

TURBULENT COMBUSTION

NORBERT PETERS

*Institut für Technische Mechanik
Rheinisch-Westfälische Technische
Hochschule Aachen, Germany*



CAMBRIDGE
UNIVERSITY PRESS

Contents

<i>Preface</i>	<i>page xi</i>
1 Turbulent combustion: The state of the art	1
1.1 What is specific about turbulence with combustion?	1
1.2 Statistical description of turbulent flows	5
1.3 Navier–Stokes equations and turbulence models	10
1.4 Two-point velocity correlations and turbulent scales	13
1.5 Balance equations for reactive scalars	18
1.6 Chemical reaction rates and multistep asymptotics	22
1.7 Moment methods for reactive scalars	29
1.8 Dissipation and scalar transport of nonreacting and linearly reacting scalars	30
1.9 The eddy-break-up and the eddy dissipation models	33
1.10 The pdf transport equation model	35
1.11 The laminar flamelet concept	42
1.12 The concept of conditional moment closure	53
1.13 The linear eddy model	55
1.14 Combustion models used in large eddy simulation	57
1.15 Summary of turbulent combustion models	63
2 Premixed turbulent combustion	66
2.1 Introduction	66
2.2 Laminar and turbulent burning velocities	69
2.3 Regimes in premixed turbulent combustion	78
2.4 The Bray–Moss–Libby model and the Coherent Flame model	87

2.5	The level set approach for the corrugated flamelets regime	91
2.6	The level set approach for the thin reaction zones regime	104
2.7	A common level set equation for both regimes	107
2.8	Modeling premixed turbulent combustion based on the level set approach	109
2.9	Equations for the mean and the variance of G	114
2.10	The turbulent burning velocity	119
2.11	A model equation for the flame surface area ratio	127
2.12	Effects of gas expansion on the turbulent burning velocity	137
2.13	Laminar flamelet equations for premixed combustion	146
2.14	Flamelet equations in premixed turbulent combustion	152
2.15	The presumed shape pdf approach	156
2.16	Numerical calculations of one-dimensional and multidimensional premixed turbulent flames	157
2.17	A numerical example using the presumed shape pdf approach	162
2.18	Concluding remarks	168
3	Nonpremixed turbulent combustion	170
3.1	Introduction	170
3.2	The mixture fraction variable	172
3.3	The Burke–Schumann and the equilibrium solutions	176
3.4	Nonequilibrium flames	178
3.5	Numerical and asymptotic solutions of counterflow diffusion flames	186
3.6	Regimes in nonpremixed turbulent combustion	190
3.7	Modeling nonpremixed turbulent combustion	194
3.8	The presumed shape pdf approach	196
3.9	Turbulent jet diffusion flames	198
3.10	Experimental data from turbulent jet diffusion flames	203
3.11	Laminar flamelet equations for nonpremixed combustion	207
3.12	Flamelet equations in nonpremixed turbulent combustion	212

3.13	Steady versus unsteady flamelet modeling	219
3.14	Predictions of reactive scalar fields and pollutant formation in turbulent jet diffusion flames	222
3.15	Combustion modeling of gas turbines, burners, and direct injection diesel engines	229
3.16	Concluding remarks	235
4	Partially premixed turbulent combustion	237
4.1	Introduction	237
4.2	Lifted turbulent jet diffusion flames	238
4.3	Triple flames as a key element of partially premixed combustion	245
4.4	Modeling turbulent flame propagation in partially premixed systems	251
4.5	Numerical simulation of lift-off heights in turbulent jet flames	255
4.6	Scaling of the lift-off height	258
4.7	Concluding remarks	261
	<i>Epilogue</i>	263
	<i>Glossary</i>	265
	<i>Bibliography</i>	267
	<i>Author Index</i>	295
	<i>Subject Index</i>	302