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Modelling the Effect of Porewall Heterogeneity on the Phase Equilibria of Fluids in Shale Nanopores

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Fluid phase behavior in shale nanopores has become a hot topic in recent years. But, most of the current investigations are based on a smooth porewall assumption. Actually, for such small-scale pores in shale, a serious porewall heterogeneity has been observed, which has been confirmed in many experimental observations.
In this paper, the methods of N2 adsorption and desorption measurement, scanning electron microscope (SEM) and atomic force microscope (AFM) are first applied to characterize the pore structure of shale rocks, and three porewall heterogeneity modes are proposed, including furrowed surface, ravine surface and sinusoidal surface. Simultaneously, the corresponding modelling procedure is developed. Then, through a comparison between the experimental observation and simulation results, the optimal porewall heterogeneity assumption is derived. Thereafter, based on a pore size depended equation of state (EOS), with the consideration of capillary pressure, adsorption layer and fluid-solid interaction, a mathematical model for the fluid phase transition behavior in shale heterogeneous nanopores is established. And the porewall heterogeneity on the fluid phase behavior is discussed.
Results indicate that among the three modes, a sinusoidal porewall assumption is the most recommended one with an average relative error (<2%). Our developed mathematical model can well simulate the fluid phase transition behavior in shale nanopores. Compared with a smooth porewall assumption, a consideration of the porewall heterogeneity can further reduce the bubble point pressure. For pure hydrocarbons, with the pore size reduces and molecule weight increases, the effect of porewall heterogeneity is enhanced. For mixtures, with the fraction of heavy component increases, the deviation between with and without the consideration of porewall heterogeneity is increased.
This paper firstly simulates the effect of porewall heterogeneity on the fluid phase behavior in shale nanopores. It sheds some new insights to understanding the phase equilibria of hydrocarbons in shale play.

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