Impact Of Inertial Effects On Proppant Conductivity For A Hydrocarbon-Producing Hydraulic Fracture

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Abstract

Subsurface oilfield operations involving high flow rates, such as production from hydraulically fractured reservoirs or water flood injection, often involve proppant or gravel pack completion. Inertial effects can become significant in such systems, adversely affecting how the reservoir or injection energy is spent.

The hydraulic conductivity and the emergence of inertial effects are first investigated at the pore scale for flow through bulk and single-layered proppant, and for various degrees of embedment into matrix. The impact the non-Darcy term has on hydrocarbon production is then assessed for a propped hydraulic fracture within a tight rock reservoir with an active natural fracture network (NFN).

Single phase modeling is employed to describe liquid flow at both microscopic and reservoir scales. The Navier-Stokes equations with periodic boundary conditions are solved within the interstitial space of packed spheres, while the Darcy and Forchheimer equations are used for the reservoir matrix and fractures. The "sugar cube" NFN and all but the near-well part of the penny-shaped hydraulic fracture are described with a 2D planar fracture flow interface, coupled to the otherwise 3D description of the system. The hydraulic contact area between the propped fracture and the well can vary.

Comparison with the empirical Ergun model for flow through multi-layer sphere packs validates the employed pore space CFD approach, which yields values of 149.5 and 1.2 for the viscous and inertial term dimensionless coefficients, respectively, for the data set corresponding to Re < 100. The overall CFD results however indicate the derived beta factor especially to be strongly-dependent on the maximum Re value for the data set. Similar behavior is observed for single-layer systems, which are analyzed for two packing densities and various degrees of embedment. Particle embedment into matrix leads to significant permeability reduction (three-fold for 50% embedment), while the beta factor is rather insensitive to it.

The flow rate Qhf variation for liquid hydrocarbon produced through a propped hydraulic fracture is investigated against drawdown DP (100 - 5000 psi), matrix permeability Kres (1 microD - 1 mD), and the effective perforation diameter dperf (0.8 - 3.0 inch) connecting it to the well. dperf strongly impacts Qhf, as inertial effects become dominant near the wellbore due to flow convergence: for the system considered, the rate-dependent skin already causes a 30% Qhf loss when Kres = 50 microD, DP = 1000 psi, and dperf = 0.8 inch.

The predictive capability of CFD pore scale modeling demonstrates its attractiveness as a tool for proppant conductivity studies, complementing if not supplanting experimental approaches. The present CFD study quantifies the adverse effect matrix embedment has on proppant conductivity, thus potentially providing input for unconventional reservoir completion models.

This study warns against excessive drawdown, which can be significantly detrimental to ultimate

hydrocarbon recovery. The methodology can be employed for other fluids and fracture geometry.

Figures used in the abstract

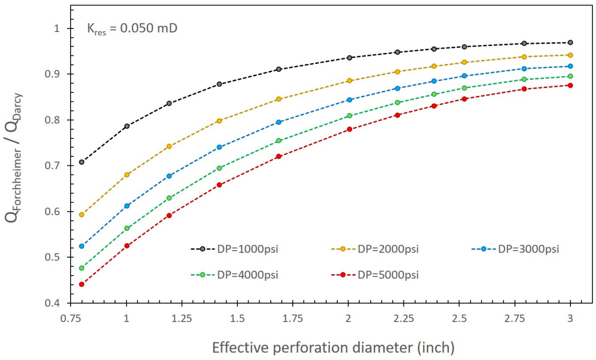

Figure 1 : Impact of inertial effects on hydrocarbon recovery through a propped hydraulic fracture. A unit value for the ratio between the Forchheimer and the Darcy flow rates corresponds to the ideal case when there are no inertial losses. The latter increase with higher drawdown (DP) and smaller effective diameter of the perforation tunnel connecting the fracture to the wellbore.