

Contents

1	Introduction	1
1.1	Examples of Integral Processes with Dead Time	1
1.1.1	Tanks with an Outlet	1
1.1.2	Supply Chain Management Processes	3
1.1.3	Communication Networks	3
1.1.4	Other Examples	4
1.2	Overview of the Book	5
Part I PID Control Schemes		
2	PID Control	9
2.1	PID Controllers	9
2.1.1	Basic Principles	9
2.1.2	Improvements	11
2.2	Identification	13
2.2.1	Open-loop Identification	13
2.2.2	Closed-loop Identification	16
2.3	Tuning Methods	24
2.3.1	Empirical Formulae	25
2.3.2	Analytical Methods	26
2.3.3	Frequency-domain Methods	34
2.3.4	Optimisation-based Methods	41
2.4	Conclusions	47
3	Stability Region	49
3.1	Stability Region Under the PI Control	49
3.1.1	Normalisation of the System	49
3.1.2	Stability Region	50
3.1.3	Achievable Stability Margins	52
3.1.4	An Illustrative Example	55
3.2	Stability Region Under the PID Control	56
3.2.1	IPDT Processes	56

3.2.2	SOIPDT Processes	64
3.3	Conclusions	70
4	Performance Assessment and Controller Retuning	71
4.1	Introduction	71
4.2	Problem Formulation	72
4.3	Performance Assessment	73
4.4	Estimation of the Process Parameters	77
4.4.1	Set-point Step Response	77
4.4.2	Load Disturbance Step Response	79
4.5	Retuning of the PID Controller	81
4.6	Simulation Results	81
4.6.1	Example 1	82
4.6.2	Example 2	83
4.6.3	Example 3	84
4.7	Conclusions	86
5	Plug&Control	87
5.1	Methodology	87
5.2	Algorithm	88
5.3	Practical Considerations	89
5.4	Simulation Results	90
5.5	Conclusions	92
 Part II Two-degree-of-freedom Control Schemes		
6	Feedforward Control	95
6.1	Standard Two-degree-of-freedom Control Scheme	95
6.2	Two-state Time-optimal Feedforward Control	96
6.2.1	Methodology	96
6.2.2	Illustrative Examples	98
6.3	Noncausal Feedforward Action: Continuous-time Case	99
6.3.1	Generalities	100
6.3.2	Modelling	100
6.3.3	PID Controller Design	101
6.3.4	Output Function Design	101
6.3.5	Stable Input–Output Inversion Algorithm	102
6.3.6	Discussions	106
6.3.7	Practical Implementation	107
6.3.8	Simulation Results	108
6.4	Noncausal Feedforward Action: Discrete-time Case	111
6.4.1	Methodology	112
6.4.2	An Illustrative Example	118
6.5	Conclusions	119

- 7 PID–PD Control 121**
 - 7.1 The Control Scheme 121
 - 7.2 PI–PD Structure 121
 - 7.2.1 A Simple Approach 122
 - 7.2.2 Tuning Method Based on the Standard Forms 124
 - 7.3 PID–P Structure 125
 - 7.3.1 Tuning Method Based on Sensitivity Specifications 126
 - 7.3.2 Tuning Method Based on Phase and Gain Margins 130
 - 7.3.3 Tuning Method Based on a New Robustness Specification 132
 - 7.4 PID–PD Structure 135
 - 7.4.1 Tuning Method Based on a New Robustness Specification 136
 - 7.4.2 A More Complex Controller 138
 - 7.5 Conclusions 140

- 8 Smith-predictor-based Control 141**
 - 8.1 Classical Smith Predictor 141
 - 8.2 Modified Smith Predictor 143
 - 8.3 Aström–Hang–Lim Modified Smith Predictor 146
 - 8.3.1 Methodology 147
 - 8.3.2 Robust Tuning Method 148
 - 8.3.3 Simplified Tuning Method 152
 - 8.3.4 Anti-windup Compensation 155
 - 8.4 Matausek–Micic Modified Smith Predictor 156
 - 8.4.1 Basic Scheme 157
 - 8.4.2 Improvement 159
 - 8.5 Normey-Rico–Camacho Modified Smith Predictor 161
 - 8.5.1 Control Scheme 162
 - 8.5.2 Robust Tuning 163
 - 8.5.3 Improvement 164
 - 8.5.4 An Alternative Approach 166
 - 8.5.5 Anti-windup Strategy 168
 - 8.5.6 Comparison with Other Schemes 168
 - 8.6 Chien–Peng–Liu Modified Smith Predictor 170
 - 8.7 Seshagiri Rao–Rao–Chidambaram Modified Smith Predictor 173
 - 8.8 Tian–Gao Modified Smith Predictor 175
 - 8.9 More Complex Schemes 176
 - 8.9.1 Majhi–Atherton Modified Smith Predictor 177
 - 8.9.2 Liu–Cai–Gu–Zhang Modified Smith Predictor 180
 - 8.9.3 Lu–Yang–Wang–Zheng Modified Smith Predictor 183
 - 8.10 Conclusions 184

- 9 Smith-principle-based PID-type Control 187**
 - 9.1 The Control Scheme 187
 - 9.2 An Equivalent Structure for Implementation 189
 - 9.3 Robustness Analysis 190

9.4	Simulation Examples	193
9.5	Conclusions	193
10	Disturbance Observer-based Control	195
10.1	Disturbance Observer	195
10.2	Control Structure	196
10.3	Controller Design to Reject Ramp/Step Disturbances	197
10.3.1	Design of $Q(s)$	197
10.3.2	Examples	199
10.4	Controller Design to Obtain Deadbeat Disturbance Responses	203
10.4.1	Design of $Q(s)$	203
10.4.2	Implementation of the Controller	205
10.4.3	Parameter Tuning and Robustness	207
10.4.4	Stability of the Controller	210
10.4.5	An Example	212
10.5	Conclusions	212
11	Quantitative Analysis	213
11.1	Introduction	213
11.2	The <i>Lambert W</i> Function	214
11.3	Achievable Specifications of the Sub-ideal Disturbance Response	214
11.3.1	Maximal Dynamic Error	217
11.3.2	Maximal Decay Rate	218
11.3.3	Control Action Bound	219
11.3.4	Approximate Recovery Time	220
11.4	Robust Stability Regions	221
11.4.1	With Gain Uncertainties	222
11.4.2	With Dead-time Uncertainties	223
11.4.3	With Dead-time and Gain Uncertainties	225
11.5	Stability of the Controller	226
11.6	Conclusions	228
12	Practical Issues	229
12.1	The Control Scheme Under Consideration	229
12.2	Zero Static Error	230
12.3	Internal Stability	231
12.4	Experimental Results	232
12.4.1	The Experimental Setup	232
12.4.2	The Scheme Shown in Figure 12.2(a)	234
12.4.3	The Scheme Shown in Figure 12.2(b)	234
12.4.4	The Scheme Shown in Figure 12.3	235
12.4.5	Comparison with a PI Controller	239
12.4.6	Robustness with Respect to Changes in the Dead Time	239
12.5	Conclusions	239
	References	241
	Index	249



<http://www.springer.com/978-0-85729-069-4>

Control of Integral Processes with Dead Time

Visioli, A.; Zhong, Q.

2011, XXV, 250 p., Hardcover

ISBN: 978-0-85729-069-4