Book Reviews

Aerodynamics of Low Reynolds Number Flyers

W. Shyy *et al*

Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, UK. 2008. 193pp. £52. ISBN 978-0-521-88278-1.

Despite the great advances made in manned flight over the last century, flight in nature has been little understood and even less studied due to overbearing demand for 'large' aircraft. Recent interest in unmanned air vehicles, particularly micro air vehicles (MAVs), has somewhat changed the landscape and rejuvenated interest in this specialised area of aerodynamics. There is a heightened appetite for biomimicry and significant research effort has been dedicated to understanding the flow physics at this scale. Birds and insects operate at this end of the aerodynamic scale – the so-called low Reynolds numbers – and this forms the basis of this book by Shyy *et al*.

After some brief introductory material on aerodynamic scaling and power implications, the authors divide the rest of the book into three sections in which the aerodynamics of rigid fixed wings, flexible wings and flapping wings is each considered in turn. The discussion in each section logically leads on to the next and the middle of the book is populated with several coloured plates aiding these discussions and results.

The section on rigid fixed wings is in effect a lesson in computational fluid dynamics (CFD), revealing the computational background of some of the authors. The theories of laminar, transitional and turbulent flow are described with recourse to the governing equations and turbulence models. A good discussion on the effects of Reynolds number and wing section shapes is presented with some interesting work on 3D aerodynamics and endplates and their effects on fixed-wing MAVs also included. The section on flexible wings is brief and predominantly qualitative, reflecting the little work done in this area thus far.

Aeroelasticity, membrane models and computational fluid-structure dynamics are touched upon with a few results shown.

Flapping-wing aerodynamics is accorded by far the largest portion of the book. Simplified aerodynamic models for flapping flight are reviewed as are various lift-enhancing mechanisms found in insect and bird flight. The all-important leading-edge vortex has its own dedicated section. Results from CFD and flow visualisation studies are used to elucidate some of the aerodynamic principles in this flow regime. Unsteady aerodynamics and its effects are examined in detail and the discussion gives special attention to wing kinematics and the time-varying nature of the forces and moments. Although the discussion here is also mainly qualitative, the inclusion of various computational and experimental studies and aerodynamic models, gives comprehensive coverage of the subject area. The work presented encompasses a wide array of research activity, led principally by aerodynamicists and biologists/zoologists.

The overall feel of the book is that of a review although it goes further. It brings together most of the contemporary work on the low-Reynolds number aerodynamics of insects, birds and MAV-scale flyers nicely into one concise volume. The book goes to varying levels of technical detail so as to cater for aerodynamicists and other enthusiasts alike. Most of the material is descriptive and will appeal to a wide readership. The prose is clear and over 150 figures make the subject content easier to follow. The discussion on flexible-wing aerodynamics is a bit wanting but this is probably a reflection of the current state of the art. To their credit, the authors fill some of this gap with results from some of their own work.

In summary, this book makes for a great reference and every library must have a copy.

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Fundamentals of Aircraft and Airship Design: Vol 1 – Aircraft Design

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American Institute of Aeronautics and Astronautics, 1801 Alexander Bell Drive, Suite 500, Reston, VA, 20191-4344, USA. 2010. Distributed by Transatlantic Publishers Group, Unit 242, 235 Earls Court Road, London, SW5 9FE, UK. (Tel: 020-7373 2515; e-mail: richard@tpgltd.co.uk 907pp. Illustrated. £80. (10% discount available to RAeS members on request). ISBN 978-1-60086-751-4.

Although the text will eventually be in two volumes, this Volume 1 is self-contained and addresses the conceptual design phase of fixed-wing aircraft. It is an update and expansion of Leland Nicolai's 1975 book *Fundamentals of Aircraft Design*, a title that could still apply. This book, published in the AIAA Education Series, feels fully up to date.

Both the authors work at the Lockheed Martin Skunk Works which is reflected in the material and many of the examples. Much attention is given to the design of supersonic aircraft and to very high altitude aircraft, both powered with air-breathing engines and solar energy. None of this, however, is at the expense of the rest of the spectrum of aircraft types; airliners, general aviation and light aircraft, human-powered aircraft, low-level missiles and other UAVs. The layout of the book is based on a single major iteration of the conceptual design process.

Characteristics to be noted are that the book does indeed address fundamentals and that it is remarkably thorough. The reader can use the sections within chapters as a checklist of the many aspects that may be considered during the conceptual phase. The book addresses each of them, the very few exceptions being excused for good or practical reasons and invariably with good pointers on how to proceed. So this book is immediately a valuable and self-contained source of formulae and data enabling the designer to evaluate each aspect of a new design. Many of the methods are based on traditional analyses that have been developed over many years, the authors citing their preferred references from the literature. They give the key formulae with supporting data, either in tables or graphs. Where such methods are not available or are unnecessarily complex for the conceptual phase, the authors have used regression analysis on a wide range of successful designs to give practical formulae distilling industry experience. At each step the advice is succinct and practical and enables the designer to evaluate. From one of the chapter heading quotations:- 'Engineering is done with numbers. Analysis without numbers is only an opinion'.

