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REVIEWS

A Modern Course in Aeroelasticity. By E. H. Dowell, H. C. Curtis & R. H. Scanlan. Sijthoff & Noordhoff, 1978. 464 pp.

In common with many engineering disciplines, aeroelasticity is both an art and a science. The would-be adherent of a strictly scientific (wholly mathematical) approach in this field must be made aware of the fact that the practical aeroelastician might consider he was doing very well if his predictions were within fifteen percent of the physical reality! Uncertainties in both aerodynamic and structural representations, the former perhaps more so than the latter in the majority of cases, are compounded to an extent that may be assessed only by an experience practitioner, and then only qualitatively. That the book reflects the above views, at least in part, is hardly surprising in view of the vast experience of its eminent authors.

Again, aeroelasticity is an international discipline, but there are strong national demarcations in its treatment, largely of historic origin. While it would certainly be unfair to label the contents of this book 'American Aero-elasticity', and while, perhaps, one should play down historical aspects in view of the appearance of the word 'Modern' in its title, the British reader will find it irksome that the pioneering work of Glauert, Frazer, Duncan, Collar and others does not receive as much as a mention. Indeed, Glauert and Frazer do not have the distinction of appearing in the Author Index, whilst Collar's name appears on page 1 (Aeroelastic Triangle) and nowhere else! What is more important, omission of any consideration of this early UK work has led, possibly, to what the reviewer considers to be a 'concept gap' in the authors' treatment of flutter and subcritical response; a matter which will be discussed later.

Following a two-page introduction (chapter 1), chapter 2 is devoted to Static Aeroelasticity. The treatment of the 'typical section', outlining the phenomena of divergence and reversal, is admirably clear and ideally suited to the 'raw' undergraduate reader, as indeed are the sections on the one-dimensional wing. It is regrettable that Galerkin's method is used (p. 20) without explanation: the student reader might rightly ask 'what is Galerkin's method and at what stage is it being applied?' Notation here, and indeed throughout the book, is clear but very clumsy e.g. C_{MAC} instead of C_{mo} and $\partial C_L/\partial(pl/U)$ instead of, say, C_{L_p}.

The reviewer feels that chapter 3, entitled, 'Dynamic Aeroelasticity', is the most disappointing feature of the book. Basic objectives seem to be confused and strongly related topics are treated piecemeal under different section headings. Sections 3.1 and 3.2 contain a sparse, but adequate, derivation of Hamilton's principle and from its Lagrange's equations. (Generalized co-ordinates are defined without mention of 'constraint', and in equation 3.2.2, the choice of q_i such that $U = U(q_i, \dot{q}_i, t)$ is surely obscure!) Sections 3.3–3.6 relate to h, α dynamics of the 'typical section'. Response calculation methods are considered first, and for simplicity of mathematical exposition, L and M are assumed (unrealistically) to be prescribed functions of time. Flutter of the 'undamped' variety is next considered by using the approximations $L \propto \alpha$, $M \propto L$, this initial treatment being (slightly) broadened to 'damped' flutter subsequently by replacement of α by $\alpha + \dot{h}/U$. From a teaching standpoint, the

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reviewer's experience is that it is unwise to introduce classical flutter via undamped theory, for not only does this theory fail to represent some types of flutter, it can also lead to the anomaly of 'zero speed flutter'. The authors appear to deem discriminant methods inappropriate in their modern text, and in consequence, physical feel for the important parameters is lost.

A useful résumé of the subject of aerodynamic actions on an oscillating aerofoil is presented in § 3.4, this being particularly good from the viewpoint of physical understanding and provision of background for the detailed aerodynamic analysis of chapter 4. The authors turn, in § 3.5, to general solution methods for the equations of motion, covering time and frequency domain techniques for the non-autonomous case and the $V-g$ method for the autonomous (flutter) case. The discussion of flutter preventives which follows is a little hollow, since detail tends to be obscured by the 'aerodynamic black box' approach and considerations of space do not allow the supporting parameter sensitivity information to be presented. Section 3.7 harks back to §§ 3.1 and 3.2, being devoted to 'generalized equations of motion for complex structures', in particular a planar representation of a complete aircraft. Finally § 3.8 deals with 'non airfoil physical problems'.

