MANUFACTURING

Engineering and Technology



LIST OF TABLES

General Introduction

- I.1 Approximate Number of Parts in Products 1
- I.2 Historical Development of Materials, Tools, and Manufacturing Processes 3
- I.3 General Manufacturing Characteristics of Various Materials 14
- I.4 Average Life Expectancy of Various Products 29
- I.5 Relative Cost of Repair at Various Stages of Product Development and Sale 29
- I.6 Typical Cost Breakdown in Manufacturing 31
- I.7 Approximate Relative Hourly Compensation for Workers in Manufacturing in 2010 (United States = 100) 32

Part I Fundamentals of Materials: Behavior and Manufacturing Properties

- 1.1 Grain sizes 46
- 1.2 Homologous Temperature Ranges for Various Processes 50
- 2.1 Relative Mechanical Properties of Various Materials at Room Temperature (in Decreasing Order). Metals Are in Their Alloy Form 56
- 2.2 Mechanical Properties of Various Materials at Room Temperature 58
- 2.3 Typical Values for K and n for Selected Metals 61
- 2.4 Typical Ranges of Strain and Deformation Rate in Manufacturing Processes 64
- 3.1 Physical Properties of Selected Materials at Room Temperature 89
- 3.2 Physical Properties of Materials (in Descending Order) 90
- 4.1 Outline of Heat-treatment Processes for Surface Hardening 120
- 5.1 Applications for Selected Carbon and Alloy Steels 135
- 5.2 Effect of Various Elements in Steels 136
- 5.3 Typical Mechanical Properties of Selected Carbon and Alloy Steels 138
- 5.4 Mechanical Properties of Selected Advanced High-strength Steels 139
- 5.5 AISI Designations for High-strength Sheet Steel 140
- Mechanical Properties and Typical Applications of Selected
 Annealed Stainless Steels at Room Temperature 143
- 5.7 Basic Types of Tool and Die Steels 144
- 5.8 Processing and Service Characteristics of Common Tool and Die Steels 145
- 5.9 Typical Tool and Die Materials for Metalworking Processes 146
- 6.1 Approximate Cost-per-unit-volume for Wrought Metals and Plastics Relative to the Cost of Carbon Steel 151
- 6.2 General Characteristics of Nonferrous Metals and Allovs 151
- 6.3 Properties of Selected Aluminum Alloys at Room Temperature 152
- 6.4 Manufacturing Characteristics and Typical Applications of Selected Wrought Aluminum Alloys 153
- 6.5 Properties and Typical Forms of Selected Wrought Magnesium Alloys 155
- 6.6 Properties and Typical Applications of Selected Wrought Copper and Brasses 157
- 6.7 Properties and Typical Applications of Selected Wrought Bronzes 157
- 6.8 Properties and Typical Applications of Selected Nickel Alloys (All Are Trade Names) 158
- 6.9 Properties and Typical Applications of Selected Nickel-based Superalloys at 870°C (1600°F) (All Are Trade Names) 159
- 6.10 Properties and Typical Applications of Selected Wrought Titanium Alloys at Various Temperatures 160
- 7.1 Range of Mechanical Properties for Various Engineering Plastics at Room Temperature 170

- 7.2 Glass-transition and Melting Temperatures of Some Polymers 178
- 7.3 General Recommendations for Plastic Products 183
- 7.4 Trade Names for Thermoplastic Polymers 184
- 8.1 Types, General Characteristics, and Principal Uses of Ceramics 197
- 8.2 Properties of Various Ceramics at Room Temperature 201
- 8.3 Properties of Various Glasses 205
- 9.1 Types and General Characteristics of Composite Materials 217
- 9.2 Typical Properties of Reinforcing Fibers 218
- 9.3 Metal-matrix Composite Materials and Applications 227
- 9.4 Summary of Fiber and Composite Properties for an Automotive Brake Caliper 228

Part II Metal-Casting Processes and Equipment

- 10.1 Volumetric Solidification Contraction or Expansion for Various Cast Metals 249
- 11.1 Summary of Casting Processes 257
- 11.2 General Characteristics of Casting Processes 259
- 11.3 Properties and Typical Applications of Some Common Die-casting Alloys 280
- 12.1 Normal Shrinkage Allowance for Some Metals Cast in Sand Molds 297
- 12.2 Typical Applications for Castings and Casting Characteristics 305
- 12.3 Properties and Typical Applications of Cast Irons 305
- 12.4 Mechanical Properties of Gray Cast Irons 306
- 12.5 Properties and Typical Applications of Nonferrous Cast Alloys 306
- 12.6 General Cost Characteristics of Casting Processes 308

