

Editors

Hans-Georg Bock
Frank de Hoog
Avner Friedman
Arvind Gupta
Helmut Neunzert
William R. Pulleyblank
Torgeir Rusten
Fadil Santosa
Anna-Karin Tornberg

THE EUROPEAN CONSORTIUM
FOR MATHEMATICS IN INDUSTRY



SUBSERIES

Managing Editor
Vincenzo Capasso

Editors

Robert Mattheij
Helmut Neunzert
Otmar Scherzer

A. Di Bucchianico
R.M.M. Mattheij
M.A. Peletier
Editors

Progress in Industrial Mathematics at ECMI 2004

With 299 Figures, 44 in Color, and 35 Tables

 Springer

Editors

A. Di Bucchianico
R.M.M. Mattheij
M.A. Peletier

Technische Universiteit Eindhoven
Department of Mathematics and
Computer Science
Postbus 513
5600 MB Eindhoven, The Netherlands

A.d.Bucchianico@tue.nl
R.M.M.Mattheij@tue.nl
M.A.Peletier@tue.nl

Library of Congress Control Number: 2005933612

Mathematics Subject Classification (2000):
35-XX, 60-XX, 62-XX, 65-XX, 76-XX, 92-XX

ISBN-10 3-540-28072-3 Springer Berlin Heidelberg New York
ISBN-13 978-3-540-28072-9 Springer Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable for prosecution under the German Copyright Law.

Springer is a part of Springer Science+Business Media
springeronline.com

© Springer-Verlag Berlin Heidelberg 2006
Printed in Germany

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Typeset by the editors using a Springer TeX macro-package
Production: LE-TeX Jelonek, Schmidt & Vöckler GbR, Leipzig
Cover design: *design & production* GmbH, Heidelberg
Printed on acid-free paper 46/3142/YL - 5 4 3 2 1 0

Preface

In the autumn of 1985 ESMI (European Symposium on Mathematics in Industry), the predecessor of ECMI, took place in Amsterdam. During that meeting the ideas were born that eventually lead to the foundation of ECMI as we know it now. Many successful meetings followed this ‘ECMI-1985’ and during this period ECMI became a brand name for Industrial Mathematics. The adulthood of ECMI is apparent from the many things it has achieved since then, as a truly European institution devoted to promote Industrial Mathematics in education and research. It took nearly 20 years to have another ECMI meeting, the 13-th, held in the Netherlands again, now in Eindhoven, June 2004. During the preparations for this meeting we were joined by the European Network for Business and Industrial Statistics (ENBIS), an organisation with objectives similar to those of ECMI. It enlarged the scope of the meeting and opened up a number of opportunities for further co-operation. For one thing, ECMI-people have less tradition in employing theory and methods from Stochastics. Yet new challenges in Science and Industry increasingly cross borders between traditional mathematical areas. Multidisciplinarity applies to Industrial Mathematics as a whole and in fact Industrial Mathematics is multidisciplinary par excellence.

The Technische Universiteit Eindhoven (TU/e) is a relatively young university. Although not large, it recently came out as second in ranking of European Universities of Technology (see Third European Report on S&T Indicators 2003). Also the city of Eindhoven looks rather young, despite the fact that it has an old history. This modern face of the city is probably typical for the spirit here and, for that matter, in the larger region. Also the greater Eindhoven region does well as it ranks among the top three regions in Europe regarding technological and industrial innovation. The theme of this conference, Industrial Mathematics, is aptly fitting in with this. Indeed, nowadays Mathematics is generally accepted as a Technology, playing a crucial role in many branches of industrial activity, for optimising both processes and products.

Since Industrial Mathematics is a vast and diverse area, each ECMI conference chooses a number of (application) themes to focus on. This time they were Aerospace, Electronic Industry, Chemical Technology, Life Sciences, Materials, Geophysics, Financial Mathematics and Water flow. The majority of the subjects of the talks were on these topics indeed. In particular the talks of the invited speakers were related to these main themes. They delivered excellent lectures, most of which are reported in these proceedings. In alphabetical order the speakers were Søren Bisgaard (Amherst, MA), Rainer Helmig (Stuttgart), John Hinch (Cambridge), John Hunt (London), Chris Rogers (Cambridge), Cord Rossow (Braunschweig), Fabrizio Ruggeri (Milano), Wim Schoenmakers (Leuven), Bernard Schrefler (Padova), and Michael Waterman (Los Angeles, CA). Moreover there was a plenary talk by Sabine Zaglmayr, the winner of the Wacker price for the best thesis on Industrial Mathematics.

Organizing a meeting like this is a multi-person undertaking. During the last three years a dedicated group of people has devoted much of their time to making this event a success, eventually growing to quite a large number of persons who were actively involved in the lubrication of it all at the meeting. We are very grateful for their help. Special mention should be made of the help we received from our university congress bureau and our CASA secretariat. It goes without saying, however, that the actual success of this meeting was due to the participants. The conference was attended by some 400 people, from all continents, who altogether gave over 300 talks. There were excellent contributions by the invited speakers, a large number of high quality minisymposia, and many interesting contributed talks. All speakers were invited to submit a contribution to these proceedings, which therefore record the majority of the talks. We are most grateful to the many reviewers who helped us in the refereeing process.

