
Rubber Processing

An Introduction

Peter S. Johnson



HANSER

Contents

1	Overview of Rubber Processing	1
1.1	Introduction	1
1.2	Testing	2
1.2.1	Raw Materials Quality Assurance	2
1.2.2	Processability Testing of Mixed Compounds	2
1.2.3	End Product Testing	3
1.3	Conclusion	3
	References.....	4
2	Raw Materials Acceptance and Specifications	5
2.1	Introduction	5
2.2	Raw Materials Specifications	5
2.2.1	Elastomers	6
2.2.2	Fillers	7
3	Mixing of Rubber Compounds.....	9
3.1	Introduction	9
3.2	Material Flow to the Mixer	10
3.2.1	Receipt and Storage of Raw Materials.....	11
3.2.2	Feeding, Weighing, and Charging Raw Materials.....	12
3.2.2.1	Weighing Major Ingredients.....	14
3.2.2.2	Small Component Weighing.....	14
3.3	The Mixing Process	15
3.3.1	Incorporation	16
3.3.2	Dispersion.....	17
3.3.3	Distribution.....	19
3.3.4	Plasticization	20
3.3.5	Natural Rubber Mastication	20
3.3.6	Flow Visualization and Modeling of the Mixing Process	20
3.3.6.1	Flow Visualization	21
3.3.6.2	Modeling	21
3.3.7	Flow Behavior on Mills	24
3.4	Internal Mixers	26
3.4.1	Developments in Internal Mixers	29
3.4.1.1	Farrel Mixers.....	29
3.4.1.2	Kobelco Stewart Bolling Mixers.....	30
3.4.1.3	Krupp-Midwest Werner und Pfleiderer Mixers	31
3.4.1.4	Pomini Mixers	31

3.4.2	Choosing a Mixer.....	32
3.4.3	Inspection and Preventative Maintenance of Mixers	32
3.4.4	Internal Mixer Operation	33
3.4.4.1	Mixing Procedures	33
3.4.4.2	Temperature Control in Internal Mixers.....	37
3.4.4.3	Rotor Speed	37
3.4.4.4	Ram Pressure	38
3.4.4.5	Batch Size	38
3.4.4.6	Dump Criteria	40
3.4.5	Control of the Mixing Process	41
3.4.6	Scale-Up.....	41
3.5	Take-Off Systems	43
3.5.1	Dump Mills.....	43
3.5.2	Packaging	44
3.5.3	Single Pass Mixing	45
3.6	Other Mixing Equipment.....	45
3.6.1	Mill Mixing	45
3.6.2	Continuous Mixing	47
3.7	Custom Compounding	47
3.8	Troubleshooting the Mixing Process	48
3.8.1	Inadequate Dispersion or Distribution.....	49
3.8.2	Scorchy Compound.....	49
3.8.3	Contamination.....	49
3.8.4	Poor Handling on Dump Mill.....	49
3.8.5	Batch-to-Batch Variation.....	49
3.9	Concluding Comments.....	50
	References	50
4	Flow Behavior of Compounds.....	53
4.1	Introduction.....	53
4.2	Fundamentals of Rheology.....	53
4.3	Effect of Compounding Ingredients on Processing Behavior	58
4.3.1	Elastomers.....	58
4.3.2	Fillers	59
4.3.2.1	Carbon Blacks.....	59
4.3.3	Plasticizers and Processing Aids	60
4.3.3.1	Plasticizers	61
4.3.3.2	Processing Aids	62
4.3.4	Elasticity	63
4.3.5	Conclusion	64
	References	64
5	Testing of Compounds After Mixing	65
5.1	Introduction.....	65
5.2	Processability Test Instruments.....	68
5.2.1	The Mooney Viscometer.....	68
5.2.1.1	Delta Mooney	69
5.2.1.2	TMS Rheometer.....	70

