

# Contents

<b>Abstract</b>	<b>ix</b>
<b>Zusammenfassung</b>	<b>xi</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Motivation . . . . .	1
1.2 Objective . . . . .	3
1.3 Outline . . . . .	3
<b>2 Cycle Averaged Efficiency of Hybrid-Electric Vehicles</b>	<b>5</b>
2.1 Introduction . . . . .	5
2.2 Energy Demand of a Vehicle . . . . .	7
2.2.1 No Recuperation . . . . .	8
2.2.2 Perfect Recuperation . . . . .	9
2.2.3 Results for two Standard Driving Cycles . . . . .	9
2.3 Fuel Energy . . . . .	10
2.3.1 Recuperation Efficiency . . . . .	11
2.3.2 Fuel-to-Traction Efficiency . . . . .	12
2.3.3 Lumped Efficiency . . . . .	13
2.3.4 Loss Analysis . . . . .	13
2.4 Analysis of Simulation Results . . . . .	14
2.4.1 Simulation . . . . .	14
2.4.2 Influence of Hybridization Ratio on Efficiencies and Fuel Energy . . . . .	16
2.4.3 Influence of Hybridization Ratio on Losses . . . . .	19
2.5 Conclusions . . . . .	20
2.A List of Notation . . . . .	21
2.B Quasi-Static Vehicle Model . . . . .	22

<b>3</b>	<b>Hybrid-Electric Vehicle with Natural Gas-Diesel Engine</b>	<b>27</b>
3.1	Introduction . . . . .	27
3.1.1	Carbon Dioxide Emissions of a Vehicle . . . . .	28
3.1.2	Required Fuel Energy of a Vehicle . . . . .	28
3.1.3	Influence of Hybridization . . . . .	28
3.1.4	Dual-Fuel Natural Gas-Diesel Engine . . . . .	29
3.1.5	Contribution . . . . .	29
3.1.6	Outline . . . . .	30
3.2	Materials and Methods . . . . .	30
3.2.1	Engine Test Bench . . . . .	30
3.2.2	Engine Control . . . . .	31
3.2.3	Measurements and Calculations . . . . .	32
3.2.4	Vehicle Emulation . . . . .	35
3.3	Results and Discussion . . . . .	42
3.3.1	Static Engine Measurements . . . . .	42
3.3.2	Vehicle Emulation Results . . . . .	45
3.4	Conclusions . . . . .	53
<b>4</b>	<b>Feedback Control of Combustion in a Dual Fuel Engine</b>	<b>55</b>
4.1	Introduction . . . . .	55
4.1.1	Motivation . . . . .	55
4.1.2	Problem Description . . . . .	57
4.1.3	Hardware . . . . .	57
4.1.4	Outline . . . . .	58
4.2	Modeling and System Analysis . . . . .	59
4.2.1	Modeling . . . . .	59
4.2.2	Identification . . . . .	59
4.2.3	Linearisation . . . . .	61
4.2.4	System Analysis . . . . .	61
4.3	Controller Design . . . . .	62
4.3.1	Control of Center of Combustion . . . . .	63
4.3.2	Control of Center of Combustion and Maximum Pres- sure Rise Rate . . . . .	66
4.4	Experimental Results . . . . .	68
4.4.1	Control of Center of Combustion . . . . .	69
4.4.2	Control of Center of Combustion and Maximum Pres- sure Rise Rate . . . . .	70

4.4.3	Comparison of the SIMO and MIMO Controllers .	73
4.5	Conclusions . . . . .	74
4.A	List of Notation . . . . .	75
<b>5</b>	<b>Conclusions</b>	<b>77</b>
5.1	Main Conclusion . . . . .	77
5.2	Byproducts . . . . .	77
	<b>Bibliography</b>	<b>79</b>
	<b>Curriculum Vitae</b>	<b>85</b>
	<b>List of Publications</b>	<b>86</b>