

Contents

1	Requirements for Efficient Troubleshooting	1
1.1	Instrumentation	1
1.2	Understanding the Extrusion Process	2
1.3	Collection and Analysis of Historical Data (Time Line)	2
1.4	Team Building	4
1.5	Condition of the Equipment	4
1.6	Information about the Feed Stock	4
2	Tools for Troubleshooting	7
2.1	Temperature Measurement Devices	7
2.2	Data Acquisition Systems	7
2.2.1	Portable Data Collectors/Machine Analyzers	8
2.2.2	Fixed-Station Data Acquisition Systems	9
2.3	Light Microscopy	11
2.4	Thermochromic Materials	12
2.5	Thermal Analysis	13
2.5.1	Differential Thermal Analysis and Differential Scanning Calorimetry	13
2.5.2	Thermogravimetric Analysis	15
2.5.3	Fourier Transform Infrared Spectroscopy	16
2.5.4	Thermomechanical Analysis	17
2.5.5	Torque Rheometer	17
2.5.6	Other Thermal Characterization Techniques	18
2.6	Miscellaneous Tools	19
3	Systematic Troubleshooting	21
3.1	Upsets versus Development Problems	21
3.2	Machine-Related Problems	21
3.2.1	The Drive System	21
3.2.2	The Feed System	23
3.2.3	The Heating and Cooling System	23
3.2.4	Wear Problems	24
3.2.4.1	Wear Mechanisms	25
3.2.4.2	Test Methods for Wear	26
3.2.4.3	Causes of Wear	30
3.2.4.4	Solutions to Wear Problems	36
3.2.4.5	Rebuilding Worn Screws and Barrels	41
3.2.5	Screw Binding	45
3.2.5.1	Introduction	45
3.2.5.2	The Mechanics of Screw Binding	45
3.2.5.3	Changes in Clearance Due to Temperature Differences	46

3.2.5.4	Analysis of Temperature Distribution in Extruder Screws	48
3.2.5.5	Change in Clearance Due to Compressive Load	49
3.2.5.6	Results from Analysis	49
3.3	Polymer Degradation	50
3.3.1	Types of Degradation	50
3.3.1.1	Thermal Degradation	51
3.3.1.2	Mechanical Degradation	51
3.3.1.3	Chemical Degradation	52
3.3.2	Degradation in Extrusion	54
3.3.2.1	Residence Time Distribution	54
3.3.2.2	Temperature Distribution Simple Calculations	58
3.3.2.3	Temperature Distribution Numerical Calculations	62
3.3.2.4	Reducing Degradation	70
3.4	Extrusion Instabilities	71
3.4.1	Frequency of Instability	71
3.4.1.1	High-Frequency Instabilities	72
3.4.1.2	Screw Frequency Instabilities	75
3.4.1.3	Low-Frequency Instabilities	76
3.4.1.4	Very Slow Fluctuations	77
3.4.1.5	Random Fluctuations	77
3.4.2	Functional Instabilities	79
3.4.2.1	Solids-Conveying Instabilities	79
3.4.2.2	Plasticating Instabilities	79
3.4.2.3	Melt-Conveying Instabilities	80
3.4.2.4	Devolatilization Instabilities	81
3.4.2.5	Mixing Related Instabilities	81
3.4.2.6	Distributive Mixing Sections	81
3.4.2.7	Dispersive Mixing Sections	86
3.4.2.8	Solving Mixing Problems	92
3.4.3	Solving Extrusion Instabilities	93
3.5	Air Entrapment	95
3.6	Gel Problems	96
3.6.1	Measuring Gels	97
3.6.2	Gels Created in the Extrusion Process	98
3.6.3	Removing Gels Produced in Polymerization	99
3.7	Die-Flow Problems	100
3.7.1	Melt Fracture	100
3.7.2	Die-Lip Buildup (“Die Drool”).	102
3.7.3	V- or W-Patterns	103
3.7.4	Specks and Discoloration	103
3.7.5	Lines in Extruded Product	104
3.7.5.1	Weld Lines	104
3.7.6	Optical and Appearance Properties	105
4	Case Studies	107
4.1	Film Coextrusion—Degradation in the Middle Layer	107
4.1.1	Description of the Problem	107

4.1.2	Analysis of the Problem	107
4.1.3	Solution	108
4.2	Film Coextrusion with Interfacial Problems	110
4.2.1	Description of the Problem	110
4.2.2	Analysis of the Problem	110
4.2.3	Solution	111
4.3	Lines in the Extruded Film	111
4.3.1	Description of the Problem	111
4.3.2	Analysis of the Problem	112
4.3.3	Solution	112
4.4	Color Variation in Polypropylene Carpet Fiber	113
4.4.1	Description of the Problem	113
4.4.2	Analysis of the Problem	114
4.4.3	Solution	114
4.5	Plastic Film with Poor Transparency	116
4.5.1	Description of the Problem	116
4.5.2	Analysis of the Problem	116
4.5.3	Solution	118
4.6	Wear Problem in Film Extrusion	118
4.6.1	Description of the Problem	118
4.6.2	Solution	119
4.7	Multilayer Film—Several Appearance Problems	119
4.7.1	Problem Description	119
4.7.2	Analysis of the Problem	120
4.7.3	Solution	120
4.8	Dispersion Problem in a High-Density Polyethylene Bottle	121
4.8.1	Description of the Problem	121
4.8.2	Analysis of the Problem	122
4.8.3	Solution	122
4.9	Polymer Degradation	124
4.9.1	Description of the Problem	124
4.9.2	Analysis of the Problem	124
4.9.3	Solution	126
4.10	Heat-Sealing Problems in a Coextruded Film	128
4.10.1	Problem Description	128
4.10.2	Analysis of the Problem	128
4.10.3	Solution	129
4.11	Output Problem in a Blown Film Line	130
4.11.1	Description of the Problem	130
4.11.2	Analysis of the Problem	131
4.11.3	Solution	132
4.12	Master Batch Selection	133
4.12.1	Description of the Problem	133
4.12.2	Analysis of the Problem	134
4.12.3	Solution	135
4.13	Pipe Extrusion Problem	136
4.13.1	Description of the Problem	136
4.13.2	Analysis of the Problem	136
4.13.3	Solution	136

References 139

Appendices 143

Appendix 1 Systematic Problem Solving 143

Appendix 2 Machine Troubleshooting and Maintenance 145

 2.1 Check the Oil 145

 2.2 Unusual Noises 146

 2.3 Vibration Monitoring 146

 2.4 Drive Motors and Belts 147

 2.5 Spare Parts 148

 2.6 Screw and Barrel 148

 2.7 Extruder Maintenance Checklist 148

Appendix 3 Setting Extruder Temperatures 153

Index 155