Part III Forming and Shaping Processes and Equipment

- III.1 General Characteristics of Forming and Shaping Processes 314
- 14.1 General Characteristics of Forging Processes 339
- 14.2 Range of k Values for Eq. (14.3) 344
- 14.3 Forgeability of Metals, in Decreasing Order (See also Table 15.1) 349
- 14.4 Typical Speed Ranges of Forging Equipment 356
- 14.5 Comparison of Suspension Upright Designs for the Lotus Elise Automobile 360
- 15.1 Typical Extrusion Temperature Ranges for Various Metals and Alloys. (See also Table 14.3.) 369
- 16.1 General Characteristics of Sheet-metal Forming Processes (in alphabetic order) 388
- 16.2 Important Metal Characteristics for Sheet-metal Forming Operations 398
- 16.3 Minimum Bend Radius for Various Metals at Room Temperature 403
- 16.4 Typical Ranges of Average Normal Anisotropy, for Various Sheet Metals 415
- 17.1 Compacting Pressures for Various Powders 454
- 17.2 Sintering Temperature and Time for Various Metals 462
- 17.3 Mechanical Properties of Selected PM Materials 464
- 17.4 Comparison of Mechanical Properties of Selected Wrought and Equivalent PM Metals (as Sintered) 465
- 17.5 Mechanical Property Comparisons for Ti-6AL-4V Titanium Allov 465
- 17.6 Forged and PM Titanium Parts and Cost Savings 469
- 18.1 General Characteristics of Ceramics Processing 476
- General Characteristics of Forming and Shaping Processes for Plastics and Composite Materials 495
- 19.2 Comparative Production Characteristics of Various Molding Methods 530

Manufacturing Engineering and Technology, eBook, SI Units

Table of Contents

	١.			
(·C	W	ľ	ı٢

List of Tables

Title Page

Copyright

Dedication

Companion Website Access

Contents

Case Studies

Preface

About the Authors

General Introduction

- I.1 What is Manufacturing?
- I.2 Product Design and Concurrent Engineering
- I.3 Design for Manufacture, Assembly, Disassembly, and Service
- I.4 Green Design and Manufacturing
- I.5 Selection of Materials
- I.6 Selection of Manufacturing Processes
- I.7 Computer-integrated Manufacturing
- I.8 Quality Assurance and Total Quality Management
- I.9 Lean Production and Agile Manufacturing
- I.10 Manufacturing Costs and Global Competition
- I.11 Trends in Manufacturing
- Part I: Fundamentals of Materials: Behavior and Manufacturing Properties



Chapter 1: The Structure of Metals

- 1.1 Introduction
- 1.2 Types of Atomic Bonds
- 1.3 The Crystal Structure of Metals
- 1.4 Deformation and Strength of Single Crystals
- 1.5 Grains and Grain Boundaries
- 1.6 Plastic Deformation of Polycrystalline Metals
- 1.7 Recovery, Recrystallization, and Grain Growth
- 1.8 Cold, Warm, and Hot Working

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 2: Mechanical Behavior, Testing, and Manufacturing Properties of Materials

- 2.1 Introduction
- 2.2 Tension
- 2.3 Compression
- 2.4 Torsion
- 2.5 Bending (Flexure)
- 2.6 Hardness
- 2.7 Fatigue
- 2.8 Creep
- 2.9 Impact
- 2.10 Failure and Fracture of Materials
- 2.11 Residual Stresses
- 2.12 Work, Heat, and Temperature

Summary

Key Terms

Bibliography

Review Questions



Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 3: Physical Properties of Materials

- 3.1 Introduction
- 3.2 Density
- 3.3 Melting Point
- 3.4 Specific Heat
- 3.5 Thermal Conductivity
- 3.6 Thermal Expansion
- 3.7 Electrical, Magnetic, and Optical Properties
- 3.8 Corrosion Resistance

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 4: Metal Alloys: Their Structure and Strengthening by Heat Treatment

