

Table of Contents

1	Introduction	1
1.1	Introduction	1
1.2	Background and motivation	2
1.2.1	The Global Energy Outlook	2
1.2.2	Emission standards for light duty vehicles	3
1.2.3	Main technology trends in R&D of modern powertrains for passenger cars	7
1.3	Context of the research	10
1.4	Objectives of the research	13
1.5	Outline of the thesis	15
	Bibliography	17
2	Literature review	21
2.1	Introduction	22
2.2	Overview of the Conventional Diesel Combustion concept	22
2.2.1	Phenomenological description of the mixing-controlled combustion process	23
2.2.1.1	Pre-combustion jet dynamics, ignition and stabilization period	26
2.2.1.2	Quasi-steady period	31
2.2.1.3	Late-cycle mixing and ignition transient period	34
2.3	Fundamentals of advanced combustion concepts	40
2.3.1	Paths to achieve a clean in-cylinder combustion process	40

2.3.2	Phenomenological description of the partially premixed combustion process	47
2.3.2.1	Mixture preparation	51
2.3.2.2	Ignition and combustion process	58
2.3.3	Fuel effects in PPCI or PPC engines	65
2.4	Summary and concluding remarks	68
	Bibliography	71
3	Experimental setup and theoretical tools	83
3.1	Introduction	84
3.2	Two-stroke single-cylinder research engine	84
3.2.1	Main engine geometric characteristics	85
3.2.2	Scavenge architecture and valvetrain system	85
3.2.3	Fuel injection system	89
3.2.4	Fuels specifications	90
3.3	Test cell characteristics and equipment	93
3.3.1	Engine dynamometer	93
3.3.2	Auxiliary systems	94
3.3.3	Gas analysis	100
3.3.4	Data acquisition system	103
3.3.5	On-bench fast post-processing code	106
3.4	Engine testing procedure	107
3.5	Theoretical tools	113
3.5.1	IGR estimation model	113
3.5.2	Combustion diagnosis	119
3.5.3	Adiabatic flame temperature estimation	122
3.5.4	1D Spray evaporation and mixing modeling	124
3.5.5	Multi-dimensional combustion modeling	126
3.6	Conclusions	134
	Bibliography	135

4 Conventional diesel combustion in the poppet valve two-stroke engine	140
4.1 Introduction	141
4.2 Operating conditions and optimization targets	141
4.3 General methodology of the studies	143
4.4 Preliminary study of the gas exchange process	143
4.4.1 Experimental characterization of the air management process	144
4.4.1.1 Overview of the study	144
4.4.1.2 RSM and trade-off analysis	146
4.4.1.3 Model validation and optimization	152
4.4.2 CFD modeling of the air management process	154
4.5 Analysis and optimization of the combustion process during CDC operation	159
4.5.1 Medium load operation	161
4.5.1.1 Overview of the study	161
4.5.1.2 Discussion of results and trade-off analysis ..	162
4.5.1.3 Final optimization	172
4.5.2 Extension to high and low load operation	174
4.5.2.1 Optimization of low load conditions	174
4.5.2.2 Evaluation of engine performance at full load	184
4.6 Concluding remarks	193
Bibliography	196
Appendix A Optimization methodology	199
A.1 Air management DoE optimization	199
A.2 Injection settings parametric optimization	204
5 Advanced combustion concepts in the poppet valve two-stroke engine	207
5.1 Introduction	208

5.2	Preliminary study of premixed LTC concepts in the poppet valve two-stroke engine	209
5.2.1	Implementation of the early-injection Highly Premixed Combustion (HPC) using diesel fuel	210
5.2.1.1	General methodology of the studies	210
5.2.1.2	Summary of main trends	211
5.2.2	Implementation of the Partially Premixed Combustion (PPC) using gasoline fuel	220
5.2.2.1	General methodology of the studies	220
5.2.2.2	Summary of main trends	221
5.3	Analysis of the multiple injection PPC concept using gasoline fuel	231
5.3.1	Medium load operation	232
5.3.1.1	General methodology of the studies	232
5.3.1.2	Effect of injection timing	234
5.3.1.3	Effect of injection pressure and fuel split	254
5.3.2	Extension to low load operation	260
5.3.2.1	General methodology of the studies	260
5.3.2.2	Effect of injection timing	262
5.3.2.3	Effect of injection pressure and fuel split	273
5.3.3	Comparative analysis between gasoline PPC and CDC concepts	283
5.4	Concluding remarks	287
	Bibliography	290
6	Conclusions and future work	293
6.1	Introduction	293
6.2	Summary and main conclusions of this thesis	294
6.3	Future activities and new research directions	305
	Bibliography	308
	Bibliography	309