

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	8.4	Therm
4.1 Some Unique Properties of Particulate Solids, 145	8.5	Diffus
4.2 Agglomeration, 150	8.6	Boiling
4.3 Pressure Distribution in Bins and Hoppers, 150	8.7	Boiling
4.4 Flow and Flow Instabilities in Hoppers, 152	8.8	Ultraso
4.5 Compaction, 154	8.9	Bubble
4.6 Flow in Closed Conduits, 157	8.10	Bubble
4.7 Mechanical Displacement Flow, 157	8.11	Scanni
4.8 Steady Mechanical Displacement Flow Aided by Drag, 159		Devola
4.9 Steady Drag-induced Flow in Straight Channels, 162		
4.10 The Discrete Element Method, 165		
5 Melting, 178	9	Single Rotor
5.1 Classification and Discussion of Melting Mechanisms, 179	9.1	Modelin
5.2 Geometry, Boundary Conditions, and Physical Properties in Melting, 184	9.2	The Sing
5.3 Conduction Melting without Melt Removal, 186	9.3	The Sing
5.4 Moving Heat Sources, 193	9.4	The Co-
5.5 Sintering, 199	10	Twin Screw a
5.6 Conduction Melting with Forced Melt Removal, 201	10.1	Types o
5.7 Drag-induced Melt Removal, 202	10.2	Counte
5.8 Pressure-induced Melt Removal, 216	10.3	Co-rotat
5.9 Deformation Melting, 219		
6 Pressurization and Pumping, 235	11	Reactive Poly
6.1 Classification of Pressurization Methods, 236	11.1	Classes
6.2 Synthesis of Pumping Machines from Basic Principles, 237		Reactiv
6.3 The Single Screw Extruder Pump, 247	11.2	Reactor
6.4 Knife and Roll Coating, Calenders, and Roll Mills, 259	11.3	Mixing
6.5 The Normal Stress Pump, 272		Polymer
6.6 The Co-rotating Disk Pump, 278	11.4	Reactiv
6.7 Positive Displacement Pumps, 285		Compati
6.8 Twin Screw Extruder Pumps, 298	11.5	Polymer
7 Mixing, 322	12	Die Forming,
7.1 Basic Concepts and Mixing Mechanisms, 322	12.1	Capillar
7.2 Mixing Equipment and Operations of Multicomponent and	12.2	Elastic
Multiphase Systems, 354	12.3	Sheet F
7.3 Distribution Functions, 357	12.4	Tube, B
7.4 Characterization of Mixtures, 378	12.5	Wire Co
7.5 Computational Analysis, 391	12.6	Profile E
8 Devolatilization, 409	13	Molding, 753
8.1 Introduction, 409	13.1	Injection
8.2 Devolatilization Equipment, 411	13.2	Reactiv
8.3 Devolatilization Mechanisms, 413	13.3	Compre

s, 144

59

79
in Melting, 184

37

d

- 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

1 History of the Steps, a

- 1.1** Historical Notes, 1
- 1.2** Current Polymer Pro
- 1.3** Analysis of Polymer
- 1.4** Future Perspectives: 1

Polymer processing is carried out on polymeric deals with the conversion only shaping but also modifications and morphology. This chapter briefly reviews the history of polymer processing methods, the future of the field, which are based on first molecular

1.1 HISTORICAL NOTES

Plastics and Rubber Manufacturing

Modern polymer processing industry and the processes of rubber-processing machines, such as the winch inside a toothed belt, was invented in England, to reclaim scrap rubber. In 1839, Charles Goodyear, a New Englander, developed the *roll calender* for the continuous processing of rubber, which is still being used in the rubber industry. Goodyear, is credited with the discovery of the process, and Richard Brooman applied for a patent for the process, which was used in wire drawing.