

Contents

1	Introduction to the Technology of Injection Molding	1
1.1	The Injection Molding Process	1
1.2	Components of the Injection Molding Process	3
1.2.1	Injection Molding Machine	3
1.2.1.1	Plasticating Unit	3
1.2.1.2	Clamping Unit	4
1.2.2	Mold	6
1.2.2.1	Runner System	7
1.2.2.2	Cavity	8
1.2.2.3	Ejector System	9
1.2.2.4	Tempering System	10
1.2.3	Machine Control System	12
1.3	References	12
2	Injection Molding Materials	14
2.1	Properties of Plastics	14
2.2	Classification of Plastics	16
2.3	The Molecular Structure of Plastics	18
2.4	Processing Behavior of Plastics	19
2.4.1	Rheological Behavior	19
2.4.1.1	Fundamentals	19
2.4.1.2	Measuring Methods	22
2.4.1.3	Results of Viscosity Measurements	26
2.4.1.4	Mathematical Approximation of Rheological Behavior	28
2.4.2	Application of Viscosity Data	31
2.4.3	Thermal and Thermodynamic Material Behavior	33
2.4.3.1	Measurement of Thermal Properties	37
2.4.3.1.1	PVT Determination	37
2.4.3.1.2	Differential Scanning Calorimetry (DSC)	38
2.4.3.1.3	Thermomechanical Analysis (TMA)	40
2.4.3.1.4	Thermogravimetric Analysis (TGA)	41
2.4.3.1.5	Dynamic-Mechanical Analysis (DMA)	42
2.4.3.1.6	Density Measurement	43
2.5	Mechanical Behavior of Plastics	44
2.5.1	Amorphous Thermoplastics	44
2.5.2	Semicrystalline Thermoplastics	45
2.5.3	Cross-Linked Polymers	46
2.5.4	Time- and Stress-Dependent Mechanical Behavior	47
2.5.5	Methods for Measurement of Mechanical Properties	50
2.6	References	52

3	The Injection Molding Machine	57
3.1	Injection Unit	58
3.1.1	Hopper	58
3.1.2	Screw	59
3.1.3	Nonreturn Valves (Check Valves)	61
3.1.4	Nozzle	62
3.1.5	Barrel Tempering	64
3.1.6	Guidance and Drive of the Injection Unit	64
3.2	Clamping Unit	65
3.2.1	Mechanical Clamping Units	66
3.2.2	Hydraulic Clamping Units	68
3.2.3	Hydraulic Mechanical Clamping Units	69
3.2.4	Deformation Characteristics of Mold and Clamping Unit	69
3.2.5	Comparison of Different Clamping Systems	70
3.3	Machine Hydraulics	70
3.4	Control System	73
3.5	Special Types of Injection Molding Machines	74
3.6	References	77
4	The Injection Mold	80
4.1	Tasks of the Injection Mold	80
4.2	Introduction and Classification of Molds	81
4.3	Functional Units in Injection Molds	85
4.3.1	Mold Mounting, Alignment, and Guiding	85
4.3.2	Runner System	89
4.3.2.1	Conventional Runner Systems	90
4.3.2.2	Hot Runner Systems	93
4.3.3	Cavity	97
4.3.4	Heat Transfer System	99
4.3.4.1	Design of Heat Transfer Units	99
4.3.5	Ejector System	102
4.4	References	105
5	Course of Process and Process Control in Injection Molding	110
5.1	Course of Process in Injection Molding	110
5.1.1	Phases of the Injection Molding Cycle	110
5.2	Injection Phase	111
5.2.1	Flow Process in the Mold	112
5.2.2	Frozen Layer and Orientation	114
5.2.3	Pressure Course in the Cavity	117
5.3	Holding Pressure Phase	118
5.3.1	Switching to Holding Pressure	118
5.3.2	Influence of Process Parameters on Pressure Curves	120
5.3.3	Course of State in the PVT Diagram	122
5.3.4	Influence of Different Parameters on the Course of State	124

5.4	Cooling Phase	127
5.4.1	Residual Stresses	127
5.4.1.1	Cause of Residual Stresses	128
5.4.1.2	Influence of Process Parameters on Residual Stresses	130
5.4.2	Crystallization	131
5.4.2.1	Dependence of the Degree of Crystallinity on Various Process Parameters	132
5.5	Influence of Internal Properties on External Properties	135
5.5.1	Influence of Internal Structure on Final Part Properties	136
5.6	References	140
6	Automation	145
6.1	Mold Changing Systems	146
6.1.1	Quick Clamping Devices	147
6.1.2	Quick Coupling Systems	150
6.1.3	Mold Changing Devices	151
6.1.4	Mold Transport System	153
6.1.5	Stepwise Automation of Mold Changing Systems	153
6.1.6	Requirements for Injection Molds	154
6.2	Automation of the Injection/Plasticating Side	155
6.3	Raw Material Supply	157
6.4	Handling of the Parts	158
6.5	Computer Control in Automation	160
6.6	References	163
7	Quality Assurance	165
7.1	Quality Control in Production	165
7.1.1	Control Chart	165
7.1.2	Machine Process Capability	166
7.1.3	Process Capability	167
7.1.4	Controlling Production with Statistical Process Models	168
7.2	Incoming Inspection	169
7.2.1	Acceptance Sampling Inspection	169
7.3	References	170
8	Special Processes	171
8.1	Intrusion Injection Molding	171
8.2	Injection/Compression Molding	171
8.3	Injection Press–Stretching Process (IPS Process)	172
8.4	Lost-Core Process	172
8.5	Push/Pull Process (Live-Feed Injection Molding)	174
8.6	In-Mold Decoration (IMD)	175
8.7	In-Mold Lamination	175
8.8	Overmolding	176
8.9	Multicomponent Injection Molding	176

8.10	Gas-Assisted Injection Molding	178
8.11	Injection Molding of Thermoplastic Foam	180
8.12	Insert/Outsert Process	180
8.13	Metal/Ceramic Powder Injection Molding	181
8.14	Reaction Injection Molding (RIM)	182
8.15	Resin Transfer Molding (RTM)	183
8.16	Compression Molding	184
8.17	Transfer Molding	185
8.18	References	186

Index	191
--------------------	------------