Enhancing Reservoir Characterization with Rate- and Pressure-transient Analysis (RTA/PTA) Core Analysis Methods

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Summary

Reservoir engineers traditionally utilize rate-transient analysis (RTA) and pressure-transient analysis (PTA) methods for the quantitative assessment hydraulic fracture and reservoir properties of multi-fractured horizontal wells (MFHWs) completed in unconventional reservoirs. This study investigates the implementation of the innovative laboratory technique, rate-transient analysis permeameter ('RTAPK'), specifically designed to reproduce the operational conditions of MFHWs in the field. The objective is to enhance the accuracy of reservoir properties derived in the laboratory by collecting and analyzing the data consistent with field data. Our previous studies (Clarkson et al., 2019; Shabani et al., 2022; Shabani et al., 2023; Vahedian et al., 2018) demonstrate the efficacy of the RTAPK method in achieving notable results within a short test time. Simultaneously, the RTAPK results serve as a tool for investigating sample heterogeneity (e.g., matrix vs. fracture, multiple permeability layers) and its influence on permeability.

Method

To date, the RTAPK experimental setup has undergone multiple improvements (Clarkson et al., 2019; Shabani et al., 2022; Shabani et al., 2023; Vahedian et al., 2018), allowing for 1) both injection/falloff analysis and production analysis; 2) production tests on both dry (Shabani et al., 2022) and partially saturated samples, the latter yielding relative permeability data (Shabani et al., 2023); 3) expansion of the dynamic range of permeability measurements, currently from 10s of nanodarcy to 10s of microdarcy. Additionally, the setup facilitates a direct comparison of RTAPK results with other commonly applied permeability determination methods, including steady-state (SS) and non-steady-state methods (NSS) (Shabani et al., 2022).

Results and Discussion

For the majority of RTAPK measurements, the observed flow-regime sequence for both RTA and PTA core tests is transient linear flow (TLF) followed by boundary-dominated flow (BDF), consistent with what is commonly observed in the field for MFHWs completed in low-permeability unconventional reservoirs (Clarkson et al., 2019; Vahedian et al., 2018). Employing RTA and PTA methods derived for these specific flow regimes, such as the square root time plot (SQRT), distance of investigation combined with the end of linear flow (telf), the flowing material balance plot (FMB), and the contacted fluid in place plot (CFIP), multiple independent permeability values can be estimated, demonstrating satisfactory agreement with conventional (e.g., SS, NSS) core testing methods (Shabani et al., 2022). Notably, the RTAPK method has a significant advantage over conventional methods due to its accelerated test time, offering permeability estimates within a matter of minutes for samples with permeabilities in the range of 10s of nanodarcy.

In some of the measured samples, a deviation from the expected trend was observed, caused by the presence of a transitional flow regime between TLF and BDF. This deviation prompted further investigation into its cause and controls. Additional methods, including visual thin section and CT scanning analyses revealed traces of heterogeneity in the analyzed samples, manifested in the presence of fractures and/or multiple permeability zones. Numerical simulation with commercial software (Eclipse™) confirmed the existence of a transitional flow regime in heterogeneous samples. Notably, for the analyzed heterogeneous samples, the derived permeabilities from various permeability determination methods exhibited variations in magnitude. However, both SQRT and CFIP methods were consistent in calculating the average permeability of the sample. This underscores another advantage of the RTAPK method over other commonly used techniques (SS and NSS) – the capability of recognizing sample heterogeneity (e.g., matrix vs. fracture, multiple permeability layers) and its influence on permeability.

Attempts have also been made to design and develop an experimental setup capable of measuring liquid permeability using RTA and PTA methods, with promising initial results. A typical flow-regime sequence (TLF and BDF) for homogeneous samples was observed, while a deviation from this trend was noted for heterogeneous samples during the production tests performed with water. As with gas permeability tests, the liquid RTAPK permeability tests were completed within a few minutes, emphasizing the 'time advantage' of this new core analysis technique.

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