5.2.2	Capillary Rheometers	80
5.2.3	Oscillating Disk Curemeters	73
5.2.4	Rotorless Curemeters	75
5.2.5	Dynamic Mechanical Rheological Testers	75
5.2.6	Stress Relaxation Instruments	75
5.2.7	ODR Cure Times Correlation with MDR	77
5.3	Comparison of Alpha Technologies Processability Test Instruments	78
5.4	Conclusion	80
	References	80
6	The Curing Process	83
6.1	Introduction	84
6.2	Scorch or Premature Vulcanization	84
	References	85
7	Calendering of Rubber	87
7.1	Introduction	87
7.2	Equipment	87
7.3	Processes	88
7.3.1	Feeding	88
7.3.2	Sheeting	88
7.3.3	Frictioning	88
7.3.4	Coating	89
7.3.5	Roller Dies	89
7.3.6	Downstream Processes	90
7.4	Modeling the Calendering Process	90
7.5	Troubleshooting Problems in Calendering	91
7.5.1	Scorch	91
7.5.2	Blistering	91
7.5.3	Rough or Holed Sheet	91
7.5.4	Tack	91
7.5.5	Bloom	91
7.6	Conclusions	91
	References	92
8	Extrusion of Rubber	93
8.1	Introduction	93
8.2	Feeding	93
8.2.1	Cold-Feed versus Hot-Feed Extruders	94
8.3	Mass Transfer, Conveying, or Pumping	96
8.3.1	Flow Mechanism	97
8.3.2	Extruder Designs	98
8.3.2.1	The Maillefer Screw	99
8.3.2.2	The Iddon Screw	100
8.3.2.3	The Transfermix	101

8.3.2.4	The EVK Screw	101
8.3.2.5	The Pin Barrel Extruder	101
8.3.2.6	The Cavity Transfer Mixer	102
8.3.2.7	Vented Extruders	104
8.3.2.8	Dump Extruders	104
8.3.2.9	Strainers	105
8.3.2.10	Extruder Barrels	105
8.4	Extruder Operation and Control	105
8.5	Shaping	108
8.5.1	Extruder Heads	108
8.5.1.1	Coextrusion	109
8.5.1.2	Crossheading	109
8.5.1.3	Shear Heads	109
8.5.2	Dies	111
8.5.2.1	Pressure Drop	111
8.5.2.2	Die Swell	111
8.6	Take-Off and Curing	112
8.6.1	Continuous Vulcanization Systems	113
8.6.1.1	Pressurized Steam Systems	113
8.6.1.2	Hot Air Curing Systems	113
8.6.1.3	Hot Air Fluidized Bed Systems	114
8.6.1.4	Liquid Salt Bath Systems	114
8.6.1.5	Microwave Systems	114
8.6.1.6	Shear Head Systems	115
8.6.1.7	Electron Beam Systems	115
8.6.1.8	Steel Belt Presses	116
8.6.1.9	Ultrasonic Vulcanization	116
8.7	Troubleshooting the Extrusion Process	116
8.7.1	Low Output Rate	116
8.7.2	Poor Dimensional Stability of Extrudate	117
8.7.3	Excessive Heat Buildup in Compound	117
8.7.4	Rough Surface on Extrudate	117
8.7.5	Contamination	117
8.7.6	Porosity in Extrudate	117
8.7.7	Strip Difficult to Feed	117
8.7.8	Surging Output	118
8.8	Concluding Comments	118
	References	118
9	Molding of Rubber	119
9.1	Introduction	119
9.2	Compression and Transfer Molding	120
9.3	Injection Molding of Rubber	122
9.3.1	Injection Molding Equipment	125
9.3.1.1	Delivery Systems	125
9.3.1.2	Nozzles, Runners, and Gates	127
9.3.1.3	Molds	128
9.3.1.4	Automatic Ejection	129
9.3.1.5	Deflashing	129

9.3.2 The Injection Molding Process	130
9.3.2.1 Injection Temperature	130
9.3.2.2 Screw Speed	131
9.3.2.3 Back Pressure	131
9.3.2.4 Injection Pressure	131
9.3.2.5 Summary	131
9.3.3 Monitoring and Modeling the Injection Molding Process	131
9.3.4 Control of the Injection Molding Process	132
9.3.5 Compounds for Injection Molding	133
9.3.6 Problems in Injection Molding of Rubber	133
References	136
10 Finished Product Testing	137
10.1 Introduction	137
10.2 Test of Filler Distribution and Dispersion	138
10.2.1 Microscopy	138
10.2.2 Surface Roughness	138
10.3 Tests on Cured Specimens	138
10.3.1 Tensile Tests	139
10.3.2 Hardness	139
10.3.3 Compression Set	139
10.3.4 Solvent Resistance	140
10.3.5 Aging	140
10.3.6 Ozone Cracking	140
References	140
Index	143