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RESEARCH PAPER

Computation method for water influx in different layers of natural edge water

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Abstract: To scientifically and objectively evaluate the development effectiveness and separated layer production of favorable natural water edge reservoir and to improve the computation method for volumes of water influx in different layers, this study applies a novel technique to simulate the process of natural water invasion by utilizing various geological and single wells' data and deploying virtual injection wells at the oil-water interface of arbitrary shape. The denser the virtual injection wells are deployed, the more precise the water invasion process can be. This study calculates water influx direction and intrusion resistance of natural edge water by discriminating connection relationship of separated layer between the virtual injection wells and production wells. Referring to hydropower similarity principle, it calculates intrusion resistance of each layer and total invasion resistance of the reservoir, thus deriving the volume of water influx of each layer. The new method has been implemented in software and applied to over ten blocks in Dagang Oilfield, Liaohe Oilfield, Jidong Oilfield, etc. The results have shown that the method is more accurate for splitting production data to calculate separated layer water influx volume in each unit in natural water edge reservoir.

Key words: edge water; water influx in different layers; water influx direction; water intrusion resistance; water influx volume; one-line connection

Introduction

Reservoir development experiences show most reservoirs are connected with external natural water, including open water with external supply, or limited edge water, bottom water. Natural water body of some oil reservoirs is large and high in energy, and have significant impact on reservoir development performance, so it is very important to quantify volume of water influx layer by layer. With the producing of crude oil and natural gas during development of reservoir, drop in formation pressure would transmit gradually to external natural water in elastic way, causing elastic expansion of formation water and formation rock in the natural water body. Pressure difference between natural water body and oil reservoir may lead to continuous influx of natural water into oil reservoir[1−2]. Different production performance, perforated layers and perforation thickness of producers would give rise to different pressure drop in different sublayers. Meanwhile, different physical properties of rock and fluid in the sublayers may also lead to significant differences in seepage capability of natural water in such sublayers. Due to different geometric shapes of Oil-water contact (OWC) in different reservoir formations, the influx of natural water body is different in direction, resulting in different pressure drops between natural water body and different reservoir sublayers, and big differences in water influx volume from natural water in different reservoir formations. Generally speaking, formations with higher volume of water influx may lead to higher fluid production from the layer.

In recent years, several techniques have been developed to separate fluid productivity from oil productivity in such producers. Since water influx from natural water to different reservoir sublayers are different, natural energy supply in such sublayers may vary accordingly. To separate productivity of different sublayers in producers, it is necessary to consider volume of natural water influx in such sublayers.

At present, there are well-developed techniques available for calculating total volume of water influx in reservoir formations both at home and abroad[1−2], but the calculation of water influx volume from natural water in different sublayers hasn't been reported in literatures.

In this research, by using over ten different kinds of data,

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considering a host of relevant factors, and based on computational geometry, fluid dynamics, reservoir engineering and other theories, an innovative calculating method of water influx volume in each individual sublayer has been proposed, to assess development effect of oil reservoirs with natural water body more accurately and objectively.

1. Basic data and fundamental principles for calculating water influx volume in different sublayers

1.1. Basic data

To calculate water influx volume in different sublayers, the following basic data is essential: (1) physical properties of rock and fluid in reservoir formation; (2) physical properties (permeability, effective thickness, thickness of sandstone formations, buried depth of bottom and top of such sandstone formation) of individual sublayers in the well; (3) monthly production data of such producers; (4) data related to EOR operations (perforation, additional perforation, plugging, fracturing, etc.); (5) fluid-production profile; (6) data related to boundaries (boundaries of sandstone formations, boundaries of oil-bearing sandstone, pinchout, mudstone and fault boundaries); and (7) geometric shape and size of natural water body, and physical properties of formation rock and fluid.

1.2. Fundamental principles

Objectives of the research are oil reservoirs with large natural edge water body. By using classical calculation methods for natural water influx volume, cumulative water influx volume during reservoir development over the years can be calculated, and then the proportion of water influx volume of each individual layer can be calculated, subsequently to get the water influx volume of each layer.