Chapter 4 deals with 'non-steady aerodynamics of lifting and non-lifting surfaces'. This is the culmination of the 'general' part of the book and almost certainly offers more in this important field than any previous textbook on aeroelasticity. Section 4.1 deals with the basic fluid dynamic equations for general isentropic inviscid flows, these being developed in terms of the velocity potential and linearized in the usual manner. Section 4.2 deals with supersonic flows. The Laplace transform solution of the linearized equations of motion is outlined for the two-dimensional case. The case of non-uniform flow (gusts) is also considered, as is transient motion of the aerofoil. Three-dimensional flow is then studied and the basis of the Mach-box method explained. Section 4.3 concerns subsonic flows (kernal function method). Incompressible two-dimensional flow (Theodorsen) is then studied and forces associated with aerofoil SHM, step input and sharp-edged gust encounters derived. Some 'representative results' are presented in § 4.4. A valuable appraisal of the transonic flow problem is given in § 4.5 based on the first author's 'rational approximate method' which is broadly related to the local linearization technique. This section concludes with a brief appraisal of recent transonic flow calculations (finite differences/elements) and experimental work, supported by an excellent bibliography.

Chapter 5 is devoted to 'Stall Flutter'. The sense in which this term is used is the broad one, implying instability, essentially in a single degree of freedom, associated in some way with separated flows. Thus, for example, the galloping of an overhead cable is classified (somewhat misleadingly in the reviewer's opinion) as a case of stall flutter. The mathematical treatment, indeed, is along the simple lines of that adopted in galloping studies, namely C_F and C_M are expanded in polynomial series of incidence and $WD/$cycle (or power) evaluated in order to assess instabilities of the 'soft' and 'hard' types. Hysteresis effects which give rise to aerofoil stall flutter appear to be considered only summarily and in a qualitative manner.

Chapter 6 concerns 'aeroelastic problems of civil engineering structures', and comprises a well-illustrated review of the major constituent phenomena in this area. Divergence is exemplified for the case of a bridge deck, although the treatment obviously extends to other cases. Galloping is defined very broadly indeed, embracing practically all low-frequency instability modes of elongated bluff bodies. Standard cross-wind galloping is first described leading to the den Hartog criterion and its non-linear extension. 'Wake galloping' (a term with which the reviewer strongly disagrees) is then introduced in relation to the 'subspan oscillation' problem on multi-conductor overhead lines. The question of classification here goes awry (as it possibly does in the previous chapter) because of the desire to group phenomena on grounds of flow types, frequency and whether or not the forces are autonomous, rather than to group them according to the conservativeness or nonconservativeness of the force fields and whether one or more degrees of freedom are required to sustain them. Section 6.3 is concerned with vortex shedding and means of suppressing the resulting oscillations, while in §6.4 flutter is discussed, mainly in relation to bridge decks. Buffeting theory for line-like structures is developed in §6.5, leading in the following section to practical formulae for bridge buffeting response.

In chapter 7, certain aeroelastic and other stability problems of rotorcraft are dealt with. The approach is essentially conceptual and the mathematics easy – being based on the simplest rotor-blade structural idealisations and aerodynamic strip theory. Initially, the flap and lag equations for a rigid articulated blade in the hover condition are formulated in simple Newtonian fashion. Pitch-lag coupling is discussed, pointing to the need for lag dampers. Flap-lag instability is discussed, and in this context on page 347, we have the first mention of Routh's criteria! Lag-flap-pitch coupling is also briefly treated. A section on retreating blade stall flutter follows and unfortunately there is no attempt to 'tie in' with chapter 5. The remainder of the chapter is devoted to blade motion/body coupling. Here, there is rather too much emphasis on ground resonance than befits a text on aeroelasticity, although there is mention of air resonance. On the positive side, the chapter is distinguished by excellent diagrams of superb clarity.

The final chapter provides an introduction to aeroelastic problems in turbomachinery. The compressor performance map is used to define the aerodynamic operating conditions of the blades. Blade mode shapes and construction materials are then discussed, along with a call for more precise structural damping information. There follows a terse mathematical section on non-steady, incompressible potential flow in cascades, pointing ultimately to the added difficulties as compared with the case of an isolated aerofoil. The compressible flow case is then discussed, along with the important topic of acoustic resonances. The chapter ends with brief outlines of periodic stealing phenomena, stall flutter, choking flutter and supersonic torsion and bending flutters. Unfortunately, the bibliography is not sufficiently extensive. There are two useful appendices comprising worked examples relating to chapters 2–4.

