J. Fluid Mech. (1992), *vol.* 234, *pp.* 691–693
Printed in Great Britain

REVIEWS

The Kinematics of Mixing: Stretching, Chaos and Transport. By J. M. Ottino. Cambridge University Press, 1987. 364 pp. £50.

As an important process in chemical engineering, mixing has attracted the attention of specialists for many years. In their attempts to make this process more efficient, various mathematical models and tools were used; however, there was nothing distinctive in this branch of chemical engineering science. Owing to the activity of a rather small group including the author of the present book, Professor J. M. Ottino, over a number of years mixing has achieved the status of an important subject, interesting to a wide audience including non-specialists. Of course, the time was very suitable for this activity and this step in the development of mixing studies was well prepared, especially due to recent great achievements in dynamical systems and chaos. The book presents an up-to-date state of the art in this field, and, what is essential, is self-contained; it includes all necessary educational material at a suitable level of rigour. This makes the book suitable for a wide spectrum of readers, from specialists in chemical engineering to students of continuum mechanics.

The book consists of nine chapters. The first chapter, the introduction, not only outlines the content of the book but also gives a clear idea of its spirit. In the second chapter kinematical foundations of continuum mechanics are informally but rather rigorously presented. This section is not only preparation for further reading: students and teachers of continuum mechanics will find good illustrations, and problems useful for solving at student seminars. The third chapter contains foundations of continuum dynamics – again, teachers and students will find some fine points and observations, as well as useful problems.

The fourth chapter begins with the proper presentation of mixing as a quantitative study. Definitions of stretching efficiency are given here as well as their calculation for two classes of flow. These classes of flow with special forms of the velocity gradient tensor include flows close to ones used in technical applications, and, importantly, possess the 'integrability' property, exactly in the sense of four integrability cases in a classical problem of solid-body rotation around a fixed point. Such flows are in fact a rare exception; in general the motions are chaotic. Therefore in the fifth chapter the author presents some generalities concerning chaos in dynamical systems. Again, the presentation is, I would say, transparent; it progresses at a suitable level of rigour and many illustrations contribute to clear understanding. Chaos in Hamiltonian systems is presented in the sixth chapter with such topics as the Poincaré–Birkhoff theorem, the Kolmogorov–Arnol'd–Moser theorem, and the Moser twist theorem concerning the fate of perturbed Hamiltonian systems.

In one sense the next two chapters are central ones. They are concerned with mixing and chaos in two-dimensional time-periodic flows and mixing and chaos in three-dimensional and open flows. In the first part of the seventh chapter two idealized 'building blocks' for complex velocity fields are considered, the so-called tendril-whorl mapping and blinking vortex flow. Stokes time-modulated flow in a journal bearing and time-dependent creeping cavity flows are presented in the second part of the seventh chapter. The presentation includes many instructive computer pictures; in the case of cavity flow, experimental results are also presented for comparison. The experimental pictures are expressive; one of them even appears on the book cover. In the eighth chapter the mixing process under conditions of three-

dimensional creeping flows, with time and space periodicity close that in practically used devices, is studied first. The following section is concerned with an example where inertial effects are essential. There is some relevance to turbulence in two other examples. Numerical results are expressed presenting Poincaré sections in various flows and the patterns of streaklines under realistic conditions. In the last chapter, the diffusion and reaction effects neglected completely before are considered with some instructive illustrations and examples. I would like to mention here especially a section concerning the interaction of active microstructures and a chaotic flow field. Some auxiliary material (Cartesian vectors and tensors, vector spaces, etc.) is given at the end.

Summing up, I can say not only that the author has written a good and useful book. In one sense it can be said that in this book the creation of a new branch of classical hydrodynamics is signalled. This creation required new recently elaborated tools, in mathematics, mechanics and numerical analysis, which were respected but not sufficiently used before. The author shows how they work conceptually and technically in studying an important class of problem which has many practical applications.

After reading this book many researchers will be stimulated to work out ways of applying these tools to their own problems.

For the next edition, which obviously will soon be necessary, I can recommend the addition of a detailed description of a classical G. I. Taylor experiment with creeping shear flow, where the dye blob being stretched recovers completely when the flow is reversed. In general more detailed discussion of the effect of reversing the flows could be instructive. A peculiar nonlinearity connected with the introduction into the flow of solid bodies of the same density, leading to randomness and enhanced mixing in creeping flows, could also be of some interest.

