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Book reviews

Navier–Stokes Equations and Turbulence
by C. Foias, O. Manley, R. Rosa and R.Temam, Cambridge University Press

Fluid dynamics deals with fundamental dynamical concepts related to fluid motions. Most flows occurring in nature and in engineering applications are turbulent. Scales of motions surrounding us vary from a few seconds (Kolmogorov time scales at which the atmosphere and oceans dissipate their energy) to centuries (where ice ages make their appearance). With current analytical tools, a general theory covering all motions may seem impossible, at least in our lifetimes, yet substantial progress has been made in understanding and predicting fluid motions. Though the progress is often made through approximations, precision is required to make the results elegant and meaningful. Unfortunately, the bane to our search for precision has been the strong nonlinear coupling of most scales of motion which hinders precise mathematical or numerical treatment. Yet, fluid dynamicists have continued their quest to understand how and when different motions arise, are maintained, and then dissipate. In 1941, A.N. Kolmogorov translated, using mathematical language, this picture of energy transfer from large-scale motion to small-scale motion into a phenomenological theory. The turbulent velocity field can be thought of as being made of many eddies of different sizes. Energy is usually fed into the system in a way to produce large eddies. Kolmogorov's theory is based on the notion that large eddies can feed energy to the smaller eddies and these in turn feed still smaller eddies, resulting in a cascade of energy from the largest eddies to the smallest ones. Kolmogorov [1] proposed a theory to calculate the energy spectrum of such a system and began a new era in the theory of turbulence.

It is well accepted that many types of turbulent fluid flows surrounding us are described by the three-dimensional incompressible Navier–Stokes equations. From the mathematical point of view, we presently only have the existence of Leray's weak solutions to the Navier–Stokes Equations but we do not know if the solutions exhibit some local singularities or whether they are unique. The global unique solvability of the 3D Cauchy problem for the Navier–Stokes Equations is an outstanding problem of applied analysis [2,3]. Whereas global regularity for two-dimensional initial data are well known, there is a dearth of results for large 3D initial data (see [4,5] for recent developments and reviews on the subject). The interest of scientists to the problem of global regularity of the 3D Navier–Stokes equations is supported by the fact that the positive or negative answer to this question could provide deeper insight to the problem of turbulence. In any case, there is a clear challenge to establish more direct connections between the mathematical analysis of solutions of the Navier–Stokes Equations and the more heuristic and phenomenological models of physical turbulence.

As with all interdisciplinary work, it is not easy to write a book for applied mathematicians, engineers and physicists with different technical backgrounds and interests, especially on such demanding topics as fluid dynamics and turbulence. The book *Navier–Stokes Equations and Turbulence* by C. Foias, O. Manley, R. Rosa and R. Temam faces this challenge admirably. It is written by distinguished researchers who have made fundamental contributions to mathematical fluid dynamics over their careers. The book is the result of many years of research by the authors, who analyze turbulence using Sobolev spaces and functional analysis. In this way the authors recover parts of the conventional theory of turbulence, deriving rigorously from the Navier–Stokes equations what had been arrived at earlier by phenomenological arguments. The book is specialized in the sense that it focuses primarily on the author's own research results. The book is exciting for those of us dealing with mathematical fluid dynamics. However, it should have broader appeal. The book presents the mathematical theory of turbulence to engineers and physicists as well as the physical theory of turbulence to mathematicians bridging the gap between mathematical community and the practitioners of turbulence theory. The mathematical technicalities are kept to a minimum within the book, enabling the discussion to be understood by a broad audience. This is a very well written book that will be useful to mathematicians, engineers and physicists.

There are five chapters: 1. Introduction and Overview of Turbulence. 2. Elements of the Mathematical Theory of the Navier–Stokes Equations. 3. Finite Dimensionality of Flows. 4. Stationary Statistical Solutions of the Navier–Stokes Equations, Time Averages, and Attractors. 5. Time-Dependent Statistical Solutions of the Navier–Stokes Equations and Fully Developed Turbulence. Each chapter is accompanied by appendices that give full details of the mathematical proofs and subtleties. Chapter 1 contains an introduction to the theory of incompressible fluid flows and physics of turbulence. Chapter 2 summarizes some classical and some more recent aspects of the mathematical theory of the incompressible Navier–Stokes Equations. Chapter 3 focuses on fundamental issues related to finite dimensionality of turbulent flows in the context of determining modes and nodes. The authors also discuss the large time behaviour in the context of attractors and show finite dimensionality of

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attractors. All these dimensions are related to physical parameters and phenomenological theories of turbulence. The remainder of the book (Chapters 4 and 5) consists of applications of the statistical approach to the study of turbulent transport and turbulent spectra. This topic is among the new results developed in the monograph. For instance, the authors establish a rigorous link between the Kolmogorov spectrum and the Navier–Stokes Equations and show how the intermittency of turbulent flows is related to the fractal nature of energy dissipation in 3-dimensional flows.

In summary, the monograph is an excellent reference for anyone who is interested in the mathematical theory of the Navier–Stokes Equations and Turbulence. This book is a delightful source of elegant and powerful ideas, packed with mathematical gems and far-reaching applications. It fills a major gap in the literature and will be useful to students and practitioners alike for many years to come. I highly recommend this book. I hope that Cambridge University Press will publish a 2nd edition of this book in paperback so that it will be available to a broader audience.

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Shock Focusing Effect in Medical Science and Sonoluminescence
by R.C. Srivastava, D. Leutloff, K. Tkayama, H. Gröning (Eds.) (Springer 2003) ISBN 3-540-42514-4

The book is a collection of 9 papers devoted to shock focusing effects. In general, paper collections as compared to textbooks can more timely target on certain aspects of research at the cutting-edge. In the present book edited by Srivastava et al. this advantage has not been taken. The references only span till the end of the year 2000. At this time it was not decided if shock waves are a prerequisite for the shortness of light emission. Thus, novel findings are lacking in the rapidly developing field of single bubble sonoluminescence. Roberts and Wu in Chapter 1 model the acoustic wave propagation with the self similar solution of Guderley and extend it for the case of an non-ideal gas. Further they address the linear stability of the shock front. In contrast, Kwak and Lee in Chapter 3 object the validity of Guderley's solution for the specific radial dynamics at work. Hence, they find only propagating pressure waves without steepening. Additionally, they address the temperature distribution of the gas phase and emission of acoustic transients into the liquid. The third work dealing with wave focusing inside the bubble by Srivastava and Leutloff in Chapter 5 again supports the hypothesis that a shock front forms. Here, I missed the bubble dynamics in their model which is known to be crucial for the energy concentration in the last stage of collapse. The last chapter on sonoluminescence by Hilgenfeldt and Lohse poses the question if "Upscaling single-bubble sonoluminescence" can be achieved by lowering the frequency of the acoustic forcing. Yet, only short time later this question has been answered by the same group [1]. Furthermore, two carefully written reviews have surfaced meanwhile, one from Hammer and Frommhold [2] discussing the source of light emission and a comprehensive article in Review of Modern Physics by Brenner et al. [3] encompassing most of what is known in this field. Although interesting from the perspective on the art of modeling spherical converging waves, this book can be considered outdated for the present understanding of single bubble sonoluminescence.

The second topic of the book is dealing with medical applications of shock waves. There, maybe due to the more senior research field, I found less drawbacks from the long delay till publishing. A sweeping and concise article on the interplay of cavitation bubbles with shock waves, bubble–bubble interaction, and the effect of rigid surfaces is presented in Chapter 4 by