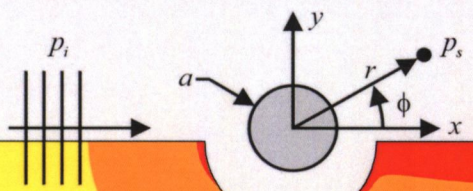
Acoustic Analyses Using MATLAB® and ANSYS®

Carl Q. Howard and Benjamin S. Cazzolato



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Acoustical Engineering

"This book is a must for those wanting to explore and investigate the world of computational engineering acoustics. ...Its comprehensive instructional framework supports a conversational, down-to-earth narrative style."

—Andrew Peplow, Noise and Vibration Specialist, Atlas Copco Rock Drills, Sweden

"These guys know their stuff!! ...I thoroughly recommend this book to anyone who is involved in acoustic modelling—it forms the perfect basis for acoustic coursework as well as being useful for research and industrial modelling of acoustic devices."

—Ian Bedwell, Thales Australia, Underwater Systems, Technical Consultant

This is the first book of its kind that describes the use of Ansys® finite element analysis (FEA) software, and MATLAB® engineering programming software to solve acoustic problems. It covers simple text book problems, such as determining the natural frequencies of a duct, to progressively more complex problems that can only be solved using FEA software, such as acoustic absorption and fluid-structure-interaction. It also presents benchmark cases that can be used as starting points for analysis. There are practical hints too for using ANSYS software. The material describes how to solve numerous problems theoretically, and how to obtain solutions from the theory using MATLAB engineering software, as well as analyzing the same problem using ANSYS Workbench and ANSYS Mechanical APDL.

The source code for MATLAB scripts and ANSYS models, which provide readers with valuable tools for doing their own validations are available for download at http://www.mecheng.adelaide.edu.au/avc/software. **Acoustic Analyses Using MATLAB® and ANSYS®** can be used as a textbook for graduate students in acoustics, vibration, and related areas in engineering; undergraduates in mechanical and electrical engineering; and as an authoritative reference for industry professionals.

Dr. Carl Howard is a lecturer at the University of Adelaide. He has been a consultant with Vipac Engineers and Scientists, Worley, and Colin Gordon and Associates, and also worked at United Technologies Research Center.

Dr. Ben Cazzolato is an associate professor at the University of Adelaide. He has over two decades' experience as an acoustic consultant and academic researcher.

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Foreword

Although ANSYS Mechanical has supported acoustic and vibroacoustic analyses for more than two decades, it was not until relatively recently that the demand for performing these simulations has grown appreciably. Over the past several years, noise considerations for rotating machinery, passenger comfort in vehicles, and acoustic performance of tablets and other ubiquitous electronic devices have taken a more dominant role in their respective design processes. These, of course, are but a few examples out of many applications where the engineer must now consider the acoustic response along with traditional structural and thermal simulations in evaluating product design.

Development of the acoustic capabilities in ANSYS Mechanical has been driven by customer feedback and requirements, and the fruit of these efforts have enabled analysts to solve challenging problems in ANSYS Workbench in a fraction of the time historically needed. That being said, however, for many engineers, acoustics may be a new field to them; conversely, acousticians may not be familiar with how certain concepts are implemented in a finite element software program.

This book provides an in-depth and practical guide on performing acoustic and vibroacoustic simulations using ANSYS Mechanical. For the engineer with limited background in acoustics, this text serves as an excellent companion to other books that cover acoustic fundamentals; the numerous examples provide many opportunities for the reader to relate finite element results with theory and learn best practices along the way. For the acoustician, the explanations focused on numerical methods as well as the comparisons with MATLAB results are illuminating, and the step-by-step instructions are invaluable for readers new to ANSYS Workbench.

It is a pleasure for me to write the introduction to this book, and I am certain it will have a wide appeal in both academic and industrial circles. Carl Howard and Ben Cazzolato have produced a well-written and practical reference that will help the reader enter the exciting world of acoustical numerical simulation.

Sheldon Imaoka
Principal Engineer
ANSYS, Inc.

Preface

The use of finite element analysis (FEA) to solve acoustic problems has enabled investigation of complex situations that would otherwise be too cumbersome or time consuming to solve using analytical methods. Many analytical methods are only suitable for solving regular-shaped objects such as ducts, hard-walled rectangular cavities, and so on.

Although finite element analysis can be used to solve complex problems, there is a steep learning curve for practitioners. One must have a good grasp of the science of acoustics. They must understand many concepts and limitations of finite element analysis. Even if they have all this knowledge, they must also know the nuances of a particular finite element analysis software package and its particular quirks. Lastly, if a practitioner has been able to calculate answers using finite element analysis, they need to have a sense of whether the answers predicted by the software are reasonable. The Garbage-In-Garbage-Out (GIGO) principle applies as it is easy to generate misleading results.

The contents of this book attempt to address only the last few of these hurdles: "how to drive" the ANSYS® finite element analysis software to solve a variety of acoustic problems. The fundamentals and applications of acoustics are covered in many other textbooks and are not the focus of this book. As for training in finite element analysis, many books are written by mathematicians or academics and their target audience seems to be for other mathematicians or academics. These books contain derivations of shape functions for various finite elements and the nuts-and-bolts of various matrix inversion algorithms so that someone with a lot of time on their hands can create their own finite element software. Whilst these are important topics, a practicing engineer has no spare time and is not going to create his or her own finite element software. Instead, an engineer wants a short sharp bullet list of instructions to get the job done.

We are both mechanical engineers and our backgrounds are in consulting engineering, academic research, and university training of students to become professional engineers. This book contains examples with flavors from these arenas. The goal was to provide instruction in solving acoustic problems starting with simple systems such as a duct, and then progressively more involved problems such as acoustic absorption and fluid–structure interaction. The theory of the acoustic problem is presented and then implemented in MATLAB® code, which is included with this book. An ANSYS finite element model of the problem is described and the completed models are included with this book. The combination of these three aspects provides the practitioner with

benchmark cases that can be used as starting points for the analysis of their own acoustic problems.

At times a reader might find the instructions in this book to be verbose or repetitive. Although this might irritate some readers, it is better to provide detailed instructions rather than frustrate a new analyst, or someone that has started halfway through the book. We have tried to avoid using expressions such as "clearly," or "it is obvious," as what might be obvious for some readers is baffling to another and instead provide detailed instructions and comprehensive explanations.

The release of the ACT Acoustics extension for ANSYS Workbench has made the use of the software significantly easier for a new analyst to solve acoustic problems. The extension is essentially a toolbar that enables the user to select the relevant acoustic feature that he or she wants to include in the analysis, such as an acoustic mass source, an absorbing boundary, and so on.

We trust that you will find this book a useful resource for learning how to conduct acoustic analyses using ANSYS and MATLAB® and will enable you to solve your own acoustic problems.

Carl Howard and Ben Cazzolato
Adelaide

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