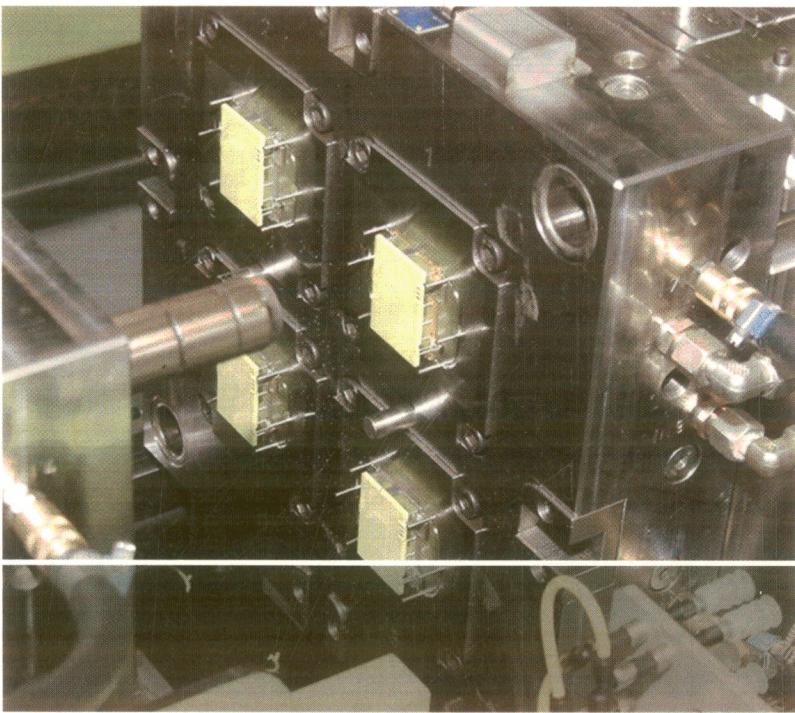


Gerd Pötsch
Walter Michaeli

Injection Molding

An Introduction



2nd Edition

HANSER

Contents

Preface 2nd Edition	V
1 Introduction to the Technology of Injection Molding	1
1.1 The Injection Molding Process	1
1.2 Components of the Injection Molding Process	4
1.2.1 Injection Molding Machine	4
1.2.1.1 Plasticating Unit	4
1.2.1.2 Clamping Unit	5
1.2.2 Mold	7
1.2.2.1 Runner System	8
1.2.2.2 Cavity	9
1.2.2.3 Ejector System	9
1.2.2.4 Tempering System	10
1.2.3 Machine Control System	12
References	13
2 Injection Molding Materials	15
2.1 Properties of Plastics	15
2.2 Classification of Plastics	17
2.3 The Molecular Structure of Plastics	19
2.4 Processing Behavior of Plastics	20
2.4.1 Rheological Behavior	20
2.4.1.1 Fundamentals	20
2.4.1.2 Measuring Methods	23
2.4.1.3 Results of Viscosity Measurements	28
2.4.1.4 Mathematical Approximation of Rheological Behavior	30
2.4.2 Application of Viscosity Data	33
2.4.3 Thermal and Thermodynamic Material Behavior	35
2.4.3.1 Measurement of Thermal Properties	40
2.4.3.1.1 PVT Determination	40
2.4.3.1.2 Differential Scanning Calorimetry (DSC)	40
2.4.3.1.3 Thermomechanical Analysis (TMA)	42
2.4.3.1.4 Thermogravimetric Analysis (TGA)	43
2.4.3.1.5 Dynamic–Mechanical Analysis (DMA)	45
2.4.3.1.6 Density Measurement	46
2.5 Mechanical Behavior of Plastics	46
2.5.1 Amorphous Thermoplastics	46

