This is followed by a rationale for ILES with a mathematical justification of non-oscillatory finite volume methods. It is emphasised how numerical methods should be built upon a physical understanding and modified equation analysis is used to show that the numerical methods create an 'implicit subgrid stress' that have similar properties to more traditional explicit subgrid-scale models.

The following section delves into considerable detail describing several classes of numerical methods used for ILES including high order total variation diminishing schemes, the piecewise parabolic method and vorticity confinement (VC). Strangely, at the beginning of the section there is a chapter from Pierre Sagaut on explicit subgrid-scale modelling that only refers to implicit LES in a single sentence near the end. Whilst this chapter is an excellent summary of the traditional LES approach, the reader is left confused as to why it is included at this point and how it relates to the rest of the material in the book.

The book is structured so that validation and verification of the numerical methods is placed into the following major section rather than accompanying their descriptions. However, within two of the numerics chapters, results are shown for the Taylor-Green Vortex test case, which should really be within the validation and verification section. Most of the validation and verification cases are on problems that use simple Cartesian meshes with no wall boundaries (such as the decay of turbulence) – it is only well over halfway through the book that wall-bounded flows are treated! The two chapters on incompressible wall-bounded flows and compressible turbulent shear flows are particularly good in that they lead through from simple cases – such as channel flows – to calculations around ship hulls and supersonic base flows from projectiles.

The final section covers 'frontier flows' – which includes geophysics, turbulent stellar convection, complex engineering flows and simulation of contaminant transport in urban environments. For many readers who may be a specialist in only one of these fields, the other areas may be new and interesting. The book concludes with a chapter on the future outlook for ILES and issues to be tackled. This is particularly useful as it pulls together lessons learned throughout this large piece of work.

For those that are already active in the research field of large eddy simulation, they may already have much of the material in the form of journal and conference publications from the book's many contributors. The book is probably most useful to those commencing doctoral studies as it brings together authoritative material into a single, albeit weighty, volume.

The main criticism of the book would be that there seems little link across the different strands of numerical methods and their associated validation flows – each is essentially self contained with little comparison in common test cases or how the numerical methods compare to each other. This is probably inevitable with multiple contributors.

In terms of the aim of the book to promote acceptance of ILES within the turbulence modelling community, I feel that it is only partially successful: the analysis of the numerical methods clearly justify that the design of subgrid scale models and numerical methods is closely linked and cannot be considered independently, but few ILES predictions have been shown for wall-bounded and complex geometry problems and in many cases where a comparison has been made between traditional LES with an explicit model and the ILES approach there seems to be no advantage in accuracy for the latter.

**Dr G.J. Page**

## A Practical Guide to Reliable Finite Element Modelling

## A. Morris and A. Rahman

*John Wiley and Sons, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK. 2008. 364pp. Illustrated. £85. ISBN 978-0-470-01832-3.*

This textbook attempts to answer 'how can an error controlled finite element analysis be performed' and it achieves this goal. The book is not a standard finite element method textbook that can be used to provide all the information required in obtaining a well-grounded understanding covering all aspects of the finite element method – nor is it intended that way. As the book's title implies, the emphasis is on 'reliable' finite element modelling and this can be achieved with the error-controlled procedures outlined.

A lot can go wrong in a finite element analysis. The book takes the reader through a methodology that can provide a set of procedures or processes that allow error and uncertainty sources to be identified and their influence quantified such that accurate and reliable analysis results are obtained.

Chapter 1 provides a useful book overview for easy chapter referral. The following three chapters are concerned with the basics (both static and dynamic) of the finite element method focusing on how a computer goes about setting up and solving finite element analysis problems and emphasising the convergent nature of the process. The entire process, starting with the derivation of the individual element stiffness matrix through solution of problem at global level is covered. Topics such as condensation and sub-structuring are also addressed. The use of simple checks that assist the analyst in establishing a robust solution are highlighted.

These introductory chapters provide a good background to the finite element method though the essence of the book is contained in Chapters 5 through 10. Chapter 5 introduces the reader to some of the likely causes of error that can be encountered in a finite element analysis. It introduces an overall qualification process and the need for an analysis validation plan. The latter allowing the analyst to draw conclusions on the validity of the analysis and make judgements on the quality of the final results.

Chapter 6 provides simple rules and guidance to assist an analyst in the selection of appropriate elements and mesh layouts. The chapter opens with a discussion on using simple rules to work out what a particular element can deliver in terms of stress output which can then be linked to the required level of accuracy. Meshing issues relating to element shape distortions and element grading are discussed.

Chapter 7 covers the range of error types and error sources that can occur in the various stages of a finite element analysis. Many of the error types and sources are attributed to the presence of uncertainties in the problem definition or model data. The chapter explains the nature of the error sources, their potential influence on the results and points to ways that these can be identified so that they can be controlled and treated.

Chapter 8 describes the process of controlling error through a hierarchical methodology starting with engineering formulae and ending with sophisticated numerical methods. The use of different mathematical models or levels of abstraction to control errors are described. This is followed by a detailed consideration of sensitivity methods. The chapter lays the foundation for creating a methodology, termed FEMEC (finite element method error control), which can be used as the basis of a quality control methodology.

Chapter 9 describes in detail the multi-level and multi-stage analysis procedure (FEMEC) that allows potential error and uncertainty sources latent within a finite element analysis to be identified and their magnitude assessed and bounded. The chapter discusses the requirement for the construction of a quality report which provides the basis for establishing that an analysis has been performed to an adequate standard. A well illustrated FEMEC case study/walkthrough example is presented in Chapter 10.

