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An analytical model of apparent permeability for shale gas reservoir considering characteristics of nanopore distribution

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The structure of nanopore in shale is complex, multiple gas migration mechanisms coexist. In this paper, we have used a bundle of tortuous capillary tubes with different diameters to represent porous structure of shale considering slippage effect and Knudsen diffusion and surface diffusion. Fractal theory is applied to mathematically express the capillary diameter distribution and their tortuosity. A multi-scale gas flow model for shale is established, and an analytical model of apparent gas permeability for shale is deduced. Simulation results show that the ratio of apparent permeability to Darcy permeability increases with the decrease of pressure and the increase of temperature. Apparent permeability increases with the increase of fractal dimension for pore size and the decrease of fractal dimension for tortuosity. Apparent permeability decreases rapidly as pressure increases, and then stays steady. With the increase of pressure, the contribution of slip flow to apparent permeability increases quickly first and stays stable after, but the contribution of surface diffusion to apparent permeability is inverse. The contribution of slip flow to apparent permeability dominates, followed by surface diffusion. The contribution of Knudsen diffusion is minimum. The contribution of surface diffusion to the apparent permeability is underestimated with constant surface diffusion coefficient. The model provides a kind of method and theoretical basis for analysis of shale gas flow behavior.

References

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