
Contents

Contents	i
List of Figures	v
List of Tables	xiv
Nomenclature	xv
1 Introduction	1
1.1 General context	1
1.2 Objectives and methodology	2
1.3 Thesis outline	4
References	5
2 The diesel injection process and spray development	11
2.1 Introduction	11
2.2 The diesel spray	11
2.2.1 Air-fuel mixture formation	13
2.2.2 Autoignition process	14
2.2.3 The diffusion flame	16
2.3 Fuel injection process	17
2.3.1 The common-rail system	17
2.3.2 The common-rail injector	18
2.3.3 Internal flow in the diesel nozzle	20
2.4 External flow characterization	22
2.4.1 Spray penetration	22
2.4.2 Liquid length	23

2.4.3	Spray spreading angle	24
2.4.4	Temporal evolution of the macroscopic variables	24
2.5	Multiple injection strategies	25
2.5.1	Injections before the main pulse	28
2.5.2	Injections after the main pulse	29
2.5.3	Split injections	31
References		32
3	Experimental tools and methodologies	51
3.1	Introduction	51
3.2	Injection system	51
3.2.1	High-pressure unit	52
3.2.2	Diesel injector	52
3.3	Rate of injection	54
3.3.1	Measurement setup	56
3.3.2	Measurement procedure	57
3.4	Momentum flux	59
3.4.1	Measurement setup	60
3.4.2	Measurement procedure	61
3.5	High-temperature and high-pressure test rig	63
3.5.1	Description of the facility	63
3.6	Optical techniques for spray visualization	65
3.6.1	Diffused back-illumination	65
3.6.2	Single-pass schlieren	67
3.6.3	Chemiluminescence	69
3.6.4	Optical configuration for the non-reactive spray measurements	70
3.6.5	Optical configuration for the reactive spray measurements	71
3.6.6	Camera configuration for both optical setups	72
3.7	Image processing methods	72
3.7.1	Image masking	73
3.7.2	Background subtraction	74
3.7.3	Contour detection	76
3.7.4	Contour analysis	78
3.7.5	Data averaging and calculation of the start of injection .	79
3.7.6	OH chemiluminescence lift-off length	81
3.7.7	Soot DBI	82
References		84
4	Hydraulic performance	95

4.1	Introduction	95
4.2	Test plan	95
4.3	Rate of injection	96
4.3.1	Averaged signal treatment for multiple injections	97
4.3.2	Rate of injection for multiple injection strategies	98
4.3.3	Effect of the boundary conditions on the shot-to-shot dispersion	105
4.3.4	Validation of the upstream scale	108
4.4	Momentum flux	109
4.4.1	Mass distribution per hole	109
4.4.2	Mass quantification for multiple injection strategies	109
4.4.3	Momentum flux for multiple injection strategies	111
4.5	Hydraulic analysis	117
4.6	Summary and conclusions	120
	References	122
5	Evaporative non-reactive spray development	125
5.1	Introduction	125
5.2	Test plan	125
5.3	Spray segmentation for multiple injection strategies	126
5.3.1	Effect of the injected quantity on the spray segmentation	129
5.3.2	Effect of the dwell time on the spray segmentation	130
5.3.3	Other factors affecting the spray segmentation	130
5.4	Spray tip penetration	134
5.4.1	Liquid phase penetration for multiple injection strategies	135
5.4.2	Vapor phase penetration for multiple injection strategies	138
5.5	Spray spreading angle	143
5.5.1	Liquid phase spreading angle for pilot-main strategies .	143
5.5.2	Vapor phase spreading angle for pilot-main strategies .	144
5.6	Summary and conclusions	146
	References	148
6	Spray ignition and combustion	155
6.1	Introduction	155
6.2	Test plan	155
6.3	Ignition delay	156
6.3.1	Calculating the start of combustion for multiple injection events	158
6.3.2	Ignition delay for multiple injection strategies	161
6.4	Lift-off length	167

6.4.1	Effect of a pilot injection on the lift-off length of the main pulse	167
6.5	Soot measurements through diffused back-illumination	170
6.5.1	Soot distribution for single injection cases	170
6.5.2	Soot distribution for pilot-main strategies	173
6.5.3	Soot distribution for main-post strategies	180
6.6	Summary and conclusions	184
6.A	Measurements of combustion noise with a pressure transducer .	188
	References	190
7	Summary and future works	199
7.1	Summary	199
7.2	Future directions	203
	Global Bibliography	205