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Production-induced pressure-depletion and stress anisotropy changes near hydraulically fractured wells: Implications for intra-well fracture interference and fracturing treatment efficacy

J. Wang [a], R. Weijermars [b,*]

[a] Department of Earth Resources and Environmental Engineering, Hanyang University, Seoul, South Korea

[b] Department of Petroleum Engineering & Center for Integrative Petroleum Research, College of Petroleum Engineering and Geosciences, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia

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ABSTRACT

This study investigates the changes in the principal stress trajectories during development of hydrocarbon (and/or geothermal) reservoirs with hydraulically fractured wells. Our analysis indicates four phases in the well-life with typical stress states, *i.e.,* Pre-fracturing Phase (Stress State 0): the natural stress state prior to the drilling intervention; Fracturing Phase (Stress State 1): stress state prevailing during fracturing treatment; Flowback Phase (Stress State 2): stress state prevailing during flowback; and Production Phase (Stress State 3): stress state prevailing during production. The various stress changes are computed and visualized using the Linear Superposition Method (LSM). Two episodes of stress trajectory alterations occur, a first one during the Fracturing Phase (transition from Stress State 0 to 1), and a second one during the Flowback Phase (transition from Stress States 1 to 2), with respectively positive and negative fracture net pressures. During the Production Phase (Stress State 3), the spatial advance of the pressure depletion around the fractured well system due to production was modeled using recently developed Gaussian pressure transient equations. Our new results show that the early stress reversals (Stress State 1) near the pressured fractures during fracturing treatment are short-lived. In addition, the residual stress change magnitude during flowback (Stress State 2) depends on the final fracture-width aperture. In any case, the local stress reversals due to engineering interventions are a short-term phenomenon and remain limited to the near-fracture regions. The regions with the reversed stress will increase when more stages are fractured, assuming the elevated fracture pressure is not fully released before the next stage is completed. Subsequently, the stress anisotropy decreases during production as a result of pressure depletion. Our improved analysis of the stress reversal phenomenon is important for optimizing drilling plans for infill wells, and for improving fracturing treatment designs.

1. Introduction

Hydraulic fracture geometries and the subsequent stimulated reservoir volume (SRV), which contribute to the unconventional reservoir productivity, strongly depend on the stress distributions during the fracturing treatment process (Lin et al., 2017; Ren et al., 2018; Warpinski and Branagan, 1989). In addition, for a multi-stage fracturing design, the stress distribution alteration would occur during a nearby fracturing treatment by the pore pressure change (Gao et al., 2019; Guo et al., 2019; Lin et al., 2016). Therefore, the stress distributions and its alterations during the fracturing treatment is very important to establish the optimal treatment designs for unconventional reservoir development, where the hydraulic fracturing is required due to its extremely low permeability (Weijermars and Wang, 2021).

This study analyzes the changes in principal stress magnitudes and the identification of stress reversals near hydraulic fractures. To grasp the true impact of the key engineering interventions on the state of stress in the reservoir, one must analyze both the short-term changes in the net pressure on the hydraulic fracture as well as the longer-term pressure depletion in the matrix regions around the hydraulic fractures. This study solves for both effects comprehensively using new closed-form solutions methods that provide unlimited resolution. The high-resolution modeling is enabled by applying a closed-form LSM solution (Weijermars et al., 2020a), which is shown here to reveal *two*

* Corresponding author.
E-mail address: ruud.weijermars@kfupm.edu.sa (R. Weijermars).

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