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Numerical Flow Simulation III

CNRS-DFG Collaborative Research Programme
Results 2000-2002

Ernst Heinrich Hirschel (Editor)



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Foreword

This volume contains eighteen contributions of work, conducted since 2000 in the French – German Research Programme “Numerical Flow Simulation”, which was initiated in 1996 by the Centre National de la Recherche Scientifique (CNRS) and the Deutsche Forschungsgemeinschaft (DFG).

The main purpose of this third publication on the research programme is again to give an overview over recent progress, and to make the obtained results available to the public. The reports are grouped, like those in the first and the second publication (NNFM 66, 1998, and NNFM 75, 2001), under the four headings “Development of Solution Techniques”, “Crystal Growth and Melts”, “Flows of Reacting Gases, Sound Generation” and “Turbulent Flows”. All contributions to this publication were reviewed by a board consisting of T. Alziary de Roquefort (Poitiers, France), H. W. Buggisch (Karlsruhe, Germany), S. Candel (Paris, France), U. Ehrenstein (Nice, France), Th. Gallouet (Marseille, France), W. Kordulla (Göttingen, Germany), A. Lerat (Paris, France), J. Piquet (Nantes, France), R. Rannacher (Heidelberg, Germany), G. Warnecke (Magdeburg, Germany), and the editor. The responsibility for the contents of the reports nevertheless lies with the contributors.

E. H. Hirschel
Editor

PREFACE

This volume contains the contributions communicated at the 9th Joint CNRS-DFG Workshop on Numerical Flow Simulation, held October 26 - 27, 2002 at the Laboratoire J. A. Dieudonné of the Université de Nice-Sophia Antipolis. The workshop, organised by Dr. Roger Peyret from the Université de Nice-Sophia Antipolis and Dr. Patrick Bontoux from the Université of Aix-Marseille was one of the periodically arranged meetings, sponsored by the Centre National de la Recherche Scientifique (CNRS) and the Deutsche Forschungsgemeinschaft (DFG) since 1996 in the frame of the Joint French-German Program under the title "Numerical Flow Simulation". About 90 French and German scientists, who participated in the program, followed the invitation to the workshop in order to present their results, obtained during the past two years. Grouped into four main topics the twenty partner projects of the program were aimed at developing advanced numerical solutions of the Navier-Stokes equations, and investigating the numerical solutions developed, at solving flow problems of particular interest, as for example crystal growth and melts, at simulating flows of reacting gases, and at studying turbulent flows.

The topics mentioned signalise, that the problems posed were not selected from traditional hydro- and aerodynamics, but mainly from technical physics, including chemical processes, as they occur in melts and flows of reacting gases, in addition to constructing and testing numerical solutions to be implemented on high-performance computers, and to simulating turbulent flows.

All projects of the program were defined as French-German partner projects with the aim to strive for an interdisciplinary and complementary approach to the solutions of the problems specified, as proposed by the joint French-German evaluation committee. From the very beginning on interdisciplinarity was one of the major goals of the program to be achieved. As in the years before, the evaluation committee included members of several disciplines, mathematicians, mechanicians, thermodynamicists, and engineers: Professor Thierry Alziary de Roquefort of the Laboratoire de Études Aérodynamiques des CNRS in Poitiers, Professor Hans Buggisch of the University Karlsruhe, Professor Thierry Gallouet of the Université Aix-Marseille, Professor Patrick Huerre of the Ecole Polytechnique in Palaiseau, Dr. Wilhelm Kordulla of the Deutsches Zentrum für Luft- und Raumfahrt in Göttingen (DLR), Professor Alain Lerat of ENSAM, Paris, Professor Rolf Rannacher of the University of Heidelberg, and Professor Gerald Warnecke of Magdeburg University. This third, jointly published volume of proceedings gives an overview over the present state of the investigations carried out during the past two years.

