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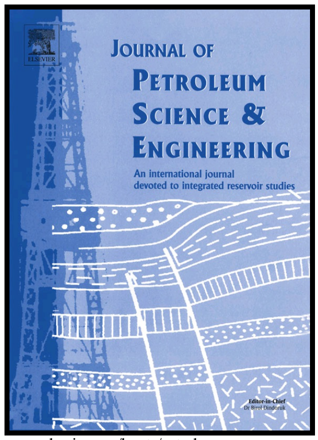

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Dharmendra Kumar, Ahmad Ghassemi

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A Three-Dimensional Analysis of Simultaneous and Sequential Fracturing of Horizontal Wells

Dharmendra Kumar, Ahmad Ghassemi*

Mewbourne School of Petroleum and Geological Engineering, The University of Oklahoma, Norman, Oklahoma, USA

*Corresponding Author: Tel: +1 405 325 4347. *Email address*: ahmad.ghassemi@ou.edu

Abstract

Horizontal well fracturing is most commonly used to improve well productivity from the lower quality formations that could not have been economically developed using the conventional hydraulic fracturing approach. These horizontal wells can be stimulated to increase reservoir permeability via multiple hydraulic fractures using different design concepts. In this paper, we present a 3D fully coupled numerical model with capabilities to simulate multiple fracture clusters propagation from horizontal wells. The numerical model is developed using a combination of the boundary element method, the finite element method, and the linear elastic fracture mechanics for the fracture propagation. The fluid flow inside the fracture is assumed to be laminar flow and the fluid follows Newtonian behavior. The Galerkin's finite element approach is used for fluid flow modeling, the rock mass deformation is simulated using elastic displacement discontinuity method, and crack tip displacement approach is used for the mixed-mode fracture propagation. The brief descriptions of the governing equations and their numerical implementation are presented first. Then, the fracture propagation model is verified using semi-analytical solution from the Khristianovic-Geertsma-de Klerk (KGD) model for a circular planar fracture. A sensitivity analysis of various parameters effecting the mechanical interaction among multiple propagating fractures is conducted. Finally, numerical examples of multiple fracture propagation for sequential and simultaneous fracturing procedures from a single horizontal well and multiple horizontal wells are presented. In simultaneous fracturing case, the fluid injection rate is dynamically partitioned among the fractures depending upon wellbore frictional losses, perforation frictional losses, and fluid pressure drop in the fractures. Results of a sensitivity analysis demonstrate the effects of the in-situ stresses, rock and fluid properties, and "stress shadowing". The simultaneous and sequential fracturing results show that the generated fracture network geometries are strongly influenced by the mechanical interactions among the fractures or fracturing stages. The conventional zipper fracturing tends to generate nearly straight fractures with potential for tip coalescence and thus wellbore communications. The modified zipper fracturing tends to yield potentially more complex fracture geometries due to fracture turning.

Keywords: Displacement discontinuity method, simultaneous fracturing, sequential fracturing, zipper fracturing, modified zipper fracturing, stimulated reservoir volume

1. INTRODUCTION

In last two decades horizontal well fracturing technology has been advanced significantly. It is used to effectively enhance well productivity in the unconventional reservoirs (e.g., shale gas and tight oil reservoirs). The multiple perforation clusters and multiple treatment stages are used

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