Flow Simulation with High-Performance Computers II

Edited by
Ernst Heinrich Hirschel

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DFG Priority Research Programme
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Foreword

This volume contains thirty-seven reports on work, which was conducted between 1993 and 1995 in the Priority Research Programme "Flow Simulation with High-Performance Computers" of the Deutsche Forschungsgemeinschaft (DFG, German Research Society), 1989 to 1995.

The main purpose of this publication is to give an overview over the work conducted in the second half of the programme, and to make the results obtained available to the public. The reports are grouped under the four headings "Flow Simulation with Massively Parallel Systems", "Direct and Large-Eddy Simulation of Turbulence", "Mathematical Foundations, General Solution Techniques and Applications" and "Results of Benchmark Computations". All contributions to this publication have been reviewed by a board consisting of F. Durst (Erlangen), R. Friedrich (München), D. Hänel (Duisburg), R. Rautmann (Paderborn), H. Wengle (München), and the editor. The responsibility for the contents of the reports nevertheless lies with the authors.

E.H. Hirschel
Editor

Preface

The Deutsche Forschungsgemeinschaft (DFG) sponsored the development of numerical simulation techniques in fluid mechanics since 1989 in a Priority Research Program "Flow Simulation with High-performance Computers". The major results obtained in this program until 1992 were published in summarizing articles in Volume 38 of the "Notes on Numerical Fluid Mechanics" of the Vieweg Verlag. The present volume summarizes the results of the second half of the program, which completed its investigations December 1995.

The problems studied included developments of solution techniques as well as applications. Altogether 35 projects were supported. It is worthwhile to point out, that 13 projects concentrated on the parallelization of algorithms and related work. The program thereby stimulated research in this relatively new branch of computational fluid dynamics in Germany with marked success. Development of general solution techniques and their application were pursued in 17 projects, and the remainder 5 projects were devoted to the development of simulation techniques for transitional and turbulent flows.

The work on parallel solution techniques included development of a time and space multi-grid method, of parallel finite element methods for the solution of the Navier-Stokes equations, performance enhancement of parallelized algorithms, adaptive operator techniques, and parallel interactive and integrated visualization techniques. The applications of parallelized algorithms comprised simulation of turbulent flow, of various viscous incompressible flows, of unsteady flows in turbomachinery, of chemically reacting flow, and of aerodynamic flows.

The work on other solution techniques included approximations in high order norms, low Mach number solutions based on asymptotic analysis, solutions based on the artificial compressibility concept, on higher order upwind schemes on unstructured grids, and others. The applications included simulation of aerodynamic and of hypersonic flows, of flows in turbomachinery and other complex internal flows. The investigations of transitional and turbulent flows were aimed at direct simulation of internal compressed turbulent flow and of separated flows; at large-eddy simulation of near-wall turbulence, of turbulent flows in curved pipes, and of turbulent boundary-layer flow over a hemisphere.

The cooperation with the Groupment de Recherche Mécanique des Fluides Numérique of the French Centre National de la Recherche Scientifique (CNRS) was continued. The second joint workshop was held May 3 - 5 1993 in Lambrecht (Pfalz) on the topic "Three-Dimensional Flow - Alternative Formulations and Solution of the Conservation Equations". At this occasion several representatives of the CNRS and the DFG under the chairmanship of one of the vice presidents of the DFG, Prof. S. Wittig, met and discussed possibilities of cooperation. Agreement was reached on the following points: Cooperation in 10 joint

projects within the frame of existing programs; participation of a French representative in the meetings of the German reviewing board and vice versa; organization of a joint meeting in Sophia-Antipolis at the end of 1994 with the aim of preparing a joint CNRS-DFG research program on computational fluid dynamics.

A third joint CNRS-DFG workshop was organized December 9 - 10, 1993 at Stuttgart University under the topic "Computational Fluid Dynamics on Parallel Systems". The contributions were published in volume 50 of the "Notes on Numerical Fluid Dynamics" of the Vieweg Verlag under the title of the workshop. They were edited by S. Wagner of Stuttgart University. The fourth workshop was held in Sophia-Antipolis November 25 - 26, 1994. As proposed in Lambrecht one year earlier, 20 projects for a prospective joint program entitled "Numerical Flow Simulation, A French - German Research Initiative" were discussed in the presence of official representatives of the CNRS and the DFG, and in March 1995 a proposal for such a program was submitted to the CNRS and the DFG under the title "Joint French - German Research Program: Numerical Flow Simulation". The individual proposals were reviewed by a French - German reviewing board November 27, 1995 and submitted for final decision to the CNRS and the DFG.

The DFG Priority Research Program "Flow Simulation on High-Performance Computers" substantially stimulated and fostered research in this field over a long period of time. It was a safe stepping stone for initiating and supporting work on paralellization. It brought together engineers and applied mathematicians in fruitful cooperation. The program helped to maintain international competiveness in flow research and markedly fastened the ties to the corresponding French program.

It is with great pleasure, that the undersigned take this opportunity to thank the DFG for supporting work on numerical flow simulation over more than six years. The efforts of the reviewers, Profs. Dr. G. Böhme and Dr. R. Rannacher are gratefully acknowledged. Their invaluable expertise helped to shape the program in many ways. They stimulated interdisciplinary discussion between engineers and mathematicians, who participated in the program. Their efforts are reflected in the articles published in this volume. Without the continuous help and far-sighted administering of the program by Dr. W. Lachenmeier it would have been impossible to maintain continuity in the research activities over the years. We thank him for his efforts.

Finally the Vieweg Verlag is gratefully acknowledged for publishing the results in the Notes on Numerical Fluid Mechanics, and Prof. Dr. E. H. Hirschel for editing this volume.

Bonn-Bad Godesberg, January 1996

E. Krause E. A. Müller

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