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Reservoir Numerical Simulation Study Based on Formation Parameters' Time-Variability

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Abstract

A novel simulation function is added into a reservoir simulator to consider the reservoir parameters' variation by defining the variation pattern of reservoir porosity, permeability and relative permeability in water flooding. It indicates that considering the variation of porosity and permeability causes the increase of reservoir heterogeneity and thus the decrease of predicted oil recovery. In actual reservoir development, the influence of permeability's variation on oilfield development rules is stronger than that of porosity.

Keywords: reservoir numerical simulation; reservoir parameters; model; recovery; variation pattern

1. Introduction

After long-term, especially the late high-strength water flooding, many reservoir parameters have changed. The time-variability of reservoir parameters has a great impact on the oilfield development rules [1-2]. However, the simulators commonly used had no description about the variation of reservoir parameters, which may caused certain deviations to the reservoir dynamic analysis. Therefore, a reservoir simulator is improved by adding the simulation function of considering the porosity and permeability's time-variability during water flooding in this paper, based on which reservoir parameters' influence on oilfield development rules is discussed.

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2. Mathematical model of oil-water two-phase flow

The mathematical model of oil-water two-phase flow is described as follows. As for water and oil components, the mass conservation equations are expressed as:

$$\nabla \cdot \left[\frac{KK_{rl}}{B_l \mu_l} (\nabla P_l - \gamma_l \nabla Z) \right] + q_{lsc} = \frac{\partial}{\partial t} \left(\frac{\phi S_l}{B_l} \right), l = o, w \quad (1)$$

where K is the absolute permeability, ϕ is the porosity, K_{rl} is oil or water relative permeability, S_l is oil or water saturation, P_l is oil or water pressure, q_{lsc} is volume injected or produced per volume of unit rock, per unit time in surface conditions, B_l is oil or water volume factor, γ_l is oil or water gravity, μ_l is oil or water viscosity, Z is formation depth, and t is production time.

In order to ensure the model's integrity, the following auxiliary equations are needed:

$$S_o + S_w = 1 \quad (2)$$

$$P_{cwo} = P_o - P_w \quad (3)$$

where P_{cwo} is the oil-water capillary pressure.

3. Improvement of reservoir numerical simulator

Injecting fluid for a long time is the basic reason of reservoir attaints for parameters' variation. In order to improve the reservoir numerical simulator, a parameter related with injected water volume should be determined to establish the relationship between it and reservoir parameters' variation. There are two methods to establish the reservoir parameters' variation pattern: one is to establish a relationship between reservoir parameters' variation and the injected water pore volume multiple, the other is to establish a relationship between reservoir parameters' variation and water cut data [3-5].

In this paper, a relationship with the injected water eroding multiple of pore volume is established to describe the variation rules of reservoir parameters including porosity and permeability. Injected water eroding multiple of pore volume in every grid F_{DG} is defined as:

$$F_{DG} = \frac{Q_{TG}}{V_{PG} \cdot N} \quad (4)$$

where Q_{TG} is the total flow of grid, V_{PG} is the pore volume of grid, and N is the total number of grids simulated. In this way, injected water eroding multiple of pore volume F_{DG} is regard to be defined in a sense of the whole simulation area, which is essentially consistent with the physical meaning of the injected water eroding multiple defined in laboratory experiments.

3.1. Modification for permeability s time-variability

Fluid erosion to formation has the greatest effect on permeability. Considering different change speeds of reservoir parameters in water flooding, two variation patterns are presented: linear variation pattern and secondary variation pattern. The change multiple of permeability can be described as:

$$R_k = \frac{K}{K_0} = \frac{R_{K\max}}{F_{DG\max}^n} F_{DG}^n \quad (5)$$