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REVIEWS

Perspectives of Nonlinear Dynamics, Vols. 1 and 2. By E. ATLEE JACKSON. Cambridge University Press. Vol. 1, 1989, 495 pp., $54.50. Vol. 2, 1990, 632 pp., $59.50.

Chaotic Evolution and Strange Attractors. By DAVID RUELLE. Cambridge University Press, 1989. 96 pp. £8.95.

These three books are products of a period of intense and fruitful research on dynamical systems. Spanning two volumes, *Perspectives of Nonlinear Dynamics* gives a semi-rigorous treatment in textbook form of numerous mathematical methods, many of which have been developed or significantly extended in research on chaos and simple nonlinear systems. The first volume begins with a historical outline sketching the development of nonlinear dynamics from the 19th century to the present day. Then follows a basic introduction of concepts culminating in discussions of stability, invariants, and measure. This sets the stage for a discussion of three main topics: first-order differential equations, first-order difference equations, and second-order differential equations. A whole gambit of subjects are briefly described in the concluding pages, including elliptic functions, structural stability, singular perturbation theory, and averaging methods, to name but a few. The second volume considers larger systems: second-order and third-order differential equations, 'moderate-order' systems, and large systems. Included in this latter category are solitons, coupled maps, and cellular automata. Interspersed between specific mathematical results are general thoughts about perhaps the most challenging of all topics: order and organization in large systems such as 'turbulence' and 'life'.

It is clear that no one work can present a comprehensive survey of this vast subject, and it is admirable that the author can at least give a flavour of many of the past and present ideas. On the technical side, though, the volumes are in need of extensive editing, including proper cross-referencing. On the contents side, the second volume in particular contains many interesting comments and results for moderate- to large-order systems, some of which apply at least loosely to fluid dynamics. The discussion of the unexpected finding of organizing behaviour by Fermi, Pasta, and Ulam in diffusively coupled nonlinear systems – rather than statistical equilibration – captures the excitement of this original discovery and indicates that much remains to be understood. Though fluid systems are frequently coupled in a non-diffusive manner and through long-range forces, a similar kind of organizing behaviour is found, and this too remains to be understood. Indeed, this is at the very heart of turbulence.

The author's development of the subject, from small to large systems, indicates that the distribution of effort and understanding often runs contrary, from large to small. At the first level of complexity, chaos is characterized by highly patterned and intricate structure. With a few more than three essential dimensions, the patterns and intricacies soon become too bewildering to follow. One begins then to wonder whether it is futile to characterize larger systems by the structures visible in only the lowest-order systems. Increasing the dimensions still further, there is a transition, it seems, perhaps a gradual one, to the organizing behaviour first discovered by Fermi, Pasta, and Ulam. Now, 'structures' appear, and to go further in understanding, we must make a transition in our characterization of such systems, one which examines the robustness of and the interactions between 'structures'. In fluid dynamics, the familiar 'structure' is a vortex, an entity which becomes increasingly more sharply defined as the Reynolds number increases to infinity. One wonders whether a more successful programme to understand large systems, by analogy, would be to perturb about infinite dimensions, where structures might be most clearly defined, rather than to try to extend the concepts of chaos through a large range of dimensions.

The increasingly useful and often necessary role of computation in nonlinear dynamics is discussed in some depth in volume 2. The author points out that the computer has become an experimental laboratory in addition to a device to solve tedious problems. However, I think that the author underestimates the computer resources that may be required. These resources are not needed simply for the sake of conducting specific experiments, they are also needed to interpret, in novel ways, the data produced, to identify structures and characterize their behaviour. The experimentalist must become part of the experiment.

Chaotic Evolution and Strange Attractors does not omit mention of large systems, but gives the impression that such systems often have dynamics characteristic of small systems. This book takes one through the modern techniques of extracting information from raw experimental data, using new or newly extended ideas connected with the recent activity in dynamical systems. We are given a signal from a hypothetical turbulent flow – a series of one or several measurements in time – and we are shown what we can learn from these data, how to do it, and, to some extent, why it is useful or informative to do it. There is limited mathematical rigour, though no shortage of mathematical complexity, with subjects from attractors, measures, characteristic exponents, entropy, to dimensions covered.

At times, the book endeavours to connect some of the simple systems studied, for example the Lorenz system of three first-order equations, to convection in the Earth's atmosphere, a system of far greater complexity judging from present research. In my view, there are fundamental differences between small and large systems (see *J. Fluid Mech.* vol. 216, 1990, pp. 657–658), and the information which can be extracted by the mathematical techniques illustrated in this book is generally both inadequate and inappropriate for these large systems.

Despite this reservation, it is pleasing to read about a seemingly self-contained problem – that of time-series analysis – in such a brief account. The book makes no attempt to go into detail on any one subject and assumes familiarity with contemporary mathematical notions, thereby leaving space to introduce a wide variety of advanced subjects on a general level. This permits the reader to grasp the overall problem and perhaps to study individual points at greater depth through the references.

D. G. DRITSCHEL

Boundary Layers. By A. D. YOUNG. BSP Professional Books, 1989. 269 pp. £16.95.

