

Contents

Part I Generalities and methods

1	Introduction	3
	Dominique Thévenin	
	References	16
2	A Few Illustrative Examples of CFD-based Optimization .	17
	Gábor Janiga	
2.1	Introduction	18
2.1.1	Purpose	18
2.1.2	Heat Exchanger Optimization (Case A)	19
2.1.3	Optimization Coupled with Chemical Reactions (Case B)	21
2.1.4	Determination of Turbulence Model Parameters Based on Optimization (Case C)	22
2.2	Evolutionary Algorithms for Multi-objective Optimization	23
2.2.1	Multi-objective Optimization	23
2.2.2	The Concept of Pareto Dominance	25
2.2.3	Evolutionary Algorithm for Multi-objective Problems	26
2.3	The Optimal Position of the Tubes in a Heat Exchanger (Case A)	28
2.3.1	Tube Bank Heat Exchanger	28
2.3.2	Problem Parameters	29
2.3.3	Opal (OPTimization ALgorithms) Package	29
2.3.4	Evaluation of the Objectives for Case A	30
2.3.5	Parallelization	33
2.3.6	Computational Results	34
2.4	Multi-objective Optimization of a Laminar Burner (Case B)	38

2.4.1	Governing Equations	38
2.4.2	Numerical Solution	40
2.4.3	Optimization of the Laminar Burner	42
2.5	Optimization of the Standard k - ω Turbulence Model	
	Parameters (Case C)	46
2.5.1	Governing Equations	48
2.5.2	Numerical Results	50
2.6	Conclusions	52
	References	56
3	Mathematical Aspects of CFD-based Optimization	61
	Hans Georg Bock and Volker Schulz	
3.1	Introduction	62
3.2	Simultaneous Model-based Optimization	63
3.2.1	Sequential Quadratic Programming (SQP)	63
3.2.2	Modular SQP Methods	65
3.2.3	Multiple Set-point Optimization	69
3.2.4	Multigrid Optimization	70
3.3	Unsteady Problems	72
3.3.1	Time-domain Decomposition by Multiple Shooting	73
3.3.2	Parallel Multiple Shooting	75
3.3.3	Real-time Optimization and Nonlinear Model Predictive Control	75
3.3.4	Sensitivity Driven Multiple Shooting	76
	References	77
4	Adjoint Methods for Shape Optimization	79
	Kyriakos C. Giannakoglou and Dimitrios I. Papadimitriou	
4.1	Introduction	80
4.2	Principles of the Adjoint Approach	83
4.2.1	The Discrete Adjoint Approach	83
4.2.2	The Continuous Adjoint Approach	84
4.2.3	Differences Between Discrete and Continuous Adjoint	85
4.3	Inverse Design Using the Euler Equations	86
4.4	Inverse Design Using the Navier-Stokes Equations	90
4.5	Viscous Losses Minimization in Internal Flows	91
4.5.1	Minimization of Total Pressure Losses	92
4.5.2	Minimization of Entropy Generation	93
4.6	Computation of the Hessian Matrix	94
4.6.1	Discrete Direct-adjoint Approach for the Hessian ...	95
4.6.2	Continuous Direct-adjoint Approach for the Hessian (Inverse Design)	96
4.7	Applications	97

4.7.1	Gradient and Hessian-based Inverse Design of a 2D Duct	97
4.7.2	Losses Minimization of a 2D Compressor Cascade	99
4.8	Conclusions	104
	References	106

Part II Specific Applications of CFD-based Optimization to Engineering Problems

5	Efficient Deterministic Approaches for Aerodynamic Shape Optimization	111
	Nicolas R. Gauger	
5.1	Introduction	112
5.2	Parameterization by Deformation	113
5.2.1	Surface Deformation.....	114
5.2.2	Grid Deformation	115
5.3	Sensitivity-based Aerodynamic Shape Optimization.....	117
5.4	Sensitivity Computations.....	119
5.4.1	Finite Difference Method	119
5.4.2	Continuous Adjoint Formulation	120
5.4.3	Algorithmic Differentiation (AD).....	122
5.5	Adjoint Flow Solvers	124
5.5.1	Continuous Adjoint Flow Solvers.....	124
5.5.2	Discrete Adjoint Flow Solvers	125
5.6	Automatic Differentiation Applied to an Entire Design Chain	126
5.6.1	Test Case Definition.....	127
5.6.2	Finite Differences	127
5.6.3	Automatic Differentiation	132
5.7	Adjoint Approach for Aero-Structure Coupling.....	133
5.7.1	Adjoint Formulation for Aero-Structure Coupling.....	133
5.7.2	Implementation	140
5.7.3	Validation and Application	141
5.8	One-shot Methods.....	142
	References	144
6	Numerical Optimization for Advanced Turbomachinery Design.....	147
	René A. Van den Braembussche	
6.1	Introduction	147
6.2	Optimization Methods	150
6.2.1	Search Mechanisms.....	150
6.2.2	Objective Function	156

