# Contents

1 Introduction 1
  1.1 Background 2
  1.2 General Motivations 9
  1.3 Objectives 11
  1.4 Methodology 12
  References 16

2 Literature Review of Boosting Systems 17
  2.1 Introduction: Single Stage Turbocharging Systems 18
  2.2 Two-stage Turbocharging Systems 21
    2.2.1 Sequential Parallel Boosting Systems 21
    2.2.2 Serial Boosting Systems 26
  2.3 Mechanical Superchargers 40
    2.3.1 Single Stage Mechanical Supercharging 40
    2.3.2 Mechanical auxiliary supercharging 48
  2.4 Electric Boosting Systems 54
    2.4.1 Electrically Assisted Turbochargers 54
    2.4.2 Electric Boosters 60
  2.5 Centrifugal Compressor Performance Enhancement 64
    2.5.1 Pre-Whirl Generators 64
    2.5.2 Casing Treatments 74
    2.5.3 Variable Geometry Diffusers 78
  2.6 Energy Recovery: Turbocompounding 81
    2.6.1 Mechanical Turbocompounding 82
    2.6.2 Electric Turbocompounding 87
  2.7 Concepts 91
  2.8 Conclusions 94
  References 113
3 Analytical study of two-stage turbocharging performance 115
  3.1 Introduction ................................................. 116
  3.2 Governing Equations ........................................ 116
    3.2.1 Relation between Compression and Expansion Ratio 117
    3.2.2 Model Validation ........................................ 125
  3.3 Main Variables Influences on Two-Stage Architectures ....... 126
    3.3.1 HP and LP Expansion Ratio ............................ 127
    3.3.2 Coolers Performance .................................... 129
    3.3.3 Exhaust Temperature and Turbochargers Efficiencies 131
    3.3.4 Comparison between Single-Stage and Two-Stage Per-
           formance ................................................ 134
  3.4 Conclusions .................................................. 135
References ......................................................... 137

4 Experimental engine and turbocharger characterization 139
  4.1 Introduction .................................................. 140
  4.2 Experimental Facilities ...................................... 141
    4.2.1 Flow Test Rig .......................................... 141
    4.2.2 Injection Rig ........................................... 144
    4.2.3 Turbocharger Test Bench ................................. 146
    4.2.4 Engine Test Bench ....................................... 148
  4.3 Turbocharger Characteristic Maps ............................. 151
    4.3.1 Standard Characteristic Maps ............................ 151
    4.3.2 Adapted Characteristic Maps ............................ 153
  4.4 Conclusions .................................................. 163
References ......................................................... 168

5 0D Diesel Engine Modeling 169
  5.1 Introduction .................................................. 170
  5.2 Mean Value Based Gas-Path Description ........................ 174
    5.2.1 Intake Line ............................................. 174
    5.2.2 Exhaust Line ............................................. 180
  5.3 Crank Angle Resolved Model .................................. 184
    5.3.1 Filling & Emptying Modeling ............................ 184
    5.3.2 Cylinder Model .......................................... 189
    5.3.3 Combustion Model ........................................ 194
  5.4 A Fully Integrated 0D Engine Model ............................ 197
    5.4.1 0D Engine Model Structure ............................... 197
    5.4.2 Algorithm Resolution and Control ........................ 198

xvi