The first topic mentioned, the development of solution techniques, includes numerical grid generation, pursued at INRIA in Sophia Antipolis and at Duisburg University, and in a second partner project at the universities in Valenciennes und Stuttgart. In another project scientists of the universities in Paderborn, Erlangen and Nice-Sophia Antipolis combine the finite-element method with the spectral

method, investigate the mathematical properties of the combined solution, and apply it to the solution of incompressible flow problems. At the universities in Bonn, Karlsruhe, and at the Ecole Normale Supérieure in Paris wavelet-based solutions of the Navier-Stokes equations are constructed. The multi-scale method is used to construct numerical solutions of the conservation equations for weakly compressible flows in a joint project of the universities in Stuttgart, Bretagne-Sud, Louis Pasteur in Strasbourg, and at the Freie Universität Berlin. Free-surface flows often play a dominant role in technical flow processes. Solutions of the Navier-Stokes equations based on the multi-grid method are jointly being developed for such problems and applied by scientists of the Université Pierre-et-Marie-Curie in Paris and of the University of Heidelberg.

Free-surface problems were also investigated in another project of the universities in Marseille, the CNRS in St. Martin d'Herès, the Institut National des Sciences Appliquées in Rouen, and the RWTH Aachen. Numerical methods are successfully applied in the optimization of crystal growth after the Czochralski- and other processes. This work is jointly carried out in a project of the universities in Erlangen-Nürnberg, Darmstadt, and Marseille. Scientists of the universities in Potsdam und Ilmenau, the Observatoire de la Côte d'Azur in Nice, and the Ecole Normale Supérieure in Lyon simulate numerically flows of electrically conducting fluids under the influence of magnetic fields.

Flows of chemically reacting gases and sound generation pose the third research area of the program. Scientists of the Institut National des Sciences Appliquées in Rouen and of the RWTH Aachen construct methods for simulating numerically self-ignition and the combustion of partially premixed turbulent flows. The problem of supersonic combustion, so important for high-speed flight is jointly investigated by the RWTH Aachen, the CNRS, and other research institutions in Mont-Saint Aignan. Flame stabilisation, related to the previous problem, is studied at the Ecole Centrale in Lyon and at the TU Berlin. The simulation of three-dimensional flows of chemically reacting gases with parallelized multi-grid solutions of the Navier-Stokes equations is pursued at the University of Heidelberg and by the CNRS at the Ecole Centrale in Paris.

Turbulent flows in general are investigated with statistical and direct methods, and with the method of large-eddy simulation by scientists at the TU München and the Ecole Centrale in Nantes, while the Université Louis Pasteur in Strasbourg and the RWTH Aachen have specialised on turbulent wakes. Turbulent flow separation is studied at the TU Harburg and by the CNRS at the Ecole Centrale in Nantes with the aid of capturing coherent structures. The last two joint projects, carried out by scientists of the University in Karlsruhe, the Ecole Centrale de Lyon in Ecully and the Electricité de France in Chatou, and of the Universities in Marseille and of the Bundeswehr in München are concerned with the development and application of the large-eddy method. In June 2001, several LES-methods were benchmarked in a workshop at Hamburg University. The main results were presented in Nice. They are presently being prepared for publication.

The last, the ninth workshop in Nice of the French-German Joint Program "Numerical Flow Simulation", after a funding period of more than six years impressively demonstrated, that by long-term planing and combining the scientific potentials in France and Germany the international competitiveness in numerical flow simulation can successfully be maintained. Extension of the French-German initiative to other countries seems possible, if certain rules, securing the success of international and interdisciplinary co-operation are obeyed. The continuous support of the CNRS and the DFG is gratefully acknowledged, in particular the Direction Scientifique des Sciences pour l'Ingénieur is to be mentioned: Dr. J. J. Gagnepain, Dr. M. Champion, Dr. V. Sanchez, Dr. P. Le Quéré and Professor D. Vandromme secured the French contributions for the past two years. In the DFG Dr. W. Lachenmeier safeguarded the long-term support of the program.

In recognition of his outstanding administrative management of the program, the Direction Scientifique of the SPI Department of CNRS, chaired by Dr. Victor Sanchez - on behalf of the Directrice Générale of CNRS, Dr. Geneviève Berger, awarded Dr. Walter Lachenmeier the CNRS-Medal. The award was officially given to Dr. W. Lachenmeier by Professor S. Candel, Ecole Centrale and Académie des Sciences de Paris, during the reception of the 26th of October. The award was also extended to three other distinguished German scientists who took an important part in the program: Professor O. M. Mahrenholtz, representative of the President of the DFG, Professor E. Krause, who has promoted the French-German Collaboration since 1991, and has chaired the DFG-CNRS Program on Numerical Flow Simulation since 1996, Professor E.H. Hirschel, who is Editor of the Series Numerical Notes in Fluid Mechanics, formerly published by Vieweg, and now by Springer and who chaired the editorial board of the three successive special issues devoted to the Program. These three awards were delivered by Dr. Patrick Le Quéré, Deputy-Director of the SPI Department, Dr. Roger Peyret, Directeur de Recherche at CNRS, Dr. Pierre Perrier, Académie des Sciences and formerly at Dassault Aviation, respectively. The members of the CNRS-DFG Program and representatives of the Computational Fluid Dynamics community - more than hundred persons - attended the ceremony and enthusiastically congratulated the four awardees.

