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Book review

A. Bejan, I. Dincer, S. Lorente, A.F. Miguel, A.H. Rei, Porous and Complex Flow Structures in Modern Technologies, Springer-Verlag, New York, ISBN 0-387-202250. pp. 396

Flow through porous media is a subject of research undergoing rapid growth in fluid mechanics and heat transfer. This is quite natural because of its important applications in environmental, geophysical and energy related engineering problems. Prominent applications are the utilization of geothermal energy, the control of pollutant spread in groundwater, the design of nuclear reactors, compact heat exchangers, solar power collectors, heat transfer associated with the deep storage of nuclear waste high performance insulation for buildings, the heat transfer from stored agricultural products that release energy as a result of metabolism of the products. Applications of porous media include also environmental pollution of water resources by toxic synthetic chemical residues. Some of the environmental issues that are addresses on research in porous media include sources of the major toxic residues, their chemistry, distribution, persistence and interaction in aquatic environments as well as their harmful effects on ecology and aquatic organisms. The aim of research on this topic is to generate data on concentration levels of the toxic residues in water, sediment and aquatic organisms and determining their residual lifetime in water and soil and how harmful they are to aquatic life. The results of these studies contribute towards a scientific database on persistent toxic chemical residues, which is needed for the implementation of international environmental conventions. On the practical side, there is a great interest in a new generation of engineering problems connected with the topical issues of thermal insulation engineering, and on the theoretical side there remains a continuous need for a comprehensive theoretical framework which covers the field in much the same way as the solutions of the Navier–Stokes, energy and concentration (solutal) conservation equations cover thermal and solutal convection in viscous (non-porous) fluids.

The purpose of this monograph is to provide valuable and important contributions to the theory of flows through porous media. It also brings to the attention of the interested researchers the state-of-the-art of this theory. The book includes classical and recent results, pointing out the most important methods and directions. To achieve this objective, the authors started with two chapters on porous media fundamentals (mass conservation, Darcy equation model and its extensions, energy, equation, coupled heat and mass fluxes, etc.) and analytical methods and relatively simple problems. The second part of the book contains (Chapters 3 to 8) important engineering application (energy engineering, environmental and civil engineering, compact heat transfer structures, biomedical engineering, drying of porous materials and additional directions). A brief summary of the book follows.

The first chapter: *Porous Media Fundamentals* presents an introduction to the theory of porous media and the derivation of the basic equations governing the flows through a porous medium in the most general form. It is shown that transport in porous media is devoted to the presentation of original basic and applied research work on the mathematical, physical and chemical aspects of transport of extensive quantities such as mass of fluid phase, momentum and energy, in single and multiphase flow in a porous medium domain, as encountered in a variety of scientific and engineering disciplines: mechanical and civil engineering, chemical, agricultural, petroleum, biological, to mention but a few.

The second chapter: *Flows in Porous Media* gives some basic properties of convective flows in porous media, which has important applications in the modern industry. Thus, the method of scale analysis is very successfully applied to forced convection boundary layer flows over a flat plate, a sphere and a horizontal circular cylinder. This method is also applied to study the natural convection boundary layers from a vertical flat plate, a sphere and a horizontal circular cylinder. The cases of enclosures heated from the side and heated from below are also considered. The new method of intersecting the asymptotes is also described for the porous layer heated from below, as an application of constructal theory. The results are presented in terms of local and mean Nusselt numbers which are important for design engineers.

The third chapter: *Energy Engineering* is devoted to some fundamental questions of thermodynamics, such

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as entropy generation or exergy destruction in porous media with some important practical applications, such as energy storage, sensible-heat storage, aquifer thermal energy storage, latent-heat storage, cold thermal energy storage, principles of fuel cell operation, and the concept of exergy-cost–energy-mass analysis.

The forth chapter: *Environmental and Civil Engineering* reviews the fundamentals of some of the most important types of flows that govern the behavior of environmental fluids (air, water) and fluid-saturated porous media. These flows refer to concentrated heat sources in forced convection, concentrated heat sources in natural convection (plumes), penetrative convection, aerosol transport and collection in filters, filtration theories, pressure drop and permeability, electro-diffusion, optimal size of flow elements, etc.