At this place we would also like to thank the companies and institutions that participated in the exhibition, which was conducive to providing a proper atmosphere. We are particularly indebted to the many sponsors who made it possible to keep the fees quite moderate and yet have a nice social programme and affordable catering. The Local Organising Committee deserves special thanks for the many smaller and larger things that they have done. In particular I am personally very indebted to my two co-editors, Sandro Di Bucchianico and Mark Peletier. Their continuous enthusiasm, constructive ideas, as well as their skills in technical editing have proven invaluable. On behalf of all three of us I trust that these proceedings will be useful for all those who are interested in the use and the usefulness of Mathematics in Industry.

Bob Mattheij
Eindhoven, February 2005

Contents

Part I Theme: Aerospace

The MEGAFLOW Project – Numerical Flow Simulation for Aircraft

<i>C.-C. Rossow, N. Kroll, D. Schwamborn</i>	3
1 Introduction	3
2 MEGAFLOW software	4
2.1 Grid Generation	4
2.2 Flow Solvers	5
3 Software validation	13
4 Industrial Applications	16
5 Multidisciplinary simulations	23
6 Numerical optimization	25
7 Conclusions and perspective	29
References	30

Gradient Computations for Optimal Design of Turbine Blades

<i>K. Arens, P. Rentrop, S.O. Stoll</i>	34
1 Introduction	34
2 Model Problem	34
3 Gradient Computation	36
3.1 Finite Differences	36
3.2 Sensitivity Equation	36
3.3 Adjoint Method	36
4 Optimal Turbine Blade	37
References	38

Fast Numerical Computing for a Family of Smooth Trajectories in Fluids Flow

<i>G. Argentini</i>	39
1 Introduction	39

2	Fitting trajectories with cubic polynomials	40
3	Computing splines	41
4	Valuating splines	41
5	Computing values of splines	43
6	Conclusions	43
	References	43

Optimal Control of an ISS-Based Robotic Manipulator with Path Constraints

	<i>S. Breun, R. Callies</i>	44
1	Introduction	44
2	Optimal Control Problem	45
3	Transformation into Minimum Coordinates	45
4	Optimal Control Theory	47
5	Numerical Example	48
	References	48

Rigorous Analysis of Extremely Large Spherical Reflector Antennas: EM Case

	<i>E.D. Vinogradova, S.S. Vinogradov, P.D. Smith</i>	49
1	Introduction	49
2	The Decoupled System at High Frequencies	50
3	Algorithm Performance on the Decoupled System	52
4	Conclusions	53
	References	53

Part II Theme: Electronic Industry

Simulation and Measurement of Interconnects and On-Chip Passives: Gauge Fields and Ghosts as Numerical Tools

	<i>Wim Schoenmaker, Peter Meuris, Erik Janssens, Michael Verschaeve, Ehrenfried Seebacher, Walter Pflanzl, Michele Stucchi, Bamal Mandeep, Karen Maex, Wil Schilders</i>	57
1	Introduction	57
2	The Maxwell Equations and the Drift-Diffusion Equations	59
3	Gauge Fields and Ghost Fields	61
4	Applications	65
5	Conclusions	72
	References	73

Eigenvalue Problems in Surface Acoustic Wave Filter Simulations

	<i>S. Zaglmayr, J. Schöberl, U. Langer</i>	74
1	Introduction	75
2	Problem Description and First Model Assumptions	77

2.1	Surface Acoustic Wave Filters	77
2.2	Quasi-periodic Wave Propagation and the Dispersion Diagram	78
3	The Piezoelectric Equations	79
4	A Scalar Model Problem	81
4.1	Bloch's Theorem and the Quasi-Periodic Unit-Cell Problem ...	82
4.2	The Mixed Variational Formulation	83
4.3	The Frequency-Dependent Eigenvalue Problem	83
4.4	Galerkin-Discretization of the Frequency-Dependent EVP	84
4.5	A Model Improvement by Absorbing Boundary Conditions	85
4.6	Solution Strategies	86
5	Piezoelectric Equations and Periodic Structures	87
5.1	2-D Geometry and Anisotropic Materials	88
5.2	The Underlying Infinite Periodic Piezoelectric Problem	88
5.3	Piezoelectric Equations in Weak and Discretized Form	89
5.4	The Quasi-Periodic Unit-Cell Problem	90
6	Numerical Results	93
6.1	The Scalar Model Problem	93
6.2	Simulation of a Piezoelectric Periodic Structure	95
7	Conclusions	96
	References	97

Diffraction Grating Theory with RCWA or the C Method

<i>N.P. van der Aa</i>	99
1 Introduction	99
2 Mathematical problem	100
3 Solution methods	100
4 Results	102
References	103

Relocation of Electric Field Domains and Switching Scenarios in Superlattices

<i>L.L. Bonilla, G. Dell'Acqua, R. Escobedo</i>	104
1 Introduction	104
2 The Sequential Tunnelling Model	105
3 Switching Scenarios	106
References	108

