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Journal of Fluids and Structures 23 (2007) 157–158

JOURNAL OF FLUIDS AND STRUCTURES

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Book review

Suspension Acoustics, An Introduction to the Physics of Suspensions, S. Temkin, Cambridge University Press, Cambridge, 2005, ISBN 0-521-84757-5.

Suspension Acoustics is a detailed account of how particulates dispersed in liquids and gases influence the passage of sound waves. For newcomers who are already familiar with suspension mechanics in non-acoustical settings, it may come as an interesting surprise to learn that non-interacting particles can produce large, measurable bulk acoustical properties, even when the particle loading is extremely small. Indeed, the book is primarily concerned with the dynamics of non-interacting inclusions and, therefore, dilute suspensions. The scope is also limited to uncharged, non-Brownian particulates, with sizes in the range 1–100 μm. Nevertheless, the problems are rich due to the coupling of heat, mass and momentum transfer. While there are noteworthy natural and technological applications, particularly for characterizing the micro-structure of multi-phase fluids, the emphasis is very much on the physics of individual oscillating spherical *bubbles*, *drops*, and *solids*, and their collective dynamics as traveling (sound) waves. In particular, we learn how basic characteristics of the dispersed and continuous phases, such as size, density and compressibility, influence *wave speed*, *attenuation* and *dispersion*.

Temkin sets the stage by presenting in detail the parameters necessary to characterize the micro-structure of aerosols, bubbly liquids, emulsions and hydrosols. From the outset, the style is descriptive and physically motivated. For example, three representative plots of experimentally measured quantities are presented to introduce the extensive theoretical developments that follow. The reader is also encouraged to perform a simple 'kitchen bench' experiment to illustrate several tangible aspects of acoustical phenomena in multi-phase fluids.

The other introductory chapters address fundamental conservation principles (mass, linear and rotational momentum, and mechanical and internal energy). An illustrative one-dimensional derivation is usually presented before turning to vector calculus. Following chapters present a series of detailed studies examining the dynamics of single spherical inclusions responding to harmonic fluctuations in the far-field pressure and velocity. These case studies are valuable on their own, but they also contribute to the later chapters dealing with wave propagation. The book is primarily concerned with (small) perturbations to an 'equilibrium' state and, accordingly, Temkin exploits this to deal with translations, shape perturbations, and pulsations separately.

When treating translational motion, Temkin introduces several important and more general aspects of classical and modern theoretical hydrodynamics. Building on quasi-steady Stokes flow, he discusses singularities, Faxen laws, superposition, and spatial and temporal inertia (non-linear, finite Reynolds number effects). The presentation of some of this material is, understandingly, brief, but, nevertheless, clear and informative. It is not unlikely that graduate students will find this an excellent introduction to more specialized and, perhaps, difficult monographs on microhydrodynamics, for example.

Temkin often points the reader to important texts and research literature in specialized, but related, areas; for example sonoluminescence and electroacoustics. Accordingly, a comprehensive bibliography that lists books, review articles, and research articles is provided, with the latter sub-divided into approximately 25 subject headings. It is also a bonus to have readily available concise presentations of important classical results on the dynamics of small particles; for example, the Basset–Boussinesq–Oseen and Rayleigh–Plesset equations.

One appealing aspect of the book is the generous offering of illustrative plots to complement unwieldy formulas involving complex variables. Temkin often derives comprehensive results before focusing on easily digestible simplifications. Accordingly, it will not be surprising if the book appeals particularly well to students who are primarily interested in learning step by step, from the bottom up. Temkin is not shy about deriving results that have little practical significance if there is something valuable to learn from the exercise. He is also careful to highlight shortcomings of approximations adopted for pedagogical merit.

Considerable care has been taken to arrive at a clean and systematic notation, and to help, a comprehensive index of symbols is provided. For tensorial quantities, direct notation is adopted almost exclusively, except when index notion provides a significant advantage; for example, when working with the Levi-Civita (permutation) symbol. Readers who

doi:10.1016/j.jfluidstructs.2006.08.005

are unfamiliar with index notion will find the compilation of vector identities in the appendix a must. Other appendices (including quantities in polar coordinates, spherical Bessel functions, and Legendre polynomials) are concise and clear.

The author has faced the difficult task of balancing the needs of readers who wish to 'jump' straight into suspension acoustics with those who need to refresh (or learn from scratch) classical transport phenomena and thermodynamics. Many readers will already be quite familiar with incompressible hydrodynamics, and, as such, they will find sections dealing with the fundamentals of compressibility, heat transfer and dissipation as useful points of reference; these readers may also find themselves in a hurry to reach chapters six to eight, discovering that it is necessary to first become acquainted with the terminology introduced in earlier chapters.

One minor criticism is that equations referred to in the main text are often referenced only by their number, whereas it would have been helpful to occasionally provide accompanying verbal descriptors to save the reader having to turn back pages. Some readers will also be disappointed to uncover a number of minor typographical errors. Otherwise, the typesetting and overall presentation of figures, mathematical formulas and text is of a very high standard.

The final chapter addresses a variety of topics appropriately referred to as applications and extensions. Understandingly, these topics are addressed relatively quickly. Nevertheless, they provide a vital link between fundamental theory, which forms the basis of the book, and practical applications.

It is humbling to be reminded that, despite the impressive and extensive theoretical developments in the field, important outstanding problems remain. Temkin's book also has the potential to inspire readers to take up these challenges. I found *Suspension Acoustics* to be interesting, comprehensive and 'readable'. As a text for graduate students interested in the physics of acoustic wave propagation in multi-phase fluids, this is an excellent place to start. It will also serve as a valuable reference for researchers in the field.

Reghan J. Hill
Department of Chemical Engineering and McGill Institute for Advanced Materials, McGill University, Montreal, Québec, H3A 2B2, Canada
E-mail address: reghan.hill@mcgill.ca