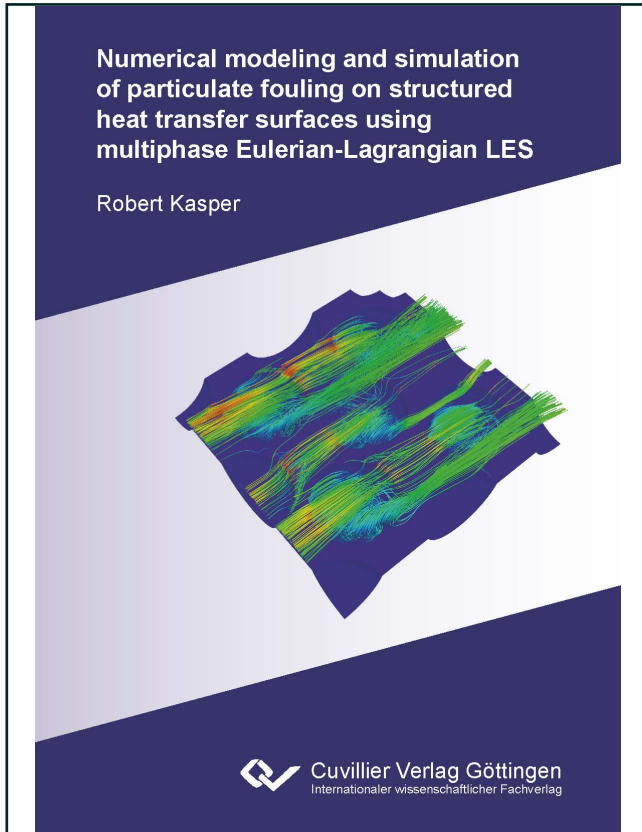




Robert Kasper (Autor)

Numerical modeling and simulation of particulate fouling on structured heat transfer surfaces using multiphase Eulerian-Lagrangian LES



<https://cuvillier.de/de/shop/publications/8442>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentzsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen, Germany
Telefon: +49 (0)551 54724-0, E-Mail: info@cuvillier.de, Website: <https://cuvillier.de>

Contents

Abstract	V
Preface	VII
List of Figures	XIII
List of Tables	XIX
Nomenclature	XXI
1 Introduction	1
1.1 Motivation	1
1.2 Fouling of heat transfer surfaces	3
1.2.1 Fouling resistance and fouling curves	5
1.2.2 Modeling of particulate fouling	6
1.3 Objectives and thesis outline	8
2 Description of the continuous phase	9
2.1 Governing equations of fluid motion	9
2.1.1 Continuity equation	9
2.1.2 Momentum equation	10
2.1.3 Energy equation	11
2.2 Turbulence in wall-bounded flows	12
2.3 Mathematical modeling of turbulent flows	17
2.4 Large-eddy simulation	19
2.4.1 Spatial filtering	19
2.4.2 Filtered transport equations	21
2.4.3 Subgrid-scale modeling	22
3 Description of the dispersed phase	27
3.1 Characterization of dispersed multiphase flows	27
3.2 Numerical modeling of dispersed multiphase flows	30
3.3 Forces on particles	32
3.3.1 Drag force	33
3.3.2 Other forces	33
3.4 Phase coupling	34
3.5 Particle dispersion	35

3.6	Particle interactions	35
3.6.1	Particle-particle collisions	36
3.6.2	Particle-wall interaction	38
4	Numerical methodology	39
4.1	Spatial discretization	40
4.2	Temporal discretization	45
4.3	Pressure-velocity coupling	46
4.4	Boundary conditions	48
4.5	Numerical procedure of the applied Lagrangian particle tracking	49
5	Modeling of particulate fouling on structured heat transfer surfaces	51
5.1	Eulerian-Lagrangian approach	51
5.1.1	Formation of fouling deposits	52
5.1.2	Removal and resuspension of fouling deposits	55
5.2	Multiscale modeling for the simulation of long-term fouling intervals	57
5.2.1	Capturing of the macroscale and microscale fouling behavior	57
5.2.2	Application of the multiscale approach	59
6	Validation	61
6.1	Particle-laden Taylor-Green vortex flow	61
6.1.1	Case description and numerical setup	61
6.1.2	Influence of the particle response time on particle dynamics	62
6.2	Particle-laden turbulent backward-facing step flow	63
6.2.1	Case description and numerical setup	63
6.2.2	Fluid statistics	64
6.2.3	Particle statistics	66
6.3	Particle-laden flow in a simplified combustion chamber	67
6.3.1	Case description and numerical setup	67
6.3.2	Fluid statistics	68
6.3.3	Particle statistics	70
6.4	Particle-laden turbulent channel flow	72
6.4.1	Case description and numerical setup	73
6.4.2	Fluid statistics	75
6.4.3	Particle statistics and distribution	76
6.4.4	Particle deposition	79
7	Particulate fouling on dimpled heat transfer surfaces	81
7.1	Particulate fouling on a single spherical dimple	81
7.1.1	Case description and numerical setup	81
7.1.2	Flow structures	83
7.1.3	Thermo-hydraulic performance analysis	89
7.1.4	Prediction of particulate fouling	93
7.1.5	Experimental confirmation of numerical results	99
7.1.6	Summary	103

7.2	Particulate fouling on spherical dimples in a staggered arrangement	104
7.2.1	Case description and numerical setup	104
7.2.2	Thermo-hydraulic performance analysis	106
7.2.3	Prediction of particulate fouling	109
7.2.4	Summary	111
8	Conclusion	113
	Bibliography	115
A	Appendix	129
A.1	High order statistical moments	129
A.2	Unladen turbulent channel flow over a single spherical dimple	129
A.2.1	Grid independence study	130
A.2.2	Influence of the subgrid-scale model	131
A.2.3	Influence of the Reynolds number ($t/D = 0.26$)	132
A.2.4	Influence of the Reynolds number ($t/D = 0.35$)	133
A.2.5	Streamwise velocity distributions $\langle u \rangle / u_b$	134
A.2.6	Vorticity distributions $\langle \boldsymbol{\omega} \rangle$	135
A.2.7	Vorticity distributions $\langle \omega_x \rangle$	136
	Statutory declaration in lieu of an oath	137
	List of publications	139