Aachen and Marseille, June 2002

E. Krause & P. Bontoux

CONTENTS

I. DEVELOPMENT OF SOLUTION TECHNIQUES	1
W. Borchers, S. Kräutle, R. Pasquetti, R. Peyret, R. Rautmann: Multi-Domain Finite Element – Spectral Chebyshev Parallel Navier-Stokes Solver for Viscous Flow Problems	3
F. Deister, F. Waymel, E. H. Hirschel, F. Monnoyer: Self-Organizing Hybrid Cartesian Grid Generation and Application to External and Internal Flow Problems ...	18
D. Hänel, A. Dervieux, O. Gloth, L. Fournier, S. Lanteri, R. Vilsmeier: Development of Navier-Stokes Solvers on Hybrid Grids	30
II. CRYSTAL GROWTH AND MELTS	47
O. Czarny, P. Droll, M. El Ganaoui, B. Fischer, M. Hainke, L. Kadinski, P. Kaufmann, R. Krastev, E. Mešić, M. Metzger, I. Raspo, E. Serre, P. Bontoux, F. Durst, G. Müller, M. Schäfer: High Performance Computer Codes and their Application to Optimize Crystal Growth Processes, III	49
I. Ginzburg, G. Wittum, S. Zaleski: Adaptive Multigrid Computations of Multi-phase Flows	77
E. Zienicke, N. Seehafer, B.-W. Li, J. Schumacher, H. Politano, A. Thess: Voltage-Driven Instability of Electrically Conducting Fluids	97
III. FLOWS OF REACTING GASES, SOUND GENERATION	113
R. Baron, S. Paxion, O. Gicquel, N. Simous, P. Bastian, D. Thévenin: Development of a 3D Parallel Multigrid Solver for Fast and Accurate Laminar Steady Flame Computations	115
R. Fortenbach, E. Frénod, R. Klein, C.D. Munz, E. Sonnendrücker: Multiple Scale Considerations for Sound Generation in Low Mach Number Flow	129
M. Herrmann, B. Binninger, N. Peters, J. Réveillon, L. Vervisch: Modeling Partially Premixed Turbulent Combustion	139
C. Huhn, W. Koschel: Supercritical Mixing of Flows with High Density Gradient	159
J. Yan, F. Thiele M. Buffat: Turbulence Model Sensitivity Study for Bluff Body Stabilized Flames	173

IV. TURBULENT FLOWS	189
J. Fröhlich, W. Rodi, A. Dewan, J. P. Fontes: Large-Eddy Simulation of the Flow Around the Free End of a Circular Cylinder.....	191
M. Griebel, F. Koster: Multiscale Methods for the Simulation of Turbulent Flows	203
I. Hadžić, M. Perić, M. Schmid, G. Deng, E. Guilmineau, P. Queutey, M. Visonneau: Computation of Turbulent Flows with Separation.....	215
J. Krömer, W. Schröder, M. Meinke, P. Comte, C. Brun, M. Haberkorn: LES of Transitional Boundary Layers and Wakes with Trailing Edge Blowing	230
M. Manhart, R. Friedrich, G. Deng, J. Piquet: Direct Versus Statistical Simulation of Accelerated/Retarded and Separating/Reattaching Turbulent Boundary Layers	244
K. Schneider, M. Farge: Coherent Vortex Simulation (CVS) of 2D Bluff Body Flows Using an Adaptive Wavelet Method with Penalisation.....	261
H. Wengle, R. Schiestel, I. Befeno, A. Meri: Large-Eddy Simulations of the Spatial Development of a Shearless Turbulence Mixing Layer	271