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Book review

Statistical Mechanics of Turbulent Flows
by Stefan Heinz, Springer-Verlag, Berlin etc., 2003. 214 pages

This is a nicely written textbook, aiming to present the methods of stochastic modelling of turbulent fluid flow. It is based on lectures about this subject by the author. The expected audience are students, who want to become acquainted with the interdisciplinary field of statistical mechanics and turbulence, as well as researchers, who wish to apply the method of stochastic modelling to turbulent flow. While physics students will know many of the prerequisites to model stochastic processes, for the engineering students the elements of stochastic theory are developed here from scratch – paying the price that fluid dynamics only starts on page 57 out of 188 text pages and real stochastic modelling of turbulent fluid flow even only on page 92. But then the reader is lead to the frontier of research in this field.

The book is restricted to single-phase flow and to one-point averages. While the first restriction seems reasonable, there would certainly be much interest also in two-point functions. And on the basis of a theory using statistical distribution functions one has access. The equations of fluid motion are derived in terms of stochastic processes and molecular motion. Therefore one finds some oversimplification in the viscous properties of the fluids. The Prandtl number e.g. is not of order one in all relevant applications. It can be orders of magnitudes larger or smaller, depending on the effects of the intermolecular forces and thus on density and on temperature. Consequences to be dealt with in stochastic modelling are very different time and spatial scales (e.g. boundary layer thickness) for the velocity and the temperature fields. The presentation based on atomic motion, favoured by the author, seems too narrow.

The first third of this book serves as an introduction into elementary stochastics, explaining PDFs, moments and cumulants, characteristic functions, etc. The reader even learns the definition and the properties of the δ-function. I mention this to encourage the beginner to use these lectures and to caution the experienced reader. Also, the stochastic processes are introduced rather slowly and in great detail, Markoff and Fokker–Planck mainly, including such interesting but far from turbulence details as Pawula's theorem. The useful projection technique is shifted into the appendix, also coloured noise processes.

The reader wonders, why there are no exercises added, together with proper support how to solve.

The author nicely and convincingly expands on the advantages of stochastic modelling as opposed to direct numerical simulation. For the latter the numerical efforts increase more steeply. A restriction to presently Re_λ of order 200 results. Stochastic modelling is offered as an attractive alternative to direct numerical simulations, suitable for extension to stronger turbulence.

The main sections are Chapters 5 and 6, in which the basic tools of stochastic modelling together with hints how to apply them are described. First stochastic velocity models for the large scales are discussed, then for the small scales. These chapters are not only on the heart of this textbook, they are of considerable interest also for the experts, including those coming from direct numerical simulations. The respective advantages of the methods are elucidated in comparison. These main chapters are considerably closer to research than the others. They demonstrate satisfactory agreement of stochastic modelling with direct simulations in cases of overlap but the stochastic Langevin and diffusion models extend to larger Re_λ. In the last part of these main sections the audience is taken in a few steps just into present research activities, whose results are partly only published simultaneously.

The author is well aware of relevant applications of stochastic modelling in turbulence. It seems useful for reacting flow problems and mixing of species, for turbulent transport, turbulent combustion, and also for studying the effects of nonzero compressibility. The method allows for applying it to industrial flows and environmental problems. Both usually need larger Reynolds numbers than simulations of the Navier–Stokes equations presently can provide.

This textbook covers a broad span in the scientific level as well as in the presentation. It starts from low, too low indeed, level with commonly known details, and passes over in its last sections to latest insight published at the same time as original work. Here the text is not yet sufficiently mature and needs clearer presentation as well as filtering of unnecessary details and concentration on the gross features.

To summarise, this is a monograph on the method of stochastic modelling of turbulent fluid flow, comprising the necessary prerequisites and the main features of the method, up to the present research level. It deserves attention by the specialists and

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the beginners as well and has useful applications. It is clearly presented, with careful argumentation and interesting scientific contents. The book's use is nicely supported by an extended list of all symbols and abbreviations and, of course, with references. The reviewer can well recommend it.

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