Bubbles, Drops, and Particulates in Non-Newtonian Fluids (2nd Edition)

By R. P. Chhabra, CRC Press, Taylor & Francis Group, Boca Raton, FL. 2007, 771 pp. $269.95.

This is the second edition of a book first published in 1993. The author states that the goals and structure have remained the same, which are "to provide a reference text for graduate students and researchers by presenting a *comprehensive* and *critical* [italics mine] evaluation of the available extensive literature relating to the non-Newtonian effects in multiphase flows. . .".

The comprehensiveness of this volume is staggering, and in this respect the author has provided a compendium not even approximately matched elsewhere. Even in this age of instant retrieval, it is impressive that one person could be aware of the range of work described by Professor Chhabra. References are collected at the end of the book and they alone occupy a space of 134 pages!

The progression of topics follows a reasonable sequence, beginning with a 40-page primer of non-Newtonian fluid behavior. This is followed by chapters describing the behavior of rigid particles, first in time-independent, then visco-plastic, and finally viscoelastic fluids. The emphasis is on single particles, with occasional references to interactive effects observed in, for example, the settling of multiple spheres. Not surprisingly, the next major topic is a corresponding treatment of fluid, i.e., deformable, particles in non-Newtonian media.

Difficult as these topics are from a fundamental point of view, they are simpler than the situations often encountered in processing operations. The author does not neglect these, and chapters are included on flow through porous media, fluidized beds, wall effects, and even heat and mass transfer. The approach for each topic is to review our knowledge of Newtonian systems, and then to launch sequentially into results for inelastic and viscoelastic fluids. The book concludes with a chapter on "Falling Object Rheometry", itself an example of particulate flow through non-Newtonian fluids.

This book is an excellent source for those wishing to find collections of published data and theoretical results for interactions of particulates with non-Newtonian fluids under a wide variety of conditions. For example, Table 5.1 (pages 163–167) is a summary of theoretical studies of viscoelastic fluids flowing past spheres and cylinders at low Reynolds numbers. There are more than 75 entries, each annotated with a brief description. The book contains several tables comparable in completeness to this one. I noted at the outset the author's goal to match comprehensiveness with a critical evaluation of the work presented. Here the book is less successful, perhaps in part because of its encyclopedic approach. If one is patient, it is possible, eventually, to uncover some general recommendations, but these are often not easy to find. An example, I would have liked to see repeated more often is a series of bullets on page 111 summarizing what can be concluded about drag on nonspherical objects in power-law fluids. As it stands, the nature of the book is more of an encyclopedia than it is a handbook or guide. It is a source from which one learns what has been done but not how it has been done.

Hence, even though the book is described in the Preface as a *text*, I would not recommend it as a place to learn principles. If one is not already familiar with Cartesian tensors, the explanation of the stress tensor (pages 12–13), and the use without explanation of invariants of the rate of deformation tensor (page 59) will be unsatisfying.

I found the writing to be, in general, clear. The few typos I found were obvious and did not cause confusion. Exceptions were the description of the Kumar-Kuloor model for drop formation, where the zero-time from which t_c, the time of detachment, is measured is not stated, and a problem with the abscissa in Figure 5.9, where the units should be time in seconds rather than its reciprocal.

The author's honesty cannot help but engender a modicum of despair over our meager ability to predict behavior of non-Newtonian fluids in all but highly constrained situations. In chapter after chapter the author is forced to conclude with a statement along the lines of that given on p 94, where he writes: ". . . unfortunately, none of the custom-built correlations developed for the estimation of free-fall velocity in power-law liquids seem to offer any significant improvement over [the Newtonian expression]". (Perhaps this is the *critical evaluation* referred to in the Preface.)

One must ask the question, "Why?" I believe the basic difficulty remains our inability to classify real non-Newtonian fluids into categories with a clarity that permits sufficiently useful generalization, either experimental or theoretical. We can perform experiments with a given fluid and can correlate the results into forms with predictive value for that fluid under the conditions for which the data exist. We can also perform simulations for fluids possessing rheological characteristics as an input to the simulations. However, a robust way to match any given fluid to either the correlations or the simulations still eludes us.

While we wait for this gap to close—and the wait may be long—we do have in Professor Chhabra's book a means to explore and to test whether a fluid/particle interaction of interest is likely to be described, at least semi-quantitatively, by some of the predictions developed during the past 50 years.

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