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# REVIEWS

**The Science of Aviation – A History.** By JOHN ACKROYD. 1984. Eleven video programmes, each 25–30 mins long, on VHS or Betamax (or, to order, on U matic) cassettes, with supplementary printed notes. £300 for the set on 6 cassettes, or £30 each for individual programmes, + VAT and postage from Manchester University Television Productions, Oxford Road, Manchester M13 9PL.

These tapes have two main subjects. In the foreground is a history of man's attempts to understand 'the way of an eagle in the air' and then to fly with the eagles himself, taken as far as the epoch-making achievements of the Wright brothers. That is accompanied by a substantial introduction to the incompressible fluid mechanics that is relevant to the aeronautical theme. In part, the fluid mechanics too is presented historically, but the history is filled out where appropriate with more recent advances, going beyond what was available to the Wright brothers into the Prandtl era and beyond. Looked at the other way round, the history of aviation provides a dramatic setting for some of the elements of a course in fluid mechanics.

The two histories together illustrate the interactions between science and invention, between applied mathematics and empiricism, between theory and experiment in one of the most exciting fields of human endeavour and enquiry (or perhaps, for those of us who enjoy our fluid mechanics to the full, in two of them).

The main purpose of this review is to give an opinion of the value of the tapes for teaching fluid mechanics.

The material is set out in a series of 11 programmes, each presented in 25 to 30 minutes of viewing time. Generous accompanying notes 'to assist teachers wishing to use the series in a class' provide some fortification of the fluid mechanics as well as a general synopsis of the contents of each programme. They also include a bibliography.

After a general introduction, the first two programmes deal with the study of fluid motion up to the time of Euler, and summarize the state of understanding of the basic principles at the end of the 18th century. There is little to be said about aviation in this period, of course; no time is wasted on Icarus and his imitators, but Leonardo's insight and practical ideas are given due credit. From the educational point of view, the fluid dynamics so far is mainly that of one-dimensional inviscid flow in ducts or in streamtubes, together with the general form of the dependence of forces on bodies in motion on their size, their relative velocity, and the fluid density. Bernoulli's theorem is stated, without proof. Newton's particle-deflection attempt at the force on an inclined plate is recorded because of its relevance to later efforts to estimate the lift of aerofoils. His ideas on viscosity are supplemented by an introductory explanation of the role of shear stresses in modern terms. The concept of the boundary layer is introduced in a preliminary way, partly to justify setting d'Alembert's paradox aside and pursuing the dynamics of an inviscid fluid. There is also some preliminary discussion of the flow about a lifting aerofoil and the aerodynamic loading on it, applying Bernoulli's equation and arguments about streamtube cross-sectional areas to a flow-pattern sketch.

The next two programmes are about experimental aerodynamics in the 18th and early 19th centuries, with applications to ballistics by Robins, to windmills by

Smeaton, (the first model tests), and especially by Cayley to his gliders, all using the whirling arm as their main tool for small-scale experiments. Cayley's contributions are recognized as landmarks in the history of aviation, in particular his realization that the way ahead lay with fixed-wing aircraft, his description of the force on a wing in terms of lift and drag components, and his observation that sustained steady flight would require power to overcome drag at a forward speed sufficient for lift to be generated equal to aircraft weight. His experiments on aerofoils and his remarkable successes with gliders are described.

The subject of Programmes 5 and 6 is specifically fluid dynamics, partly in terms of advances in the subject in the 19th and early 20th centuries and partly from a modern point of view. The main object here is to give the viewer a more complete understanding of the dynamics of a real fluid, with particular reference to drag in Programme 5 and to two-dimensional aerofoil lift in Programme 6.

The Reynolds number is introduced with the aid of Reynolds' celebrated demonstration of laminar and turbulent flow in a pipe, recreated in his original apparatus, which still exists in working order in Manchester! The uses of dimensionless statements such as $C_D = f(Re)$ are explained and illustrated to good effect. A more detailed treatment of boundary layers follows, including some quantitative results for laminar boundary layers and a good dicussion of boundary-layer separation. The account of aerofoil lift is based on $L = \rho V \Gamma$ and the Kutta–Joukowsky condition, with circulation introduced via the Magnus effect (the explanation of which is less complete than it could have been, but avoids the misleading statements often made about it in otherwise quite respectable places). The results of Kutta's and Joukowsky's investigations of lift are described, and the properties of aerofoil sections of various shapes are compared, including the primitive sections used by the aeronautical pioneers. The phenomenon of stalling is considered and is illustrated, like other matters in these tapes, by simple wind-tunnel demonstrations. Finite-wing theory and induced drag are not included. As a further indication of the level of the fluid mechanics, it may be noted that vorticity makes no formal appearance, nor does the solving of Laplace's equation.