- 4.1 Introduction
- 4.2 Structure of Alloys
- 4.3 Phase Diagrams
- 4.4 The Ironcarbon System
- 4.5 The Ironiron-carbide Phase Diagram and the Development of Microstructures in Steels
- 4.6 Cast Irons
- 4.7 Heat Treatment of Ferrous Alloys
- 4.8 Hardenability of Ferrous Alloys
- 4.9 Heat Treatment of Nonferrous Alloys and Stainless Steels
- 4.10 Case Hardening
- 4.11 Annealing
- 4.12 Heat-treating Furnaces and Equipment



4.13 Design Considerations for Heat Treating

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 5: Ferrous Metals and Alloys: Production, General Properties, and Applications

- 5.1 Introduction
- 5.2 Production of Iron and Steel
- 5.3 Casting of Ingots
- 5.4 Continuous Casting
- 5.5 Carbon and Alloy Steels
- 5.6 Stainless Steels
- 5.7 Tool and Die Steels

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 6: Nonferrous Metals and Alloys: Production, General Properties, and Applications

- 6.1 Introduction
- 6.2 Aluminum and Aluminum Alloys
- 6.3 Magnesium and Magnesium Alloys
- 6.4 Copper and Copper Alloys
- 6.5 Nickel and Nickel Alloys
- 6.6 Superalloys
- 6.7 Titanium and Titanium Alloys



- 6.8 Refractory Metals and Alloys
- 6.9 Beryllium
- 6.10 Zirconium
- 6.11 Low-melting Alloys
- 6.12 Precious Metals
- 6.13 Shape-memory Alloys (Smart Materials)
- 6.14 Amorphous Alloys (Metallic Glasses)
- 6.15 Metal Foams

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 7: Polymers: Structure, General Properties, and Applications

- 7.1 Introduction
- 7.2 The Structure of Polymers
- 7.3 Thermoplastics
- 7.4 Thermosetting Plastics
- 7.5 Additives in Plastics
- 7.6 General Properties and Applications of Thermoplastics
- 7.7 General Properties and Applications of Thermosetting Plastics
- 7.8 Biodegradable Plastics
- 7.9 Elastomers (Rubbers

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 8: Ceramics, Glass, Graphite, Diamond, and Nanomaterials: Structure,



General Properties, and Applications

- 8.1 Introduction
- 8.2 The Structure of Ceramics
- 8.3 General Properties and Applications of Ceramics
- 8.4 Glasses
- 8.5 Glass Ceramics
- 8.6 Graphite
- 8.7 Diamond
- 8.8 Nanomaterials

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 9: Composite Materials: Structure, General Properties, and Applications

- 9.1 Introduction
- 9.2 The Structure of Reinforced Plastics
- 9.3 Properties of Reinforced Plastics
- 9.4 Applications of Reinforced Plastics
- 9.5 Metal-matrix Composites
- 9.6 Ceramic-matrix Composites
- 9.7 Other Composites

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Part II: Metal-casting Processes and Equipment

Chapter 10: Fundamentals of Metal Casting



- 10.1 Introduction
- 10.2 Solidification of Metals
- 10.3 Fluid Flow
- 10.4 Fluidity of Molten Metal
- 10.5 Heat Transfer
- 10.6 Defects

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 11: Metal-casting Processes and Equipment

- 11.1 Introduction
- 11.2 Expendable-mold, Permanent-pattern Casting Processes
- 11.3 Expendable-mold, Expendable-pattern Casting Processes
- 11.4 Permanent-mold Casting Processes
- 11.5 Casting Techniques for Single-crystal Components
- 11.6 Rapid Solidification
- 11.7 Inspection of Castings
- 11.8 Melting Practice and Furnaces
- 11.9 Foundries and Foundry Automation

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 12: Metal Casting: Design, Materials, and Economics

- 12.1 Introduction
- 12.2 Design Considerations in Casting



- 12.3 Casting Alloys
- 12.4 Economics of Casting

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Part III: Forming and Shaping Processes and Equipment

Chapter 13: Metal-rolling Processes and Equipment

- 13.1 Introduction
- 13.2 The Flat-rolling Process
- 13.3 Flat-rolling Practice
- 13.4 Rolling Mills
- 13.5 Various Rolling Processes and Mills

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 14: Metal-forging Processes and Equipment

