J. Fluid Mech. (1979), *vol.* 92, *part* 2, *pp.* 393–399
Printed in Great Britain

REVIEWS

Mechanics of Underwater Noise. By DONALD ROSS. Pergamon Press, 1976. 375 pp. $25.00 (hardback) or $15.00 (paperback).

Public reaction has caused widespread discussion of aerodynamic noise in daily newspapers, and publicized controversy in legislative halls. Meanwhile in almost silence the secret war beneath the seas goes on, largely waged by scientists and engineers devoted both to quieting and detection of the noise of submarines and naval ships. The stakes are enormous: the relative security of sea-based nuclear deterrents. This technical book provides a peek at the noise game, and a partial catalogue of the truly cross-disciplinary tools in trade. At the same time the material will be of great interest to naval architects and ocean engineers required to deal with both noise and vibration aspects of commercial ship and off-shore structural design. The very great increase in ship-installed power and speeds over the last few decades has put commercial ship designers in need of information and tools presented in this text which were previously of interest to naval engineers alone.

Donald Ross has had a long and productive career in the field of underwater noise, at a variety of important laboratories, as well as in industry, and now at the NATO school in La Spezia, Italy. He is the author of a large number of engineering publications on a wide variety of subjects in the field, ranging from diesel-piston slap to boundary-layer noise, and he has been continuously involved in teaching other engineers his art, as a part-time professor at various U.S. universities. He is eminently qualified to prepare a summary text of this kind.

Underwater noise is operationally vital both because it allows passive detection of radiated noise and because self-noise hampers both passive and active detection. This book is generally concerned with the origins and to a lesser extent the detection of underwater noise, leaving to other texts, and wisely so, the separate question of its propagation within the ocean. Only occasionally does this restriction become bothersome, as in the discussion of the sound patterns due to a near-surface source which excludes even mention of the important refraction effects due to ocean sound speed gradients. Neglect of propagation does, however, leave the ocean to be reckoned with as a background noise source, and this subject is dealt with briefly in §4.4, Sounds from splashes. Therein, a great strength of Ross's text is exemplified: first, the reference to, and over-view of, much of the available pertinent research work on the mechanics of the origin of noise (in this case, mainly the classical work of Franz); secondly the reference to, and presentation of, practically useful information from the field in both written and figurative form.

Throughout this text, Ross demonstrates that special and highly useful engineering talent to parameterize, correlate, and explain practical measurements in terms of the underlying hydrodynamic, solid-mechanic and acoustic phenomena. In so doing he treads a path paved with potential for controversy. In addition, the author must no doubt have been hampered in his discussions by considerations of security classification: it is ironic that he has in this situation made optimum use of unclassified Soviet works in hydro-acoustics. Despite these difficulties the author has had the

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courage and tenacity to get to 'the bottom line'. The discussion of hull radiation serves as a good example. After a brief but clear summary of hull frequency regimes and their relation to vibration modes and structural features, the author proceeds to develop beam and plate bending theories in reasonable rigour and then to the application of these theories to treatment of forced vibrations of resonant structures, including attenuation means; very practical discussions are included of isolators, damping layers, impedance mismatches, vibration absorbers, and suppressors. The critical effects of fluid loading and of acoustical–structural wave matching (coincidence) are discussed. Taken all together, this portion of 80 pages should be highly valuable to engineers interested in ship hull vibrations as well as noise. Finally, at the end of this detail, Ross quotes test results for the noise radiation from entire ship-like structures in water (Donaldson) and their good correlation with two quite simple formulae, based on all the preceding discussions, which are quite independent of the details of the hull structural construction!

An important portion (50–60%) of the text deals with noise of hydrodynamic origin, including: splashes, bubbles, cavitation, thrust fluctuations, vortex shedding, and boundary-layer noise. The treatment of hydrodynamic phenomena are, while often searching and always interesting, also simplistic in style – as if for teaching to graduate students without special preparation in fluid dynamics. In spots the discussions seem to lack depth and sometimes sufficient touch with the latest thinking and results; examples are the sections on boundary-layer structure, propeller cavitation, and vortex shedding from bluff bodies.

For the reasons just cited, the hydrodynamic material might prove disappointing to the critical *JFM* reader. He might note, in addition, the occasional but irritating mis-statement or ambiguity [page 224,'...whenever fluid flows past a body, the fluid must speed up near the nose']; sometimes imprecisions in instruction [in discussing the important question of cavitation inception for propeller sections operating in wakes, the author makes the correct point that 'thin sections have much less tolerance for changes in attack angle than do thicker ones', but he fails first to note that it is only the nose radius which matters, and second to specify the simple but adequate quantitative relation between cavitation index, angle of attack, and nose radius]; sometimes imprecise figures [there are inexplicable oscillations in the nozzle pressure coefficient in figure 7.25, and the ordinates in figures such as 7.3 have not been made non-dimensional]; and historical omissions [as the failure to mention Osborne Reynolds's classical observations of cavitation in a venturi, in 1894].