Quantum Kinetic and Drift-Diffusion Equations for Semiconductor Superlattices

<i>L.L. Bonilla, R. Escobedo</i>	109
References	113

Model Order Reduction of Nonlinear Dynamical Systems

C. Brennan, M. Condon, R. Ivanov 114

1 Introduction 114

2 Linear time-varying systems 115

3 Nonlinear systems 116

4 Illustrative numerical example 117

References 118

Electrolyte Flow and Temperature Calculations in Finite Cylinder Caused by Alternating Current

A. Buikis, H. Kalis 119

1 Introduction 119

2 Mathematical Model 120

3 The Finite-Difference Approximations and Numerical Results. 121

4 Conclusion. 122

References 123

Numerical Simulation of the Problem Arising in the Gyrotron Theory

J. Cepitis, O. Dumbrajs, H. Kalis, A. Reinfelds 124

1 Introduction 124

2 Numerical Simulation 126

 2.1 Quasistationarization 126

 2.2 Method of Lines 127

3 Conclusions 128

References 128

A Deterministic Multicell Solution to the Coupled Boltzmann-Poisson System Simulating the Transients of a 2D-Silicon MESFET

C. Ertler, F. Schürerer, O. Muscato 129

1 Introduction 129

2 Physical Assumptions 130

3 The Multicell Method for Spatially Two-Dimensional Problems 131

4 Numerical Results 132

References 133

Some Remarks on the Vector Fitting Iteration

W. Hendrickx, D. Deschrijver, T. Dhaene 134

1 Introduction 134

2 An iterative scheme for solving rational LS problems 135

3 The Vector Fitting methodology 136

4 How VF fits in 136

5 Initial pole placement 138

References 138

Krylov Subspace Methods in the Electronic Industry

P. Heres, W. Schilders 139

1 Introduction 139

2 Equation setting 140

3 Model Order Reduction 140

4 Validation of results 142

5 Redundancy 142

6 Conclusions 143

References 143

On Nonlinear Iteration Methods for DC Analysis of Industrial Circuits

M. Honkala, J. Roos, V. Karanko 144

1 Introduction 144

2 Equation formulation 145

3 Line-search methods 146

4 Trust-region methods 146

5 Non-monotone strategy 146

6 Dog-leg method 146

7 Tensor methods 147

8 Results 147

References 148

Implementing Efficient Array Traversing for FDTD-lumped Element Cosimulation

L. R. de Jussilainen Costa 149

1 Introduction 149

2 Implementing the Data Types and Array Traversing 150

3 Comparison of the Two Data Types 151

4 Conclusions 153

References 153

Thermal Modeling of Bottle Glass Pressing

P. Kagan, R.M.M. Mattheij 154

1 Introduction 154

2 Physical model 154

3 Finite element model 156

4 Results 157

5 Conclusions 158

References 158

Simulation of Pulsed Signals in MPDAE-Modelled SC-Circuits

S. Knorr, U. Feldmann 159

1 Introduction 159

2 Switched capacitor filter 159

3 Multidimensional approach 160

4	Miller integrator	162
5	Conclusions	163
	References	163

A More Efficient Rigorous Coupled-Wave Analysis Algorithm

	<i>M.G.M.M. van Kraaij, J.M.L. Maubach</i>	164
1	Introduction	164
2	The model	165
3	The equations and boundary conditions	166
4	Numerical results	168
5	Conclusions	168
	References	168

Iterative Solution Approaches for the Piezoelectric Forward Problem

	<i>M. Mohr</i>	169
1	Introduction	169
2	Mathematical Model	170
3	Iterative Solution	170
4	Numerical Experiments	171
	References	173

Hydrodynamic Modeling of an Ultra-Thin Base Silicon Bipolar Transistor

	<i>O. Muscato</i>	174
1	Introduction	174
2	The Extended Hydrodynamic Model	175
3	Limit Models	175
4	Numerical Results	176
	References	178

Warped MPDAE Models with Continuous Phase Conditions

	<i>R. Pulch</i>	179
1	Introduction	179
2	Multivariate Signal Model	180
3	Warped MPDAE System	181
4	Numerical Simulation	181
5	Conclusions	183
	References	183

Exact Closure Relations for the Maximum Entropy Moment System in Semiconductor Using Kane’s Dispersion Relation

	<i>M. Junk, V. Romano</i>	184
1	The Maximum Entropy Moment Systems for Electrons in Semiconductors	184
2	Solvability of the Maximum Entropy Problem	186

3 The Euler-Poisson Model 187
 References 188

Reduced Order Models for Eigenvalue Problems

J. Rommes 189
 1 Introduction 189
 2 Reduced Order Modelling Problem 190
 3 Reduced Order Modelling Methods 190
 4 New Research Directions 192
 References 193

DRK Methods for Time-Domain Oscillator Simulation

M.F. Sevat, S.H.M.J. Houben, E.J.W. ter Maten 194
 1 Introduction 194
 2 DRK methods 194
 2.1 Order conditions 195
 2.2 Stability conditions 195
 3 Two-stage Example 196
 4 Alternative Formulation 197
 5 Conclusions 198
 References 198

Digital Linear Control Theory Applied To Automatic Step-size Control In Electrical Circuit Simulation

