

Spray Combustion

Dr.-Ing. Rainer Koch
Institut für Thermische Strömungsmaschinen
Universität Karlsruhe
Germany

May 27, 2009

Contents

1	Introduction	3
2	Atomization and sprays	5
2.1	Atomizers basics	5
2.2	Types of atomizers	5
2.3	Liquid breakup mechanism	7
2.3.1	Rayleigh breakup	7
2.3.2	Prompt atomization	8
2.4	Secondary breakup	10
2.5	Droplet breakup in turbulent flows	11
2.6	Mechanisms of droplet breakup	11
2.7	Characteristics of sprays	14
2.7.1	Rosin-Rammler droplet size distribution function	17
2.7.2	Log-normal droplet size distribution function	17
2.8	Dense and dilute sprays	18
3	Mechanics of droplet motion	19
3.1	Laminar gas flow	19
3.2	Turbulent gas flow	20
3.3	Numerical approaches	21
3.3.1	Locally homogeneous flow(LHF)	21
3.3.2	Euler-Euler technique (EET)	22
3.3.3	Euler-Lagrange technique (ELT)	24
3.3.4	Comparison of the numerical approaches	25
4	Droplet evaporation	27
4.1	Basics of droplet evaporation	27
4.1.1	Single - multi fluid evaporation	27
4.1.2	Processes of droplet evaporation	27
4.2	Models for single component fuels	28

4.2.1	D ² Model	28
4.2.2	Simplified single component evaporation models	30
4.2.3	The uniform temperature model	33
4.3	Models for multi component fuels	34
5	Single droplet combustion	41
5.1	Quasi-steady theory	41
5.1.1	Nomenclature	42
5.1.2	Conservation equations for quasi-steady droplet combustion	42
5.1.3	Boundary conditions	42
5.1.4	Fuel concentration at the droplet surface	43
5.1.5	Droplet surface temperature	43
5.1.6	Droplet evaporation without flame	44
5.2	Combustion with convection	45
5.2.1	Flame types of single droplet combustion with convection	45
5.2.2	Transition between the flame types of single droplet combustion	45
5.2.3	Concluding remarks	47
6	Spray combustion	49
6.1	Droplet group combustion theory	49
6.1.1	Concluding remarks	52
6.2	Modern low emission spray flames	52
7	Selected examples	55
7.1	Study of a spray flame	55