Fluid Mechanics and Its Applications

Volume 113

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Aims and Scope of the Series

The purpose of this series is to focus on subjects in which fluid mechanics plays a fundamental role.

As well as the more traditional applications of aeronautics, hydraulics, heat and mass transfer etc., books will be published dealing with topics which are currently in a state of rapid development, such as turbulence, suspensions and multiphase fluids, super and hypersonic flows and numerical modeling techniques.

It is a widely held view that it is the interdisciplinary subjects that will receive intense scientific attention, bringing them to the forefront of technological advancement. Fluids have the ability to transport matter and its properties as well as to transmit force, therefore fluid mechanics is a subject that is particularly open to cross fertilization with other sciences and disciplines of engineering. The subject of fluid mechanics will be highly relevant in domains such as chemical, metallurgical, biological and ecological engineering. This series is particularly open to such new multidisciplinary domains.

The median level of presentation is the first year graduate student. Some texts are monographs defining the current state of a field; others are accessible to final year undergraduates; but essentially the emphasis is on readability and clarity.

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M. Darwish

The Finite Volume Method in Computational Fluid Dynamics

An Advanced Introduction with OpenFOAM® and Matlab®

Springer

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Preface

The impetus to write this book came about from three sources:

The first source was the bi-yearly computational fluid dynamics (CFD) course, which has been offered over the last 15 years at the American University of Beirut (AUB) by both Drs. Darwish and Moukalled to senior and graduate mechanical engineering students, a course that focuses on the finite volume method (FVM) and CFD applications.

The second source grew over the years to become more significant as it was noticed that graduates have started working on increasingly more focused areas and topics in CFD while becoming less cognizant of the general algorithmic expertise that earlier students developed. It became clear that there is a need not only to cover the basis of the numerics at the core of CFD codes but also to discuss the implementation issues to ensure that all students receive a robust understanding of the techniques they are working on.

Finally, the collaborative work in advanced numerics with Prof. Dr. Mangani from HSLU, Lucerne, Switzerland, which started during the Ph.D. supervision of M. Buchmyer (Ph.D.) from TUGraz, provided all the incentive to clarify and detail much of the numerical basis of the algorithms used in OpenFOAM®.

To this end, it was decided that the book would combine a mix of numerical and implementation details allowing the reader, if she/he desires, to fully understand and implement a robust and versatile CFD code based on the FVM.

This ambitious task was possible only by selecting from the various numerical methods in each of the topics covered in the book a handful set with which the authors are intimately familiar. The result is a book that covers intimately all the topics necessary for the development of a robust CFD code for the simulation of fluid flow at all speeds within the framework of the collocated unstructured finite volume method.

The book was also written with the classroom in mind as reflected by the use of copious illustrations; the provision of many exercises covering numerics, programming, and applications; the availability of an academic code (in MATLAB®) that imbeds much of the numerics presented in the book; and finally the various programs and routines in OpenFOAM®.

The hope is that as you read through this book, you will share with us the excitement and intense interest that we have grown to have for this subject.

Beirut F. Moukalled
Horw L. Mangani
Beirut M. Darwish
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It took nearly two years to complete this book, but much of what went in it was learned over a much longer period from interaction with numerous people in conferences and academic visits, from answering pertinent questions in our CFD courses and from our research work. However the enabler for all that is foremost the patience and kindness of our families.

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About the Authors

Fadl Moukalled received his Ph.D. in Mechanical Engineering from Louisiana State University in 1987. During that same year, he joined the Mechanical Engineering Department at the American University of Beirut where currently he serves as a professor. His research interests cover several aspects of the finite volume method and its use in computational fluid dynamics. As a founding member of the CFD Group at AUB, he worked on convection schemes, pressure-based segregated algorithms for incompressible and compressible flows, adaptive grid methods, multigrid methods, transient schemes for free surface flows, multiphase flows, and fully coupled pressure-based solvers for incompressible, compressible, and multiphase flows.

Luca Mangani received his Ph.D. form the University of Florence in 2006, where he worked on the development of a state-of-the-art turbo machinery code in OpenFOAM® for heat transfer and combustion analysis. After three years of postdoc work, he joined the Lucerne University of Applied Sciences and Arts as senior research and chief engineer for CFD simulations. Since 2014, he is serving as an associate professor at the Fluid Mechanics and Hydro-machines Department, where he manages a variety of projects with industrial partners aimed at developing advanced and novel CFD tools. His research interests include pressure- and density-based solvers, segregated and fully coupled algorithms, fluid-structure interaction (FSI), turbulence, and conjugate heat transfer modeling.

Marwan Darwish received his Ph.D. in Materials Processing from BRUNEL University in 1991. He worked at the BICOM institute for one year as a postdoc before joining the Mechanical Engineering Department at the American University of Beirut in 1992, where he currently serves as a professor. His research interest covers a range of topics including solidification, advanced numerics, free surface flow, high-resolution schemes, multiphase flows, coupled algorithms, and algebraic multigrid. He is a founding member of the CFD Group at AUB.