet-Metal-Forming Operations 432
- 19.6 Sheet-Metal Operations Not Performed on Presses 435
- 19.7 Bending of Tube Stock 440
- Part VI Material Removal Processes 443**
- 20 THEORY OF METAL MACHINING 443
- 20.1 Overview of Machining Technology 445
- 20.2 Theory of Chip Formation in Metal Machining 448
- 20.3 Force Relationships and the Merchant Equation 452
- 20.4 Power and Energy Relationships in Machining 458
- 20.5 Cutting Temperature 460
- 21 MACHINING OPERATIONS AND MACHINE TOOLS 463
- 21.1 Machining and Part Geometry 463
- 21.2 Turning and Related Operations 466
- 21.3 Drilling and Related Operations 475
- 21.4 Milling 479
- 21.5 Machining Centers and Turning Centers 487
- 21.6 Other Machining Operations 489
- 21.7 Machining Operations for Special Geometries 494
- 21.8 High-Speed Machining 500
- 22 CUTTING-TOOL TECHNOLOGY 503
- 22.1 Tool Life 503
- 22.2 Tool Materials 509
- 22.3 Tool Geometry 517
- 22.4 Cutting Fluids 526
- 23 ECONOMIC AND PRODUCT DESIGN CONSIDERATIONS IN MACHINING 530
- 23.1 Machinability 530
- 23.2 Tolerances and Surface Finish 531
- 23.3 Machining Economics 536
- 23.4 Product Design Considerations in Machining 543
- 24 GRINDING AND OTHER ABRASIVE PROCESSES 546
- 24.1 Grinding 547
- 24.2 Related Abrasive Processes 562
- 25 NONTRADITIONAL MACHINING AND THERMAL CUTTING PROCESSES 567
- 25.1 Mechanical Energy Processes 568
- 25.2 Electrochemical Machining Processes 571
- 25.3 Thermal Energy Processes 575
- 25.4 Chemical Machining 584
- 25.5 Application Considerations 589
- Part VII Property Enhancing and Surface Processing Operations 592**
- 26 HEAT TREATMENT OF METALS 592
- 26.1 Annealing 592
- 26.2 Martensite Formation in Steel 593
- 26.3 Precipitation Hardening 597
- 26.4 Surface Hardening 598
- 26.5 Heat Treatment Methods and Facilities 599
- 27 SURFACE PROCESSING OPERATIONS 602
- 27.1 Industrial Cleaning Processes 602
- 27.2 Diffusion and Ion Implantation 606
- 27.3 Plating and Related Processes 607
- 27.4 Conversion Coating 611

- 27.5 Vapor Deposition Processes 612
- 27.6 Organic Coatings 618
- 27.7 Porcelain Enameling and Other Ceramic Coatings 620
- 27.8 Thermal and Mechanical Coating Processes 621

Part VIII Joining and Assembly Processes 623

- 28 FUNDAMENTALS OF WELDING 623
 - 28.1 Overview of Welding Technology 624
 - 28.2 The Weld Joint 627
 - 28.3 Physics of Welding 629
 - 28.4 Features of a Fusion-Welded Joint 633
- 29 WELDING PROCESSES 635
 - 29.1 Arc Welding 635
 - 29.2 Resistance Welding 644
 - 29.3 Oxyfuel Gas Welding 651
 - 29.4 Other Fusion-Welding Processes 655
 - 29.5 Solid-State Welding 657
 - 29.6 Weld Quality 663
 - 29.7 Weldability and Welding Economics 667
 - 29.8 Design Considerations in Welding 670
- 30 BRAZING, SOLDERING, AND ADHESIVE BONDING 672
 - 30.1 Brazing 672
 - 30.2 Soldering 677
 - 30.3 Adhesive Bonding 681
- 31 MECHANICAL ASSEMBLY 687
 - 31.1 Threaded Fasteners 687
 - 31.2 Rivets and Eyelets 694
 - 31.3 Assembly Methods Based on Interference Fits 695
 - 31.4 Other Mechanical Fastening Methods 698
 - 31.5 Molding Inserts and Integral Fasteners 699
 - 31.6 Design for Assembly 700

OC Part IX Special Processing and Assembly Technologies (Available in e-text for students) W-1

- OC** 32 ADDITIVE MANUFACTURING W-1
(Available in e-text for students)
- OC** 33 PROCESSING OF INTEGRATED CIRCUITS W-21
(Available in e-text for students)
- OC** 34 ELECTRONICS ASSEMBLY AND PACKAGING W-50
(Available in e-text for students)
- OC** 35 MICROFABRICATION TECHNOLOGIES W-71
(Available in e-text for students)
- OC** 36 NANOFABRICATION TECHNOLOGIES W-83
(Available in e-text for students).

OC Part X Manufacturing Systems (Available in e-text for students) W-97

- OC** 37 AUTOMATION TECHNOLOGIES FOR MANUFACTURING SYSTEMS W-97
(Available in e-text for students)
- OC** 38 INTEGRATED MANUFACTURING SYSTEMS W-122
(Available in e-text for students)

OC Part XI Manufacturing Support Systems W-144

- OC** 39 PROCESS PLANNING AND PRODUCTION CONTROL W-144
(Available in e-text for students)
- OC** 40 QUALITY CONTROL AND INSPECTION W-170
(Available in e-text for students)

REVIEW QUESTIONS AND PROBLEMS P-1

INDEX I-1