Preface

The technological value of computational fluid dynamics has become undisputed. A capability has been established to compute flows that can be investigated experimentally only at reduced Reynolds numbers, or at greater cost, or not at all, such as the flow around a space vehicle at re-entry, or a loss-of-coolant accident in a nuclear reactor. Furthermore, modern computational fluid dynamics has become indispensable for design optimization, because many different configurations can be investigated at acceptable cost and in short time. A distinguishing feature of the present state of computational fluid dynamics is, that large commercial computational fluid dynamics computer codes have arisen, and found widespread use in industry. The days that a great majority of code users were also code developers are gone. This attests to the importance and a certain degree of maturity of computational fluid dynamics as an engineering tool. At the same time, this creates a need to go back to basics, and to disseminate the basic principles to a wider audience. It has been observed on numerous occasions, that even simple flows are not correctly predicted by advanced computational fluid dynamics codes, if used without sufficient insight in both the numerics and the physics involved. The present book aims to elucidate the principles of computational fluid dynamics. With a variation on Lamb's preface to his classic Hydrodynamics, owing to the elaborate nature of some of the methods of computational fluid dynamics, it has not always been possible to fit an adequate account of them into the frame of this book.

When technology progresses from the pre-competitive to the competitive stage, unavoidably, something like an information stop sets in. To protect investments, and because of the relatively long learning curve to be traversed in order to become familiar with a large computer code, a certain sluggishness of change makes itself felt. These consequences of the widespread distribution of large computational fluid dynamics codes needs to be counteracted by the dynamics of unencumbered scientific enquiry, not to pursue change for change's sake, but because much improvement seems feasible. Therefore I hope the book will be helpful not only to users of computational dynamics codes, but also to researchers in the field.

The book has grown out of graduate courses for doctoral students and practicing engineers, held under the auspices of the J.M. Burgers Center, the national inter-university graduate school for fluid dynamics in The Netherlands. I expect teachers of advanced courses of computational fluid dynamics courses will find this a useful book. For an introductory course the book seems too advanced, but I have found selected material from the manuscript useful in teaching an introductory undergraduate course.

Other relatively recent introductions to the subject of computational fluid dynamics that the reader will find useful are Ferziger and Perić (1996), Fletcher (1988), Hirsch (1988), Hirsch (1990), Peyret and Taylor (1985), Roache (1998a), Shyy (1994), Sod (1985), Tannehill, Anderson, and Pletcher (1997), Versteeg and Malalasekera (1995), Wendt (1996). The two volumes by Hirsch give an especially wide coverage. The present book differs from these works in the following respects. More mathematical and numerical analysis is given, but the mathematical background of the reader is assumed not to go beyond what physicists and engineers are generally familiar with. The maximum principle for differential equations and numerical schemes gets generous attention, in order to put discussions of spurious 'wiggles', accuracy of schemes on nonuniform grids, and accuracy of numerical boundary conditions on a firm footing. Singular perturbation theory is introduced to predict qualitative features of the flow, to which numerical methods can be adapted for better accuracy and efficiency. In particular, singular perturbation theory is used with a fair amount of rigor to demonstrate convincingly how it is possible to achieve accuracy and computing cost uniform in the Reynolds number, showing that a 'numerical windtunnel' that operates at arbitrarily high Reynolds number is feasible, notwithstanding the effect of 'numerical viscosity'. Much attention is given to the principles and the application of von Neumann stability analysis, giving useful stability conditions, some of them new, for many schemes used in practice. Godunov's order barrier and how to overcome it by slope-limited schemes is discussed extensively. The theory of scalar conservation laws including the nonconvex case is treated. Distributive iteration is used as a unifying framework for describing iterative methods for the incompressible Navier-Stokes equations. The principles of Krylov subspace and multigrid methods for efficient solution of the large sparse algebraic systems that arise are introduced. Much attention is given to the complications brought about by geometric complexity of the flow domain, including an introduction to tensor analysis. A chapter on unified methods to compute incompressible and compressible flows is included. In order to help the reader along who wants to delve deeper and to quickly reach the current research frontier, references to more advanced literature are provided.

Errata and MATLAB software related to a number of examples discussed in the book my be obtained via the author's website, to be found at
`ta.twi.tudelft.nl/nw/users/wesseling`

Combining the writing of a textbook of this size with the daily tasks of a university professor was not always easy, and would have been impossible without the support of the numerical team, and in particular our secretary Tatiana Tijanova. Her dedication, love of perfection and capability to cope with repeated stress were of vital importance for keeping the manuscript organized, and finally bringing it into publishable form. I am indebted to dr. C. Vuik for advice on Chap. 7, to professor G.S. Stelling for checking up on Chap. 8, and to professor F.T.M. Nieuwstadt for casting a critical eye on what I wrote about turbulence. The enthusiasm of the students in the graduate courses on computational fluid dynamics of the J.M. Burgers Center, and the cooperation with my fellow teacher professor A.E.P. Veldman, were inspiring and stimulating. The moral support of my wife Tineke was and remains invaluable.

Delft, June 2000 P. Wesseling

Springer
http://www.springer.com/978-3-642-05145-6

Principles of Computational Fluid Dynamics
Wesseling, P.
2001, XII, 644 p., Softcover
ISBN: 978-3-642-05145-6