

Contents

Symbols and abbreviations	9
Zusammenfassung	15
Abstract	21
1. Introduction	25
1.1. Engine concepts and specific challenges for exhaust purification	26
1.2. Heat-integrated exhaust purification	27
1.3. Thesis objectives and structure	30
2. Simulation models	31
2.1. 1D-multiphase simulation models	31
2.1.1. Heat-exchanger reactor	31
2.1.2. Reference system	38
2.2. Simplified mathematical models for stationary analysis	38
2.2.1. Introduction and motivation	38
2.2.2. Quasihomogeneous models for exemplary design cases	38
3. Stationary simulations	53
3.1. Parameter continuation and stability analysis in DIANA	54
3.2. Analysis of stationary operating behavior	55
3.2.1. Standard ceramic monolith with catalytic coating	55
3.2.2. Fully coated heat-exchanger concept	57
3.2.3. Partially coated heat-exchanger concept	64
3.3. Continuation of design specifications	65
3.3.1. Standard ceramic honeycomb	67
3.3.2. Heat-integrated systems	69
3.4. Conclusions	72
4. Dynamic simulations	73
4.1. Transient behavior of partially coated heat exchanger	74
4.1.1. Heating in countercurrent operating mode	74

4.1.2. Heating with flap/bypass system	76
4.2. Heating strategies for operation under drive cycle conditions	82
4.2.1. Feed conditions for drive cycle simulations	82
4.2.2. Geometric properties of full-scale systems	82
4.2.3. Bypass/flap system, no auxiliary heating	84
4.2.4. Bypass/flap system with electric auxiliary heating	89
4.3. Sequential system	93
4.3.1. Geometric properties of full-scale sequential prototype	94
4.3.2. Comparative study on NEDC performance	96
4.4. Conclusions	99
5. Reactor prototypes and experimental evaluation	103
5.1. Folded sheet prototype	104
5.1.1. Reactor layout and dimensions	104
5.1.2. Stationary experimental evaluation	106
5.2. Brazed prototype	113
5.2.1. Reactor layout and dimensions	113
5.2.2. Stationary experimental evaluation	115
5.2.3. Comparison of heat exchanger performance	117
5.2.4. Stationary stoichiometric conditions	117
5.3. Sequential system - experimental evaluation	122
5.3.1. Reactor layout and dimensions	123
5.3.2. Transient cold start experiments	127
5.3.3. Stationary experiments	131
5.4. Conclusions	133
6. Directions for future work	135
Bibliography	141
A. Experimental Facilities	149
A.1. Test rigs for experimental evaluation of heat-exchanger prototypes . .	149
A.1.1. Experimental setup for stationary, fuel-lean conditions	149
A.1.2. Experimental setup for stationary, stoichiometric conditions . .	150
A.1.3. Experimental setup for transient, stoichiometric conditions . .	152
A.2. Exhaust gas generator	153
B. Derivation of quasihomogeneous model equations	157
B.1. Catalytically coated, countercurrent reactor	157
B.2. Standard ceramic monolith	163

C. Approximation of light-off temperatures	167
C.1. Ignition time	168
C.2. Estimation of ignition temperatures in case of multiple reactions	169
D. Geometric and thermophysical properties of simulation models	171
D.1. Geometric properties of different reactor prototypes	171
D.1.1. Folded-sheet prototype	171
D.1.2. Brazed prototype	174
D.1.3. Ceramic monolith	176
D.2. Properties of gas phases and solid materials	177
D.2.1. Gas density	177
D.2.2. Heat capacity and enthalpy	177
D.2.3. Viscosity	178
D.2.4. Heat conductivity	179
D.2.5. Diffusion coefficients	180
D.2.6. Properties of reactor materials	181
D.3. Transport parameters	181
D.3.1. Axial dispersion of heat and mass	181
D.3.2. Coefficients for heat and mass transfer	181