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6[65-01, 76-01]—*Computational methods for multiphase flows in porous media*, by Z. Chen, G. Huan, and Y. Ma, SIAM, Philadelphia, PA, 2006, xxx+531 pp., softcover, US$125.00; SIAM member US$87.50, ISBN 978-0-898716-06-1

Simulating multiphase flow in petroleum reservoir is a challenging task for applied and computational mathematicians. One needs to understand the fundamental partial differential equations describing the flow and transport of chemical species, the complex underlying geological structure of the reservoir, the appropriate numerical discretizations in space and time, and the efficient solution techniques with preconditioning for solving the resulting linear systems. In about 500 pages, this book succeeds in presenting and covering all of these topics. The authors are experts in this research field. The book is self-contained. However, because of the complexity of the task, it is understandable that the mathematical treatment is at the introductory level and theoretical proofs are not included.

The plan of the book is as follows. Chapter 1, Introduction, briefly presents the main ideas covered in the book. Chapter 2, Flow and Transport Equations, gives a general description of several models: single phase flow, two-phase immiscible flow, transport of one or several components, black-oil model, oil volability, compositional flow, nonisothermal flow and flows in fractured porous media. Chapter 3, Rock and Fluid Properties, contains a nice summary of the different properties of the underlying reservoir. The rock properties include the capillary pressures, the relative permeabilities for two-phase and three-phase flows and the rock compressibility. The fluid properties include the formation volume factors, densities, solubilities, viscosities, equations of state (Peng-Robinson, Redlich-Kwong, Redlich-Kwong-Soave). Chapter 4, Numerical Methods, serves as a compact and useful introduction to the numerical methods that are popular in reservoir modeling. Important concepts and results are given without theoretical proofs. Emphasis is made on finite difference methods, standard continuous finite element methods, control volume finite element methods and mixed finite element methods. The chapter also covers briefly the discontinuous finite element methods and the characteristic finite element methods and it is ended by a discussion of issues relevant to adaptive mesh refinement. Chapter 5, Solution of Linear Systems, deals with several techniques for solving linear systems. In particular, the Krylov-based algorithms such as conjugate gradient, GMRES, orthomin, BiCGSTAB are presented. However, for realistic flow and transport simulations, the resulting matrix is often ill-conditioned and there is a need for preconditioning. One of the attractive parts in this chapter is the treatment of effective preconditioners. The rest of the book covers in detail the models introduced in Chapter 2. Chapter 6, Single Phase Flow, considers the flow of a slightly compressible fluid in the primary recovery process where oil is simply produced by natural decompression. First, a one-dimensional radial flow for which an analytical solution is obtained. Next, the nonlinear equation can be linearized by time-lagging the coefficients and it can be solved by the standard finite element method combined with a backward Euler time discretization. Another scheme is obtained by solving the nonlinear problem with a Newton-Raphson loop. Finally, using the forward Euler technique, an explicit scheme can be derived. The latter method is computationally cheaper but it requires a stability constraint on the mesh size and the time step. Chapter 7, Two-Phase Flow, deals with the secondary oil recovery process in which a fluid is injected in some wells and pushes part of the oil through other wells. The one-dimensional Buckley-Leverett problem is discussed in detail. Next, the authors treat the IMPES model and a variation of it: the pressure and saturation are solved by an implicit and explicit time discretization respectively. The chapter ends with a comparison of numerical solutions obtained by the mixed method, the control volume method and the characteristic method. Chapter 8, The Black Oil Model, is devoted to the case where the reservoir contains three phases (oil, water, gas). It is assumed that the water phase does not exchange mass with the other phases. After reviewing the basic equations introduced in Chapter 2, the authors discuss several solution techniques including a fully coupled scheme using the Newton-Raphson method and a sequential scheme in which each partial differential equation is solved separately and sequentially. The chapter ends with numerical results, in particular, comparisons between coupled and sequential solutions for both an undersaturated and a saturated reservoir. Chapter 9, The Compositional Model, deals with the tertiary (or enhanced) recovery process in which the flow is characterized by a number of chemical species and a number of phases. As in Chapters 7 and 8, the solution techniques are fully coupled schemes, sequential schemes and an IMPES model. Chapter 10, Nonisothermal Flow, removes the assumption of isothermal flow that was made up to now. An energy equation is added and the rock and fluid properties now depend on the temperature. The solution technique that solves the system of coupled equations simultaneously is discussed. Chapter 11, Chemical Flooding, contains interesting material on different types of chemical flooding, namely surfactant, alkaline, polymer and foam flooding. This chapter ends with a numerical study and development prediction of an oil field located in Asia and operating since 1963. Chapter 12, Flows in Fractured Porous Media, is a relatively short presentation of the dual porosity models. Chapter 13, Welling Modeling, deals with a practical and crucial issue in reservoir modeling, namely the integration of wells into an existing numerical flow model. The authors treat separately the finite difference method, the standard finite element method, the control volume method and the mixed finite element method. Chapter 14, Special Topics, briefly touches on other important aspects of an efficient reservoir simulator: upscaling, history matching, parallel computing, optimization and surface network systems. The last two chapters of the book are a summary of the notation and units.

This book has several merits. The presentation of some of the benchmark problems organized by the Society of Petroleum Engineers (SPE) with the help of several organizations is particularly enlightening. These benchmark problems appear throughout the volume: the second SPE project deals with a coning problem (Chapter 8); the third SPE project deals with compositional flow (Chapter 9); the fourth SPE project deals with nonisothermal flow in steam injection (Chapter 10); the sixth SPE project deals with dual porosity in modeling fractured porous media (Chapter 12); the seventh SPE project deals with horizontal well modeling (Chapter 7 and Chapter 13); the eighth SPE project deals with black oil simulation on different grids (Chapter 4) and finally the ninth SPE project deals with black oil model for heterogeneous permeability and discontinuous water-oil capillary pressure (Chapter 8).

As mentioned above, the authors succeed in presenting an exhaustive list of topics important in the use of numerical methods for petroleum reservoirs. This book is a reference on multiphase flow for researchers and engineers.

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