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Interpretation of indicator studies of multistage fracturing

Mazo A., Sattarov R., Khamidullin M., Potashev K., Trifonov T.
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

Copyright 2017, Society of Petroleum Engineers. The paper presents a technique for interpreting indicator studies of multi-stage hydraulic fracturing (MSHF) on horizontal wells (HW), based on numerical modeling of indicator transfer in the near-well zone. Two problems are distinguished in the simulation: the direct problem of calculating the pressure, water saturation, and concentration of the indicator at the given parameters of the well during the injection of the indicator and the further operation of the well; the inverse problem of selecting the parameters of the hydraulic fractures (geometry and permeability) from the measured curves of the indicator removal after the transfer of the well to the withdrawal. In the course of solving the inverse problem, the separation of the total water and oil rates along the fracturing intervals is determined. The direct problem is based on the mathematical model of a three-dimensional two-phase multicomponent filtration taking into account diffusion and sorption in the region of drainage of HW with MSHF. The case of water-soluble indicators is considered in the model. In the numerical implementation of this model, we use structured finite-volume grids with significant condensation near the fractures and wells, as well as fast-acting algorithms for the end-to-end solution of the problem for pressure in the reservoir and fractures and an explicit-implicit scheme for solving the tracer transfer problem. The solution of the inverse problem minimizes the deviation of the calculated tracer output curves, total production rate and water cut from the corresponding observation data. The minimization is performed iteratively (by modifying the Broyden-Fletcher-Goldfarb-Shanno method with the limitation of the memory used). The direct problem is solved at each iteration. In this case, a simplified model is used that takes into account the rectilinear-parallel structure of the filtration flow in the penetration region of the tracer, which makes it possible to expand the three-dimensional problem into a series of one-dimensional ones and substantially accelerate the calculation. The proposed algorithm for the interpretation of indicator studies is demonstrated by the example of processing real data obtained during the 4-interval transverse MSHF on a HW of a productive reservoir represented by the interlacing of sandy-siltstone rocks with dense interlayers of clays belonging to the terrigenous deposits of the Achimov strata of Western Siberia. The length of the horizontal section of the wellbore was 820 m. The water-soluble indicators DCT-WS-01, DCT-WS-03, DCT-WS-04, and DCT-WS-07 were used as tracers. The main hydraulic fracturing was preceded by mini-fracturing. The fractures contained 80 tons of ceramic proppant for the first three stages and 60 tons for the fourth stage. The average half-length of the hydraulic fractures was 100 m, height - 50 m, and thickness - 4 mm.

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