LARGE-EDDY SIMULATION FOR ACOUSTICS

Noise pollution around airports, trains, and industries increasingly attracts environmental concern and regulation. Designers and researchers have intensified the use of large-eddy simulation (LES) for noise-reduced industrial design and acoustical research. This book, written by thirty experts, presents the theoretical background of acoustics and LES followed by details about numerical methods such as discretization schemes, boundary conditions, and coupling aspects. Industrially relevant, hybrid Reynolds-averaged Navier–Stokes/LES techniques for acoustic source predictions are discussed in detail. Many applications are featured ranging from simple geometries for mixing layers and jet flows to complex wing and car geometries. Selected applications include recent scientific investigations at industrial and university research institutions. Presently perfect solution methodologies that address all relevant applications do not exist; however, the book presents a state-of-the-art collection of methods, tools, and evaluation methodologies. The advantages and weaknesses of both the commercial and research methodologies are carefully presented.

Claus Wagner received his Ph.D. in Fluid Dynamics in 1995 at the Technical University of Munich, Germany. He is Honorary Professor for Industrial Aerodynamics, Ilmenau University of Technology, Germany. Since 1998, he has been a scientist in and head of the Section of Numerical Simulations for Technical Flows of the Institute for Aerodynamics and Flow Technology, German Aerospace Center, Göttingen, Germany. Dr. Wagner's research includes experimental investigations of the resonant control of nonlinear dynamic systems, theoretical and numerical investigations of thermal convection in cylindrical containers, and direct numerical simulation and large-eddy simulations of turbulent flows in different configurations. He has held visiting positions in Gainsville, Florida, USA as well as in Bremen, Germany.

Thomas Hüttl received his Ph.D. in Fluid Dynamics in 1999 at the Technical University of Munich, Germany. His academic research included work on the direct numerical simulation of turbulent flows in curved and coiled pipes, and direct and large-eddy simulations of boundary layer flows with and without separation, in the framework of a French–German DFG-CNRS-Cooperation project. He has held visiting positions in Nantes, France and Bangalore, India. Between 2000 and 2003, he was a senior engineer for aeroacoustics at MTU Aero Engines GmbH, Germany's leading manufacturer of engine modules and components and of complete aero engines. Dr. Hüttl led MTU's contribution for the European research project TurboNoiseCFD and contributed to the European research project SILENCER. After some years working as IT quality manager and internal auditor, he is now Chief Privacy Officer for the entire MTU Aero Engines concern. Among his many honors, Dr. Hüttl was elected a member of the Senate of the DGLR, Deutsche Gesellschaft für Luft- und Raumfahrt - Lilienthal - Oberth e.V. in 2003 and 2006.

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Large-Eddy Simulation for Acoustics

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CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
32 Avenue of the Americas, New York, NY 10013-2473, USA

www.cambridge.org
Information on this title: www.cambridge.org/9780521871440

First published 2007

Printed in the United States of America

A catalog record for this publication is available from the British Library.

Library of Congress Cataloging in Publication Data

Large-eddy simulation for acoustics / edited by Claus Albrecht Wagner, Thomas Hüttl, Pierre Sagaut.
p. cm. – (Cambridge aerospace series)
Includes bibliographical references and index.
ISBN-13: 978-0-521-87144-0 (hardback)
ISBN-10: 0-521-87144-1 (hardback)
1. Noise control–Mathematics. 2. Noise–Simulation methods. 3. Eddies–Mathematical models.
I. Wagner, Claus Albrecht, 1962– II. Hüttl, Thomas, 1970– III. Sagaut, Pierre, 1967– IV. Title.
V. Series.
TD892.L26 2007
620.2′3 – dc22 2006019237

ISBN 978-0-521-87144-0 hardback

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Preface

Two branches of the same tree are growing together: Acoustics and the large-eddy simulation (LES) technique are based on the same fundamental equations of fluid dynamics. In the past, both scientific disciplines developed independently from each other. Acoustics is one of the classical disciplines of mechanics, having its roots in Greek and Roman times. LES is a comparatively young field of research that has benefited from the exponential growth in computational possibilities over the last few decades. Each scientific community has developed its own methods, definitions, and conventions, and it sometimes seems that experts and scientists in acoustics and LES techniques speak different languages. During the last few years, the LES and the acoustics communities realized that LES can be a comprehensive tool for acoustical research and design and intensified its use.

This book presents the current state of the art for LES used in acoustical investigations and comprises 19 contributions from 30 authors, each an expert in his field of research. A general introduction to the subject is followed by descriptions of the theoretical background of acoustics and of LES. A chapter on hybrid RANS–LES for acoustic source predictions follows. More details are given for numerical methods, such as discretization schemes, boundary conditions, and coupling aspects. Numerous applications are discussed ranging from simple geometries for mixing layers and jet flows to complex wing or car geometries. The selected applications deal with recent scientific investigations at universities and research institutes as well as applied studies at industrial companies. Side areas of LES for acoustics are addressed in a contribution on vibroacoustics.

The book is a collection of different methods, tools, and evaluation methodologies. Currently it is not possible to offer a perfect solution methodology that generally covers all possible applications. Although interesting results of several commercial codes are presented, a recommendation for any specific solver cannot be made because a benchmark of the codes has not been established and several other codes have not been considered yet. Each method, both scientific and commercial, has its individual advantages and weaknesses. It was also not our intention to harmonize the definitions

and conventions in acoustics and LES computing. Therefore, the same nomenclature is not used by all authors.

The book is intended to be used by students, researchers, engineers, and code developers willing to become more familiar with the use of the LES technique for acoustical studies. The limitations of the method have been outlined as well as its requirements. The reader should acquire an impression of possible and appropriate applications for this methodology. The editors would welcome any initiatives motivated by this book for international cooperation in the development or application of LES for acoustics.

The idea for this book came from Eric Willner, the former commissioning editor for engineering at Cambridge University Press, when he read the first call for papers for the International Workshop on LES for Acoustics organized by Thomas Hüttl, Claus Wagner, and Jan Delfs in Göttingen, 2002.* At this time, Cambridge University Press was actively seeking a book on LES for acoustics for its aerospace series. Thomas Hüttl and Claus Wagner agreed to edit a scientific book based on the contributions of the workshop in Göttingen. Several speakers and participants of the workshop and other experts promised to contribute to the book, which was conceived as more of a scientific handbook than a simple workshop proceedings. Pierre Sagaut separately developed the idea of a book on LES for acoustics and joined the team of editors.

The book would not exist without the contributions from each of the authors. The editors are not only grateful for these contributions but also for valuable review comments from several authors during two book reviews as well as interesting scientific discussions of review comments and proposals. We would also like to thank Peter Gordon, Senior Editor of Engineering at Cambridge University Press, for his help in preparing the book but also for enthusiasm, patience, and confidence during the last 2 years when the progress of the book was sometimes slow but never stopped.

Thomas Hüttl gratefully acknowledges the advice and comments of MTU Aero Engines aeroacoustics specialist Fritz Kennepohl, who introduced him to the secrets of acoustics during the TurboNoiseCFD research project.

Pierre Sagaut, Thomas Hüttl, and Claus Wagner
Europe, May 2006

* International ERCOFTAC-DGLR-DLR-Workshop on LES for Acoustics organized by T. Hüttl, C. Wagner and J. Delfs, German Aerospace Center (DLR), Göttingen, Germany, 7–8 October 2002.

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