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BOOK REVIEW

M. KAVIANY, **Principles of Heat Transfer in Porous Media.** Springer-Verlag, 1991.

THE MONOGRAPH by M. Kaviany is concerned with a theory of heat and mass transfer processes in porous bodies, i.e. with a field of knowledge presently undergoing a new upsurge owing to a significant extension of possible engineering applications. In fact, the range of problems it tackles is far wider than stated in the book title. Alongside analyzing heat transfer in porous bodies *per se*, the book gives a good deal of attention to the hydrodynamics (filtration) and mass transfer problems. This imparts a completed character to the monograph and allows its employment as a general methodological guidance in constructing calculational models for specific systems.

The author's main goal lies, in our opinion, in obtaining the macroscopic continuity equations of transfer in a porous medium and the physical coefficients entering thereinto using the local volume averaging with allowance for the system structure and properties. At the same time, the book attaches much attention to heuristic (phenomenological) models and to experimental results, which enables an estimation of adequacy of the theoretical treatments and a selection of the most appropriate description of the phenomenon in each specific case.

The monograph is distinguished by the profoundness and breadth of the material encompassed, it contains a unique historical review of the development of the area of science in question and an analysis of extensive publications, including the latest ones. It also deals with the author's original work (some of which has not yet been issued).

The modernness and opportuneness of the book make it highly valuable for experts, whereas the width of material coverage and the representation method originating from 'first principles' also make it valuable for those who set about studying heat and mass transfer in porous bodies.

Unfortunately, a considerable part of the Russian language literature pertaining to the monograph's subjects remained outside the author's field of vision. The objective reasons for such a deficiency are quite understandable. It can be presumed that its elimination would be interesting both in respect of the problem history and in the sense of conceptual enrichment of the material set forth.

The book consists of an introduction and two parts. The first part treats the transfer processes in porous materials in singe-phase flows. The basic range of application of the results presented is a wide scope of phenomena involving gas filtration through a porous medium.

It is the beginning of the first part (chapter 2) that deals with the filtration theory. Along with expounding the classical filtration laws and the models for predicting a porous medium permeability, consideration is given to a variety of nontraditional problems associated with the features of hydrodynamics near the porous body boundaries, namely to the account of macroscopic viscosity, to the porosity variations at the boundary, and to various versions of boundary conditions. Interesting are the author's own results, obtained (together with M. Sahraoui) by the direct numerical simulation of flow near the boundary of the porous medium consisting of periodically arranged cylinders, and the suggested slip-boundary conditions at the interface with a plain medium.

Debatable, to our mind, is the author's standpoint regarding the vector form of writing the inertial contribution to the momentum equation. The expression proposed by M. Kaviany, proportional to $|u_{\mathrm{Di}}|u_{\mathrm{Di}}$, results in the fact that, for the isotropic medium, the filtration flow direction will not coincide with the pressure gradient direction at an arbitrary choice of the coordinate axes. An expression proportional to $|\mathbf{u}_{\mathrm{D}}|u_{\mathrm{Di}}$ seems to be more correct.

Chapter 3 examines conductive heat transfer in the approximation of local thermal equilibrium. A detailed comparison is conducted between different computational formulae for effective thermal conductivity and the experimental data. A good agreement between the Hadley formula and experiments is demonstrated even for large ratios of k_s/k_f.

Emphasis is placed on conduction transfer near the porous body boundary. Based on his own model predictions of thermal conductivity in the porous medium consisting of cylinders, the author suggests using the 3rd-kind boundary conditions. It must be borne in mind, however, that the range of applicability of the model predictions is limited and the problem of identifying the value of temperature jump at the interface with a plain medium generally remains unsolved.

In the chapter conclusion it is stressed that porosity is frequently not the only parameter governing effective thermal conductivity. The internal structure of the porous medium also plays a significant role. Therefore, a certain prudence is needed when employing the theoretical and empirical formulae for calculating the thermal conductivity coefficient with reference to each new specific system.

