

Contents

Acknowledgements	V
Introduction	1
1 Materials for Blown Film	5
1.1 Polymers	5
1.1.1 Polyethylene (PE)	6
1.1.2 Low Density Polyethylene (LDPE)	6
1.1.3 High Density Polyethylene (HDPE)	8
1.1.4 Linear Low Density Polyethylene (LLDPE)	9
1.1.5 Metallocene Polyethylene (mPE)	10
1.1.6 Polypropylene (PP)	10
1.1.7 Polystyrene (PS)	11
1.1.8 Ethylene Vinyl Acetate (EVA)	12
1.1.9 Ethylene Vinyl Alcohol (EVOH)	13
1.1.10 Polyvinyl Chloride (PVC)	13
1.1.11 Polyvinylidene Chloride (PVDC)	14
1.1.12 Polyamide (PA)	14
1.1.13 Polyurethane (PU)	15
1.2 Additives	15
1.2.1 Antiblocking Agents	16
1.2.2 Antioxidants	16
1.2.3 Antistatic Agents	16
1.2.4 Colorants	17
1.2.5 Lubricants	18
1.2.6 Reinforcements and Fillers	18
1.2.7 Stabilizers	20
1.2.8 Tackifiers	20
2 Extrusion Overview	23
2.1 Extruder Hardware Systems	23
2.1.1 Drive System	25
2.1.1.1 Motor	25

2.1.1.2	Speed Reducer	25
2.1.1.3	Thrust Bearing.....	26
2.1.2	Feed System	28
2.1.3	Screw/Barrel System	30
2.1.3.1	Screw	30
2.1.3.2	Barrel	32
2.1.4	Head/Die System	33
2.1.4.1	Head Assembly.....	34
2.1.4.2	Adapter	34
2.1.4.3	Breaker Plate.....	34
2.1.4.4	Melt Filter	35
2.1.4.5	Die.....	37
2.1.5	Instrumentation and Control System	38
2.1.5.1	Temperature Control	39
2.1.5.2	Head Pressure.....	42
2.1.5.3	Motor Current	43
2.2	Extrusion Functional Zones	44
2.2.1	Solids Conveying	45
2.2.1.1	Gravity-Induced Region	45
2.2.1.2	Drag-Induced Region.....	46
2.2.2	Melting	47
2.2.3	Melt Pumping	49
2.2.4	Mixing.....	51
2.2.4.1	Distributive Mixing.....	52
2.2.4.2	Dispersive Mixing	52
2.2.4.3	Mixing Devices	53
2.2.5	Degassing	55
2.2.6	Die Forming.....	56
3	Hardware for Blown Film.....	61
3.1	Upstream Components.....	62
3.2	Grooved Feed Throat	64
3.3	Screws for Blown Film Extrusion.....	66
3.4	Blown Film Dies	67
3.5	Bubble Geometry	72
3.6	Bubble Cooling.....	75
3.7	Bubble Stabilization.....	80
3.8	Collapsing Frames	80
3.9	Haul-off.....	81

3.10	Winders	83
3.11	Film Treatment	84
3.12	Line Control	85
4	Processing	91
4.1	Process Variables vs. Bubble Geometry	92
4.2	Characteristic Bubble Ratios	94
4.3	Process/Structure/Property Relationships	97
4.4	Double Bubble Processing	99
5	Coextrusion	101
5.1	Dies	102
5.2	Interfacial Instabilities	104
5.3	Product Applications	105
5.3.1	Breathable Packaging	105
5.3.2	Shrink Film	106
5.3.3	High Barrier Film	107
6	Film Properties	109
6.1	Tensile Strength (ASTM D882)	111
6.2	Elongation (ASTM D882)	113
6.3	Tear Strength (ASTM D1004, ASTM D1922, and D1938)	113
6.4	Impact Resistance (ASTM D1709, D3420, and D4272)	115
6.5	Blocking Load (ASTM D3354) and Coefficient of Friction (ASTM D1894)	116
6.6	Gel (Fisheye) Count (ASTM D3351 and D3596)	117
6.7	Low Temperature Brittleness (ASTM D1790)	117
6.8	Gloss (ASTM D2457)	118
6.9	Transparency (ASTM D1746)	118
6.10	Haze (ASTM D1003)	119
6.11	Density (ASTM D1505)	119
6.12	Melt Index (ASTM D1238)	120
6.13	Viscosity by Capillary Rheometry (ASTM D3835)	122
7	Troubleshooting	125
7.1	Extruder Problems	126
7.1.1	Surging	126
7.1.2	High Melt Temperature	127
7.1.3	Excessive Cooling	129

7.1.4	Low Output	130
7.2	Film Problems.....	131
7.2.1	Melt Fracture.....	131
7.2.2	Thickness Variation.....	132
7.2.3	Die Lines.....	136
7.2.4	Gels	137
7.2.5	Low Mechanical Properties	138
7.2.6	Poor Optical Properties	139
7.2.7	Wrinkles	140
Appendix A: The Blown Film Extrusion Simulator.....		141
A.1	Introduction	141
A.2	Installation	142
A.3	Running the Program	143
A.4	Worksheet	150
Appendix B: Useful Equations		153
References		161
Subject Index		165