

Contents

1 *History, Structural Formulation of the Field Through Elementary Steps, and Future Perspectives*, 1

- 1.1 Historical Notes, 1
- 1.2 Current Polymer Processing Practice, 7
- 1.3 Analysis of Polymer Processing in Terms of Elementary Steps and Shaping Methods, 14
- 1.4 Future Perspectives: From Polymer Processing to Macromolecular Engineering, 18

2 *The Balance Equations and Newtonian Fluid Dynamics*, 25

- 2.1 Introduction, 25
- 2.2 The Balance Equations, 26
- 2.3 Reynolds Transport Theorem, 26
- 2.4 The Macroscopic Mass Balance and the Equation of Continuity, 28
- 2.5 The Macroscopic Linear Momentum Balance and the Equation of Motion, 32
- 2.6 The Stress Tensor, 37
- 2.7 The Rate of Strain Tensor, 40
- 2.8 Newtonian Fluids, 43
- 2.9 The Macroscopic Energy Balance and the Bernoulli and Thermal Energy Equations, 54
- 2.10 Mass Transport in Binary Mixtures and the Diffusion Equation, 60
- 2.11 Mathematical Modeling, Common Boundary Conditions, Common Simplifying Assumptions, and the Lubrication Approximation, 60

3 *Polymer Rheology and Non-Newtonian Fluid Mechanics*, 79

- 3.1 Rheological Behavior, Rheometry, and Rheological Material Functions of Polymer Melts, 80
- 3.2 Experimental Determination of the Viscosity and Normal Stress Difference Coefficients, 94
- 3.3 Polymer Melt Constitutive Equations Based on Continuum Mechanics, 100
- 3.4 Polymer Melt Constitutive Equations Based on Molecular Theories, 122

4 The Handling and Transporting of Polymer Particulate Solids, 144

- 4.1 Some Unique Properties of Particulate Solids, 145**
- 4.2 Agglomeration, 150**
- 4.3 Pressure Distribution in Bins and Hoppers, 150**
- 4.4 Flow and Flow Instabilities in Hoppers, 152**
- 4.5 Compaction, 154**
- 4.6 Flow in Closed Conduits, 157**
- 4.7 Mechanical Displacement Flow, 157**
- 4.8 Steady Mechanical Displacement Flow Aided by Drag, 159**
- 4.9 Steady Drag-induced Flow in Straight Channels, 162**
- 4.10 The Discrete Element Method, 165**

5 Melting, 178

- 5.1 Classification and Discussion of Melting Mechanisms, 179**
- 5.2 Geometry, Boundary Conditions, and Physical Properties in Melting, 184**
- 5.3 Conduction Melting without Melt Removal, 186**
- 5.4 Moving Heat Sources, 193**
- 5.5 Sintering, 199**
- 5.6 Conduction Melting with Forced Melt Removal, 201**
- 5.7 Drag-induced Melt Removal, 202**
- 5.8 Pressure-induced Melt Removal, 216**
- 5.9 Deformation Melting, 219**

6 Pressurization and Pumping, 235

- 6.1 Classification of Pressurization Methods, 236**
- 6.2 Synthesis of Pumping Machines from Basic Principles, 237**
- 6.3 The Single Screw Extruder Pump, 247**
- 6.4 Knife and Roll Coating, Calenders, and Roll Mills, 259**
- 6.5 The Normal Stress Pump, 272**
- 6.6 The Co-rotating Disk Pump, 278**
- 6.7 Positive Displacement Pumps, 285**
- 6.8 Twin Screw Extruder Pumps, 298**

7 Mixing, 322

- 7.1 Basic Concepts and Mixing Mechanisms, 322**
- 7.2 Mixing Equipment and Operations of Multicomponent and Multiphase Systems, 354**
- 7.3 Distribution Functions, 357**
- 7.4 Characterization of Mixtures, 378**
- 7.5 Computational Analysis, 391**

8 Devolatilization, 409

- 8.1 Introduction, 409**
- 8.2 Devolatilization Equipment, 411**
- 8.3 Devolatilization Mechanisms, 413**

- 8.4 Thermodynamic Considerations of Devolatilization, 416
- 8.5 Diffusivity of Low Molecular Weight Components in Molten Polymers, 420
- 8.6 Boiling Phenomena: Nucleation, 422
- 8.7 Boiling–Foaming Mechanisms of Polymeric Melts, 424
- 8.8 Ultrasound-enhanced Devolatilization, 427
- 8.9 Bubble Growth, 428
- 8.10 Bubble Dynamics and Mass Transfer in Shear Flow, 430
- 8.11 Scanning Electron Microscopy Studies of Polymer Melt Devolatilization, 433

9 *Single Rotor Machines, 447*

- 9.1 Modeling of Processing Machines Using Elementary Steps, 447
- 9.2 The Single Screw Melt Extrusion Process, 448
- 9.3 The Single Screw Plasticating Extrusion Process, 473
- 9.4 The Co-rotating Disk Plasticating Processor, 506

10 *Twin Screw and Twin Rotor Processing Equipment, 523*

- 10.1 Types of Twin Screw and Twin Rotor-based Machines, 525
- 10.2 Counterrotating Twin Screw and Twin Rotor Machines, 533
- 10.3 Co-rotating, Fully Intermeshing Twin Screw Extruders, 572

11 *Reactive Polymer Processing and Compounding, 603*

- 11.1 Classes of Polymer Chain Modification Reactions, Carried out in Reactive Polymer Processing Equipment, 604
- 11.2 Reactor Classification, 611
- 11.3 Mixing Considerations in Multicomponent Miscible Reactive Polymer Processing Systems, 623
- 11.4 Reactive Processing of Multicomponent Immiscible and Compatibilized Immiscible Polymer Systems, 632
- 11.5 Polymer Compounding, 635

12 *Die Forming, 677*

- 12.1 Capillary Flow, 680
- 12.2 Elastic Effects in Capillary Flows, 689
- 12.3 Sheet Forming and Film Casting, 705
- 12.4 Tube, Blown Film, and Parison Forming, 720
- 12.5 Wire Coating, 727
- 12.6 Profile Extrusion, 731

13 *Molding, 753*

- 13.1 Injection Molding, 753
- 13.2 Reactive Injection Molding, 798
- 13.3 Compression Molding, 811

14 Stretch Shaping, 824

- 14.1** Fiber Spinning, 824
- 14.2** Film Blowing, 836
- 14.3** Blow Molding, 841

15 Calendering, 865

- 15.1** The Calendering Process, 865
- 15.2** Mathematical Modeling of Calendering, 867
- 15.3** Analysis of Calendering Using FEM, 873

Appendix A Rheological and Thermophysical Properties of Polymers, 887

Appendix B Conversion Tables to the International System of Units (SI), 914

Appendix C Notation, 918

Author Index, 929

Subject Index, 944