In the remaining programmes we return to the history of aeronautics. Programmes 7, 8 and 9 are about the more important of the 19th century pioneers, between Cayley and the Wright brothers; Programmes 10 and 11 end the story with the work of the Wrights up to 1905. The associated advances in aerodynamics are shown to have been almost entirely empirical results of aerofoil tests carried out on whirling arms, in the natural wind, and from 1871 in simple wind tunnels. Aerofoil data were needed not only to design wings with more lift for less drag, but also to design more controllable aircraft, supplementing the flight tests. Longitudinal stability and control in particular depended on aerofoil-section characteristics in ways that were beyond satisfactory explanation at the time.

The aerofoil experiments of the period are recorded along with the more exciting account of progress in design and practical flying. The outstanding experimental work of the Lilienthals and the Wrights gets particular attention. The last programme gives a fascinating account of the Wright brothers' systematic approach to their goal, and of the many facets of their extraordinary accomplishment. It ends with their *Flyer III* capable of flying many miles and performing turning manoeuvres as required.

It is interesting here to observe the extent to which progress was influenced by communication of experimental data and flight experience, or lack of communication, and the perils, sometimes, of using other people's data.

The author suggests that these tapes would be useful material in connection with A-level mathematics and physics courses, and in connection with first-year undergraduate courses in engineering and the physical sciences, as well as being of more general interest to a wider audience, perhaps with Programmes 2, 5 and 6 omitted in that case. They will indeed be found useful at many levels, not least as a supplement to introductory courses in fluid mechanics. Students often find the subject difficult to get to grips with, partly because in the early stages they cannot easily understand how well it applies to the behaviour of real fluids. They are required to take a great deal on trust, and are more likely to succeed in acquiring a feel for the subject if they can be encouraged to go back, now and then, to think afresh about what they have been taught. An encounter with the aerodynamics of aircraft, attractively presented in a form specifically designed to reinforce a fluid-mechanics course, as here, could be invaluable to many students.

From this point of view, Programmes 5 and 6 are the core of the series. The general standard of the account given there of real fluid flows in relation to inviscid theory is rather good. It stands up to critical scrutiny better than that of many engineering textbooks designed to accompany introductory courses. There is less than I would have liked to see on differences between flows with laminar and with turbulent boundary layers as regards separation and its consequences. Perhaps that is not very important for the purposes in hand, and it can easily be made good on the foundations provided.

I did not find the material on aircraft longitudinal stability which forms a small part of Programmes 4 and 7 to 11 as satisfactory. It obviously deserves a place there, as an important topic in the history of aeronautics, but it does not seem to me to have been explained well enough to satisfy many of the wide range of likely viewers. For the stability concepts themselves, adding a reference to Irving's (1965) book to the accompanying notes could be useful. For the underlying aerodynamic properties of primitive aerofoil sections, a really satisfactory explanation would have required a short extra programme on the same lines as those on lift and drag – in which simple demonstrations with elementary models could have played a useful part. More practically, it would be worthwhile to add a page or so on the subject to the printed notes. (Aeromodellers in particular would probably be grateful for a clear explanation of the matter.)

With that exception (which is not central to the fluid mechanics anyway) I found the series well conceived and constructed. The presentation is lively and attractive, and the editing is very good technically.

Readers of this Journal may be familiar with an excellent semi-popular outline of aerodynamics in O. G. Sutton's† books: *The Science of Flight* published in 1949 as a paperback, and the later version published in 1965 with a new title, *Mastery of the Air*. Both are listed as recommended reading in the bibliography at the end of the printed notes. They have done excellent service for many years as supplementary reading for students of fluid mechanics, but are now out of print, alas. Their setting in the history of aviation, and the attention that they give to relating the contributions of theoreticians and practical men, make them attractive reading. To quote their author, aerodynamics is 'an exciting and alluring study, looked at against the background of human achievement and not merely as an exercise in logic'. This series of tapes is a worthy successor to Sir Graham's books, in a similar spirit; or perhaps, rather, a worthy complement, since each includes topics not to be found in the other.

† The distinguished meteorologist Sir Graham Sutton (not related to this reviewer!)

The tapes are much more expensive than a book, and it remains to consider whether they justify their price. It depends, of course, on how intensively they are employed if they are available. Shown as an accompaniment to a fluid-mechanics course slightly adapted to suit them, they should prove good value for money.

E. P. SUTTON

## REFERENCE

IRVING, F. G. 1965 *An Introduction to the Longitudinal Static Stability of Low-Speed Aircraft*. Pergamon.

