

Contents

1	Introduction	1
1.1	Background	1
1.2	The need of information in diesel engines	4
1.3	Scope of the work	6
1.4	Objectives	8
1.4.1	Methodology	8
1.A	Publications	10
	References	11
2	Exhaust gas concentrations estimation in diesel engines	15
2.1	Introduction	15
2.2	Diesel engine subsystems	16
2.2.1	The fuel path system	16
2.2.2	The air path system	16
2.2.3	The after-treatment systems	22
2.2.4	The control system	23
2.2.4.1	Summary on the information required for a global diesel management	24
2.3	Dynamic exhaust gas concentration estimation	26
2.3.1	Sensors	26
2.3.1.1	Test bed sensors	27
2.3.1.2	On-board gas concentration sensors	27

2.3.2	Models and virtual sensors	33
2.3.2.1	λ models	35
2.3.2.2	NO_x models	36
2.3.2.3	Identification of sensor and physical dynamics	38
2.3.3	Adaptive filtering	39
2.3.3.1	Adaptive estimators based on KF	42
2.3.3.2	Online adaptation of models	45
	References	47
3	System setup and sensors characterisation	59
3.1	Introduction	59
3.2	Experimental set-up	60
3.2.1	Engine sensors	62
3.2.1.1	Exhaust gas concentrations sensors	62
3.2.1.2	Intake gas concentration sensors	65
3.3	Engine tests	67
3.3.1	Steady-state tests	67
3.3.2	Transient tests	69
3.3.2.1	Steps	69
3.3.2.2	Cycles	69
3.4	Gas concentration sensors characterisation	77
3.4.1	Static calibration	78
3.4.1.1	Static calibration of NO_x output	79
3.4.1.2	Static calibration of λ^{-1} output	80
3.4.2	Dynamic calibration	80
3.4.2.1	Dynamic calibration of NO_x output	81
3.4.2.2	Dynamic calibration of λ^{-1} output	88
3.4.2.3	Delay in the NO_x sensor	90
3.5	Conclusions	93
3.A	Gas concentration sensor specifications	93
3.B	Principle of NO_x measurement	94
	References	95

4 Control models for engine-out NO_x and λ^{-1}	99
4.1 Introduction	99
4.2 λ^{-1} model	100
4.3 NO _x model	102
4.3.1 Previous considerations	103
4.3.2 Real Time NO _x model	111
4.3.2.1 EGR flow model	117
4.3.3 Tuning methodology	120
4.3.4 NO _x model results	122
4.3.4.1 Steady-state results	123
4.3.4.2 Dynamic results	125
4.4 Conclusions	127
References	130
5 Adaptive observers for dynamic estimation of engine variables	133
5.1 Introduction	134
5.2 Augmented models for drift correction	136
5.2.1 Drift correction algorithm	137
5.2.2 Observer tuning	139
5.3 Learning algorithms for updating look-up tables	142
5.3.1 The extended Kalman Filter, KF	144
5.3.2 The steady-state KF approach, SSKF	146
5.3.3 The simplified Kalman filter, SKF	147
5.3.4 Simulation of the updating algorithms	151
5.3.4.1 Simulation 1: Input with random variation . .	152
5.3.4.2 Simulation 2: Input with linear variation . .	154
5.3.4.3 Simulation 3: Measurement noise rejection .	156
5.3.4.4 Conclusions from simulations	156
5.3.5 Dynamic equations for learning	159
5.4 Conclusions	162

5.A	Analytical solutions to the Riccati equations	163
5.A.1	Drift correction model	164
5.A.2	SSKF for updating look-up tables	167
5.B	Pseudo-codes for the SSKF and SKF	170
5.C	The dynamic system for the SKF method	172
	References	173
6	Adaptive estimation of NO_x and λ^{-1}	175
6.1	Introduction	175
6.2	Fast estimation of λ^{-1}	176
6.2.1	Problem set-up and methodology	176
6.2.2	Robustness against signal uncertainties	178
6.2.3	An adaptive look-up table for modeling the drift	182
6.2.4	Experimental results	183
6.3	Fast estimation of NO _x	186
6.3.1	Online updating of look-up tables for modeling NO _x	187
6.3.1.1	Comparison of the updating methods	188
6.3.1.2	Adaptive maps for predicting NO _x	193
6.3.2	Online updating of the NO _x model	196
6.3.3	Online observation of the actual NO _x	200
6.4	Conclusions	204
	References	204
7	Conclusions and future works	207
7.1	Main contributions and conclusions	207
7.1.1	Online characterisation of gas concentration sensors	208
7.1.2	Control oriented models for λ^{-1} and NO _x	209
7.1.3	Observers for fast estimation of engine variables	210
7.1.4	Application of adaptive estimators to infer λ^{-1} and NO _x in diesel engines	213
7.1.4.1	Fast observation of λ^{-1}	213

7.1.4.2 Fast observation of NO _x	214
7.2 Future works	215
References	219
References	221