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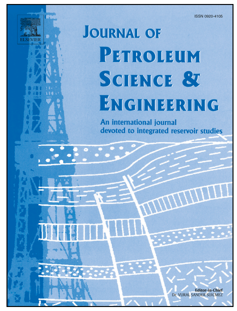

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Bing Kong, Shengnan Chen

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Numerical Simulation of Fluid Flow and Sensitivity Analysis in Rough-wall Fractures

Bing Kong, Shengnan Chen, University of Calgary

1 ABSTRACT

Activated natural fractures, poorly-propped and un-propped secondary hydraulic fractures may serve as the connection between reservoir fluids and the main hydraulic fractures (i.e., well-propped fractures). These branched fractures also contribute considerably to well after-fracturing productivity in unconventional tight/shale reservoirs. Rough fracture surface and its effects on fluid flow behavior in such fractures with very limited width is very important in understanding total mass transport in fractured rocks. In this paper, the effect of rough surface properties on fracture conductivity is studied through 3D numerical simulation of fluid flow behavior within the fractures. First, a tensile fracture was created on a core sample retrieved from the Montney formation, and the rough fracture surface topography was scanned via a high-resolution optical profilometer. The surface roughness characterizations were then used as reference to numerically reconstruct multiple three-dimensional fracture models. A finite element method was adopted to simulate fluid flow in the rough-wall fractures, using Navier-Stokes equation, for various fracture surface properties such as mean aperture, root mean square (RMS) asperity height, correlation length, anisotropy and shear displacement distance. Results showed that cubic law tends to overestimate the conductivity of the fractures with rough-wall surfaces, especially when the fracture aperture is small. Other surface properties, including correlation length, anisotropy and Hurst exponent also exert considerable impacts on fracture hydraulic properties. As the shear displacement distance increases, deviation of the fracture conductivity from cubic law first increases and then maintains at a constant level. The results of this paper have advanced the understanding of fracture conductivity and its dependence on fracture surface properties and will aid in improving production prediction and optimization in fractured tight reservoirs.

2 INTRODUCTION

The technique of combining hydraulic fracturing and horizontal drilling has unlocked vast unconventional tight/shale resources development and enhanced recovery (Zheng et al. 2017; Yuan et al. 2018). Understanding multiphase fluid flow in fractures is critical to analyze mass transfer behavior in the fractured reservoirs, as well as other processes such as CO_2 sequestration and enhanced oil recovery (Sahimi 2011; Neuman 2005; Berkowitz 2002; Adler et al. 2013; Adler & Thovert 1999; Yuan et al. 2017a; 2017b). One of the main technical challenges in hydraulic fracturing stimulation is the limited reach of the proppants within the created hydraulic fractures (the ability to place the proppants deep into the formation) (Hammond, 1995; Warpinski et al, 2009; Kong et al, 2015). Industry practice has indicated that although hydraulic fractured wells may have pressure interference effects that extend over 1000 feet, the placement of proppant is mostly within 300 feet from the wellbore, leaving a large portion of the hydraulic fractures and most of the activated natural fractures unpropped (Sharma and Manchanda, 2015; Cipolla et al, 2008). The width of an unpropped fracture is small and the effects of rough fracture surfaces on fluid flow must be investigated. In most of the applications, the fluid flow through a single unpropped fracture is assumed analogous to the laminar flow between the two flat parallel plates. The cubic law, which is derived from Navier-Stokes equation based on such an assumption, has been widely adopted when characterizing fluid flow in these fractures (Gangi 1978; Kranzz et al. 1979; Tsang 1984; Witherspoon et al. 1980). For rough surface fractures, cubic law was modified using a hydraulic aperture