

Table of Contents

1	Introduction	1
1.1	Introduction	2
1.2	Motivation of the study	2
1.3	Objectives of the study	4
1.4	Methodology	4
1.5	Outline of this work	5
	Bibliography	8
2	Bibliographic review	9
2.1	Introduction	10
2.2	Injection process – Basic concepts	10
2.2.1	Injector nozzle geometry	11
2.2.2	Hydraulic characterization of the nozzle.....	13
2.3	Diesel spray development	15
2.3.1	Atomization	16
2.3.2	Evaporation	25
2.4	Spray characterization	27
2.5	Model approaches for simulation	34
2.5.1	Approaches for the definition of the interphase.....	37
2.5.1.1	Volume-of-Fluid method	38
2.5.1.2	Level-set method	39
2.5.2	Eulerian-Lagrangian models	40

2.5.3	Eulerian multi-fluid models	41
2.5.4	Homogeneous flow or Single-fluid models	42
	Bibliography	44
3	Spray model description and implementation	51
3.1	Introduction	52
3.1.1	Fuel spray modeling approach	52
3.1.2	Model fundamentals	53
3.2	Fundamental model equations and initial implementation	54
3.2.1	Governing equations	55
3.2.2	Density equation	62
3.2.3	Pressure equation – Pressure-velocity coupling	63
3.3	Model development	69
3.3.1	Turbulence Model	69
3.3.2	Evaporation Model	71
3.3.3	Fluid properties definition	74
3.3.3.1	Liquid equation of state – HBT Correlation	74
3.3.3.2	Thermodynamic Model	76
3.3.4	Coupling with a combustion model	78
3.4	Summary	81
	Bibliography	83
4	Model set-up and assessment. Non-vaporizing spray	87
4.1	Introduction	88
4.1.1	Motivation	88
4.1.2	Objectives of the study	89
4.1.3	Methodology of the study	89
4.2	Model set-up	93
4.2.1	Mesh study	93
4.2.2	Numerical schemes	95
4.2.3	Turbulence model	97

4.2.4	Surface area density model	100
4.3	Evaluation of the model – Parametric studies	102
4.4	Conclusions	110
	Bibliography	112
5	Coupled internal/external flow application	115
5.1	Introduction	116
5.1.1	Motivation	116
5.1.2	Objectives of the study	117
5.1.3	Methodology of the study	117
5.2	Near-field internal structure	122
5.2.1	3D vs 2D coupled simulations	122
5.2.2	Coupled simulations – Effect of turbulence models . . .	125
5.2.3	Decoupled simulations	129
5.3	Optimization of primary break-up	135
5.3.1	Optimization stage	136
5.3.2	Parametric studies	142
5.4	Conclusions	144
	Bibliography	147
6	Vaporizing sprays application	151
6.1	Introduction	152
6.1.1	Motivation	152
6.1.2	Objectives of the study	152
6.1.3	Methodology of the study	153
6.2	Inert vaporizing sprays – Spray A	156
6.2.1	Validation cases	157
6.2.2	Parametric studies	164
6.3	Vaporizing/non-vaporizing sprays comparison	170
6.4	Reactive spray – Spray A	172
6.4.1	Set-Up – Inert spray variance distribution	173

6.4.2	Reactive spray evaluation	174
6.5	Conclusions	180
	Bibliography	182
7	Conclusions and future work	185
7.1	Summary and conclusions	185
7.2	Future work	189
	Bibliography	191