A. Verhoeven, T.G.J. Beelen, M.L.J. Hautus, E.J.W. ter Maten 199
 1 Introduction to error control 199
 2 Control-Theoretic Approach to Step-size Control 200
 3 Derivation of Process Model for BDF-Methods 201
 4 Design of Finite Order Digital Linear Step-size Controller 201
 5 Numerical Experiments 202
 6 Conclusions 203
 References 203

Part III Theme: Chemical Technology

On the Dynamics of a Bunsen Flame

M.L. Bondar, J.H.M. ten Thije Boonkkamp 207
 1 Introduction 207
 2 Flame front dynamics 207
 3 Solution in the case of a Poiseuille flow 208
 4 Flame response to flow perturbations 210
 References 211

Index Analysis for Singular PDE Models of Fuel Cells

<i>K. Chudej</i>	212
1 Time Index: Definition and Prototype Example	212
2 Time Index of Dynamic Fuel Cell Models	214
References	216

On the Modeling of the Phase Separation of a Gelling Polymeric Mixture

<i>F.A. Coutelieres, G.A.A.V. Haagh, W.G.M. Agterof, J.J.M. Janssen</i> ...	217
1 Introduction	217
2 Theory	218
3 Results and Discussion	219
4 Conclusion	220
References	221

Iso-Surface Analysis of a Turbulent Diffusion Flame

<i>B.J. Geurts</i>	222
1 Introduction	222
2 Diffusion flame in a mixing layer	223
3 Iso-surface analysis of turbulent flame properties	224
References	226

A Simplified Model for Non-Isothermal Crystallization of Polymers

<i>T. Götze, J. Struckmeier</i>	227
1 Introduction	227
2 Temperature Equation with Memory	228
3 Numerical Results	229
4 Conclusion	230
References	231

Numerical Simulation of Cylindrical Induction Heating Furnaces

<i>A. Bermúdez, D. Gómez, M. C. Muñiz, P. Salgado</i>	232
1 Introduction	232
2 Mathematical modelling	233
2.1 The electromagnetic submodel	233
2.2 The thermal submodel	234
3 Numerical solution	235
References	236

Thermal Radiation Effect on Thermal Explosion in a Gas Containing Evaporating Fuel Droplets.

<i>I. Goldfarb, V. Gol'dshtein, D. Katz, S. Sazhin</i>	237
1 Introduction	237
2 Physical model	238

2.1 Fast gas temperature: $\epsilon_2\gamma \ll 1$ 240
 2.2 Fast droplet radius: $\epsilon_2\gamma \gg 1$ 240
 3 Conclusions 241
 References 241

Local Defect Correction for Laminar Flame Simulation

M. Graziadei, J.H.M. ten Thijs Boonkkamp 242
 1 Introduction 242
 2 An outline of LDC 242
 3 Constructing an orthogonal curvilinear grid 244
 4 The thermo-diffusive model for laminar flames 245
 References 246

Development of a Hierarchical Model Family for Molten Carbonate Fuel Cells with Direct Internal Reforming (DIR-MCFC)

P. Heidebrecht, K. Sundmacher 247
 References 251

Modelling of Filtration and Regeneration Processes in Diesel Particulate Traps

U. Janoske, T. Deuschle, M. Piesche 252
 1 Introduction 252
 2 Simulation model 253
 3 Results 255
 4 Conclusion and Outlook 255
 References 256

Modelling the Shelf Life of Packaged Olive Oil Stored at Various Conditions

F.A. Coutelieiris, A. Kanavouras 257
 1 Introduction 257
 2 Experimental 258
 3 Theory 258
 4 Result and Discussion 259
 5 Conclusion 261
 References 261

Nonlinear Model Reduction of a Dynamic Two-dimensional Molten Carbonate Fuel Cell Model

M. Mangold, Min Sheng 262
 1 Introduction 262
 2 Spatially Distributed Reference Model of the MCFC 263
 3 Derivation of the Reduced MCFC Model 263
 4 Validation of the Reduced Model 265
 5 Conclusions 266

References	266
Liquid/Solid Phase Change with Convection and Deformations: 2D Case	
<i>D. Mansutti, R. Raffo, R. Santi</i>	268
1 Introduction	268
2 Governing Equations and Reformulation	269
3 Numerical Test and Conclusions	270
References	272
Mathematical Modelling of Mass Transport Equations in Fixed-Bed Absorbers	
<i>A. Pérez-Foguet, A. Huerta</i>	273
1 Introduction	273
2 Dimensionless model	274
2.1 Dimensionless analysis	276
3 Application: Working Capacity test	277
4 Conclusions	277
References	277
Injection Vapour Model in a Porous Medium Accounting for a Weak Condensation	
<i>J. Pousin, E. Zeltz</i>	278
1 Motivating Problem and Mathematical Model	278
2 Comparisons with Experimental Data	281
References	282
Multigrid Solution of Three-Dimensional Radiative Heat Transfer in Glass Manufacturing	
<i>M. Seaïd, A. Klar</i>	283
1 Introduction	283
2 Radiative Heat Transfer in Glass Manufacturing	284
3 Multigrid Solution Procedure	285
4 Results	286
References	287
DEM Simulations of the DI Toner Assembly	
<i>I.E.M. Severens, A.A.F. van de Ven</i>	288
1 Introduction	288
2 Force Models	289
2.1 Geometry	289
2.2 Collisions	289
2.3 Adhesion Force	290
2.4 Magnetic Force	290
2.5 Electric Force	290
2.6 Charge Model	290