These imperfections in the hydrodynamic material are more than compensated for. The careful reader will, much to his benefit, find collected here a wealth of useful relations and analyses, including statements and discussions of the fundamental relation between flow and acoustic quantities, and the uninitiated can readily acquire a very good and reasonably comprehensive view of hydrodynamic sources of noise, of their relative practical importance, often of their scaling, and of the mechanisms through which they work. The rather extensive bibliographies, grouped by subject, do readily allow the guidance needed for deeper studies. And, always, Ross gets to the practical consequences, to the 'bottom line'.

Treatments of hydrodynamic and structural sources of noise are augmented in the text by welcome introductory acoustic-related material, detailed definitions of acoustic quantities and terms, and, briefly, fundamentals of acoustic wave radiation, reflection, and generation. There is an extensive treatment of radiation from multi-monopoles, line arrays, and pistons, baffled or not.

The author indicates that he sought to write a worth-while self-education text and a reference for workers in the field. He has unquestionably succeeded. His text can also be profitably used for graduate engineering instruction in the subject, which will probably become of increasing importance in ocean engineering curricula. Engineers like Donald Ross with intensive experience in government and industry perform an important service to their profession in preparing summary texts of this kind. He deserves our thanks.

M. P. TULIN

Modelling and Prediction of the Upper Layers of the Ocean. Edited by E. B. KRAUS. Pergamon, 1977. 325 pp. £9.70 (hardback) or £6.20 (paperback).

When physical oceanographers are called upon to defend the importance of their subject to the keepers of the scientific purse-strings, it is to the upper ocean that they will normally point. Even a non-scientist can usually be convinced by purely verbal arguments that the surface layers of the ocean might have a dominant, if not controlling influence upon climate, and more important, perhaps, upon climate change. Military interest in such things as sea state and near surface thermal structure is obvious. Biological productivity can only be understood in terms of an interaction in the upper ocean of radiation, advection, nutrient distribution, temperature, salinity, predator–prey relations, etc. On the other hand, it is probably a fair statement that the major achievements in physical oceanography over the past 30 years, and indeed the greatest intellectual excitement, have been found in problems of the deep water. Only in the past decade can one see the major oceanographic institutions refocusing from deep water oceanography into the upper layers and onto the shelves and shallow seas. For despite the obvious economic and social importance of the upper ocean, it is difficult to imagine a more complex fluid system. A few examples give one some of the flavour. Consider the question of determining what is the stress imposed upon the ocean by the wind field. The question must be answered on a microscale, i.e. the stress is first transmitted on a resting ocean in the form of ripples; but from ripples one generates gravity waves. The surface layers become turbulent in a form whose details depends upon the initial stratification and the physics of its maintenance. The gravity waves interact with the turbulence, with themselves and any initially generated mean flows. As the stratification changes, the details of all these interactions change as well. On a sunny day, the erosive powers of the mechanical stirring compete with the stratification building up from the solar radiation; on a cooling night one can have instead stress transmission in the presence of free convection in the upper layers. Ultimately, Coriolis forces come into play. In a stratified upper ocean, energy can be extracted from the wind-stirred layer by internal wave radiation; its budget must be known to compute the turbulent intensity of what remains behind. In addition to these and other mechanisms, one must remember that the forcing by the atmosphere cannot be taken as given; the atmosphere itself reacts to the changing details of the surface roughness, to the changing transmitted stress and to the magnitude and sign of the heat transfer.

If one has an understanding of all of these microscale processes, then in order to

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come to grips with the economic and social questions, the distribution of stress and heat transfer on a global scale is required. How is one to obtain that? How does one obtain even the heat content of the upper ocean on a routine global basis? In fact, at the present time there is no satisfactory way, rather there exists a series of isolated and incomplete measurements relying upon merchant ships and a handful of drifting buoys.

In the upper ocean, one has an interesting coupling of normally unconnected physical processes. One of the most important social questions extant is the residence budget of CO_2 coming from fossil fuel burning, deforestation and agriculture. To understand the ultimate level of CO_2 in the atmosphere, and its possible climatic effect, one must determine the rate at which the ocean absorbs CO_2 and whether for practical purposes it will saturate.

An important link is the determination of the gas exchange coefficient across the air-sea interface. But this exchange coefficient is a strong function of sea state and temperature difference, etc. Thus an important chemical question, with ultimate climatic importance, is dependent upon the finest mechanical details of the upper ocean and must be ultimately known on the global scale.