If a large proportion of oil producers have data of fluid-production profile, the fluid production proportion of each individual sublayer can be calculated based on the fluid-production profile. Based on fluid production proportion of each individual sublayer and cumulative water influx volume of the reservoir, water influx volume of each sublayer can be derived. If there are few producers with fluid-productivity profile data and few pressure data in each individual sublayer over the years available, virtual injector was proposed in this paper to simulate influx of natural water. By calculating influx direction and intrusion resistance between virtual injectors and producers, the proportion of water influx volume of each individual sublayer can be derived, and water influx volume of each sublayer can be calculated at last. The calculation flowchart is shown in Fig. 1.

Since the method calculating sublayer water influx volume with production profile is easy, only the method calculating water influx volume of sublayers with virtual injectors is elaborated in this paper in case of no sufficient fluid-production profile available.

2. Methods for calculating water influx volume of different sublayers

2.1. Positioning of virtual injectors

Before calculating natural edge water influx volume of different sublayers, it is necessary to find out the geometric shape of natural water body in each sublayer from hydraulic model obtained through geologic model construction.

The most important objective of deploying virtual injectors is to simulate the process of natural water influx. Since each virtual injector can be used to simulate natural water on a small section of OWC, such virtual injectors shall be deployed on OWC between oil reservoir and natural water to ensure the virtual injectors deployed can effectively simulate geometric configuration of natural water. Generally speaking, the higher the density of virtual injectors deployed, the more accurate the simulated OWC geometric shape and process of water influx will be (Fig. 2). The virtual injector, v_i in Fig. 2 can be used to simulate the process of water influx of the section x_{i-1} to x_i on OWC.

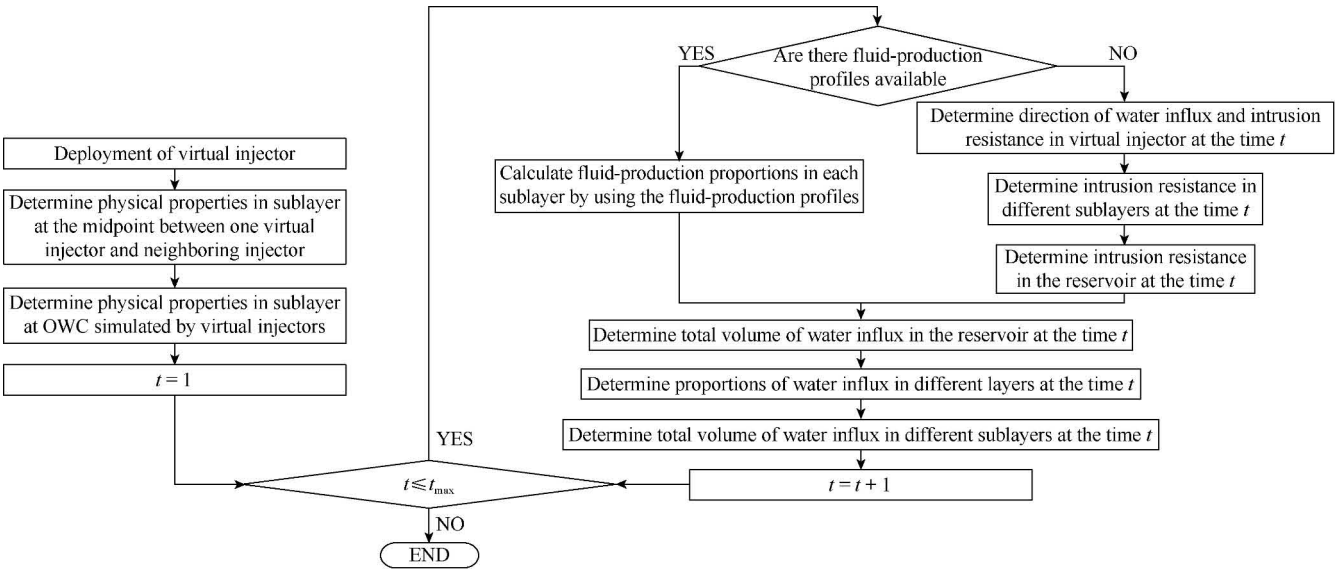

Fig. 1. Calculation flowchart of natural edge water influx volume of individual sublayers.