3 Results 291
 4 Conclusion 291
 References 292

Modeling of Drying Processes in Pore Networks

A.G. Yiotis, A.K. Stubos, A.G. Boudouvis, I.N. Tsimpanogiannis, Y.C. Yortsos 293
 1 Introduction 293
 2 Pore network modeling of drying without the presence of liquid films 294
 3 The effect of liquid films 296
 4 Conclusions 297
 References 297

Mathematical Modelling of Flow through Pleated Cartridge Filters

V. Nassehi, A.N. Waghode, N.S. Hanspal, R.J. Wakeman 298
 References 302

Comparison of Some Mixed Integer Non-linear Solution Approaches Applied to Process Plant Layout Problems

J. Westerlund, L.G. Papageorgiou 303
 1 Introduction 303
 2 Problem formulation 304
 3 Non-Linear Solution Approaches 304
 4 Illustrative examples 305
 5 Conclusions 306
 References 307

A Mathematical Model of Three-Dimensional Flow in a Scraped-Surface Heat Exchanger

S.K. Wilson, B.R. Duffy, M.E.M. Lee 308
 1 Scraped-Surface Heat Exchangers (SSHEs) 308
 2 Transverse Flow 309
 3 Longitudinal Flow 311
 4 Summary 312
 References 312

Part IV Theme: Life Sciences

Transmission Line Matrix Modeling of Sound Wave Propagation in Stationary and Moving Media

M. Bezděk, Hao Zhu, A. Rieder, W. Drahm 315
 1 Introduction 315
 2 TLM Model of Stationary Media 316
 3 TLM Model of Moving Media 318
 4 Conclusion 318

References	319
------------------	-----

Viscous Drops Spreading With Evaporation And Applications To DNA Biochips

<i>M. Cabrera, T. Clopeau, A. Mikelić, J. Pousin</i>	320
1 Introduction	320
2 The physical model and the lubrication approximation	321
3 Numerical results and comparison with experimental results	323
References	324

Similarity-Based Object Recognition of Airborne Fungi in Digital Images

<i>P. Perner</i>	325
1 Introduction	325
2 Fungi Images	325
3 Similarity-Based Object Recognition	326
3.1 Similarity Measure	326
3.2 Template Generation	327
4 Results	328
5 Conclusions	329
References	329

Rivalling Optimal Control in Robot-Assisted Surgery

<i>G.F. Schanzer, R. Callies</i>	330
1 Introduction	330
2 Manipulator Model	331
3 Optimal Control	331
3.1 Rivalling Control	331
3.2 Optimal Control Theory	332
4 Optimal Control Constraints	332
4.1 Constraints	332
4.2 Numerical Realisation	333
5 Example: Constrained Motion and Rivalling Control	334
References	334

Part V Theme: Materials

A Multiphase Model for Concrete: Numerical Solutions and Industrial Applications

<i>B.A. Schrefler, D. Gawin, F. Pesavento</i>	337
1 Numerical solution	340
2 Application of the model to concrete structures in high temperature environments	344
3 Numerical simulation of cylindrical specimen exposed to high temperature	347

References	349
Modelling the Glass Press-Blow Process	
<i>S.M.A. Allaart-Bruin, B.J. van der Linden, R.M.M. Mattheij</i>	351
1 Introduction	351
2 Governing equations	351
3 Re-initialisation of the level set function	353
4 Results	354
5 Conclusions	355
References	355
Real-Time Control of Surface Remelting	
<i>M.J.H. Anthonissen, D. Hömberg, W. Weiss</i>	356
1 Introduction	356
2 Local grid refinement	357
3 Local defect correction	358
4 Simulations	359
References	360
Fast Shape Design for Industrial Components	
<i>G. Haase, E. Lindner, C. Rathberger</i>	361
1 Modeling the problem	361
2 A short sketch on the optimization strategy	362
3 Calculating the gradient for shape optimization	363
3.1 A second look at the gradient	363
4 Numerical results for the shape optimization problem	364
References	365
Modeling of Turbulence Effects on Fiber Motion	
<i>N. Marheineke</i>	366
1 Motivation	366
2 Fiber Dynamics	366
3 Construction of Fluctuating Flow Velocity	367
4 Stochastic Force Model	369
5 Numerical Results with White Noise	370
References	370
Design Optimisation of Wind-Loaded Cylindrical Silos Made from Composite Materials	
<i>E.V. Morozov</i>	371
1 Introduction	371
2 Silo Geometry, Wall Material Structure and Loading Conditions ...	372
3 Design Optimisation of The Cylindrical Section of The Silo	373
4 Example	374
5 Conclusions	375
References	375