**Hydrodynamic Stability Theory.** By ADELINA GEORGESCU. Martinus Nijhoff, 1985. 306 pp. Dfl 155.00, $58.00, £42.95.

**Stability of Parallel Gas Flows.** By BHIMSEN K. SHIVAMOGGI. Ellis Horwood, 1986. 169 pp. £20.00.

Each of these two books treats aspects of the subject theoretically, albeit from different points of view. There is some overlap, principally in discussions of the linear theory of normal modes. Adelina Georgescu, however, is rather more concerned with the analytical foundations and structure of the subject, while B. K. Shivamoggi's interest is directed towards the effects of compressibility on stability, in the spirit perhaps of the pioneering work of Lester Lees and C. C. Lin. I shall treat each of these books in turn, before turning to an overall assessment and a comparison with other books.

Georgescu's book was first published in the Romanian language in 1976, was revised and enlarged in 1981 and has now been translated by the author into English, with Professor David Sattinger acting as a translation editor. The translation is good, apart from occasional infelicities of spelling.

There are five chapters, of which the first deals with classical concepts of hydrodynamic stability, namely the way in which laminar fluid flows develop instabilities which evolve into the complexity which we recognize as turbulence. Chapter 2 is concerned with function spaces and their role in the derivation of rigorous theorems for, for example, (i) completeness of sets of normal modes, (ii) proofs of a 'principle of exchange of stabilities' (reality of the eigenvalue) and (iii) the derivation of stability criteria for particular flows, such as plane Couette flow, and for general classes of flows.

Chapter 3 is about bifurcations, branching and stability of solutions of the Navier–Stokes equations, and treats such problems by the methods of Leray and Schauder, of Liapounov and Schmidt and of Joseph and Sattinger (for the Hopf bifurcation). Chapter 4 was written in 1981 and discusses various ideas on the nature of turbulence from a theoretical and mathematical point of view, citing famous papers of Leray, Landau, Hopf, Ruelle & Takens, and Lorenz and more recent papers of Sattinger and others on symmetry-breaking bifurcations. Chapter 5 treats instability of flows in a porous medium, a particular interest of the author.

Finally there is a set of eight appendices, six of which date from 1981, dealing with a variety of topics, including analytical and numerical methods and the stability of unsteady flows. An 'Afterword' refers to some work then currently being undertaken by a variety of scientists and mathematicians in 1980 and 1981.

First of all we may ask: how does this book treat the more classical and linear aspects of the problem? The discussion is rather brief, I find, with too much attention to obsolescent methods and too few new insights into the problems and methods of solution. A 'proof' by Romanov of the linearized stability of plane Couette flow is discussed, with reference to his derivation of rigorous bounds, and to his use of asymptotics and numerical studies, but the present reviewer is not convinced that we yet have a rigorous proof of stability. Secondly, turning to the classical, but nonlinear, aspects of the problem, I find no reference to the seminal papers of Davey and of Malkus & Veronis, for example, on bifurcations in circular Couette flow and Bénard convection respectively. Thus the present volume adds little on the linear and weakly nonlinear aspects of the subject.

Attention is best directed to the mathematical treatment of the fundamentals, which is where the author's main interests lie. The major virtue of the present book is that it does put before the reader a rigorous mathematical framework, particularly analytical, which can be of use in treatments of normal modes and bifurcations and, one hopes, in the study of evolution towards turbulence, or chaos, or both. Although the book is not especially original in spirit, and is devoted rather towards exposition of the points of view of the original authors with few novel insights, I believe that many will find this a useful reference to mathematical techniques which have been found to be of value in the theory of hydrodynamic stability in recent years.

The monograph of Shivamoggi is, I fear, less than satisfactory, with little attention to experiment and with much space devoted to unnecessary analytical detail of normal modes. And even this discussion is restricted to two-dimensional solutions for 'mathematical simplicity', although the author recognizes C. C. Lin's argument that Squire's theorem does not apply, so that three-dimensional perturbations must be considered. There are, moreover, some mathematical errors in Shivamoggi's book, in connection with an analysis in the phase plane for example.

In assessing these two books, I really must say that I cannot recommend that of Shivamoggi; the reader would be far better advised to study the article by L. M. Mack (1984) to obtain a modern and comprehensive survey of the effects of compressibility on the stability of flows.

The book of Adelina Georgescu, on the other hand, has much in common with the monograph of Joseph, although the mathematical emphasis of the two is different. There is relatively little overlap with the books of Lin, Chandrasekhar, Betchov & Criminale and Drazin & Reid. In spite of expressed reservations, I assessed the last-named volume in 1982 (*J. Fluid Mech.* vol. 124, 1982, pp. 529–533) 'a better book to use for graduate study than any possible competitor'. In 1986 I see no reason to depart from that opinion, but I would now remark that Georgescu's book has much to add from a mathematical point of view, so that many will find it of value as a complementary graduate text.

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## REFERENCE

Mack, L. M. 1984 Boundary layer linear stability theory: part B, compressible stability theory. In *Special Course in Stability and Transition*, *AGARD Rep.* 709, pp. 3-1 to 3-81.