The book is highly recommended for all engineering students, researchers and practicing engineers involved in developing/utilising finite element techniques. I have confidence that even an experienced analyst would benefit from a review of this material!

**Dr S. Thompson, CEng, MRAeS**

## Modeling and Simulation of Aerospace Vehicle Dynamics – Second edition

### P.H. Zipfel

*American Institute of Aeronautics and Astronautics, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344, USA. 2007. 567pp. Illustrated. $64.95 (AIAA Members), $94.95 (Non-Members). ISBN 1-56347-875-7.*

This book undoubtedly fills a niche in the flight mechanics literature – no mean feat, given the number of texts addressing this topic. It achieves this by taking a unique approach to the mathematical modeling of aerospace vehicle dynamics, namely by the use of tensors. The standard vector approach, adopted in the majority of books, is simpler for most engineering students and practitioners to understand but becomes complex when developed into a form used to represent aerospace vehicles. This is due to the time-dependent coordinate transformations inherent in this approach when applied to systems such as spacecraft and helicopters with rotating reference frames. Zipfel derives the kinematic and dynamic equations using cartesian tensors, the physical content of which are invariant under coordinate transformations. The equations are therefore defined for all allowable coordinate systems. For analysis and simulation, the tensor form is converted into matrices by introducing appropriate coordinate systems.

Zipfel's work is essentially in three parts: the two parts of the book itself, plus a comprehensive FORTAN-based software suite known as CADAC (Computer Aided Design of Aerospace Concepts). The latter was used to generate examples in the text and is described in Appendix B; it may be requested by those who purchase the book. Whereas Appendix C in the first edition described the FORTRAN simulations, in the 2nd edition this appendix presents a self-taught lesson plan using three separately-available CD's with simulations in C++. The other principal difference from the first edition is Appendix D giving the theoretical basis of tensor flight dynamics.

Part 1 of the book deals with modeling of flight dynamics. It follows a rigorous and logical path from various mathematical concepts, frames and coordinate systems to kinematics and dynamics and ultimately the perturbation equations. Careful and well-written explanations are given throughout, with special attention focused on the two essential elements of the coordinate-invariant tensor approach – namely the rotation tensor and the rotational time derivative. This part of the book is generic in nature and therefore valuable to any flight dynamicist wishing to develop models for real-world problems.

The approach is opposite to that of most texts aimed at giving an undergraduate-level introduction to flight dynamics modeling: the author's background in missiles and hypersonic vehicles mean that standard simplifying assumptions are often avoided in favour of a generalised approach facilitating dynamics of high-speed manoeuvring vehicles and spacecraft as well as more conventional aeronautical applications. Tools such as quaternions are introduced, along with numerous coordinate systems. The ease of use of the modeling tools is demonstrated via a range of diverse sample problems such as satellite positioning, turbojet spooling, missile-target-ground relative velocities, moments of inertia of a tilt-rotor aircraft, dual-spin spacecraft, gyrodynamics of flywheels, etc. These sustain the physical relevance of the subject matter as the reader negotiates the mathematical formulations.

The book sticks to the subject matter promised in its title and purposefully omits many topics covered in basic flight mechanics texts such as control mechanisms and trim devices, static and manoeuvring stability, dynamic stability and modes of motion for conventional aircraft, handling qualities and principles of feedback control. These should be regarded as prerequisite knowledge for effective use of the book.

Part 2 deals with simulation of aerospace vehicles, again in a comprehensive manner. It is broken down into three degree-of-freedom (DOF), pseudo-5DOF and 6DOF simulations, each supported by examples in the CADAC software. It should be noted that the majority of these computer-based examples are missiles, rockets and hypersonic vehicles (there is one F-16 aircraft example). It is in this part of the book that detailed discussions on trimming, numerous types of autopilots, navigation and guidance systems, various sensors and actuators are given. Monte Carlo analysis is introduced, as are the topics of winds and turbulence. The final chapter provides background on real-time applications: various simulators (including integration of missiles to combat simulations), hardware-in-the-loop facilities and war gaming.

The CADAC software has a long heritage, having been initiated in the 1960s. Like the book, this is not your usual undergraduate introductory software: it is more akin to computer programmes developed for industry and is not as intuitive as less experienced users may hope: it requires some familiarity with Fortran77 and – other than the plotting – is not driven by graphic user interfaces. However, it provides a versatile environment for development of general purpose simulations. Its functionality includes state variable integration, 'sweep' runs, stochastic noise sources and Monte Carlo analysis, weather inputs, management of input and output, post-processing analysis and graphical displays and the facility to produce code to run in real time. It is also well documented.

In summary, this is a most valuable book in an era in which flight dynamics is largely computational in nature. It addresses a wide array of topics that can be very helpful to practising engineers in ensuring that their modeling properly accounts for complex dynamics and that their analysis is efficiently carried out. It is also valuable in bridging the gap between the usual simplified textbook approaches to flight mechanics and more complex modeling. Some will be put off by having to learn tensor dynamics but for experienced practitioners this is not essential: it is Part 2 – and the software – from which they will derive most benefit. It is an essential resource for those working on applications involving missiles, rockets and spacecraft since there are few other texts that deal with these aspects of flight dynamics in such detail.

**Dr Mark Lowenberg**