Two-Dimensional Short Wave Stability Analysis of the Floating Process

S. R. Pop 376

1 Mathematical Formulation 376

 1.1 Governing system of motion 377

 1.2 Basic flow 377

2 The Disturbance System of Motion 378

3 Short Wave Limit 379

References 380

Optimization in high-precision glass forming

M. Sellier 381

1 Description of the forward problem 381

2 Optimization of the cooling curve 383

3 Identification of the required initial geometry 385

References 385

A Mathematical Model for the Mechanical Etching of Glass

J.H.M. ten Thije Boonkkamp 386

1 Introduction 386

2 Mathematical Model for Powder Erosion 386

3 Analytical Solution Method 387

4 Numerical Solution Method 389

References 390

FPM + Radiation = Mesh-Free Approach in Radiation Problems

A. Wawreńczuk 391

1 Project 391

2 FPM 392

3 Radiation models 392

 3.1 Rosseland approximation 393

 3.2 Radiative Transfer Equation (RTE) approximations 393

4 Results 395

References 395

Part VI Theme: Geophysics

Multiscale Methods and Streamline Simulation for Rapid Reservoir Performance Prediction

J.E. Aarnes, V. Kippe, K.-A. Lie 399

1 Introduction 399

2 Streamline Method 400

3 Multiscale Mixed Finite-Elements 401

4 Numerical Results 401

References 402

Part VII Theme: Financial Mathematics

ONE FOR ALL The Potential Approach to Pricing and Hedging

L.C.G. Rogers 407

1 Introduction 407

2 Generalities about pricing 408

3 The potential approach 411

4 Markov processes and potentials 412

5 Foreign exchange in the potential approach 413

6 Markov chain potential models 414

7 Calibration 415

8 Evidence from bond data 417

9 Hedging 419

10 Conclusions and future directions 420

References 420

The Largest Claims Treaty ECOMOR

S.A. Ladoucette, J.L. Teugels 422

1 Introduction 422

2 Results 423

 2.1 Bounds 423

 2.2 Asymptotic Equivalence 424

 2.3 Weak Convergence of $R_r(t)$ 425

 2.4 Moment Convergence 425

3 Conclusion and Remarks 426

References 426

American Options With Discrete Dividends Solved by Highly Accurate Discretizations

C.C.W. Leentvaar, C.W. Oosterlee 427

1 Black-Scholes Equation, Discretization 427

 1.1 Grid Transformation and Discretization 428

2 Numerical Results with Discrete Dividend 429

 2.1 European Call 429

 2.2 American Put 429

3 Conclusion 430

References 431

Semi-Lagrange Time Integration for PDE Models of Asian Options

A.K. Parrott, S. Rout 432

1 Asian Options 432

1.1	Semi-Lagrangian Time Integration	433
1.2	Discretisation	433
1.3	Boundary Conditions for the Fixed-Strike Call	434
1.4	Co-ordinate Stretching	434
2	Results	435
3	Conclusions	436
	References	436

Fuzzy Binary Tree Model for European Options

	<i>S. Muzzioli, H. Reynaerts</i>	437
1	Introduction	437
2	European-style Plain Vanilla Options in the Presence of Uncertainty	438
3	Solving Fuzzy Linear Systems	439
4	Conclusions	441
	References	441

Effective Estimation of Banking Liquidity Risk

	<i>P. Tobin, A. Brown</i>	442
1	Introduction	442
2	Data Handling	443
3	Correlations	444
4	Conclusion	445
	References	446

Part VIII Theme: Water Flow

Multiphase Flow and Transport Modeling in Heterogeneous Porous Media

	<i>R. Helmig, C.T. Miller, H. Jakobs, H. Class, M. Hilpert, C. E. Kees, J. Niessner</i>	449
1	Motivation	449
2	Scales and forces	453
3	Anisotropy at the pore scale	460
4	Dynamic Macroscale Model Formulation	465
	4.1 Multiphase Mass Balance Equations	465
	4.2 Multiphase Momentum Balance Equations	466
	4.3 Multiphase Flow Equations	466
	4.4 Constitutive Relationships	467
	4.5 Inclusion of Microscale Heterogeneity	469
	4.6 Inclusion of Macroscale Heterogeneity	470
5	Numerical Model	471
	5.1 Adaptive Time Discretization	473
	5.2 Subdomain collocation finite volume method (box method) ..	474
6	Examples	480
	6.1 Examination of Numerical Results for 1D	480

7 Conclusions 483
 References 485

The Unsteady Expansion and Contraction of a Two-Dimensional Vapour Bubble Confined Between Superheated or Subcooled Plates

K.S. Das, S.K. Wilson 489
 1 Introduction 489
 2 Problem Formulation 490
 3 Both Plates Superheated 491
 3.1 Delay-Equation Formulation for Continuous Films 491
 3.2 Constant-Velocity Solutions and their Stability 492
 4 Summary 492
 References 493

Animating Water Waves Using Semi-Lagrangian Techniques

M. El Amrani, M. Seaid 494
 1 Introduction 494
 2 Semi-Lagrangian Techniques 495
 3 Numerical Results 496
 References 498

A Filtered Renewal Process as a Model for a River Flow

M. Lefebvre 499
 1 Introduction 499
 2 Filtered Renewal Process 500
 3 An Application 501
 3.1 Model fitting 502
 3.2 Forecasting 502
 4 Conclusion 503
 References 503

A Parallel Finite Element Method for Convection-Diffusion Problems

J.M.L. Maubach 504
 1 The computational mesh 504
 2 The parallel finite element method 504
 3 Load balance 505
 References 507