- 14.1 Introduction
- 14.2 Open-die Forging
- 14.3 Impression-die and Closed-die Forging
- 14.4 Various Forging Operations
- 14.5 Forgeability of Metals; Forging Defects
- 14.6 Die Design, Die Materials, and Lubrication
- 14.7 Die-manufacturing Methods and Die Failure
- 14.8 Forging Machines
- 14.9 Economics of Forging



Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 15: Metal Extrusion and Drawing Processes and Equipment

- 15.1 Introduction
- 15.2 The Extrusion Process
- 15.3 Hot Extrusion
- 15.4 Cold Extrusion
- 15.5 Extrusion Defects
- 15.6 Design Considerations
- 15.7 Extrusion Equipment
- 15.8 The Drawing Process
- 15.9 Drawing Practice
- 15.10 Drawing Defects and Residual Stresses
- 15.11 Drawing Equipment

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 16: Sheet-metal Forming Processes and Equipment

- 16.1 Introduction
- 16.2 Shearing
- 16.3 Sheet-metal Characteristics and Formability
- 16.4 Formability Tests for Sheet Metals
- 16.5 Bending Sheets, Plates, and Tubes
- 16.6 Miscellaneous Bending and Related Forming Operations



- 16.7 Deep Drawing
- 16.8 Rubber Forming and Hydroforming
- 16.9 Spinning
- 16.10 Superplastic Forming
- 16.11 Hot Stamping
- 16.12 Specialized Forming Processes
- 16.13 Manufacturing of Metal Honeycomb Structures
- 16.14 Design Considerations in Sheet-metal Forming
- 16.15 Equipment for Sheet-metal Forming
- 16.16 Economics of Sheet-forming Operations

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 17: Powder Metal Processes and Equipment

- 17.1 Introduction
- 17.2 Production of Metal Powders
- 17.3 Compaction of Metal Powders
- 17.4 Sintering
- 17.5 Secondary and Finishing Operations
- 17.6 Design Considerations
- 17.7 Economics of Powder Metallurgy

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 18: Ceramics, Glasses, and Superconductors: Processing and



Equipment

- 18.1 Introduction
- 18.2 Shaping Ceramics
- 18.3 Forming and Shaping of Glass
- 18.4 Techniques for Strengthening and Annealing Glass
- 18.5 Design Considerations for Ceramics and Glasses
- 18.6 Processing of Superconductors

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 19: Plastics and Composite Materials: Forming and Shaping

- 19.1 Introduction
- 19.2 Extrusion
- 19.3 Injection Molding
- 19.4 Blow Molding
- 19.5 Rotational Molding
- 19.6 Thermoforming
- 19.7 Compression Molding
- 19.8 Transfer Molding
- 19.9 Casting
- 19.10 Foam Molding
- 19.11 Cold Forming and Solid-phase Forming
- 19.12 Processing Elastomers
- 19.13 Processing Polymer-matrix Composites
- 19.14 Processing Metal-matrix and Ceramic-matrix Composites
- 19.15 Design Considerations
- 19.16 Economics of Processing Plastics and Composite Materials

Summary

Key Terms



Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 20: Rapid-prototyping Processes and Operations

20.1 Introduction

20.2 Subtractive Processes

20.3 Additive Processes

20.4 Virtual Prototyping

20.5 Self-replicating Machines

20.6 Direct Manufacturing and Rapid Tooling

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Part IV: Machining Processes and Machine Tools

Chapter 21: Fundamentals of Machining

21.1 Introduction

21.2 Mechanics of Cutting

21.3 Cutting Forces and Power

21.4 Temperatures in Cutting

21.5 Tool Life: Wear and Failure

21.6 Surface Finish and Integrity

21.7 Machinability

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems



Quantitative Problems

Synthesis, Design, and Projects

Chapter 22: Cutting-tool Materials and Cutting Fluids

- 22.1 Introduction
- 22.2 High-speed Steels
- 22.3 Cast-cobalt Alloys
- 22.4 Carbides
- 22.5 Coated Tools
- 22.6 Alumina-based Ceramics
- 22.7 Cubic Boron Nitride
- 22.8 Silicon-nitride-based Ceramics
- 22.9 Diamond
- 22.10 Whisker-reinforced Materials and Nanomaterials
- 22.11 Tool Costs and Reconditioning of Tools
- 22.12 Cutting Fluids

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 23: Machining Processes: Turning and Hole Making

