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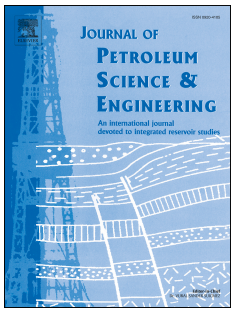

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Stimulated Reservoir Volume Estimation for Shale Gas Fracturing: Mechanism and Modeling Approach

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Abstract

Multi-stage fracturing, following horizontal well drilling, is the key technology in shale gas reservoir development to enhance the recovery from such tight formations for economic production. The stimulated reservoir volume (SRV), which correlates closely to fracturing performance, is a quantitative measure for both pre-fracturing design and post-fracturing evaluation. However, an accurate estimation of the SRV is a long-standing challenge, because it requires a great knowledge of various parameters and complex mechanisms.

In this study, we developed a mathematical model to estimate the SRV through simulating the main process during shale fracturing—multiple simultaneous hydraulic fractures propagate, perturbing the formation stress and raising the reservoir pressure; meanwhile, the stress change and pressure rise may jointly make natural fractures occur failure, and the SRV is estimated based on the volume of the naturally fractured zone that experiences tensile or shear failure.

Hybrid numerical methods have been employed in this study. It applies displacement discontinuity method (DDM) to simulate non-planar hydraulic fractures propagation and represent the induced stress triggered by hydraulic fractures. The reservoir pressure is calculated by finite difference method (FDM). The failure state of natural fractures is predicted by the tensor equations deduced from Warpinski's failure theory. The model considers complex but important physical mechanisms that involved in the shale fracturing, including unequal flow-rate distribution among each hydraulic fracture, non-planar hydraulic fractures propagation under stress interference, reservoir permeability increase with SRV extending (pressure & stress-depend), different failure states of natural fractures, etc.

We validated our model by comparing its simulation results with analytical solution, published papers and on-site microseismic monitoring data. A field case study was performed to show the dynamic processes of hydraulic fractures propagation, reservoir permeability increase, and the SRV expansion during shale gas fracturing. Sensitivity analysis was conducted to investigate the influence of geological condition and fracturing parameters on SRV.

Keywords: Hydraulic fracturing; stimulated reservoir volume; fractures propagation; shale gas; mathematical model

1. Introduction

The permeability of shale matrix is extremely low, hence the shale gas reservoir cannot be exploited economically without high-efficient stimulation method (Luffel et al., 1993; Sakhaee-Pour and Bryant, 2012). Fortunately, because of the high brittleness of shale rock, shale formation usually developed with abundant natural fractures (Walton and McLennan, 2013; Hu et al., 2014). Generally, these natural fractures are closed, but they can be stimulated (i.e., occur failure) by multi-stage multi-cluster hydraulic fracturing in horizontal well (Seale et al., 2006;