Contents

1 Introduction 1
- 1.1 Notation 1
- 1.2 Control Systems for IC Engines 4
  - 1.2.1 Relevance of Engine Control Systems 4
  - 1.2.2 Electronic Engine Control Hardware and Software 5
- 1.3 Overview of SI Engine Control Problems 6
  - 1.3.1 General Remarks 6
  - 1.3.2 Main Control Loops in SI Engines 8
  - 1.3.3 Future Developments 10
- 1.4 Overview of Control Problems in CI Engines 11
  - 1.4.1 General Remarks 11
  - 1.4.2 Main Control Loops in Diesel Engines 14
  - 1.4.3 Future Developments 18
- 1.5 Structure of the Text 19

2 Mean-Value Models 21
- 2.1 Introduction 22
- 2.2 Cause and Effect Diagrams 24
  - 2.2.1 Spark-Ignited Engines 25
  - 2.2.2 Diesel Engines 28
- 2.3 Air System 30
  - 2.3.1 Receivers 30
  - 2.3.2 Valve Mass Flows 31
  - 2.3.3 Engine Mass Flows 35
  - 2.3.4 Exhaust Gas Recirculation 37
  - 2.3.5 Supercharger 40
- 2.4 Fuel System 52
  - 2.4.1 Introduction 52
  - 2.4.2 Wall-Wetting Dynamics 53
  - 2.4.3 Gas Mixing and Transport Delays 63
- 2.5 Mechanical System 64

Bibliografische Informationen
http://d-nb.info/998588873

digitalisiert durch DEUTSCHE NATIONAL BIBLIOTHEK

2.5.1 Torque Generation 64
2.5.2 Engine Speed 76
2.5.3 Rotational Vibration Dampers 81
2.6 Thermal Systems 85
2.6.1 Introduction 85
2.6.2 Engine Exhaust Gas Enthalpy 86
2.6.3 Thermal Model of the Exhaust Manifold 88
2.6.4 Simplified Thermal Model 89
2.6.5 Detailed Thermal Model 90
2.7 Pollutant Formation 98
2.7.1 Introduction 98
2.7.2 Stoichiometric Combustion 98
2.7.3 Non-Stoichiometric Combustion 100
2.7.4 Pollutant Formation in SI Engines 102
2.7.5 Pollutant Formation in Diesel Engines 108
2.7.6 Control-Oriented *NO* Model 110
2.8 Pollutant Abatement Systems 113
2.8.1 Introduction 113
2.8.2 Three-Way Catalytic Converters, Basic Principles 114
2.8.3 Modeling Three-Way Catalytic Converters 117
2.9 Pollution Abatement Systems for Diesel Engines 137

3 Discrete-Event Models 147
3.1 Introduction to DEM 148
3.1.1 When are DEM Required? 148
3.1.2 Discrete-Time Effects of the Combustion 148
3.1.3 Discrete Action of the ECU 150
3.1.4 DEM for Injection and Ignition 153
3.2 The Most Important DEM in Engine Systems 156
3.2.1 DEM of the Mean Torque Production 156
3.2.2 DEM of the Air Flow Dynamics 161
3.2.3 DEM of the Fuel-Flow Dynamics 164
3.2.4 DEM of the Back-Flow Dynamics of CNG Engines 173
3.2.5 DEM of the Residual Gas Dynamics 175
3.2.6 DEM of the Exhaust System 178
3.3 DEM Based on Cylinder Pressure Information 180
3.3.1 General Remarks 180
3.3.2 Estimation of Burned-Mass Fraction 181
3.3.3 Cylinder Charge Estimation 183
3.3.4 Torque Variations Due to Pressure Pulsations 188

4 Control of Engine Systems 191
4.1 Introduction 192
4.1.1 General Remarks 192
4.1.2 Software Structure 193
4.1.3 Engine Operating Point 196
4.1.4 Engine Calibration 197
4.2 Engine Knock 199
4.2.1 Autoignition Process 200
4.2.2 Knock Criteria 202
4.2.3 Knock Detection 204
4.2.4 Knock Controller 208
4.3 Air/Fuel-Ratio Control 210
4.3.1 Feedforward Control System 210
4.3.2 Feedback Control: Conventional Approach 215
4.3.3 Feedback Control: H_∞ 217
4.3.4 Feedback Control: Internal-Model Control 229
4.3.5 Multivariable Control of Air/Fuel Ratio and Engine Speed 239
4.4 Control of an SCR System 244
4.5 Engine Thermomanagement 249
4.5.1 Introduction 249
4.5.2 Control Problem Formulation 250
4.5.3 Feedforward Control System 252
4.5.4 Experimental Results 255

A Basics of Modeling and Control-Systems Theory 261
A.1 Modeling of Dynamic Systems 261
A.2 System Description and System Properties 270
A.3 Model Uncertainty 276
A.4 Control-System Design for Nominal Plants 279
A.5 Control System Design for Uncertain Plants 288
A.6 Controller Discretization 291
A.7 Controller Realization 301
A.7.1 Gain Scheduling 301
A.7.2 Anti-Reset Windup 302
A.8 Further Reading 303

B Case Study: Idle Speed Control 305
B.1 Modeling of the Idle Speed System 306
B.1.1 Introduction 306
B.1.2 System Structure 307
B.1.3 Description of Subsystems 308
B.2 Parameter Identification and Model Validation 315
B.2.1 Static Behavior 315
B.2.2 Dynamic Behavior 319

B.2.3 Numerical Values of the Model Parameters 321
B.3 Description of Linear System 324
B.4 Control System Design and Implementation 326

C Combustion and Thermodynamic Cycle Calculation of ICEs 331
C.1 Fuels 331
C.2 Thermodynamic Cycles 333
C.2.1 Real Engine-Cycle 334
C.2.2 Approximations for the Heat Release 337
C.2.3 Csallner Functions 338

References 343