- 23.1 Introduction
- 23.2 The Turning Process
- 23.3 Lathes and Lathe Operations
- 23.4 Boring and Boring Machines
- 23.5 Drilling, Drills, and Drilling Machines
- 23.6 Reaming and Reamers
- 23.7 Tapping and Taps

Summary

Key Terms

Bibliography



Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 24: Machining Processes: Milling, Broaching, Sawing, Filing, and Gear Manufacturing

- 24.1 Introduction
- 24.2 Milling and Milling Machines
- 24.3 Planing and Shaping
- 24.4 Broaching and Broaching Machines
- 24.5 Sawing
- 24.6 Filing
- 24.7 Gear Manufacturing by Machining

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 25: Machining Centers, Machine-tool Structures, and Machining Economics

- 25.1 Introduction
- 25.2 Machining Centers
- 25.3 Machine-tool Structures
- 25.4 Vibration and Chatter in Machining Operations
- 25.5 High-speed Machining
- 25.6 Hard Machining
- 25.7 Ultraprecision Machining
- 25.8 Machining Economics

Summary

Key Terms

Bibliography



	\sim		
Review	()) 6	actions	3

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 26: Abrasive Machining and Finishing Operations

- 26.1 Introduction
- 26.2 Abrasives and Bonded Abrasives
- 26.3 The Grinding Process
- 26.4 Grinding Operations and Machines
- 26.5 Design Considerations for Grinding
- 26.6 Ultrasonic Machining
- 26.7 Finishing Operations
- 26.8 Deburring Operations
- 26.9 Economics of Abrasive Machining and Finishing Operations

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 27: Advanced Machining Processes and Equipment

- 27.1 Introduction
- 27.2 Chemical Machining
- 27.3 Electrochemical Machining
- 27.4 Electrochemical Grinding
- 27.5 Electrical-discharge Machining
- 27.6 Laser-beam Machining
- 27.7 Electron-beam Machining
- 27.8 Water-jet Machining
- 27.9 Abrasive-jet Machining
- 27.10 Hybrid Machining Systems
- 27.11 Economics of Advanced Machining Processes



Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Part V: Micromanufacturing and Fabrication of Microelectronic Devices

Chapter 28: Fabrication of Microelectronic Devices

- 28.1 Introduction
- 28.2 Clean Rooms
- 28.3 Semiconductors and Silicon
- 28.4 Crystal Growing and Wafer Preparation
- 28.5 Film Deposition
- 28.6 Oxidation
- 28.7 Lithography
- 28.8 Etching
- 28.9 Diffusion and Ion Implantation
- 28.10 Metallization and Testing
- 28.11 Wire Bonding and Packaging
- 28.12 Yield and Reliability
- 28.13 Printed Circuit Boards

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 29: Fabrication of Microelectromechanical Devices and Systems; Nanoscale Manufacturing

- 29.1 Introduction
- 29.2 Micromachining of MEMS Devices



- 29.3 Electroforming-based Processes
- 29.4 Solid Free-form Fabrication of Devices
- 29.5 Nanoscale Manufacturing

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Part VI: Joining Processes and Equipment

Chapter 30: Fusion-welding Processes

- 30.1 Introduction
- 30.2 Oxyfuelgas Welding
- 30.3 Arc-welding Processes: Nonconsumable Electrode
- 30.4 Arc-welding Processes: Consumable Electrode
- 30.5 Electrodes for Arc Welding
- 30.6 Electron-beam Welding
- 30.7 Laser-beam Welding
- 30.8 Cutting
- 30.9 The Weld Joint, Weld Quality, and Testing
- 30.10 Joint Design and Process Selection

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 31: Solid-State Welding Processes

- 31.1 Introduction
- 31.2 Cold Welding and Roll Bonding
- 31.3 Ultrasonic Welding



- 31.4 Friction Welding
- 31.5 Resistance Welding
- 31.6 Explosion Welding
- 31.7 Diffusion Bonding
- 31.8 Economics of Welding Operations

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 32: Brazing, Soldering, Adhesive-bonding, and Mechanical Fastening Processes

- 32.1 Introduction
- 32.2 Brazing
- 32.3 Soldering
- 32.4 Adhesive-bonding
- 32.5 Mechanical Fastening
- 32.6 Joining Plastics, Ceramics, and Glasses
- 32.7 Economics of Joining Operations

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Part VII: Surface Technology

