Advances in Applied Mathematics and Mechanics
Adv. Appl. Math. Mech., Vol. **10**, No. 3, pp. 581-610

DOI: 10.4208/aamm.OA-2017-0159
June 2018

Modeling Oil-Water Two-Phase Flow Behavior of a Fractured Vertical Well with a Finite-Conductivity Fracture in Triple Media Carbonate Reservoir

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Received 17 June 2017, Accepted (in revised version) 3 September 2017

Abstract. Because of the characteristics of carbonate reservoir, vertical well and acid fracturing have become a key technology for efficiently developing carbonate reservoir. A mathematical model for a oil-water two-phase flow fractured vertical 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 seven characteristic flow periods of fractured vertical wells in triple media carbonate reservoir can be identified. Parametric analysis shows that water saturation of matrix, vug, fracture system and acid fracture, acid fracture half-length and acid fracture conductivity can significantly influence the transient pressure responses of fractured vertical 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.

AMS subject classifications: 86A05

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

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1 Introduction

Carbonate reservoirs have complex structures, and challenged research community, such as petroleum engineers, geologists, fluid mechanics, and water resource researches [8,11, 24]. 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. [5] studied the numerical well test modeling of fractured carbonate reservoirs, and discovered that numerical well testing has its limitations. [10] examined transient flow in discretely fractured porous media, and [12] investigated pressure transient analysis of heterogeneous naturally fractured reservoirs. Additionally, [15] established a composite model with fractional flow for well test analysis in fractured reservoirs, [39] investigated a triple continuum pressure transient model for a naturally fractured vuggy reservoir, and [25] 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, [21, 22] investigated a flow model for triple porosity carbonate reservoirs by conceptualizing vugs as spherical shapes, [37] studied pressure transient analysis of horizontal wells with positive/negative skin in triple-porosity reservoirs, [13] 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, [45] investigated triple-continuum modeling of shale gas reservoirs considering the effect of kerogen, [9] investigated transient pressure behavior for a horizontal well with multiple finite-conductivity fractures in tight reservoirs, [44] studied the production performance of multistage fractured horizontal well in shale gas reservoir, [29] studied the seismic signatures of carbonate caves affected by near-surface absorptions, [30] investigated the seismic attenuation in fractured media, [19, 20] studied the oil production using the novel multivariate nonlinear model based on Arps decline model and kernel method, [40] investigated a practical method for production data analysis from multistage fractured horizontal wells in shale gas reservoirs, [38] studied pressure transient analysis for finite conductivity multi-staged fractured horizontal well in fractured-vug carbonate reservoirs, [43] investigated numerical analysis for promoting uniform development of simultaneous multiple-fracture propagation in horizontal wells, [36, 37, 41, 42] investigated transient pressure behavior of a fractured vertical well with a finite-conductivity fracture in triple media carbonate reservoir, [18] studied the seismic characterization of a carbonate reservoir in