Contents

L	intro	roduction		
	1.1	Crane	Types	
		1.1.1	Overhead Cranes	
		1.1.2	Boom Cranes	
		1.1.3	Tower Cranes	
	1.2	Review	w of Sliding Mode Control	
		1.2.1	Variable Structure Control	
		1.2.2	Sliding Mode Control	
		1.2.3	Equivalent-Control-Based Sliding Mode Control 11	
		1.2.4	Chattering Reduction	
		1.2.5	Sliding Mode Control Design for State Space Model 15	
		1.2.6	Robustness Against Uncertainties	
		1.2.7	Sliding Order and Sliding Sets	
	1.3	A Rev	riew of Crane Control	
		1.3.1	Open-Loop Control 23	
		1.3.2	Closed-Loop Control	
	1.4	Challe	nges of Sliding Mode-Based Crane Control	
		1.4.1	Theoretical Challenges	
		1.4.2	Practical Challenges	
	App	endices		
			tlab Codes to Plot Fig. 1.5a	
		B Mat	clab Codes to Plot Fig. 1.5b	
		C Mat	dab Codes to Plot Fig. 1.7	
		D Sim	rulink Model to Plot Figs. 1.8 and 1.9	
		E Sim	ulink Model to Plot Figs. 1.10 and 1.11	
		F Mat	lab Codes to Plot Fig. 1.12	
		G Sim	aulink Model to Plot Figs. 1.13 and 1.14	
		H Sim	nulink Model to Plot Figs. 1.15 and 1.16	
		I Simu	alink Model to Plot Figs. 1.17, 1.18, 1.19 and 1.20 41	
	Refe	rences		

xii Contents

2	Cra	ne Mat	hematic Model	51
	2.1	Model		51
		2.1.1		5 1
		2.1.2	Model with Uncertainties	55
		2.1.3		56
		2.1.4	5	57
		2.1.5		53
		2.1.6		53
	App	endices		55
				55
		B Mat	C	56
	Refe	rences		56
3	Ove	rhead (Crane Control by Sliding Mode Methods	57
	3.1			67
	3.2	First-C	Order Sliding Mode Control	68
		3.2.1	Control Design of Single-Pendulum-Type	
			Overhead Cranes	68
		3.2.2	Stability Analysis of the Single-Pendulum-Type Crane	
			Control System	69
		3.2.3	Simulations of Nominal Single-Pendulum-Type	
				7]
		3.2.4	Simulations of Uncertain Single-Pendulum-Type	
			Overhead Cranes	73
		3.2.5	Extensions of Double-Pendulum-Type	
			- · · · · · · · · · · · · · · · · · · ·	74
	3.3	Integr		79
		3.3.1	2	79
		3.3.2		80
		3.3.3	Simulations of Single-Pendulum-Type Cranes	
				82
		3.3.4	Simulations of Uncertain Single-Pendulum-Type	
			J	84
	3.4		C	86
		3.4.1	0	86
		3.4.2		88
		3.4.3		9(
		3.4.4	Simulations of Uncertain Single-Pendulum-Type Cranes	
			3 -	9
	3.5		ϵ	93
		3.5.1	5	9:
		352	Stability Analysis	Q_2

Contents xiii

		3.5.3	Simulations of Single-Pendulum-Type Cranes	
			by Second-Order SMC	96
		3.5.4	Simulations of Uncertain Cranes	
			by Second-Order SMC	98
	App			100
			nulink Model to Plot Figs. 3.1 and 3.2	100
			nulink Model to Plot Figs. 3.5 and 3.6	103
			nulink Model to Plot Figs. 3.7 and 3.8	107
			nulink Model to Plot Figs. 3.11 and 3.12	109
		E Sim	nulink Model to Plot Figs. 3.15 and 3.16	112
	Refe	rences		115
4	Ove	rhead (Crane Control by Hierarchical Sliding Mode	117
	4.1	Proble	em Description	117
	4.2		gated HSMC	118
		4.2.1	Control Design	119
		4.2.2	Stability Analysis	121
		4.2.3	Simulation Results	124
	4.3	Incren	nental HSMC	127
		4.3.1	Control Design	128
		4.3.2	Stability Analysis	130
		4.3.3	Simulation Results	132
	4.4	Comb	nining HSMC	135
		4.4.1	Control Design	136
		4.4.2	Stability Analysis	137
		4.4.3	Simulation Results	140
	4.5	Adapt	tive Control Design Based on Hierarchical	
		Slidin	g Surfaces	144
		4.5.1	Control Design	145
		4.5.2	Stability Analysis	146
		4.5.3	Simulation Results	147
	4.6	HSM	C Design for Double-Pendulum-Type Overhead Cranes	150
		4.6.1	Control Design	150
		4.6.2	Stability Analysis	153
		4.6.3	Simulation Results	153
	App		8	156
			nulink Model to Plot Figs. 4.2, 4.3 and 4.4	156
			nulink Model to Plot Figs. 4.6, 4.7, 4.8 and 4.9	157
			nulink Model to Plot Figs. 4.11, 4.12, 4.13, 4.14	
			.15	159
			nulink Model to Plot Figs. 4.16, 4.17, 4.18 and 4.19	161
			nulink Model to Plot Figs. 4.21 and 4.22	164
	Dof	rancec		165

xiv Contents

5	Compensator Design Based on Sliding Mode for Uncertain							
		head Cranes						
	5.1	Problem Description						
	5.2	Compensator Design Based on HSMC						
		5.2.1 Control Design						
		5.2.2 Stability Analysis						
		5.2.3 Simulation Results						
	5.3	Sliding Mode-Based Fuzzy Compensator Design 17						
		5.3.1 Control Design						
		5.3.2 Stability Analysis						
		5.3.3 Simulation Results						
	5.4	Sliding Mode-Based Neural Compensator Design 17						
		5.4.1 Control Design						
		5.4.2 Stability Analysis						
		5.4.3 Simulation Results						
	Appendices							
		A Simulink Model to Plot Figs. 5.1 and 5.2						
		B Simulink Model to Plot Figs. 5.4, 5.5 and 5.6 18						
		C Simulink Model to Plot Figs. 5.8, 5.9 and 5.10 19						
	Refe	ences						
6	Conclusions and Open Problems							
	6.1	Conclusions						
	6.2	Extensions and Open Problems						
	Refe	ences 10						