It will be clear that the reviewer has certain reservations associated with the treatment of flutter and subcritical response (chapter 3). In divesting themselves of classical aeroelasticity and its discriminant methods, the authors have failed to cover in depth such important matters as salient parameter effects on flutter and vital degrees of freedom. Modern industry, while continuing to cry out for more erudite lifting surface theories inevitably involving larger matrices and thus requiring more streamlined computing techniques, cries out more loudly for better understanding of the underlying mechanisms: e.g. what are the two, or perhaps three, degrees of freedom which are principally responsible for this particular flutter, and which parameters should we vary in order optimally to raise the flutter speed? The answers to these questions are not to be found in this book, but rather in the very early papers or developments of the techniques therein. This is the 'concept gap' referred to earlier.

A. SIMPSON

Classical Aerodynamic Theory. Compiled by ROBERT T. JONES. NASA Reference Publication no. 1050, 1979. 311 pp. $11.75 from National Technical Information Service, Springfield, Va 22161.

The motivation behind the publication of this collection is succinctly explained by the compiler: it puts together in a single volume some of the most important fundamental papers in the history of our subject, most of which display 'a degree of clarity unequalled in later interpretations', and which are, otherwise, no longer readily available to readers.

The earliest papers also have an interesting historical significance; they represent a service performed by the National Advisory Committee for Aeronautics for the benefit of American aeronautics: these were the remarkable developments achieved by the Prandtl school during World War I, virtually unknown in the U.S. in the early 1920s. NACA made them available, in English, in Technical Reports, Notes, and Memoranda.

What had occurred, especially in German, as all students of the subject know, was that – largely under the impact of interest in aviation – the mathematical treatment of fluid motion was brought out of the realm of elegant-but-useless theory and made a powerful and essential tool of engineering. This, of course, was the historic achievement of Ludwig Prandtl, who had already taken the biggest step in his boundary-layer theory of 1904. His NACA Technical Report no. 116 appropriately heads this collection. Here, in the master's own words, are all the basic ideas: Kelvin's and Helmholtz's theorems, irrotational flow and velocity potential, the Biot–Savart formula, use of singularities to represent solid bodies, stream function, circulation, Kutta–Joukowski theorem, the starting-vortex, trailing vortices and induced drag, and applications to airship bodies, monoplanes, biplanes and screw propellers. Both Munk's and Betz's optimum theories are summarized.

This is followed by a translation of the famous paper on the 'vortex-street' by von Kármán and Rubach: consideration of the *stabilities* of vortex configurations led to remarkable and practical conclusions about the drag of bodies! There follow two papers on the calculation and graphic construction of Joukowski profiles and their pressure distribution – a subject, it must be admitted, of very limited current interest.

Dr Max M. Munk, a brilliant Prandtl student, whose distinguished career as an NACA employee began in those early days, is represented in this compilation by four NACA Technical Reports. The first of these is his famous Göttingen dissertation on minimum induced drag, with an introduction added by him for the benefit of his American readers. Here is a classic case where the results are well known and eminently useful but most aerodynamicists have not actually read the original paper. The reason is pretty clear – namely that the original is difficult! 'General Multiplane Theory', as we have been taught it and have taught it, is such a beautiful subject, and not very

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difficult, that it is intriguing to explore the complexities of the original. Do they hide obscure jewels that we have missed, or did the clarity simply emerge as the years passed and the subject was better understood?

The same might be said of Munk's report on 'The Aerodynamic Forces on Airship Hulls'. The introductory discussion is very general but surely not a pedagogical landmark. Nevertheless, it led its author to his well-known approximation for elongated bodies, which has been so useful and can be imitated, to great advantage, in so many different areas of applied science.

The third Munk paper is his presentation of two-dimensional airfoil theory and Prandtl lifting-line theory. Here the author wanted to reach a non-mathematical audience, and therefore avoided, throughout, such concepts as *vortices* ('...which are not essential to the theory and better used only in papers intended for mathematicians and special experts'). He obtained his results by means of principles of momentum and energy, which, he thought, engineers understand better – a most doubtful conclusion according to this reviewer's observations. The report (besides containing most important results) therefore seems somewhat eccentric by today's standards, but a collector's item.

