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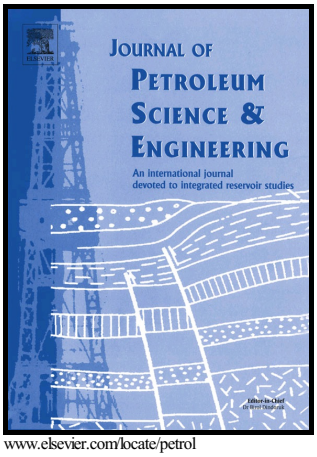

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Three-dimensional investigation of multiple stage hydraulic fracturing in unconventional reservoirs

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Abstract

Production efficiency from low permeability shale reservoirs demands promoting techniques including horizontal well drilling and multiple hydraulic fracture stimulation. What significantly affects the fracture patterns and associated geometries is the stress field changes induced by pre-existing or simultaneous fractures, depending on proposed hydraulic fracturing scenarios. Devising a reliable and robust simulation tool for hydro-mechanical modeling of hydraulic fracturing is imperative inasmuch as an appropriate fracturing job in a porous medium cannot be extended to another owing to various characteristics and limited access to the field data acquisition. In order to present a numerical technique, which is capable of capturing the non-planar hydraulically fluid-driven crack propagation with unpredictable path, in one hand, and tackling the feasible emergence of multiple cohesive cracks in a porous medium with fracture process zone at the crack tip, on the other hand, the Cohesive segments method in combination with Phantom Node Method, called CPNM herein, is established to simulate 3-D non-planar hydraulically driven fracture problem in a quasi-brittle shale medium. The present simulation fully couple fracturing fluid flow inside the crack with poro-elasticity in porous formation and continuum-based leak-off on the crack surfaces, and capture the fracture process zone at the fracture tip in quasi-brittle shale. In this paper, two different key scenarios including sequentially and simultaneously multiple hydraulic fracturing in a quasi-brittle shale multi-layer are investigated by using CPNM. The interesting and new results show that later stages in sequentially hydraulic fracturing mainly secure larger values of fracture opening than that of simultaneously hydraulic fracturing, which can be attributed to the effect of stress interactions of fractures on each other. Detailed parametric studies shed new light on the impacts of pre-existing or simultaneous fluid-driven fractures on the pore pressure of the formation, crack propagation pattern, von Mises stresses, fracture opening, leak-off flow rate, and fracturing fluid pressure.

Keywords: Quasi-brittle shale; 3-D hydraulic fracturing; Cohesive phantom node method; Fracture process zone; Non-planar crack propagation; Poro-elasticity

1. Introduction

Unconventional development of energy resource plays, such as coal bed methane, tight gas sands and shale reservoirs, has developed into a global pursuit for many oil and gas exploration companies, and launched a new way of thinking about hydrocarbon production [1,2]. Gas production from shale deposits,