

Contents

1	Introduction	1
1.1	Background	1
1.2	The need for after-treatment systems	6
1.3	Scope of the work	10
1.4	Objectives	11
1.4.1	Methodology	12
1.A	Publications	14
	References	14
2	Emission control system in Diesel engines	21
2.1	Introduction	21
2.2	Diesel engine subsystems	22
2.2.1	The fuel path system	22
2.2.2	The air path system	23
2.2.3	Control of fuel and air paths	24
2.3	After-treatment systems	24
2.3.1	Diesel oxidation catalysts	24
2.3.2	Diesel particulate filter	28
2.3.3	Lean NO _x trap	29
2.3.4	Selective catalytic reduction system	30
2.3.5	Ammonia oxidation catalyst	34
2.3.6	On-board sensors for control and diagnostics	34

2.3.6.1	NTC sensor	35
2.3.6.2	λ sensor	36
2.3.6.3	NO_x sensor	36
2.3.6.4	NH_3 sensor	37
2.3.6.5	Differential pressure sensor	38
2.3.6.6	Other sensors	38
2.3.7	Diesel exhaust layouts	39
2.4	Conclusions	42
	References	42
3	System setup and measurement systems	55
3.1	Introduction	55
3.2	Experimental setups	56
3.2.1	Setup A	56
3.2.1.1	DOCs with different failure modes	58
3.2.1.2	Engine bench control system layout	60
3.2.1.3	Measurements acquisition and characterization	61
3.2.2	Setup B	66
3.2.3	Setup C.1	67
3.2.4	Setup C.2	69
3.3	Engine tests	70
3.3.1	Steady-state tests	70
3.3.2	Dynamic tests	72
3.3.3	Dedicated tests	74
3.4	Conclusions	76
	References	76
4	Experimental characterization of sensors and catalysts	77
4.1	Introduction	78
4.2	Measurements characteristics	78
4.2.1	DOC inlet temperature measurement	78

4.2.2	Delay between up-and downstream measurements	81
4.3	Experimental DOC behaviour and ageing	82
4.3.1	Oxidation capacity	82
4.3.2	DOC oxidation measurement with λ sensors	82
4.3.3	Light-off temperature	87
4.3.4	HC and NO accumulation	88
4.3.5	Species slip	92
4.3.6	DOCs operation in regulation tests	93
4.4	Selective catalytic reduction systems	99
4.4.1	NO_x and NH_3 slip dynamics	99
4.4.2	Ageing effect on NO_x and NH_3 slip	102
4.5	Conclusions	103
	References	103
5	Thermal modelling and temperature observation	107
5.1	Introduction	107
5.2	Fast DOC upstream temperature estimation	108
5.2.1	DOC upstream temperature modelling	109
5.2.1.1	Fast DOC upstream temperature model, T_{mod}	109
5.2.1.2	T_{TC} from T_{mod}	110
5.2.1.3	T_{NTC} from T_{TC}	113
5.2.2	Fast temperature estimation	114
5.2.2.1	Observer design	114
5.2.2.2	Algorithm tuning	116
5.2.3	Algorithm validation	118
5.3	Control-oriented 1D model	120
5.3.1	Model performance with different upstream temperatures as model inputs	123
5.4	Control-oriented 0D lumped model	126
5.5	Temperature model of oxidized post-injection pulses	130
5.6	Conclusions	135
	References	135

6 Control-oriented modelling of diesel catalysts ageing	137
6.1 Introduction	137
6.2 Diesel oxidation catalyst	138
6.2.1 Modelling approach	139
6.2.2 Control-oriented model	140
6.2.2.1 HC and CO oxidation model	142
6.2.2.2 HC slip model	143
6.2.2.3 CO slip model	145
6.2.2.4 Model calibration and application	145
6.2.2.5 Ageing modelling	147
6.3 Selective catalytic reduction system	150
6.3.1 1D SCR model	152
6.3.1.1 1D SCR model application	154
6.3.2 0D SCR model	156
6.3.2.1 0D SCR model application	158
6.4 Conclusions	160
References	160
7 Diesel after-treatment catalysts diagnostics	163
7.1 Introduction	163
7.2 Diesel oxidation catalyst diagnostics	164
7.2.1 Ageing effect on species slip	164
7.2.1.1 Critical default size and OBD requirements . .	166
7.2.2 Removal detection	168
7.2.2.1 Diagnostics conditions	170
7.2.2.2 Low and high diagnosis thresholds	171
7.2.2.3 Passive diagnostics	172
7.2.2.4 Active diagnostics	173
7.2.3 DOC efficiency estimation	174
7.2.3.1 Detection concept feasibility	176

7.2.3.2	Strategy measurements characterization	179
7.2.3.3	On-board LOT estimation	180
7.3	Selective catalytic reduction system diagnostics	185
7.3.1	SCR ageing state estimation: strategy approach	186
7.3.2	Observer for SCR ageing	189
7.3.2.1	Observer development	189
7.3.2.2	System observability	191
7.3.2.3	Observer calibration	194
7.3.2.4	Simulation results	196
7.3.2.5	Experimental validation	198
7.3.3	Urea quality indicator	200
7.3.3.1	Simulation results	202
7.4	Conclusions	204
7.A	Observability matrix	205
	References	207
8	Conclusions and future work	209
8.1	Main contributions and conclusions	209
8.1.1	Experimental characterization of diesel catalysts	210
8.1.2	Thermal models and temperatures estimation	212
8.1.3	Models for diesel catalysts	213
8.1.3.1	DOC control-oriented model including ageing .	214
8.1.3.2	SCR control-oriented models including ageing	214
8.1.4	Diesel catalysts diagnostics	214
8.1.4.1	DOC diagnosis	215
8.1.4.2	SCR diagnosis	216
8.2	Future work	216
8.2.1	Catalysts diagnostics	218
	References	220
References		221