This vexatious but fascinating and important field is the subject of Kraus' book. The book is the proceedings of a N.A.T.O. Advanced Study Institute conducted in Urbino in 1975. As one usually finds with symposia the range of quality and importance is very large; one can sympathize with an editor's problem in weighting goodwill and happiness against a desire to produce a collection of uniform stature. Usually the demands of national and international goodwill prevail over the objective choices of an editor. The present collection of papers is no exception; cutting the book to about 50 % of its present size would have made a first class volume. As it is one must wade through a considerable amount of dull or tangential verbiage to find the nuggets.

Much of the book is given over to extended reviews and some of them are quite good. Many of them are similar to reviews elsewhere including extensive ones by the same authors; whole paragraphs can be found elsewhere. On the other hand, there is an argument for drawing together a summary of a field into a single volume on the grounds of convenience.

Kraus has divided the book into five sections which he calls: (1) Motivation for upper ocean modelling; (2) Physical processes; (3) Physical models; (4) Biological models; and (5) Experimental considerations. The first section is meant to set the scene in reviews by Holland & Somerville of the oceanic and atmospheric general circulation respectively. Obviously one cannot do justice to these two vast subjects in 20 pages and the authors have wisely not really tried. Holland discusses in a general way the current necessity for *ad hoc* assumptions about the upper boundary conditions on numerical models of the ocean circulation and briefly discusses the comparatively new eddy-resolving general circulation models. It seems clear that the modellers are more concerned now with sorting out the internal dynamics of eddy interactions rather than with dealing directly with the undoubted inadequacy of their parametrization of the air–sea exchange. Somerville devotes himself to reviewing the evidence for and against a significant role for sea surface temperature anomalies on atmospheric predictability (weather rather than climate forecasting). An enormous amount of effort has been devoted to this question; objectively, based upon the evidence at hand, one would have to conclude that there is no indication of any significant impact. But for obvious reasons neither the oceanographers nor the meteorologists want to let go of this idea and despite the so far insignificant results it seems clear that the idea will continue to be pursued vigorously.

Included in this section on physical processes are useful brief reviews on the absorption of solar energy (Ivanoff), the semi-empirical formulary for deducing fluxes of momentum, heat, etc. (Busch), entrainment in a stirred stratified field (Phillips) and of some of the small scale structures to be found in the uppermost layers of the ocean (Pollard). It is in this part of the book that the uninitiated reader can obtain a good view of the mixture of deduction, observation, and pure faith that underlies much of the basis for claiming that the upper ocean is understood.

The modelling section contains two extended reviews, one by Niiler & Kraus of one-dimensional models and by J. O'Brien *et al.* of two- and three-dimensional models. These two reviews are excellent statements of what can actually be done towards 'modelling and prediction'. The one-dimensional models are quite elegant in some respects and obviously useful to a degree. It is not always easy to understand their relationship to the physical processes discussed in the earlier papers, nor the degree to which their success is more than superficial. They often do seem to rest upon a fragile set of hypotheses. The paper on two- and three-dimensional models is devoted mostly to upwelling phenomena but with some discussion also of such disparate phenomena as sea breezes and open ocean fronts. Here the removal of the modellers from the detailed process oriented studies is even more pronounced. If one were to ask what is the relationship between the Langmuir cells discussed under 'structure' and the Ekman layers hypothesized by some of the modellers, one comes away without any connecting links.

I would summarize by saying that a reader of this book will obtain a good overall impression of the state of the art of upper ocean modelling, and of some of the great variety of processes that can occur there. For a deeper, more deductive understanding of specific physical mechanisms he will have to look elsewhere. Knowledge of the basic fluid dynamics is still inadequate to permit quantitative statements about how all of the multitude of pieces will ultimately fit together into useful modelling.

C. Wunsch

Magnetic Field Generation in Electrically Conducting Fluids. By H. K. Moffatt. Cambridge University Press, 1978. 343 pp. £15.50.

This monograph on dynamo theory is the first self-contained treatment of the subject in book form. It is designed to reach research workers in geophysics and astrophysics. I am confident it will be valuable as the principal text in a graduate seminar because the applied mathematical tools and magnetokinematic underpinnings of the topic are presented so thoroughly. Yet the pace is determined; there are no extra sections on magneto-acoustic or electrohydrodynamics or plasma physics. The author directly addresses the formal implications of the pre-Maxwell equations; the general representation, convection, distortion, and diffusion of magnetic fields. An adequate, perhaps more formal than physical, history of the development of ideas and theorems concerning fluid dynamos emerges from the text. There is some evidence that this may be a history of the early days of dynamo theory, for one observes that the Navier–Stokes equations are not introduced until chapter 10.

