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An analytical model for spontaneous imbibition in fractal porous media including gravity

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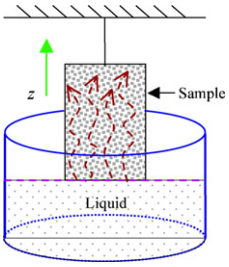
HIGHLIGHTS

- An analytical model for imbibition in porous media was derived based on fractal.
- The gravity was included over the entire imbibition process in presented model.
- Factors influencing imbibition upon approaching equilibrium weight were analyzed.

GRAPHICAL ABSTRACT



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ABSTRACT

Spontaneous imbibition of wetting liquid into porous media is regarded as a crucially important driving mechanism for enhancing oil recovery from naturally fractured reservoir, especially with low permeability. Based on the fractal character of pores in porous media, a full analytical model for characterizing spontaneous imbibition of wetting liquid vertically into gas-saturated porous media has been derived including gravity over the entire imbibition process time frame. The weight of wetting liquid imbibed into porous media is a function of contact area, porosity, pore fractal dimension, tortuosity, maximum hydraulic pore diameter, liquid density, viscosity, surface tension and liquid–solid interactions. Factors influencing the imbibition process upon approaching equilibrium weight were also analyzed. The proposed analytical model is consistent with the previous models and the predictions are in good agreement with available experimental data published in the literature.

1. Introduction

Spontaneous imbibition is a ubiquitous natural phenomenon in many fields such as petroleum engineering, groundwater engineering, engineering geology, soil physics and civil engineering. It has received great attention from theoretical perspectives to engineering applied science, since the introduction of the classical Lucas–Washburn (LW) equation [1–15]. Natural porous media usually have extremely complex pore structure with pore sizes extended over several orders of magnitude. Therefore available models, such as LW model [16,17], Aronofsky model [18], Handy model [19], and some geometrical models take into account different geometrical shaped pores and tortuosity, which have a poor agreement with the natural porous media [20–22].

It has been shown that the pore spaces of many natural porous media have fractal characters, i.e. they are self-similar over several length scales [23–28]. The fractal geometry has successfully been used to describe the pore nature and transport properties in porous media [29–33]. For spontaneous imbibition in natural porous media, Li and Zhao [34] early derived a fractal model to predict the production rate by spontaneous imbibition, and a power law relationship between imbibition rate and time was found. In

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