MATHEMATICAL MODELING OF TWO-PHASE FLOW THROUGH HOMOGENEOUS AND HETEROGENEOUS RESERVOIRS

Abstract

Multi-phase flow through highly heterogeneous porous domains is encountered in various natural systems; for example, CO_2 sequestration in subsurface flow, oil/natural gas transport inside petroleum reservoirs, groundwater networks, etc. In particular, oil and water are the fluids of interest for petroleum industry. Recovery of hydrocarbon fluids from low permeability reservoirs is extremely important since a huge amount of such fluids are trapped inside those reservoirs. One of the most effective improved recovery processes of practical interest is water-flooding technique. In this context, an important area of research is to understand oil recovery mechanism using spontaneous imbibition techniques.

Chapter 2 deals with modeling of co-current spontaneous imbibition oil recovery from partially covered homogeneous hydrocarbon reservoir. An approximate analytical solution is developed using the concept of generalized separation of variable solution technique. Consequently, the oil recovery fraction is obtained in terms of dimensionless time for 1D model from the derived approximate solution.

Chapter 3, Chapter 4 and Chapter 5 investigate various aspects of two-phase flow through spatially heterogeneous reservoir formation. In Chapter 3, we present the sensitivity of viscosity ratio, wettability and type of heterogeneity on the oil recovery fraction. A non-classical (effective viscous finger) modeling approach of imbibition process is analyzed in Chapter 4. The resulting governing equations are coupled non-linear parabolic partial differential equations, which are solved numerically using implicit pressure explicit saturation scheme (IMPES) based on finite difference method (FDM). In Chapter 5 we consider a two-phase flow model in a highly heterogeneous porous medium consisting of homogeneous layers, where the porosity and permeability vary from one layer to the other. The contrast in porosity and permeability of the two adjacent layers leads to fluid trapping at the interface between them. In order to capture the effective behavior, upscaled equations for the average saturation are derived using homogenization technique.

Chapter 6 deals with the modeling of imbibition phenomena through anisotropic reservoir formation. Here we present the influence of anisotropic ratio on the front propagation. Finally Chapter 7 deals with finding exact solution of the Stokes' problem analogue to a composite free flow and non-deformable porous matrix layer.

Keywords: Two-phase flow; Spontaneous imbibition; Heterogenous medium; Non-classical model; Upscaling; Anisotropic ratio.