2.5.2	Semicrystalline Thermoplastics	48
2.5.3	Cross-Linked Polymers	49
2.5.4	Time- and Stress-Dependent Mechanical Behavior	50
2.5.5	Methods for Measurement of Mechanical Properties	53
	References	55
3	The Injection Molding Machine	61
3.1	Injection Unit	62
3.1.1	Hopper	62
3.1.2	Screw	63
3.1.3	Nonreturn Valves (Check Valves)	65
3.1.4	Nozzle	66
3.1.5	Barrel Tempering	69
3.1.6	Guidance and Drive of the Injection Unit	69
3.2	Clamping Unit	70
3.2.1	Mechanical Clamping Units	70
3.2.2	Hydraulic Clamping Units	72
3.2.3	Hydraulic Mechanical Clamping Units	74
3.2.4	Deformation Characteristics of Mold and Clamping Unit	74
3.2.5	Clamping Units without Tie Bars	75
3.2.6	Two-Plate Clamping Units	76
3.2.7	Comparison of Different Clamping Systems	76
3.3	Drive Systems for Injection Molding Machines	77
3.3.1	Hydraulic Drive Systems	77
3.3.2	Electromechanic Drive Systems	80
3.3.3	Hybrid Drive Systems	81
3.4	Control System	82
3.5	Special Types of Injection Molding Machines	83
	References	86
4	The Injection Mold	89
4.1	Tasks of the Injection Mold	89
4.2	Introduction and Classification of Molds	90
4.3	Functional Units in Injection Molds	94
4.3.1	Mold Mounting, Alignment, and Guiding	94
4.3.2	Runner System	98
4.3.2.1	Conventional Runner Systems	100
4.3.2.2	Hot Runner Systems	103
4.3.3	Cavity	107
4.3.4	Heat Transfer System	109
4.3.4.1	Design of Heat Transfer Systems	110
4.3.4.2	Temperature Control Methods	114

4.3.5	Ejector System	115
4.4	Advanced Mold Technologies	118
4.4.1	Family Molds	119
4.4.2	Stack Molds	119
4.4.3	Tandem Molds	120
	References	121
5	Course of Process and Process Control in Injection Molding	129
5.1	Course of Process in Injection Molding	129
5.1.1	Phases of the Injection Molding Cycle	129
5.2	Injection Phase	130
5.2.1	Flow Process in the Mold	131
5.2.2	Frozen Layer and Orientation	133
5.2.3	Pressure Course in the Cavity	137
5.3	Holding Pressure Phase	138
5.3.1	Switching to Holding Pressure	138
5.3.2	Influence of Process Parameters on Pressure Curves	140
5.3.3	Course of State in the PVT-Diagram	142
5.3.4	Influence of Different Parameters on the Course of State	143
5.4	Cooling Phase	147
5.4.1	Residual Stresses	147
5.4.1.1	Cause of Residual Stresses	148
5.4.1.2	Influence of Process Parameters on Residual Stresses	150
5.4.2	Crystallization	152
5.4.2.1	Dependence of the Degree of Crystallinity on Various Process Parameters	153
5.5	Influence of Internal Properties on External Properties	156
5.5.1	Influence of Internal Structure on Final Part Properties	157
	References	161
6	Automation	165
6.1	Mold Changing Systems	166
6.1.1	Quick Clamping Devices	167
6.1.2	Quick Coupling Systems	170
6.1.3	Mold Changing Devices	172
6.1.4	Mold Transport System	174
6.1.5	Stepwise Automation of Mold Changing Systems	174
6.1.6	Requirements for Injection Molds	175
6.2	Automation of the Injection / Plasticating Side	176
6.3	Raw Material Supply	179
6.4	Handling of the Parts	180
6.5	Computer Control in Automation	182
	References	183

7 Quality Assurance	187
7.1 Quality Control in Production	188
7.1.1 Control Chart	188
7.1.2 Machine Process Capability	189
7.1.3 Process Capability	189
7.1.4 Controlling Production with Statistical Process Models	190
7.2 Incoming Inspection	191
7.2.1 Acceptance Sampling Inspection	191
References	193
8 Special Injection Molding Techniques	195
8.1 Multicomponent Injection Molding	195
8.1.1 Overmolding	195
8.1.2 Sandwich Injection Molding	199
8.2 Fluid Injection Technique	203
8.3 Foam Injection Molding	206
8.3.1 Fundamentals of the Foam Injection Molding Process	206
8.3.2 Process Concepts	208
8.3.3 Process Variants	210
8.4 Back-Injection Technique	211
8.4.1 Back-Injection Molding of Films	211
8.4.2 In-Mold Labeling	213
8.4.3 In-Mold Decoration	214
8.4.4 In-Mold Decoration/Insert-Molding	215
8.4.5 Back-Injection Molding of Textiles/Textile Melt Technique	215
8.5 Micro Injection Molding	215
8.5.1 Injection Molded Micro Components	216
8.5.2 Injection Molding of Micro-Textures	217
8.6 Insert/Outsert/Hybrid Technology	218
8.7 Lost Core Process	220
8.8 Compression Molding	221
8.9 Injection-Compression Molding	221
8.10 Transfer Molding	225
8.11 Injection Transfer Molding	225
8.12 Precompression Injection Molding	227
8.13 Injection Press-Stretching Process	228
8.14 Push-Pull Process	228
8.15 Metal/Ceramic Powder Injection Molding	230
References	231