Advances in Applied Mathematics and Mechanics
Adv. Appl. Math. Mech., Vol. **10**, No. 4, pp. 998-1024

DOI: 10.4208/aamm.OA-2017-0227
August 2018

Modeling the Nonlinear Oil-Water Two-Phase Flow Behavior for a Multiple-Fractured Horizontal Well in Triple Media Carbonate Reservoir

Yong Wang[1,2,*], Mingjun Li[3], Xin Ma[2,4], Wubin Gao[5], Guoqing Xue[3] and Jun Zhou[6,7]

[1] *School of Sciences, Southwest Petroleum University, Chengdu, Sichuan 610500, China*
[2] *State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation, Southwest Petroleum University, Chengdu, Sichuan 610500, China*
[3] *CNOOC–Ltd. Zhanjiang, Zhanjiang, Guangdong 524057, China*
[4] *School of Science, Southwest University of Science and Technology, Mianyang 621010, China*
[5] *Exploration & Development Rearch Institute, Petrochina changqing oilfield company, Xi'an 710018, China*
[6] *Sinopec Research Institute of Petroleum Engineering, Beijing, 100101, China*
[7] *State Key Laboratory of Shale Oil and Gas Enrichment Mechanisms and Effective Development, Beijing, 100101, China*

Received 10 September 2017; Accepted (in revised version) 10 January 2018

Abstract. Carbonate reservoir is one of the important reservoir in the world. Because of the characteristics of carbonate reservoir, horizontal well and acid fracturing have become a key technology for efficiently developing carbonate reservoir. Establishing corresponding mathematical models and analyzing transient pressure behaviors of this type of well-reservoir configuration can provide a better understanding of fluid flow patterns in formation as well as estimations of important parameters.

A mathematical model for a oil-water two-phase flow fractured horizontal well in triple media carbonate reservoir by conceptualizing vugs as spherical shapes is presented in this article. A semi-analytical solution is obtained in the Laplace domain by using source function theory, Laplace transformation and superposition principle. Analysis of transient pressure responses indicates that nine characteristic flow periods of fractured horizontal wells in triple media carbonate reservoir can be identified. Parametric analysis shows that water saturation of matrix, vug and fracture system and fracture half-length, fracture number and fracture spacing can significantly influence the transient pressure responses of fractured horizontal wells in triple media carbonate reservoir. The model presented in this article can be applied to obtain important parameters pertinent to reservoir or fracture by type curve matching and it can also provide useful information for optimizing fracture parameters.

*Corresponding author.
Email: ywangsc@qq.com (Y. Wang)

AMS subject classifications: 86A05

Key words: Acid fracture, oil-water two-phase flow, multiple-fractured horizontal well, transient pressure analysis, triple media carbonate reservoir.

1 Introduction

Carbonate reservoirs have complex structures and challenged research community, such as petroleum engineers, geologists, fluid mechanics and water resource researches [6, 10, 23]. Each reservoir is composed of different combinations of matrix, fracture and vug systems and thus it has various properties of porosity, permeability and fluid transport behavior. The flow problem of fluids through a reservoir is a complicated inverse problem. Therefore, a task for researchers is to establish various test models for the industry to evaluate the properties of these reservoirs.

The flow problem for vertical well production in carbonate reservoirs is well known. [2] used type curves analysis to analyse fissure volume and block size in fractured reservoirs. [3] studied an oil transient flow modeling in naturally fractured vuggy reservoirs and analyzed its pressure transient behaviors. [35–38] studied the existence and uniqueness of the solution of the seepage equation. [5] studied the numerical well test modeling of fractured carbonate reservoirs and discovered that numerical well testing has its limitations. [9] examined transient flow in discretely fractured porous media and [11] investigated pressure transient analysis of heterogeneous naturally fractured reservoirs. Additionally, [14] established a composite model with fractional flow for well test analysis in fractured reservoirs, [47–49] investigated a triple continuum pressure transient model for a naturally fractured vuggy reservoir and [24] established a well-test pressure theory of analysis for naturally fractured reservoirs, considering transient interporosity matrix, micro fractures, vugs and fractures flow, [4] investigated dynamic analysis for pressure in limit conductivity vertical fracture wells of triple-porosity reservoir, [19–21] investigated a flow model for triple porosity carbonate reservoirs by conceptualizing vugs as spherical shapes, [39, 40] studied pressure transient analysis of horizontal wells with positive/negative skin in triple-porosity reservoirs, [12] studied rate transient analysis for multistage fractured horizontal well in tight oil reservoirs considering stimulated reservoir volume, [32] investigated performance analysis of a composite dual-porosity model in multi-scale fractured shale reservoir, [53] investigated triple-continuum modeling of shale gas reservoirs considering the effect of kerogen, [27–29] investigated the flow model of multiple fractured horizontal wells with stimulated reservoir, [52] studied the production performance of multistage fractured horizontal well in shale gas reservoir, [54–56] studied the pressure response and production performance for shale gas reservoir and coal seam reservoirs, [7, 8] investigated the transient pressure and production dynamics of multi-stage fractured horizontal wells, [17, 18] studied the novel multivariate nonlinear model based on Arps decline model and kernel method, [50]