The report by Professor H. Bateman on 'The Inertia Coefficients of an Airship in a Frictionless Fluid' concerns the apparent mass and apparent inertia of certain bodies of revolution. It was obviously inspired by Munk's work and employs standard, powerful, mathematical techniques.

Two reports by A. F. Zahm follow. The first, the only experimental paper in this collection, presents results of tests carried out in an 8-foot wind tunnel at 40 m.p.h. on spheres, round and elliptic cylinders, spheroids, and a circular disk. Pressure distributions and forces are reported, together with theoretical calculations for inviscid and (in some cases) viscous flow. The second ('Flow and Force Equation for a Body Revolving in a Fluid') concerns the calculation of ideal-fluid flow about (and within!) bodies in plane, curvilinear, steady motion. The motivation must have been the aerodynamics of airships; the NACA report was a revision of a U.S. Navy publication.

A 1932 paper of A. Betz, translated and published by NACA as a Technical Memorandum ('Behavior of Vortex Systems'), has recently received considerable attention in the aeronautical world. This is Betz's study of the motion of vortices and vortex sheets, such as those behind a lifting wing, in the inviscid two-dimensional approximation. Seven intriguing theorems are proved, several of which clearly have impact on present-day research on the trailing-vortex problem in air-traffic, among other matters. The paper is lucid and convincing – truly a classic.

The volume closes with two famous papers of the 1930s, both carrying the name of T. Theodorsen. The first, with I. E. Garrick, is 'General Potential Theory of Arbitrary Wing Sections'. Here the theory by which an arbitrary wing profile is conformally transformed, by an iterative procedure, into a circle is presented. Its importance in aeronautics has been great; moreover, its mathematical significance – the proof that an arbitrary closed contour, with reasonable restrictions, can be so transformed by a convergent procedure – has been appreciated in mathematical literature in the intervening years. Readers will recall that the report presented, for the first time, what is apparently the best practical method to evaluate the famous, improper, definite integral of wing theory.

The last inclusion is Theodorsen's great paper on unsteady-airfoil theory and flutter. The reviewer has already commented (in 1938) on both the importance and the difficulty of this paper, and should not do so again. As in the Theodorsen–Garrick report, the attack is mathematical and straightforward; both reports have had tremendous significance upon aeronautical engineering and research, and are accomplishments of which NACA could be proud.

In summary, we are reminded, by Bob Jones, that NACA made important contributions to aeronautics and fluid mechanics by publishing fundamental studies. Jones has chosen the adjective 'classical' for the title of this collection; would it be impolite to suggest that this word means 'inviscid and incompressible' to him? Setting aside this possibility, we may ask whether NACA's successor, NASA, makes the same kind of contributions today. First, it must be said that the mathematical/scientific orientation of the industry that NASA addresses is quite different from that of the 1920s and 1930s; there is little demand for expository and tutelary efforts analogous to the earliest papers of this volume.

NACA's output was always a mixture of this stuff of fundamental engineering-science with very practical, configuration-oriented engineering data – one must obviously reject the adjective 'down-to-earth' – and a lot in between. They recognized their mission as 'to provide a technology base'. Happily, the same is still true of NASA, although some will argue about the proportions within the mix. Both NACA and NASA have provided the opportunity and the atmosphere where such persons as Robert T. Jones have been able to work, think, and write. As long as this is true, we are well served.

W. R. Sears

Shorter Notices

Oil on Troubled Waters. A Bibliography on the Effects of Surface-Active Films on Surface-Wave Motions. By John C. Scott. Multi-science publishing, London, 1979. 83 pp. £10.00.

The entries in the bibliography (over 300) are arranged chronologically, an author index being provided at the end. The entries for the earliest, and least accessible, publications include quotations from the source with translations if necessary; the entries for more recent publications give a summary of contents with occasional critical comments. The whole is introduced by a summary by the author of the present state of our knowledge.

Erythrocyte Mechanics and Blood Flow, Edited by Giles R. Cokelet, Herbert J. Meiselman and Donald E. Brooks. Kroc Foundation Series, Volume 13. Alan R. Liss Inc., New York, 1979. 285 pp. $30.00.

