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Production Data Analysis from Unconventional Reservoirs with a Novel Data-Driven Drainage Volume Approach

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Understanding how pressure fronts propagate (diffuse) in unconventional reservoirs is fundamental to transient flow analysis as well as reservoir drainage volume estimation. We have developed an alternative approach to the solution of the 3-D diffusivity equation by directly solving the propagation equation for the "pressure front"of the transient solution. The pressure front equation is an Eikonal equation, which is obtained from the high frequency asymptotic limit of the diffusivity equation in heterogeneous reservoirs and whose properties are well developed in the literature. Most importantly, the Eikonal equation can be solved very efficiently by a class of solutions called the Fast Marching Methods for a "diffusive time of flight"that governs the propagation of the pressure front in the reservoir. The diffusive time of flight can be used as a spatial coordinate to reduce the 3-D diffusivity equation into an equivalent 1-D formulation, leading to a simplified method for rapid reservoir modeling.

Based on this theory, we may further introduce a novel data-driven approach for production analysis of unconventional reservoirs without the traditional rate transient and pressure transient (RTA/PTA) assumptions of specific flow regimes. Our approach uses a transient generalization of the Matthews-Brons-Hazebroek method for the PSS drainage volume which relies on a $w(\tau)$ function to characterize the flow geometry from the transient drainage volume. Together with a calculated instantaneous recovery ratio, it has been successfully used to rank refracturing candidates and to obtain optimal fracture spacing. Given well pressure and flow rate data, we can calculate the transient well drainage volume with time. The time evolution of the drainage volume can be inverted to derive the $w(\tau)$ function which then provides a high resolution diagnostic plot that can be used for quantitative analysis to obtain fracture surface area, matrix properties, stimulated reservoir volume (SRV), and additional reservoir and fracture characteristics that are not apparent in the usual rate and pressure transient analysis techniques.

We have applied our methodology to field examples from the Montney and Eagleford shales. The comparison to standard RTA/PTA shows linear flow and fracture interference features more clearly than conventional RTA/PTA. It also provides detailed characterization of complex non-planar hydraulic fracture geometry, partial completion effects, the development and growth of the SRV, leading to the estimation of future decline rate and ultimate recovery.

The major advantage of the proposed approach is the data-driven model-free analysis of production data without the presumption of specific flow regimes. It provides a simple and intuitive understanding of the transient drainage volume and instantaneous recovery efficiency, irrespective of the complexity of the geometry of the reservoir depletion.

References

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