Modelling The Flow And Solidification of a Thin Liquid Film on a Three-Dimensional Surface

T.G. Myers, J.P.F. Charpin, S.J. Chapman 508
 1 Introduction 508
 2 Mathematical model 508
 2.1 Thin film flow 509

2.2	Thermal problem	510
2.3	Extension to an arbitrary substrate	510
3	Results	511
4	Conclusions	512
	References	512

Numerical Schemes for Degenerate Parabolic Problems

<i>I.S. Pop</i>	513
1 Introduction	513
2 The Numerical Approaches	514
References	517

Finite Element Modified Method of Characteristics for Shallow Water Flows: Application to the Strait of Gibraltar

<i>M. González, M. Seaid</i>	518
1 Introduction	518
2 Formulation of FEMMOC	519
3 Preliminary Results	521
References	521

LDC with compact FD schemes for convection-diffusion equations

<i>M. Sizov, M.J.H. Anthonissen, R.M.M. Mattheij</i>	523
1 Introduction	523
2 Problem description and formulation of the LDC algorithm	524
3 High order compact schemes	525
4 Combination of LDC with HOCFD	526
5 Numerical results	527
References	527

A Finite-Dimensional Modal Modelling of Nonlinear Fluid Sloshing

<i>A. Timokha, M. Hermann</i>	528
1 Single-dominant Modal System	528
2 Local and Non-Local Bifurcation Analysis	530
References	532

Part IX Other Contributions

On the Reliability of Repairable Systems: Methods and Applications

<i>F. Ruggeri</i>	535
1 Introduction	535
2 Repairable systems	536
3 Non-homogeneous Poisson processes	538
3.1 Main properties	538

3.2 Statistical analysis of simple NHPP's 539

3.3 Reliability measures 540

3.4 Covariates in NHPP's 540

3.5 Classes of NHPP's 541

3.6 Change points in NHPP's 543

3.7 Superposition of NHPP's 544

3.8 Nonparametric models 545

4 Examples 547

4.1 Parametric vs. nonparametric models 547

4.2 Model selection and sensitivity analysis 549

5 Discussion 551

References 551

New Schemes for Differential-Algebraic Stiff Systems.

E. Alshina, N. Kalitkin, A. Koryagina 554

1 Introduction 554

2 Accuracy control 555

3 Rosenbrock Schemes 556

References 557

Wavelet and Cepstrum Analyses of Leaks in Pipe Networks

S.B.M. Beck, J. Foong, W.J. Staszewski 559

1 Introduction 559

2 Theory 560

3 Experiment 561

4 Comparison between theory and experiment 561

5 Conclusions 563

References 563

Robust Design Using Computer Experiments

R.A. Bates, R.S. Kenett, D.M. Steinberg, H.P. Wynn 564

1 Introduction 564

2 The Piston Simulator 565

3 Robustness Strategies 565

4 Comparison Of Robustness Strategies on the Piston 566

References 568

Non-Classical Shocks for Buckley-Leverett: Degenerate Pseudo-Parabolic Regularisation

C. M. Cuesta, C. J. van Duijn, I. S. Pop 569

1 Introduction 569

2 Travelling waves 571

References 573

A Multi-scale Approach to Functional Signature Analysis for Product End-of-Life Management

<i>T. Figarella, A. Di Bucchianico</i>	574
1 Introduction	574
2 Experimental Setup	575
2.1 Main Tray Experiment	575
2.2 Measurements and Feature Extraction	575
3 Wavelet Approach for Analysis of Stapler Motor Data	576
3.1 Approach 1: Rough Denoising - Extracting the Features Using A_6	576
3.2 Approach 2: Extracting the Features Using the Average of Approximation Coefficients	577
4 Conclusions	577
References	578

Aspects of Multirate Time Integration Methods in Circuit Simulation Problems

<i>A. El Guennouni, A. Verhoeven, E.J.W. ter Maten, T.G.J. Beelen</i>	579
1 Introduction	579
2 Model Problem	581
3 Interface treatment fitting hierarchical sub-circuits	583
References	583

Exploiting Features for Finite Element Model Generation

<i>O. Hamri, J.-C. Léon, F. Giannini, B. Falcidieno</i>	585
1 Introduction	585
2 Analysis model preparation	586
3 Exploiting feature attributes for FE model preparation	587
3.1 Simplification features	587
3.2 Detail feature categories	588
4 Conclusion	588
References	589

Implicit Subgrid-Scale Models in Space-Time VMS

Discretisations

<i>S. J. Hulshoff</i>	590
1 Introduction	590
2 Discretisation	591
3 Burgers Test Case	591
4 Computed Results	592
4.1 Spatial discretisation effects at small time steps	592
4.2 Implicit SGS model	593
5 Conclusions	594
References	594

Multiscale Change-Point Analysis of Inhomogeneous Poisson Processes Using Unbalanced Wavelet Decompositions

