High-Resolution Visualization of Flow Interference Between Frac Clusters (Part 1): Model Verification and Basic Cases
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Abstract

The reservoir drainage around horizontal wells is visualized at high-resolution using a newly developed analytical streamline simulator based on complex potentials. Drainage contours show the progressive oil recovery from the stimulated rock volume (SRV). The method plots streamlines, the time-of-flight for fluid to fracs, velocity contours and pressure distribution around fracked wells. Independent simulations with a commercial reservoir simulator confirm the visualizations with complex potentials are accurate, and that the latter method gives high-resolution images of the pressure and flow field around individual fracs. We show the depth of investigation reflected by pressure contour gradients is a poor indicator of drained reservoir volume. Drainage contours based on particle velocity tracking give a much clearer view of the actual region drained by a well via its fracs. First, matrix drainage by 2-frac and 3-frac clusters is studied in detail. Flow separation surfaces between 2 clustered fracs (with equal length and flux) are always straight, creating planes of symmetry between adjacent drainage regions. Clusters of 3 fracs develop curved flow separation surfaces, convex toward the inner frac. For frac spacing less than 4 times total frac length, drainage of the central region of the 3-frac clusters slows down due to flow interference, which confirms earlier findings that production gains become insignificant above certain frac length/spacing ratios. Next, the analysis shows the flow field, drainage contours, velocity contours and pressure distribution for a horizontal, synthetic well with 11 transversal, kinked fractures. The basic analysis in this paper (URTeC 2670073A, Part 1 of our study) is expanded in a companion paper (URTeC 2670073B, Part 2 of our study), which applies the methodology of flow visualization using drainage and velocity contours to a sample well from the Midland Basin, Texas.

Introduction

Unconventional hydrocarbon resource development currently still suffers from ineffectively low recovery values of the hydrocarbons in place. More than 90% of oil and up to 80-65% of natural gas remains trapped in the formation. With recovery factors so low, the life cycle of unconventional reservoirs can be easily doubled or tripled if we find ways to break through the limitations of current field development approaches. An increase in the recovery factor per well and enhancement of the field life of shale plays can be achieved if the fracture treatment is optimized. Engineering the optimum frac spacing that minimizes cost and optimizes production output is a key aspect of unconventional resource development strategy (Cipolla and Wallace, 2014; Lalehrokh and Bouma, 2014). Simulation of the drainage by hydraulic fractures shows production growth becomes insignificant after frac spacing is reduced beyond a certain minimum (Fig. 1a; Yu, 2015). Declining productivity per frac in fact is due to increased flow interference between fracs.

So-called dead zones may develop in regions around the flow stagnation points between adjacent fracs where drainage is retarded, and more so when frac spacing gets narrower. The drainage patterns of Fig. 1b are visualized using an analytical streamline simulator which has been verified in earlier studies (Weijermars et al., 2016; Yu et al., 2016). The incremental addition to Estimated Ultimate Recovery (EUR) of longer wellbores becomes less efficient when frac spacing is smaller and fracture conductivity is higher. The fracture design process must be closely integrated with efforts to develop improved reservoir simulators that can properly account for the detailed effects of hydraulic and natural fractures on well productivity. Using a reservoir simulator that can account with a very high resolution for variations in the stimulated rock volume due to different fracturing completion options, the optimum fracture treatment for a given reservoir description can be