Chapter 33: Surface Roughness and Measurement; Friction, Wear, and Lubrication

- 33.1 Introduction
- 33.2 Surface Structure and Integrity



- 33.3 Surface Texture and Roughness
- 33.4 Friction
- 33.5 Wear
- 33.6 Lubrication
- 33.7 Metalworking Fluids and Their Selection

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 34: Surface Treatments, Coatings, and Cleaning

- 34.1 Introduction
- 34.2 Mechanical Surface Treatments
- 34.3 Mechanical Plating and Cladding
- 34.4 Case Hardening and Hard Facing
- 34.5 Thermal Spraying
- 34.6 Vapor Deposition
- 34.7 Ion Implantation and Diffusion Coating
- 34.8 Laser Treatments
- 34.9 Electroplating, Electroless Plating, and Electroforming
- 34.10 Conversion Coatings
- 34.11 Hot Dipping
- 34.12 Porcelain Enameling; Ceramic and Organic Coatings
- 34.13 Diamond Coating and Diamond-like Carbon
- 34.14 Surface Texturing
- 34.15 Painting
- 34.16 Cleaning of Surfaces

Summary

Key Terms

Bibliography

Review Questions



Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Part VIII: Engineering Metrology, Instrumentation, and Quality Assurance

Chapter 35: Engineering Metrology and Instrumentation

- 35.1 Introduction
- 35.2 Measurement Standards
- 35.3 Geometric Features of Parts: Analog and Digital Measurements
- 35.4 Traditional Measuring Methods and Instruments
- 35.5 Modern Measuring Instruments and Machines
- 35.6 Automated Measurement
- 35.7 General Characteristics and Selection of Measuring Instruments
- 35.8 Geometric Dimensioning and Tolerancing

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 36: Quality Assurance, Testing, and Inspection

- 36.1 Introduction
- 36.2 Product Quality
- 36.3 Quality Assurance
- 36.4 Total Quality Management
- 36.5 Taguchi Methods
- 36.6 The ISO and QS Standards
- 36.7 Statistical Methods of Quality Control
- 36.8 Statistical Process Control
- 36.9 Reliability of Products and Processes
- 36.10 Nondestructive Testing
- 36.11 Destructive Testing
- 36.12 Automated Inspection



Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Part IX: Manufacturing in a Competitive Environment

Chapter 37: Automation of Manufacturing Processes and Operations

- 37.1 Introduction
- 37.2 Automation
- 37.3 Numerical Control
- 37.4 Adaptive Control
- 37.5 Material Handling and Movement
- 37.6 Industrial Robots
- 37.7 Sensor Technology
- 37.8 Flexible Fixturing
- 37.9 Assembly Systems
- 37.10 Design Considerations for Fixturing, Assembly, Disassembly, and Servicing
- 37.11 Economic Considerations

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Quantitative Problems

Synthesis, Design, and Projects

Chapter 38: Computer-aided Manufacturing

- 38.1 Introduction
- 38.2 Manufacturing Systems
- 38.3 Computer-integrated Manufacturing
- 38.4 Computer-aided Design and Engineering
- 38.5 Computer-aided Manufacturing



- 38.6 Computer-aided Process Planning
- 38.7 Computer Simulation of Manufacturing Processes and Systems
- 38.8 Group Technology

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Synthesis, Design, and Projects

Chapter 39: Computer-integrated Manufacturing Systems

- 39.1 Introduction
- 39.2 Cellular Manufacturing
- 39.3 Flexible Manufacturing Systems
- 39.4 Holonic Manufacturing
- 39.5 Just-in-time Production
- 39.6 Lean Manufacturing
- 39.7 Communications Networks in Manufacturing
- 39.8 Artificial Intelligence
- 39.9 Economic Considerations

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Synthesis, Design, and Projects

Chapter 40: Product Design and Manufacturing in a Competitive

Environment

- 40.1 Introduction
- 40.2 Product Design
- 40.3 Product Quality
- 40.4 Life-cycle Assessment and Sustainable Manufacturing
- 40.5 Energy Consumption in Manufacturing
- 40.6 Material Selection for Products



- 40.7 Material Substitution
- 40.8 Manufacturing Process Capabilities
- 40.9 Process Selection
- 40.10 Manufacturing Costs and Cost Reduction

Summary

Key Terms

Bibliography

Review Questions

Qualitative Problems

Synthesis, Design, and Projects

Index

List of Examples

References to Various Topics