0022-1120/79/0393-6720 $00.35

There are two coupled ideas central to the progress reported by Moffatt. These are the role of fluid 'helicity' and the 'α-effect'. Helicity is the inner product of velocity and vorticity. A fluid with finite helicity lacks reflexional symmetry, a property central to geophysical and astrophysical dynamos. Utilizing insights in early studies by E. Parker, Moffatt has been principally responsible for the formal identification and exploration of helicity and its consequences for magnetic instabilities. He emphasizes and records research studies of waves with helicity and turbulence with helicity, presumed to be a consequence of motions produced in a rotating system. Such flows are shown to generate large-scale magnetic fields for realistic (not necessarily realizable) circumstances.

The second central idea, the 'α-effect' (which also emerges 'almost' from studies by E. Parker, 1955), was the product of the East Germans, M. Steenbeck, F. Krause & K.-H. Rädler in 1966. They assumed that the apparent linearity of the magnetic diffusion equation with respect to the magnetic field **B** permitted a formal expansion of the local or ensemble averaged nonlinear electric field term

$$\langle \mathbf{U} \times \mathbf{B} \rangle_i = \alpha_{ij} B_{oj} + \beta_{ijk} B_{oj,k} + \dots$$

in terms of a large scale magnetic field **B**, such an expansion converging rapidly if the velocity field **U** was small scale. Moffatt's examples of this process, for small scale and small amplitude **U**, establish that α must be linearly related to the locally averaged helicity of the fluid. The assumption of an α as a function of position (and the assumption of some not implausible large scale $\mathbf{U}_0$ field) has led to a host of kinematic dynamos, suggestive of both the periodic solar dynamo and steady aspects of the geodynamo. An adequate number of such dynamos are described and dissected in this monograph.

However, the full dynamo problem is not linear or kinematic. The velocity field is modified by the Lorentz forces, and no finite dynamo can be force free. Even the force due to small magnetic fields of a presumed initial magnetic disturbance can profoundly alter the fluid flow and hence the character of that magnetic field which grows. Indeed, finite-amplitude 'sub-critical instability' is particularly likely in fluid systems with gyroscopic constraints. The observed large magnetic fields of the sun and earth may be the principal control of both the large and small fluid motions. I do not mean to suggest that the α expansion lacks usefulness. On the contrary, asymptotic expansions typically have their greatest usefulness far outside their proven range of validity: one must discover how α and β are altered in character and amplitude by finite amplitude magnetic fields. Moffatt discusses first steps in this direction and includes two dynamo models, one by Braginsky and one by Busse, in which the authors have used smoothing techniques akin to the 'α-effect' to average over the (vitally important) small departures from the mean. Perhaps it should have been noted in the monograph that although 'first order smoothing' and the use of multiple space or time variables lead to the same lowest order kinematic results, higher order terms and dynamic modifications will differ in general. A correct path to the finite amplitude modifications of α is yet to be determined.

Moffatt also reports on his own and earlier studies on the generation of magnetic fields by homogeneous turbulence. The work of Batchelor, Kraichnan & Saffman was concerned with reflexively symmetric turbulence and the possibility of an 'α-effect' was not noted. Generation by isotropic turbulence required a (negative) β effect. There is evidence that such a β is possible, but a clear case has not been made yet. Also, as in conventional fluid dynamics, the unstable disturbances would occur at all scales, without the scale separation that justifies an α expansion. That 'lack of reflexional symmetry' in the fluid motion urged by Moffatt & Parker, and induced in rotating systems, by-passes the isotropic problem. Homogeneous turbulence with a bit of helicity on average would appear, from qualitative argument and a variety of closure schemes, to generate magnetic fields of large scale. Changing the traditional question can be its most appropriate resolution. Perhaps Moffatt will write the magnetic jingle to counter Richardson's misleading myth.

Guided by this monograph, the reader can find a path towards formulation of dynamic models of the planetary dynamos. Even the qualitative consequences of such models may resolve the physical problems of the nature and distribution of dynamo energy sources. Further along this same path we meet the other important problems of momentum transfer by magnetic fields in planets, stars, and galaxies. Other recent reviews by N. O. Weiss (*Quart. J. Roy. Astron. Soc.*, vol. 12, 1971, pp. 432–446), F. H. Busse (*Ann. Rev. Fluid Mech.* vol. 10, 1978, pp. 435–462) or S. Childress (*Woods Hole Ocean. Inst. G.F.D. Notes*, 1978, pp. 1–80) can add to Moffatt's story, but like this review, centre their attention on more limited aspects of the topic.

W. V. R. MALKUS