The fifth chapter: *Compact Heat Transfer Flow Structures* shows how to use porous media concepts in the description, simulation and optimization of compact systems with complex flow structures. Important problems, such as heat exchangers as porous media, optimal spacings in natural convection and forced convection, pulsating flow and optimal packing of fibrous insulation are in many details discussed from the point of view of constructal theory: the generation of flow configuration based on principle—the constructal law.

The sixth chapter: *Biomedical Engineering* is devoted to the description of several very important questions of biomedical engineering, such as the Darcy flow across membranes or capillary walls, transport of charged solutes across membranes, etc.

The seventh chapter: *Drying of Porous Materials* describes the mechanism of drying process in porous media. It is shown that the most important aspect of drying technology is the mathematical modeling of the drying processes and equipment. Thus, the mathematical models of this process are presented along with some basic analytical and numerical solutions.

The eighth chapter: *Additional Directions* presents the author's most recent results on the internal structure of walls with air enclosures. It is shown that the internal structure of cavities can be derived optimally from the combination of two thermal and mechanical functions. Some basic correlation equations are given for these functions and also basic equations along with corresponding boundary conditions are first established for the melting and solidification in saturated porous media. Analytical and numerical results for some specific values of the parameters entering these equations are given.

In keeping with the character of the book, which mainly contains applications of porous media to real practical problems, there are included a huge number of figures and graphs (163) and a large list of papers and books (506). Throughout the book the authors have offered not only just a description of the topics, but as much as possible solid mathematical argumentation. The applications are clearly exposed, rigorously analyzed, and followed by numerical results presented in tables and figures.

Comparing the present book with other books on this topic, I believe that it stands out for the following reasons:

1. The present book provides a solid fundamental and comprehensive presentation of the physical description and mathematical theory of flow and heat transfer in porous media pointing out the most important practical applications of the problems described. It also addresses the theoretical basis for the solution of several problems frequently encountered in the area of flow through porous media and other connected disciplines. A large number of concrete applications and validation studies are also included into the book. It also gives insight into the unity of science and nature (constructal theory), the nature of physics and applied mathematics, and the way in which mathematics can be applied to concrete practical problems.
2. The monograph presents very detailed physical and geometrical description of the practical problems considered, which are not included or not shown in sufficient details in other text books or monographs. Many of these problems were studied for the first time by the authors of this book and their Ph.D. students. Many experimental results (e.g., drying) appear in the text for the first time. It is shown in many places of the book that the theoretical results account for the quantitative agreement between theory, computations and experiments.
3. Especially, the last six chapters contain new and recent very important results in porous media obtained by the present and other authors, which are useful for practical applications, as well as for the theoretical and experimental studies. For example, a special attention is given to correlations equations, which are very important for the heat engineer designers. Only few such correlations are included into the above mentioned books.
4. Each chapter of the book contains extensive figures and graphs, which may form the basis for other studies of other connected problems with the topics of the present book, and provides researchers in theoretical and applied porous media area with the most prominent applications. We believe that this book is among the few existing books that consider in such a unitary manner the some particular aspects of the practical, physical and mathematical theory of flow through porous media.
5. The book is very carefully prepared and of high quality. It is also very well and nicely presented being easy to read. The analytical solutions presented in the

book are quite elegant, the results are logical and the simplifying assumptions are carefully considered. The topics presented into the book are very important and interesting. The book represents a major contribution to the theory of heat transfer in porous media and will surely give new impetus to researchers in porous media to deal with more complex flow and heat transfer situations. The very large number of references included at the end of the book is, no doubt, an excellent collection of papers and books which will be of great help especially for the new comers to the area of porous media.

I enjoyed reading this book and will recommend it to all researchers working in fluid mechanics and heat transfer, physicists, chemical engineers, biologists, design engineers, graduate and Ph.D. students and also researchers from pure and applied mathematics interested by the mathematical theory of flow in porous media and connected topics. I believe that the authors have done a great service to all those interested on transport phenomena in porous media providing them a sound monograph with most of the principles and applications that they need.

The new concepts presented in this book will stimulate new research in porous media both from theoretical and application point of views. With such models, one can not only gain a much deeper understanding of the phenomena of convective flows in porous media but also to develop some new approach enhancement of heat transfer in these media.

Ioan Pop
Director of the Center for Excellence in Mechanics of the Romanian Research Council, Faculty of Mathematics
University of Cluj
R-3400 Cluj, CP 253
Romania
Tel.: +40 264 594315; fax: +40 264 591906
E-mail address: popi@math.ubbcluj.ro

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