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Editorial

Mathematical Modeling of Fluid Flow and Heat Transfer in Petroleum Industries and Geothermal Applications

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Introduction

This Special Issue of Energies is dedicated to all aspects of fluid flow and heat transfer in geothermal applications, including the ground heat exchanger, conduction, and convection in porous media. The emphasis is on mathematical and computational aspects of fluid flow in conventional and unconventional reservoirs, geothermal engineering, fluid flow, and heat transfer in drilling engineering and enhanced oil recovery applications. I would like to thank all the authors who contributed to this special issue. A brief outline of each paper is given below.

For the first time, the direct observations and theoretical analyses of the relationship between the crack tip and the fluid front in a dynamic hydraulic fracture are presented. Dong et al. [1] present their observations and theoretical analyses of the relationship between the crack tip and the fluid front in a dynamic hydraulic fracture. Liu et al. [2] use the concept of frequency conversion technology (FCT) with an optimized intermittent ventilation strategy to model a coal mine by using computational fluid dynamic (CFD) approaches to study the spatiotemporal characteristics of airflow behavior and methane distribution. Wang et al. [3] use the reservoir flow dynamics approach based on the traditional capacitance–resistance (CRM) models and Darcy's percolation theory to study injector–producer-pair-based CRM models with the newly-developed Stochastic Simplex Approximate Gradient (StoSAG) optimization algorithm to estimate a waterflood operation. Bai et al. [4] use the natural tight cores from J field in China to conduct experimental studies on different fluid huff-'n-puff processes; they proposed a new core-scale fracture lab-simulation method, and their results showed that, regardless of the arrangement of fractures, CO2 has mostly obvious advantages over water and N_2 in tight reservoir development in huff-'n-puff modes. Meng at al. [5] develop analytical percolation expressions for conductivity and permeability using fractal theory by introducing the critical porosity. Their simulations indicate that the critical porosity could lead to the non-Archie phenomenon and that increasing critical porosity could significantly affect the permeability and the conductivity.

Liao et al. [6] look at a series of mechanistic models by considering stress-dependent porosity and permeability; they study the impacts of fracture uncertainties, such as natural fracture density, proppant distribution, and natural fracture heterogeneity, etc., and notice that fracture closure during the flowback can promote water imbibition into the matrix and delay the oil breakthrough time. Liu and Xiang [7] present a temporal semi-analytical method to study an enhanced geothermal system (EGS), where the finite-scale fractures and three-dimensional conduction in the rock matrix are considered. Their results indicate that enlarging the spacing between the fractures and increasing the number of fractures can improve the heat extraction. Zapukhliak et al. [8] propose a mathematical model to estimate the amplitude of the pressure fluctuations in a gas pipeline; their study indicates that the shutdown of compressor stations along the pipeline route can significantly impact the unsteady transient operating conditions. In order to understand the nature of the pore structures in sandstone reservoirs, Su et al. [9] apply single fractal theory and multifractal theory to study the characteristics of pore size distributions based on mercury intrusion porosimetry. Their results indicate that multifractal theory can better quantitatively characterize the heterogeneity of pore structures. Wang et al. [10] extend their Decoupled Implicit Method for Efficient Network Simulation (DIMENS), which was based on the 'Divide-and-Conquer Approach' ideal, to the continuity/momentum and energy equations coupled with the complex pipeline network. Their results indicate that the accuracy of the proposed method is equivalent to that of the Stoner Pipeline Simulator (SPS), used in commercially available simulation core codes, while the new method is more efficient than that of the SPS. Abba et al. [11] study the influence of permeability of the porous media with respect to the injection orientations during enhanced gas recovery (EGR) by CO2 injection using different core samples with different petrophysical properties. Their study suggests a revision of the CO2 plume propagation at reservoir conditions during injection.

Shan et al. [12] use an acoustic emission (AE) test to study the energy dissipation of coal and rock fracture due to underground coal excavation. They also devise a testing method to look at the energy release mechanism from damage to fracture of the unloading coal and rock under uniaxial compressive loading. Tao et al. [13] study the fully developed flow of a cement slurry. The slurry in the wellbore is modeled as a modified form of the second grade (Rivlin–Ericksen) fluid; they also suggest using a diffusion flux vector for the concentration of particles. They perform a parametric study and look at the effect of various dimensionless numbers on the velocity and the volume fraction profiles. Nakaten and Kempka [14] attempt to identify economically-competitive, site-specific end-use options for onshore- and offshore-produced underground coal gasification (UCG) synthesis gas, where the capture and storage (CCS) and/or utilization (CCU) of produced CO2 is considered. Their study shows that air-blown gasification scenarios are the most cost-effective ones. Wang et al. [15] develop a mathematical model of gas flow in nano-pores of shale and obtain a new shale apparent permeability model. Their study shows the influences of pressure, temperature, shape of the pore surface, and the tortuous fractal dimension on the apparent permeability, slip flow, Knudsen diffusion, and surface diffusion of the shale gas transport mechanism. Zhang et al. [16] discuss the variation of wellbore temperature and bottom-hole pressure during deep-water drilling circulation. They develop a simple model which is discretized and solved using the finite difference method and Gauss Seidel iteration. Their results indicate that the temperate variation in the annulus is sensitive to the location of the multi-pressure system.

To study the flow and heat transfer in non-isothermal conditions in porous media, where the effects of permeable groundwater and tube group are included, Lei et al. [17] develop a model and test its accuracy via the sandbox test and on-site thermal response test. Their results indicate that the tube group and permeable groundwater can affect the heat transfer and the ground temperature field of a buried pipe. Mi et al. [18] look at the highly viscous fluid (glycerin) sloshing. They use the full-scale membrane-type tank and numerically study the two-phase flow based on the spatially averaged Navier–Stokes equations. The pressures and the slamming effects are analyzed, and the frequency response is identified by the fast Fourier transformation technology. Cai and Dahi Taleghani [19] propose a semi-analytical method which can be used to characterize complex fracture networks generated during hydraulic fracturing. Their two-phase oil–water flowback model with a matrix oil influx for wells with bi-wing planar fractures can provide a simple way of studying early flowback in complex fracture networks. Hu et al. [20] propose a new porous media permeability model by using particle models, capillary bundle models, and fractal theory. Their results indicate that the tortuosity fractal dimension is negatively correlated with porosity, whereas the pore area fractal dimension is positively correlated with porosity. Also, they mention that as the particle radius increases, the greater the permeability difference coefficient will become. Tao et al. [21] provide a comprehensive review of the rheological modeling of cement slurries, which in general, behave as complex non-linear fluids. They also discuss the impact of the concentration of cement particles, water-to-cement ratio, additives/admixtures, shear rate, temperature and pressure, mixing methods, and the thixotropic behavior of cement on the stress tensor.

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