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BOOK REVIEW

Particulates and Continuum. Multiphase Fluid Dynamics, by S. L. Soo. Hemisphere, Washington, D.C. (1990). $60.

This book represents the third monograph produced by Professor Soo. The first, entitled *Fluid Dynamics of Multiphase Systems*, was published in 1967, and the revised edition, entitled *Multiphase Fluid Dynamics*, was published in 1983. In the preface of this work Professor Soo states that "the present volume treats definitive concepts, methods, and theories which have been validated by experimental results", and he identifies the audience with the comment that "this book is intended as a textbook for college seniors and graduate students and as a research reference".

Chapter 1 represents a survey of the physical phenomena that are covered in the remaining 7 chapters. The spectrum of particle sizes is discussed, Stokes law is presented along with Oseen's correction and the classic drag coefficient–Reynolds number relation for a sphere. Heat transfer, mass transfer, slip, electrical forces, thermophoresis, photophoresis, diffusion phoresis etc. are discussed from a superficial point of view, and the reader is exposed to some of the classic references such as Stokes (1891), Langmuir (1918), Hadamard (1911), Basset (1888), Boussinesq (1885), Einstein (1906) and Lorentz (1896).

Chapter 2 is entitled Basic Equations. A derivation of the transport theorem is presented along with the differential equations for mass, momentum and energy. The actual *axioms* associated with these differential equations for single component systems are not presented, nor are the axioms for *multicomponent* systems presented. This means that a discussion of mass transfer relies on *basic equations* to be found elsewhere. The spatial averaging theorem is derived, and both time and space averaging are discussed. A brief review of jump conditions at phase interfaces is given, and the chapter closes with a warning to the reader that "the present volume deals with cases where rigorous mathematical procedure can be applied, leaving *ad hoc* empirical correlations to handbooks and for future developments from fundamental procedures".

Chapter 3 is entitled Transport Properties and Processes and it deals esentially with heat, mass and momentum transfer in dilute suspensions of particles. Mass transfer is presented by analogy to heat transfer and this places a severe, but unannounced, limitation on the results. For example, in Chapter 1 the Sherwood number is expressed as

$$N_{sh} = 2ak_c/D = 2$$

for mass transfer from a sphere into a stagnant fluid. The flux is given by

$$\dot{N} = k_c(C_i - C)$$

and Langmuir (1918) is cited as the source. That this result is only valid when the mole fraction is small compared to one is not noted, nor is the fact that the general solution is available in *Transport Phenomena* by R. B. Bird, W. E. Steward & E. N. Lightfoot. If these results are used to determine the role of evaporation of a drop near its boiling point, significant error will be incurred.

A problem of considerable interest concerning the transport of a dilute suspension of particles is the momentum equation for the suspension. Given the condition of *irreversibility of momentum transfer from particle to fluid*, a momentum equation is presented in a purely intuitive manner by treating the particle phase as a *true continuum*. Failure of this result to predict experimentally observed phenomena gives rise to the "effectiveness coefficient", K_m, which is determined experimentally. After this presentation of the momentum equation for a suspensions of particles, the author discusses a number of momentum transfer problems such as particle–surface interaction, electrostatic forces, particle–particle interaction and erosion and attrition. Transport properties such as viscosity and thermal conductivity are discussed, and the results of Einstein (1906), Taylor (1932) and Happel & Brenner (1965) for the viscosity of suspensions are presented. For the effective thermal conductivity, the author refers to the work of Gorring & Churchill (1961) concerning the thermal conductivity of rigid, heterogeneous materials. In the absence of relative motion between the fluid and the particles, the approach of Gorring & Churchill could be justified; however there are very few practical situations that fit such a model. In general, shear stresses are present and the suspended particles can rotate. This rotation can enhance the heat transfer process, and the effective thermal conductivity is therefore different for a flowing suspension than it is for a stagnant suspension. The listed expression for the effective thermal conductivity *appears to be*

$$\kappa_{\mathrm{m}} = \bar{\kappa}\,\{1-(1-\alpha)[1-(\bar{\kappa}_{\mathrm{P}}/\bar{\kappa})]\}$$

in which κ_{m}, $\bar{\kappa}$ and $\bar{\kappa}_{\mathrm{P}}$ represent values for the mixture, the fluid and the particles. This expression for κ_{m} represents the component of the effective thermal conductivity tensor for conduction parallel to a layered system of fluid and solid. It would have been more appropriate to draw upon the work of Rayleigh (1892) or Maxwell (1891) for the effective thermal conductivity for a dilute suspensions of rigid spheres.

Chapter 4 is entitled Effects of Waves and Electricity and Surface Boundary Conditions and it is directed toward the problem of radiant energy transfer when the effects of absorption, emission and scattering must be taken into account. Propagation of sound waves is also considered along with electrical conductivity, ionized gases and charge distribution.

Chapter 5 deals with a set of transport equations for one-dimensional motion and this is followed by Chapter 6 which is entitled Pipe Flow of a Suspension. This represents an application of equations presented in Chapter 2 along with a discussion of a number of experimental studies. The chapter closes with a discussion of cyclone separation.

Chapter 7 is entitled General Motion of Dilute Suspensions and it begins with a discussion of vortex motion. Boundary layer flows, entrance region flows and jets are described in terms of previously listed equations; however, comparison with experiment is very limited.

The final chapter in this monograph is entitled Dense Systems and it deals with flow in porous media and fluidized beds. It is an area rich in mechanical problems; however, the chapter is restricted to the presentation of previously observed phenomena and no attempt is made to deal with the basic continuum mechanics associated with dense suspensions.

In this reviewer's opinion this monograph cannot be thought of as a text for either college seniors or graduate students. Results are listed without explanation or without justification, and this poses a serious danger to a student who might associate a certain degree of rigor with a textbook. In this era of desk-top publishing, the quality of the camera-ready copy and the artwork is not acceptable either for a research monograph or a textbook. While recent research results are few and far between the bibliography in this monograph will provide the interested reader with a list of the classic works in the field.

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