M. Jansen 595

1 Introduction 595

2 Multiscale binning 596

3 Wavelet maxima 597

4 Unbalanced wavelet analysis 598

5 Elimination of false maxima and results 599

References 599

Robust Soft Sensors Based on Ensemble of Symbolic Regression-Based Predictors

E. Jordaan, A. Kordon, L. Chiang 600

1 Introduction 600

2 Ensemble of GP-generated Predictors in Soft Sensors 601

 2.1 Genetic Programming 601

 2.2 Ensembles of GP Generated Predictors 601

 2.3 Pareto front Method for Ensemble Model Selection 602

3 Application 603

4 Conclusions 603

References 604

Two-Dimensional Patterns in High Frequency Plasma Discharges

D. Mackey, M.M. Turner 605

1 Introduction 605

2 Proposed Model 606

3 Derivation and Analysis of Amplitude Equations 606

4 Numerical Results and Conclusions 609

References 609

A Mathematical Model for the Motion of a Towed Pipeline Bundle

N.W. Manson, S.K. Wilson, B.R. Duffy 610

1 The Controlled Depth Tow Method (CDTM) 610

2 A Mathematical Model 611

3 Analytical Solutions 612

 3.1 Exact Solution in the Special Case $c_N = c_T = 0$ 612

 3.2 Asymptotic Solution in the Limit $T \rightarrow \infty$ 613

 3.3 General Stability Results 613

4 Summary 613

References 614

Operators and Criteria for Integrating FEA in the Design Workflow: Toward a Multi-Resolution Mechanical Model

<i>J.-C. Léon, P.M. Marin, G. Foucault</i>	616
1 Introduction	616
2 Simplification operators	617
3 Mechanical criteria	618
4 Conclusion	620
References	620

Wavelet Analysis of Sound Signal in Fluid-filled Viscoelastic Pipes

<i>M. Prek</i>	621
1 Introduction	621
2 Experiment	622
3 Analysis and Results	622
4 Conclusions	624
References	625

Coarse-Grained Simulation and Bifurcation Analysis Using Microscopic Time-Steppers

<i>P. Van Leemput, G. Samaey, K. Lust, D. Roose, I.G. Kevrekidis</i>	626
1 Introduction	626
2 Patch Dynamics	627
3 Coarse-grained Numerical Bifurcation Analysis	628
4 Conclusions	629
References	630

Optimal Prediction in Molecular Dynamics

<i>B. Seibold</i>	631
1 Problem Description	631
1.1 Industrial Problem	631
1.2 ITWM Project	632
1.3 One Dimensional Model Problem	632
2 Optimal Prediction	632
2.1 Low Temperature Asymptotics	633
2.2 Boundary Layer Condition	634
2.3 Computational Speed Up	634
3 Comparing Optimal Prediction to the Original System	634
4 Conclusions and Outlook	635
References	636

From CAD to CFD Meshes for Ship Geometries

<i>V. Skytt</i>	637
1 Introduction	637
2 Chart surfaces	638
3 Examples and Future Work	640

References	641
Integration of Strongly Damped Mechanical Systems by Runge-Kutta Methods	
<i>T. Stumpp</i>	642
1 Motivation	642
2 Expansion of the Analytical Solution.....	644
3 RadauIIA Methods	644
4 Error Results	645
References	646
Numerical Simulation of SMA Actuators	
<i>G. Teichelmann, B. Simeon</i>	647
1 Introduction	647
2 Mathematical Model	648
3 Numerical Treatment	650
References	651
Color Plates	653
Author index	677

Part I

Theme: Aerospace

The MEGAFLOW Project – Numerical Flow Simulation for Aircraft

C.-C. Rossow, N. Kroll, and D. Schwamborn

¹ Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR) in the Helmholtz-Association

² Institute of Aerodynamics and Flow Technology D-38108 Braunschweig, Germany
`cord.rossow@dlr.de`, `norbert.kroll@dlr.de`

Summary. Some years ago the national CFD project MEGAFLOW was initiated in Germany, which combined many of the CFD development activities from DLR, universities and aircraft industry. Its goal was the development and validation of a dependable and efficient numerical tool for the aerodynamic simulation of complete aircraft which met the requirements of industrial implementations. The MEGAFLOW software system includes the block-structured Navier-Stokes code FLOWer and the unstructured Navier-Stokes code TAU. Both codes have reached a high level of maturity and they are intensively used by DLR and the German aerospace industry in the design process of new aircraft. Recently, the follow-on project MEGADESIGN was set up which focuses on the development and enhancement of efficient numerical methods for shape design and optimization. This paper highlights recent improvements and enhancements of the software. Its capability to predict viscous flows around complex industrial applications for transport aircraft design is demonstrated. First results concerning shape optimization are presented.

1 Introduction

Aerospace industry is increasingly relying on advanced numerical flow simulation tools in the early aircraft design phase. Today, computational fluid dynamics has matured to a point where it is widely accepted as an essential, complementary analysis tool to wind tunnel experiments and flight tests. Navier-Stokes methods have developed from specialized research techniques to practical engineering tools being used for a vast number of industrial problems on a routine basis [51]. Nevertheless, there is still a great need for improvement of numerical methods, because standards for simulation accuracy and efficiency are constantly rising in industrial applications. Moreover, it is crucial to reduce the response time for complex simulations, although the relevant geometries and underlying physical flow models are becoming increasingly complicated. In order to meet the requirements of German aircraft industry, the