The ability of erythrocytes (red blood cells) to deform has long been recognized as an essential factor in blood circulation; their mechanical properties are crucial both to the passage of cells through the capillaries and to the viscosity of blood in bulk. This book constitutes the proceedings of a 1978 conference at which physiologists, biophysicists, rheologists and fluid dynamicists were brought together to examine the relationships between membrane structure, membrane deformability, whole cell mechanics and blood flow in vessels of various sizes. The result is an extremely well-balanced summary of the current state of knowledge, an excellent starting point for anyone becoming interested in the area. Readers of this journal will particularly appreciate the chapters on membrane thermodynamics and viscoelasticity, by Evans & Waugh and by Hochmuth, on measurements of blood rheology by Meiselman, on models of blood flow in narrow vessels by Skalak and in somewhat less narrow vessels by Goldsmith & Karino, and the marvellous piece of experimental detective work by Groom on the function of the spleen. The final chapter by Zweifach, pointing out that there is still a long way to go before our increasingly complete knowledge of the properties of a single cell can lead to any important new understanding of the living microcirculation, is a salutary reminder to all physical scientists in biology.

Urodynamics. By D. J. Griffiths. Medical Physics Handbooks 4. Adam Hilger Ltd., Bristol, 1979. 139 pp. £11.95 (hard-back).

Written for an audience of medical physicists and bio-engineers (student or practising), this book describes from a mechanical point of view the structure and function of the lower urinary tract: that is the bladder and the tube leading from it to the outside world, the urethra. The dynamical core of the book is a pair of chapters on the steady flow of liquids in collapsible tubes with non-uniform elastic properties, on the basis of which the author gives lucid explanations of many of the phenomena observed in clinical urology. Readers of the *Journal of Fluid Mechanics* will find the fluid dynamics a little laboured, but none the less interesting, and the book is recommended as providing a clear and useful introductory exposition of one of the less widely studied areas in physiological fluid dynamics.

Mechanics of Sound Generation in Flows. Edited by E. A. Müller. Springer 1979. 300 pp. DM. 68.

This volume comprises the five General Lectures and 33 Contributed Papers presented at the IUTAM/ICA/AIAA Symposium on 'The Mechanics of Sound Generation in, Flows', held in Göttingen, Germany, 28–31 August 1979. Papers all address basic problems in sound generation by flows of interest in aeronautics, concentrating on jets and on flow above airfoils and leaving aside the propagation of sound in ducts and the atmosphere. In addition to the now customary papers on large-scale orderly structure in the jet noise field there are some novelities, in particular 'Sound generation by head-on collision of two vortex rings' (experimental and theoretical) by T. Kambe and T. Murakami and the general lecture 'What good does industry expect from basic research in acoustics?' by R. J. Hill. The Symposium, with its emphasis on fundamentals of flow acoustics, was complementary to the series of AIAA Aeroacoustics Conferences, and the Editor and General Chairman, E.-A. Müller, and the publishers are to be congratulated on the prompt appearance of these Proceedings.

Cavitation and Inhomogeneities in Underwater Acoustics. Edited by W. Lauterborn. Proceedings of the 1st International Conference, Göttingen FRG, 9–11 July 1979. Springer Series in Electrophysics, volume 4. Springer, 1980. DM 62.

The 11 invited and 28 contributed papers in this volume are arranged in 5 groups:

(I) Cavitation (18 papers).
(II) Sound Waves and Bubbles (7).
(III) Bubble Spectrometry (6).
(IV) Particle Detection (1).
(V) Inhomogeneities in Ocean Acoustics (7).

Those in groups I, II and II give an excellent overview of the present state of understanding in cavitation, with emphasis on hydrodynamically or acoustically induced vacitation and dealing both with free and forced motion of individual bubbles and with shock and sound propagation through bubbly mixtures. High-speed photography has become a vital part of experimental studies in these fields, and the photographs in this book are well reproduced. Somewhat artificial at the present stage is the addition to this relatively homogeneous body of work of the single paper in IV on Project DUMAND (neutrino detection by an array of up to 10^7 acoustic sensors in the Pacific Ocean) and the collection in V dealing with linear acoustic propagation in inhomogeneous media and scattering by composition inhomogeneities (including bubbles, internal waves and turbulent fluctuations). Bubble spectrometry (III) is a means whereby some of the acoustic inhomogeneities in the ocean (V) may be identified, but elsewhere cavitation and underwater acoustic inhomogeneities have less in common, the former being an essentially nonlinear phenomenon, the latter essentially linear. This volume is, nevertheless, a very welcome addition to the underwater acoustic literature and contains much material of permanent value.