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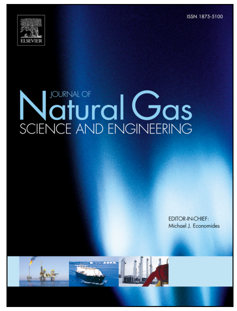

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Pore-Scale Investigation of Microscopic Remaining Oil Variation Characteristics in Water-Wet Sandstone Using CT Scanning

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ABSTRACT: With the aid of CT scanning and image processing techniques, water displacing oil experiments were performed to analyze six natural water-wet sandstone cores of different permeability and porosity visually and quantitatively. Microscopic remaining oil was categorized on the basis of quantitative characterization parameters, such as shape factor, contact ratio, Euler number etc. The remaining oil characteristics with different flow types were presented in different water displacement stages. Experimental results show that the remaining oil can be divided into five categories. They are, respectively membranous flow, droplet flow, columnar flow, multi-porous flow and clustered flow from hard-to-produce to easy-to-produce. The relative permeability of oil phase is represented by the macro-average relative permeability of all the above five flow regimes. Among them, clustered flow possesses strong producing capacity and high relative permeability, and the other four flow regimes have weaker producing capacity and lower relative permeability. Variation of number and average volume of five types remaining oil and several measurements of the ganglion size distribution have been performed in the literature. The nonlinear knee point on the relative permeability ratio curve is intrinsically caused by the decreasing of volume and quantity fraction of clustered flow when water saturation increases. This paper has studied the flowing law of microscopic remaining oil, explained the intrinsic mechanism for the appearance of an inflection point on the relative permeability ratio curve and microscopic sweep phenomena, and also presented a new effective way of upscaling to a certain extent.

Key words: water displacement; CT; shape factor; remaining oil; relative permeability

1 Introduction

Accurate description of the remaining oil distribution underground has remained a challenging task in the oilfield development. Understanding the pore structure morphology, granular property, fluid distribution and two-phase fluid dynamic migration is the basis for remaining oil study also the foundation of enhancing oil recovery. A large number of testing methods have been proposed for the study of multiphase flow movement characteristics, e.g., numerical simulation method (Dalla et al.,2002; Bryant & Anna 2004; Ramstad et al.,2012; Raeini et al.,2015), two-dimensional micromodels (Sahloul et al., 2002; Chen et al.,2007; Zhou, et al.,2014) and network model (Blunt, et al.,1991; Valvatne, et al.,2004; Løvoll et al.,2005). They can be widely used to predict various flow properties and greatly promoted the research progress of two-phase flow. However, the limitation of these methods is that the accurate representations of pore space in the porous medium, rigorous validation methods and relevant experimental data may not be fully obtained. The application of computed tomography (CT) technique in petroleum field eventually makes it possible to have an accurate recognition of 3D pore structure and fluid distribution. Through the extraction of pore structure and phase