Although courses on boundary layers are given to many engineering and mathematics undergraduates there have been few recent books on the topic. This book aims to fill this gap and is also intended to serve young research workers in the field. Such a book may also be used by research workers without formal training in fluid mechanics who first meet boundary layers in the graphic output from a code solving the Navier–Stokes equation.

After a brief introduction to laminar and turbulent boundary layers, transition and separation, the main text opens with a clear, self-contained derivation of the

Navier–Stokes equations in Cartesian coordinates for three-dimensional compressible flow. This is followed by a straightforward derivation of the boundary-layer approximations and brief introduction to some of the classical exact solutions. These early chapters provide all the details necessary for a basic understanding of laminar layers except for approximate methods of solution. These methods are introduced in the last chapter on laminar flow. Compared with the earlier chapters this chapter seems out-of-date. Clearly a brief account of integral methods may help readers of earlier references, and Thwaites' method is still used in some industrial applications. However, an introduction to numerical methods of solution of the boundary-layer equations would be more useful to students than details of the many ramifications of these simple approximate methods.

In contrast the chapter on transition to turbulent flow, although doing full justice to the early pioneers, has a very modern outlook and should be studied with care by all students of the subject.

In introducing turbulent boundary layers the author is clearly of the opinion, shared by this reviewer, that for a full understanding of turbulent flows it is essential to have a reasonable knowledge of the available experimental and empirical data. These data are introduced with concise accounts of the law of the wall, the wake law, the skin-friction power laws and the Crocco relation. A thorough reading of this material will be of considerable value to students and research workers wishing to understand and make informed criticisms of numerical solutions. Of course it is also necessary to understand the equations of turbulent flow, and the following chapters provide a comprehensive development of the Reynolds-averaged equations and of the equations for the Reynolds stresses. The author follows this derivation of the equations by a chapter on boundary-layer drag prediction by integral methods; an area where he has made significant contributions to the subject. However, although the principles involved in these integral methods are essential in understanding drag prediction, integral methods are being replaced by numerical solutions of the full Reynolds-averaged Navier–Stokes equations. For these numerical solutions to be successful adequate turbulence modelling is necessary. To some readers it may appear that this long chapter on approximate methods is out of proportion to the following brief, but informative, chapter on turbulence modelling.

Overall this book provides a good introduction to boundary layers and it is particularly strong on the physical background. Another point which adds to the valuc of the book is the fact the equations are always derived for compressible fluids and the assumption of constant density only made when strictly necessary. On the other hand students accustomed to using computers on every possible occasion may be put off by the lengthy approximate solutions.

L. C. Squire

Theoretical Geophysical Fluid Dynamics. By A. S. Monin. Translated from the Russian by R. Hardin. Kluwer Academic Publishers, 1990. 399 pp. £99 or $149.

This test attempts to cover the theoretical foundation of the whole of geophysical fluid dynamics, defined by the author to be *the fluid dynamics of natural flows of rotating baroclinic stratified fluids and gases.* The range of topics covered is certainly broad, including atmospheres, oceans and planetary interiors. The work is based on lecture courses given by the author and his colleagues at the M--cow Institute of Physics and Technology.

There are three sections, or parts. The first, containing three chapters, is concerned with general principles and lays the foundations for applications later in the book. Chapter 1 sets up the fundamental equations. Chapter 2 develops the theory of small-amplitude oscillations. It starts with the sentence. 'All the motions of a fluid during an adiabatic process are wave motions'. This extraordinary statement is not justified by the author and should provide ample scope for thought-provoking discussions! In chapter 3, hydrodynamic stability theory is developed. Amazingly, a lengthy section on baroclinic instability fails to mention the pioneering work of Eady. A considerable amount of modern nonlinear theory is included.

Part II deals with processes and has four chapters, on Surface Waves, Internal Waves, Geophysical Turbulence and Rossby Waves. The chapters on surface waves and internal waves deal mostly with the oceans. Although the theory is developed thoroughly, there is disappointingly little about the comparison between theory and observations, or about the role of the waves in the dynamics of the ocean or atmosphere. Chapter 6 develops the theory of geophysical turbulence and is probably the best chapter in the book. The theory and relevance of Rossby waves are well presented in chapter 7.

Part III is about global problems and has chapters on the General Circulation of the Atmosphere and Ocean, the Theory of Climate and the Fluid Dynamics of Planetary Interiors. The chapter on general circulation is rather out of date. Although mentioned, the full importance of synoptic-scale motions in driving the general circulation is not brought out. A section on eddy-resolving numerical models considers only the oceans and the use of general circulation models of the atmosphere for weather forecasting is not discussed. The chapter on climate (chapter 9) describes some interesting simplified climate models which are not well known in the western literature. The chapter on planetary interiors deals with the Earth's core, hydromagnetic dynamos, the evolution of planetary interiors and mantle convection.

One would have expected the principle value of a translation such as this would be as an introduction of the reader to unfamiliar Russian literature. Unfortunately, the book is severely devalued by the lack of a proper reference list. Although numerous references are quoted throughout the book, the Russian version apparently only gave 28 of them in the reference list. The translator has added more references but a very large number are still missing. This unfortunate omission greatly diminishes the value of the book as a source of references.

