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REVIEWS

Wetting, Spreading and Adhesion. Edited by J. F. PADDAY. Academic Press, 1978. 498 pp. £25.00.

The word 'spreading', as used in the title of this symposium proceedings, has two nearly distinct connotations. First, a liquid may be able to 'spread' more or less spontaneously over a surface. This occurs if the total surface energy, made up of the surface energies of the solid/vacuum, liquid/vacuum and liquid/solid interfaces, is reduced. This type of spreading is essentially static. The second connotation is a 'dynamic' one: 'spreading' implying actual motion of the liquid over the solid, and this is the situation of most interest to practitioners of fluid mechanics. Of the twenty papers presented in the collection under review, all given at a Symposium of the Society of Chemical Industry at Loughborough in 1976, only six are in the latter, 'dynamic' category. However, this does not mean that the rest can be safely ignored by those whose interests lie in free-surface flows.

There is a tendency among the applied mathematicians in this field to become impatient with the failure of Nature to provide real systems of solids and liquids that are easily described by tractable mathematical models. Even under the most refined experimental conditions, far removed from practical usefulness, using pure liquids and solids, 'impossible' situations arise – such as that exhibited by a droplet of a non-wetting liquid running freely over a smooth surface. In this example, it is common experience that clean water will simply run off the polished surfaces of most clean plastic materials. To do this, however, the layer of water immediately adjacent to the solid surface appears to have to violate its zero-tangential-flow boundary condition at the liquid/solid/air contact line. As if this were not enough of a difficulty, Nature is so additionally unreasonable as to make the static contact angle variable, depending on the direction of motion of the contact line. This makes mathematical prediction even more difficult.

It is hoped that the present volume will help fluid dynamicists understand the background to problems such as the ones mentioned above, although it will be by no means easy for them to see in what way significant progress can be made. The book does, however, give a clear idea of the factors involved in 'static' spreading, and the papers dealing with 'dynamic' aspects do indicate where and how fluid mechanics is actually being useful in the subject.

Three of the six 'dynamic' papers concern the movement of liquid interfaces in porous solid media, a subject of considerable relevance to petroleum recovery. S. Levine and G. Neale (A Theory of the Rate of Wetting of a Finely Dispersed Random Porous Medium) describe an energy balance approach to this problem, incorporating two dissipative terms in the equation of motion for the advancing meniscus: one for viscous drag at low Reynolds numbers and the other for fluid circulation in the pores between the particles. J. A. Wingrave, W. H. Wade, and R. S. Schechter (Liquid Imbibition into Evacuated Mesoporous Media) report experiments which measured the flow of n-alkanes and water into porous Vycor spheres. The principal aspects of the imbibition process are identified, and a model equation for porous spheres is proposed. N. R. Morrow and F. G. McCaffery (Dis-

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placement Studies in Uniformly Wetted Porous Media) describe experimental work on the displacement of air from sintered P.T.F.E. cores by various liquids, under a wide range of wetting conditions of the core. The importance of the contact angle in this system is clearly shown.

In his brief paper entitled 'Wetting and Spreading – Some Effects of Surface Roughness', S. G. Mason describes experiments, which are illustrated on a 16 mm film (shown at the Symposium and available on loan), on the influence of various kinds of surface roughness on spreading behaviour. R. Burley and B. S. Kennedy (Dynamic Wetting and Air Entrainment at a Liquid–Solid–Gas Junction) studied the entrainment of air when a flat tape enters a liquid surface at speed. They develop approximate theories to account for the shape of the meniscus before entrainment begins and to predict the onset of entrainment.

G. C. Sawicki (Dynamic Surface Phenomena Associated with the Spontaneous Spreading of Silicone Fluids) examined the spontaneous spreading of these low-energy liquids on a high-energy silicon metal substrate and found that a simple model of the system, in which the decrease of surface energy is balanced by viscous forces, significantly underestimates the observed rate of spreading. This anomaly is here ascribed to an orientation of the liquid molecules at the free surface, which is thought to lead to a decreased viscosity in this region.

The rest of the volume is divided into sections on the physics of the solid/liquid contact region, on model systems for equilibrium interfaces, and on applications to industrial and biological processes. One commendable feature of the presentation is that each paper is accompanied by a certain amount of discussion, based on what was said at the meeting. This is helpful in that it puts the papers into perspective to some extent, highlighting the areas of contention. This valuable function of the book is aided by a synoptic review by J. F. Padday, who has ably edited these proceedings into a most useful statement of current thinking in the subject.

J. C. Scott

Bubbles, Drops and Particles. By R. Clift, J. R. Grace and M. E. Weber. Academic Press, 1978. 380 pp. £20.80 or $32.00.

The motion of bubbles, drops and solid particles plays an important role in many diverse physical operations and hence the subject has attracted the attention of engineers, physicists, chemists, geophysicists and applied mathematicians. The authors – all three of whom are chemical engineers – here set out to provide a detailed and critical review of the relevant literature as it pertains to the fluid dynamics heat transfer and mass transfer of single bubbles, drops and particles.

