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BOOK REVIEW

Turbulence, Coherent Sructures, Dynamical Systems and Symmetry by **Philip Holmes, John L. Lumley, Gal Berkooz.**

There is a crucial need for physics based approaches which provide methods to model turbulent flows as systems of relatively few degrees of freedom. From these "simpler" systems we can quantify the role of coherent structures in the dynamics of turbulent flows. The information gleaned from such systems can then be used, for example, in the development and implementation of active control strategies for complex turbulent flows.

The authors present a timely overview of, and guide to, one of the most promising approaches to date for the development of such physics based low-dimensional models. The approach that they describe involves using the proper orthogonal decomposition (POD) in conjunction with dynamical systems theory to develop low-dimensional models for coherent structures in certain fully developed "open" flows. Such an approach is by necessity multidisciplinary in nature and requires substantial understanding of topics as diverse as the design of experiments to obtain the empirical POD eigenfunctions to dynamical systems theory to subtle issues of modeling the effect of neglected modes on the low dimensional system being developed and studied. The authors have largely succeeded in covering the latter two in one volume.

In the Introduction to part one, the authors clearly articulate the need for low-dimensional models. The reader is reminded of the difficulty of turbulence research and of the need for innovative approaches to probe its physics.

Part one gives an excellent overview of turbulence, the physics of coherent structures, the proper orthogonal decomposition and its link to Galerkin Projection and coherent structures. Much of the material discussed in part one should be familiar territory for the serious student of turbulence, the advantage here being that the material has been combined in a coherent fashion so that the reader can see how the various pieces of the puzzle fit.

Part two provides the dynamical systems theory needed to interpret the low-dimensional systems in phase space and relate these results to the behavior of coherent structures in physical space. Here the spirit is to introduce the reader, via simple example, to a number of tools (periodic orbits, Poincare maps, bifurcation theory, simple and strange attractors, etc.) for studying non-linear ordinary differential equations which perhaps are not familiar to the traditional fluid dynamicist. Comments (i)-(iii) on pages 158 and 159, where the authors argue the need for analytical methods to be coupled closely with simulation (I would also add experiment), are especially timely because of the current rush to perform numerical simulations without, in many cases, careful thought and analysis.

In part three the authors present their low-dimensional model for the wall region of the turbulent boundary layer in which they utilize the basic tools and techniques presented in the preceding two parts. In addition, the reader is introduced to the subtle issues of truncation, modeling the mean flow and modeling the interaction of the resolved modes with the unresolved modes. The behavior of various low-dimensional models (with different truncations) is discussed and related back to the physics of the wall region. These results clearly show the utility of such low-dimensional models for extracting relevant physics and their potential use for the development of active feedback control strategies.

Part four contains a review, from the authors perspective, of related work and applications by other researchers. The authors restrict the discussion to six applications where the POD eigenfunctions are used as an empirical basis to construct low-dimensional models. These six are; the high Reynolds number turbulent circular jet, the transitional boundary layer, a forced transitional mixing layer, flow in a grooved channel, flow around and in the wake of a circular cylinder and full channel wall layer models. Each application is reviewed in sufficient detail to provide the reader with a good sense of what was done and what major conclusions were found. Part four ends with a summary and discussion on prospects for rigor for such systems. In this summary, the authors provide a future road map, based on recent applications of dynamical and probabilistic ideas, for the development of a general theory for these systems.

This is in an excellent research book which is intended for a fairly advanced audience and the serious turbulence researcher will find it stimulating. This monograph, when combined with the reviews of Adrian (1991, Annual Review of Fluid Mechanics 23:261-304) and Glauser and George (1992, Experimental Thermal Fluid Science 5:617-632) of multipoint experimental methods and their proper interpretation, provides the engineer and scientist with the tools necessary to develop and interpret such POD based low-dimensional dynamical systems.

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