6.2.3	Parameterization.....	159
6.3	Two-level Optimization	160
6.3.1	Artificial Neural Networks	162
6.3.2	Database	164
6.4	Single Point Optimization of Turbine Blade.....	166
6.4.1	2D Blade Geometry Definition.....	166
6.4.2	Penalty for Non-optimum Mach Number Distribution P_{Mach}	168
6.4.3	Design of a Transonic Turbine Blade	170
6.5	Multipoint Optimization of a Low Solidity Diffuser	172
6.6	Multidisciplinary Optimization	175
6.6.1	3D Geometry Definition	176
6.6.2	Multidisciplinary Objective Function	178
6.6.3	Design Conditions and Results.....	180
6.7	Conclusions	187
	References	188
7	CFD-based Optimization for Automotive Aerodynamics ..	191
	Laurent Dumas	
7.1	Introducing Automotive Aerodynamics.....	192
7.1.1	A Major Concern for Car Manufacturers	192
7.1.2	Experiments on Bluff Bodies	192
7.1.3	Wake Flow Behind a Bluff Body	193
7.1.4	Drag Variation with the Slant Angle.....	194
7.2	The Drag Reduction Problem	195
7.2.1	Drag Reduction in the Automotive Industry	196
7.2.2	Numerical Modelization.....	197
7.3	Fast and Global Optimization Methods	199
7.3.1	Evolutionary Algorithms	199
7.3.2	Adaptive Hybrid Methods (AHM)	201
7.3.3	Genetic Algorithms with Approximated Evaluations (AGA).....	203
7.3.4	Validation on Analytic Test Functions	205
7.4	Car Drag Reduction with Numerical Optimization.....	207
7.4.1	Description of the Test Case.....	207
7.4.2	Details of the Numerical Simulation	207
7.4.3	Numerical Results	209
7.5	Another Possible Application of CFD-O: Airplane Engines	212
7.5.1	General Description of the Optimization Case	212
7.5.2	Details of the Computation	213
7.5.3	Obtained Results	213
7.6	Conclusion	214
	References	214

8	Multi-objective Optimization for Problems Involving Convective Heat Transfer	217
	Marco Manzan, Enrico Nobile, Stefano Pieri and Francesco Pinto	
8.1	Introduction	218
8.2	Literature Review	219
8.3	Problem Statement	222
8.3.1	Governing Equations	223
8.3.2	Fluid Dynamic Boundary Conditions	224
8.3.3	Temperature Boundary Conditions	225
8.4	Numerical Methods	228
8.4.1	Fluid Dynamic Iterative Solution	228
8.4.2	Thermal Field Iterative Solution	229
8.5	Geometry Parametrization	231
8.5.1	Wavy Channels	231
8.5.2	CC Module	234
8.6	Optimization Methods	235
8.6.1	Design of Experiment	238
8.7	Optimization Algorithms	239
8.7.1	Genetic Algorithm	242
8.7.2	Multi-objective Approaches	243
8.7.3	Multi-Criteria Decision Making (MCDM)	246
8.7.4	Optimization Process	247
8.8	Results and Discussion	249
8.8.1	Linear Piecewise Optimization	249
8.8.2	NURBS Optimization	250
8.8.3	Linear Piecewise versus NURBS	255
8.8.4	Three-dimensional Analysis	256
8.8.5	CC Module	258
8.9	Concluding Remarks	262
	References	263
9	CFD-based Optimization for a Complete Industrial Process: Papermaking	267
	Jari Hämäläinen, Taija Hämäläinen, Elina Madetoja and Henri Ruotsalainen	
9.1	Introduction	267
9.2	Optimal Shape Design of the Tapered Header	269
9.3	Optimal Control of the Fiber Orientation in the Slice Channel	272
9.3.1	On Modeling Fiber Orientation	272
9.3.2	HOCS Fiber – A Trouble Shooting Tool	273
9.3.3	Depth-averaged Navier-Stokes Equations	274
9.3.4	Validation of the Depth-averaged Navier-Stokes Equations	276
9.4	Multi-objective Optimization of Papermaking	278

9.4.1	Multi-objective Optimization	279
9.4.2	Modeling and Optimizing the Complete Papermaking Process	281
9.4.3	Numerical Examples	284
9.5	Towards Decision Support Systems	286
9.6	Conclusions	287
	References	288
Index		291

Optimization and Computational Fluid Dynamics

Thévenin, D.; Janiga, G. (Eds.)

2008, XV, 294 p., Hardcover

ISBN: 978-3-540-72152-9