A short introductory chapter deals with the basic equations, boundary conditions and the principal dimensionless groups to be used later on in the text. Particularly valuable is the early discussion of the 'thin concentration boundary layer approximation', a useful concept which often simplifies the analysis of liquid-phase mass transfer problems when concentration variations are confined to thin layers near interfaces. In chapter 2 the shapes of rigid and fluid particles are classified and the various shape regimes found experimentally for drops and bubbles are presented as functions of the three principal dimensionless groups: the Eötvos number E_0; the

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Morton number M; and the Reynolds number Re. The motion of spherical drops – and the associated mass transfer problems – under conditions of small values of the Reynolds number are then discussed in chapter 3, which contains a particularly valuable account of the effects of surface contaminants on the motion of small bubbles. Spheres and non-spherical rigid particles at higher Reynolds numbers are taken up next in chapters 5 and 6, respectively, and ellipsoidal drops are treated in chapter 7. The chapter which follows contains an account of large drops and bubbles – including the well-known 'spherical caps' first treated quantitatively by G. I. Taylor – while chapter 9 deals with wall effects and the motion of 'slugs'. Miscellaneous effects, e.g. surface roughness, natural convection, simultaneous heat and mass transfer, free stream turbulence, etc. are considered in chapter 10, accelerated motion without volume charge is discussed in chapter 11, while the last chapter is concerned with the formation of drops and bubbles primarily at an orifice, and their break-up in stagnant media and in shear flows.

The book contains a large number of references, some as recent as 1975. The authors have gone to great lengths to discuss many of these in some detail and have striven, wherever possible, to compare exact theoretical predictions (obtained, mostly, *via* a numerical solution of the basic equations), approximate analytical results (mostly asymptotic), and experimental findings. The value of such a comparison cannot, of course, be overemphasized.

In short, the book represents a carefully written, detailed and essentially complete account of the subject matter under discussion and is recommended as a valuable and up-to-date reference book. It should be remembered though that it is not a textbook. It contains very few derivations or detailed explanations of theoretical results and, therefore, may have limited appeal to more theoretically inclined readers. Also, it deals exclusively with the behaviour of single particles and hence its scope is rather narrow in that it does not cover the many important and fascinating phenomena which arise because of particle–particle interactions.

A. Acrivos

Analysis of Groundwater Flow. By A. J. Raudkivi and R. A. Callander. Edward Arnold, 1976. 214 pp.

There are many books available which cover various aspects of groundwater flow and which approach the problem from different directions. The current book is very much an analytical text, concentrating on developing formulae for different configurations of groundwater flow. It has barely a mention of either graphical, experimental, analog, or numerical techniques for investigating flow problems – many of which may give the investigator a better feel for the nature of the flow than will an analytical expression plucked out of this book. However, that is perhaps to criticize the book for not doing something which it does not claim or set out to do.

The first chapter introduces the subject with definitions of various features of groundwater conditions and flow, and consideration of the general properties of water and of porous media. Though of interest, and of relevance to the general subject of the book, this chapter fits in curiously with the rest of the book which is very much in the form of a handbook of analytical results.

A wide range of problems is dealt with in subsequent chapters. These include:

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problems of steady confined flow – such as flow in aquifers to wells and drains, and from lakes, and flow under various water-retaining structures such as dams or cofferdams; problems of steady unconfined flow – such as flow through beds of soil to wells or drains, or flow through earth dams; and problems of unsteady flow, both confined and unconfined – the latter being particularly difficult to solve analytically unless certain approximations are introduced. Although some mathematical techniques commonly used for analysing flow are specifically avoided in order to keep the mathematics as simple as possible, some fairly advanced mathematical ability is presumed, and also needed, in order to be able to follow the rather abbreviated style. A final chapter tackles the problem of interfaces between salt and fresh water; mixing effects at the interface are negligible and the results are consequently relevant to the interface between the flow or intrusion of any two non-mixing fluids.

The concise style of presentation has already been mentioned: on the whole the presentation is good, and the diagrams clear. There are a number of typographical errors, several of which have obviously crept in through the somewhat fussy constant interchange between type faces. Not all the parameters and symbols are clearly defined when introduced so that some care will be required in abstracting results from this particular well of information.

D. M. Wood

Shorter Notices

A Bibliography of Thermal Anemometry. By Peter Freymuth. Thermo Systems Inc., 1978. 26 pp.

This is a bibliography of papers dealing with thermal anemometry for the measurement of fluid flows. It references in chronological order those papers which have contributed to the techniques of anemometry from 1817 to 1978, and is intended to be used by specialists to locate literature on particular topics. Each entry is given one of the 42 subject index numbers, allowing the contents of each reference to be assessed.

International Symposium on Ship Viscous Resistance. Edited by Lars Larsson. Liber Distribution, Sweden. 343 pp. Sw.Kr. 99.50.

The 16 papers in this volume were presented at a conference held at the Swedish State Towing Tank in August/September 1978. The introductory paper by Landahl treats wall turbulence in a general context. The remaining contributions are applied to the steady flow past a ship hull. Several papers are devoted to three-dimensional numerical simulations of turbulent boundary-layer flow. Other topics include experiments on models and full-scale ships, separation, and interaction of the boundary layer with longitudinal vortices. An appendix contains the written discussion and authors' replies.

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