The book should be recommended to a wide audience of researchers, teachers and students.

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Operational Analysis and Prediction of Ocean Wind Waves. By M. L. Khandekar. Springer, 1989. 214 pp. DM 77.

Guide to Wave Analysis and Forecasting. World Meterological Organization, 1988. 206 pp. SFR 47.

Growing wind waves extract energy from the shear flow in the atmospheric boundary layer. Most of this energy is lost through whitecaps to the oceanic mixed layer. It is hard to estimate the resulting net balance from first principles. Therefore, for practical applications, one tended to use empirical relations between wind speed and wave growth. Another important process, resonant four-wave interaction, requires huge amounts of computer time. As a result wave modelling was somewhat detached from (geophysical) fluid dynamics, but this has changed now: recent work has resulted in an accurate wave prediction model based on our knowledge of microscale processes. This model is used by the European Centre for Medium-Range Weather Forecasts to make routine global wave forecasts. Since the model is 'physical' rather than empirical, it can also serve as a building block for a coupled atmosphere–ocean wave–ocean model, which is needed to understand weather and climate better. Finally, it provides first-guess fields for the interpretation of satellite radar observations of the ocean; as such it is an essential tool for the observation of our planet.

Neither *Operational Analysis* nor the *Guide* conveys to the reader the feeling of

excitement associated with these recent developments. The *Guide* is a revised, expanded and updated version of the *Handbook on Wave Analysis and Forecasting* published in 1976. It was written by a team of wave experts to provide guidance to forecasters as regards predicting sea waves. *Operational Analysis* is a monograph, written for the same group; it is also meant as a reference book for modellers and engineers and as a textbook for students of ocean-wave modelling and marine meteorology.

Both books begin with a chapter on free waves. The *Guide* saves space by omitting all derivations and is by far more comprehensive: its discussion of orbital motion, refraction, Fourier decomposition, statistical aspects of a random sea and the wave spectrum is missing from *Operational Analysis*, which instead touches on internal waves and attempts to give some elementary derivations. Unfortunately – and this holds for all of the book – the arguments accompanying derivations are hard to understand as they are often inaccurate or incomplete. In the *Guide* there follows a fairly thorough discussion of wave-observing methods. Both texts then continue to describe wave generation, propagation and dissipation. The *Guide* discusses the subject in terms of the basic evolution equation of the wave spectrum, stating relevant results of microscale investigations; it also has an extensive discussion on wind-field analysis, which has a separate chapter in the other book. In my opinion both books fail to emphasize the importance of correctly determining the friction velocity rather than the wind speed at a given height. To do this we must know the drag coefficient, which depends on both wind speed and sea state. Its value is crucial for the correct prediction of wave heights. In *Operational Analysis* the spectral evolution equation comes out of the blue, but some insight is given into historic developments leading to our present understanding of shear flow instability over water. Both books devote a whole chapter to traditional wave prediction techniques. Useful as this may be to some, one wonders how all of this obsolete truth could stimulate (young) people entering the field. Nevertheless, the approach of *Operational Analysis* does have some historical charm. In their discussion of modern spectral models both books follow the usual distinction between first-generation models (ignoring resonant four-wave interaction), second-generation (parametrizing it) and third-generation (computing it). The *Guide* gives a useful list of 'all' existing numerical models. *Operational Analysis* has a discussion on model validation and model intercomparison. Particular attention is given to the Canadian Atlantic Storms Program in which the author took part. As usual not much is learned from this type of intercomparison except that you know what model with what particular wind field analysis performs best for the storms considered, which of course is relevant for certain applications. The *Guide* has a useful chapter on wave climatology. Both books discuss shallow-water effects.

The *Guide* is produced in WMO style: it is typewritten, there are no authors on the cover, it has sections like 3.3.2.4.3, the book begins with a useless list of figures and it is loose-leaf. It has a good reference list at the end, but no index. Because it was written by many authors there is occasionally some duplication, but this is not really disturbing. *Operational Analysis*, also typewritten, is hardbound and has a much better appearance. It has references after each chapter, which is not handy; the index is not very useful.

Both books may be of use to marine forecasters. *Operational Analysis* is not suitable as a textbook: it lacks lucidity in derivations as well as an integrating opinion on the relationship between various approaches and their validity.

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