The primary focus in chapter 4 ('Convection Heat Transfer') is on the discussion of dispersion effects. The author avails himself of an apt technique: the subject presentation starts with the description of thermal dispersion in tube flow (G. I. Taylor) which gives a clear idea of the phenomenon nature. Further on, the chapter considers different models of describing dispersion in periodic and, afterwards, disordered structures. The relations for longitudinal and transverse dispersion coefficients, proposed by various authors, are compared with the experimental values. Unfortunately, the majority of available experimental data relate to the case $(\rho C_p)_s = k_s = 0$, which narrows the range of possible comparisons and lessens reliability of the formulae suggested.

The last part of chapter 4 reviews approaches used to describe thermal dispersion near the porous body boundary based mainly on the porosity variation.

Chapter 5 is devoted to radiation heat transfer within a porous body. Relying on the results of his own investigations (performed together with co-authors), M. Kaviany analyzes various situations in which preference can be given to one or another way of describing radiation heat transfer, namely, to continuum (as compared with the direct simulation), independent or dependent scattering on particles. It is pointed out that, at the present time, radiative properties of the medium in many situations (for example, with a disordered arrangement of particles of arbitrary sizes) can only be determined experimentally.

Apropos of taking radiation transfer into account it is to be noted that the inclusion of the radiative transfer equation into the process description adds appreciably to computational difficulties. A simple approach to describing radiation propagation and absorption in porous bodies can be employed for the high-porous media with an opaque skeleton. In the cases when the characteristic thermal dimension is much in excess of the free path length of radiation quanta, the additive radiation contribution the effective coefficient can be used successfully.

Mass transfer in the 'gas–porous medium' system is treated in chapter 6. Two possible diffusion regimes in pores are analyzed, namely the Knudsen and Fick ones. The chapter ends with the discussion of the way of formulating the source term in the diffusion equation via averaging over the representative volume.

As far as this chapter contents are concerned, the reviewers would like to remark that the kinetic theory admits a more accurate computation of the multicomponent diffusion coefficients than set forth in the monograph, with a view of the parameters of molecular interaction potentials (see, for instance, the book by J. O. Hirschfelder *et al.* *'Molecular Theory of Gases and Liquids'*). Beyond the scope of representation remained the question as to the role of thermodiffusional effects which can prove to be noticeable at high temperature gradients occurring, for instance, in combustion inside porous media. Besides, for model porous media, the literature reports the methods of describing nonequilibrium transfer processes in a gas phase based on the solution directly of the kinetic equation.

Chapter 7, the last of the first part of the monograph, deals with heat transfer in two-temperature systems. In rigorous derivation of the transfer equations, four tensors of effective thermal conductivity (including dispersion) appear in them, namely D_{ff}, D_{ss}, D_{fs} and D_{sf}, as well as the internal heat transfer coefficient h_c (independent of the filtration rate). In practice, as M. Kaviany points out, the heuristic models with the effective interphase heat transfer coefficient $h_{sf} = f(Re, Pr)$ are more frequently used. It is noted that the experimental finding of h_{sf} is based in each case on a definite transfer model and, therefore, the h_{sf} value obtained cannot be utilized for other models.

The subject of the second part of the monograph is transfer in porous media with two-phase flows. The topicality of the problems discussed therein for the processes of drying, boiling and all kinds of physicochemical transformations in porous media raises no doubts. Without considering in detail the contents of this section of the book, we will only remark that it tackles the problems of mechanics of a two-phase medium inside a porous body, various mechanisms of transfer, including that across the bounding surface, and phase changes.

Summarizing the first reading of the book by M. Kaviany *'Principles of Heat Transfer in Porous Media'*, we would like to mark its doubtless usefulness and likelihood of recurrently addressing it in the future. In our opinion, the translation of the book into Russian would certainly be justifiable.

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