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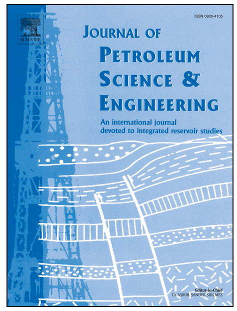

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Modeling of Hydraulic Fracture Closure on Proppants with Proppant Settling*

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Abstract

The placement of proppants in a hydraulic fracture is governed by slurry flow, proppant transport and settlement. The proppant distribution can significantly affect the conductivity of the hydraulic fracture, and hence will impact the productivity of hydraulic fractured wells. Past studies have investigated fracture closure on proppants by envisioning hydraulic fractures as two parallel plates with uniformly distributed proppants. However, in reality, hydraulically induced fractures are wider in the middle and narrower near the fracture edges. In addition, a proppant dune is likely to be accumulated at the bottom of the fracture because of proppant settling. As a result, fracture closure on proppants is controlled by both fracture geometry and the distribution of proppant in the fracture. This is a dynamic process where fracture geometry and the proppant pack will evolve as a function of pressure, and the associated surface contact problem is notoriously challenging to solve because of its nonlinear and nonlocal nature. In this study, we proposed a general approach to model hydraulic fracture closure. The residual fracture width profile for both propped and un-propped sections can be obtained at different drawdown pressures for rocks with different clay content. The maximum stress acting on proppants can be calculated to guide the selection of proppants with appropriate strength. Most importantly, the effect of stress concentration and stress amplification can be quantified when a proppant dune is formed. We show that the traditional method of estimating the maximum stress on a proppant pack is an underestimation.

Keywords: hydraulic fracture; fracture closure; proppant transport; proppants settlement; proppant dune; stress amplification

1. Introduction

Hydraulic fracturing has been widely used to enhance the recovery of hydrocarbons from very low permeability reservoirs, as well as prevent sand production in high permeability reservoirs (Economides and Nolte 2000). In unconventional reservoirs, the connected fracture surface area and the conductivity of created fractures play a vital role in shaping production and its decline trend (Sharma and Manchanda 2015; Wang 2017). The conductivity of both propped and un-propped fracture is highly stress-dependent (Fredd et al. 2000; Wu and Sharma 2017), because of the deformation, embedment and crushing of proppants and fracture surface asperities, which leads to a reduction of residual fracture width. Drawdown pressure can be optimized to alleviate the adverse impacts of decreasing fracture conductivity due to increasing effective stress during production (Mirani et al. 2018).

During a hydraulic fracturing treatment, high pressurized liquid is injected to fracture subsurface rock. In order to keep the fracture open, the proppant-laden fluid is injected after the fracture is created. For conventional reservoirs, high viscosity fracturing fluids are normally used because of their ability to minimize leak-off and strong transport capabilities of proppants, the injected proppants almost remain suspended after shut-down. For unconventional reservoirs, thin fracturing fluids such as slick-water are commonly used. The success achieved with slick-water is attributed mainly to the large created network of induced fractures and low fluid-chemical additivities. These two advantages increase reservoir stimulated volume and reduce the fracture-fluid formation damaging potential in some settings. However, since slick-water is a low-viscosity hydraulic-fracturing fluid with poor proppant transport capability, the injected proppants tend to quickly settle out of the fracturing fluid and accumulate at the bottom of fracture, forming a proppant dune. **Fig.1** illustrates concepts of both uniformly distributed proppants (perfect proppants transport fluid with high viscosity) and non-uniformly distributed proppants (poor proppant transport fluid with low viscosity).

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