Readers should beware of many instances of terminology which is different from the western conventions. For example, the author uses Kibel' number rather than Rossby number, 'adaptation' to mean geostrophic adjustment, the 'traditional approximation' to mean the neglect of the horizontal components of the Earth's rotation vector, MacDonald function for modified Bessel function, and many others. Whilst these differences are quite understandable and should not present difficulties for the experienced researcher, they make the book much less attractive for new graduate students. Many of the diagrams are of poor quality.

Overall, the book contains some interesting material which is not readily accessible in the western literature and it could be a useful addition to library collections. On the other hand, the lack of a proper reference list and the unfamiliar terminology severely limit the value of the book for those new to the subject.

S. D. Mobbs

Compressor Aerodynamics. By N. A. Cumpsty. Longman, 1989. 509 pp. £49.

For better or worse the wide-bodied commercial transport aircraft powered by high-bypass-ratio, high-pressure-ratio, turbofan engines has changed the civilized world. Derivatives of those engines also now power the majority of medium-sized warships, and smaller gas turbine engines power a multiplicity of other vehicles, ranging from rescue helicopters and executive jets through to much of the military arsenal. This hugely successful engineering development has been made possible by many advances in gas turbine technology, and one of the most important areas of progress has been in compressor aerodynamics. Professor Cumpsty is one of a small number of internationally recognized experts in this field, and his book records the progress and status of axial and centrifugal compressor research.

This is a major contribution to the bibliography, which is principally carried forward by individual papers for an international readership. The book admirably recognizes this, listing the significant references, interpreting and inter-relating them in a most useful, comprehensive and informative manner. It is also adequately self-sufficient, in that each topic is explained and developed in physical terms, supported by engineering mathematics, so that a sound understanding can be achieved. That said, however, it is not a basic text – it is most suitable for those already working in the field or those planning to become deeply involved, for whom it is a goldmine. The treatment of important related disciplines, such as vibration and noise generation, is well pitched for this purpose.

The foundation on which present capability rests is principally experimental, and all theoretical or numerical methodology is validated by comparison with measured achievement. However analysis systems are powerful and are improving fast. They already provide a sound basis for industrial design, and they yield improved performance together with reduced experimental development. At the individual bladerow level, they are starting to rival experiments as a source of reliable data. The success with which this balance of emphasis has been maintained in the book shows how well the author has judged the pulse of both industrial and academic activity.

Widespread use of perfect-gas assumptions is justified, but more regular warnings of their use would protect the inexperienced or those making infrequent reference to the book. Even those working in aviation, who may have been spared the rigours of real-gas properties, need to maintain awareness for airbreathing sub-orbital applications. Some mention should be made in Section 10.2 of acoustic resonance as a potent cause of blade vibration failure in axial compressors (see, for example, The excitation and consequences of acoustic resonances in enclosed fluid flow around solid bodies, by R. Parker & S. A. T. Stoneman, *Proc. Inst. Mech. Engrs* Vol. 203, 1989, pp. 9–19). Although some work by Calvert and Ginder at RAE is mentioned, the influence of that group on axial compressors in recent years deserves more prominence.

In spite of the huge investment of talent and resources recorded by this volume, the process of compressing gases in rotating machines involves a struggle against the laws of physics to find a narrow path between designs which are unstable and unreliable, and those which are uneconomic. Modern understanding and modern approaches, which are excellently presented in this volume, have provided a sound basis for successful designs. But the conflicting demands of performance, cost and weight require that each successive new application must renew the challenge. Many practitioners in the difficult but exciting field of compressor aerodynamics will wish to thank the author for this outstanding contribution.

H. Tubbs

The following volumes of conference proceedings have also been received:

Environmental Forces on Offshore Structures and their Prediction. Kluwer, 1990. 429 pp. £82 or $145.

Fluid Power Components and Systems. Edited by C. R. BURROWS and K. A. EDGE. Research Studies Press, 1989. 350 pp. £69.95.

Condensed Matter Theories. Edited by V. C. AGUILERA-NAVARRO. Plenum, 1990. 384 pp. $115.

Free Boundary Problems: Theory and Applications. Volumes I and II. Edited by K. H. HOFFMAN and J. SPRECKELS. Longman, 1990. 901 pp. £63.

Measures of Complexity and Chaos. Edited by N. B. ABRAHAM, A. M. ALBANO, A. PASSAMANTE and P. E. RAPP. Plenum, 1989. 476 pp. $105.

Nonlinear Evolutions of Spatio-Temporal Structures in Dissipative Continuous Systems. Edited by F. H. BUSSE and L. KRAMER. Plenum, 1990. 569 pp. $125.

Partially Integrable Evolution Equations in Physics. Edited by R. CONTE and N. BOCCARA. Kluwer, 1990. 605 pp. £111.

The Physical Oceanography of Sea Straits. Edited by L. J. PRATT. Kluwer, 1990. 587 pp. £99.