The authors clearly identify assumptions being made and explain the significance and limitations of each piece of

https://doi.org/10.1017/S0001924000005388 Published online by Cambridge University Press

analysis. Methods are deliberately chosen to be appropriate for the level of precision practical in the conceptual phase. For instance, at the start of the chapter on wing-body aerodynamics, it is pointed out that in industry today the design would be handed over for CFD analysis. Here, in the spirit of the text, they provide the reader with well-respected methods selected from the publications of the (US) Air Force Flight Dynamics Laboratory, NACA and NASA. Again, in a cost estimating example the authors advise that a value within 22% is considered quite close.

Examples of some of the more unusual topics included in the book are methods of evaluating aerodynamic heating of the airframe above M2.0, the new chapter on stealth, sections on powered high-lift devices for V/STOL, the design and sizing of supersonic engine intakes and an introduction to the graphics (carpet plots and knotholes) used in displaying the results of trade studies.

The authors' style is brief, succinct and to the point which results in a very rich text. The publication is excellent. Presentation, using half tones, is clear and easy to follow. Drawings and charts are clear. A block of 24 colour plates is included at the back of the book. There is also an ample scattering of side notes and comments which adds to the pleasure of browsing. The few shortcomings are small and trivial in comparison with the wealth of useful material presented.

I can't recommend this book strongly enough. It is well-written and rich with information. Although the authors have aimed it at 'upper-level undergraduate and graduate students as well as at practicing engineers', I feel that many will find it gives valuable insights into the designs of the full range of fixed-wing aircraft and shows why they are the shapes they are. This is a book to be enjoyed and returned to. It should prove a valuable reference source.

Footnote regarding Volume 2. This is not yet in print; the authors anticipate publication in Spring 2012. The text will concentrate on lighter-than-air craft. The significance of this may be apparent from a quick reflection on recent Lockheed Martin activity in this area, both on hybrid airships for heavy-lift and the ISIS programme to put surveillance airships into the stratosphere. What will be of special interest to readers of this review is that the volume will also contain a number of case studies of fixed wing aircraft including; Boeing 777, F-35B Joint Strike Fighter, T46A primary jet trainer, SR-71 Blackbird, Cessna 172 Skyhawk and the Daedalus human-powered aircraft that flew across the Sea of Crete.

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What Every Engineer Should Know About Computational Techniques of Finite Element Analysis – Second edition

L. Komzsik

CRC Press, Taylor and Francis Group, 2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN. UK, 2009. 331pp. Illustrated. £54.99. ISBN 978-1-4398-0294-6.

This book is an authoritative and valuable addition to the literature on the subject. It offers an insider's view of the mathematical formulation underpinning NASTRAN, still regarded by many as the leading finite element code worldwide. I cannot determine whether the initial line of the title 'What every engineer should know about…' is written in hope or is simply 'tongue in cheek'. In that respect it may be regarded as probable as 'What every driver should know about the thermal cycles of the internal combustion engine' – much as one may like it to be otherwise, it just isn't going to happen.

That said, the book offers a clear development of the mathematics underpinning the coding of a finite element system. Whilst mathematical sophistication, such as the use of Banach or Hilbert spaces is avoided, the reader will still need to be comfortable reading through matrix algebra on virtually every page.

Part 1 of the book on Numerical Model Generation is unexceptional. It briefly mentions Ritz and variational methods before homing in on Galerkin's method that dominates the derivation of finite elements. Unusually in an FE book, the author also introduces CAD geometric concepts from Bezier splines to NURBS objects before moving to topics such as Delaunay tessellation. Many of the theoretical developments are supported by, or even made in the context of, simple examples.

For me, much of the interest of the book lies in Part 2 - Computational Reduction Techniques. Here one gets to look 'under the bonnet' and gain understanding of how sparse matrix techniques as multi-frontal factorization work and produce benefit in terms of computational efficiency. There are also chapters describing spectral computations and dynamic reduction.

The story is completed in Part 3 of the book with derivation and description of some of the more arcane solution sequences and the representation of the computed results.

Whether one regards the book as a fascinating read or a reference book of last resort will depend on the mathematical upbringing of the reader, though in either case the book earns its space on the shelf.

Peter Bartholomew MSc, DPhil,

Rocket and Spacecraft Propulsion: Principles, Practice and New Developments – Third edition

M. J. L. Turner

Springer-Verlag, Tiergartenstrasse 17, D-69121 Heidelberg, Germany. 2009. 414pp. Illustrated. £89.99, ISBN 978-3-540-69202-7.

Rocket Propulsion Elements – Eighth edition

G. P. Sutton and O. Biblarz

John Wiley and Sons, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK, 2010. 768pp. Illustrated. £90. ISBN 978-0-470-08024-5.

Introduction to Rocket Science and Engineering

T. S. Taylor

CRC Press, 2 Park Square, Milton Park; Abingdon, Oxon, OX14 4RN, UK. 2009.

https://doi.org/10.1017/S0001924000005388 Published online by Cambridge University Press