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Transient-flow analysis of an acid fracturing well in a fractured-vuggy carbonate reservoir

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Acid fracturing is a stimulation technique that has been widely used in developing fractured-vuggy carbonate reservoirs. Wormholes and hydraulic fractures, which are created by this technique, form the main channels of the fluid flowing into the wellbore. Complex seepage systems near the wellbore pose significant challenges to study the transport process in these reservoirs. Based on the concept of composite reservoir, we proposed a new model with two concentric regions: the inner region containing finite number of hydraulic fractures and wormholes, flow in both of which follows Darcy's linear law, and the outer region showing a triple-porosity medium (natural fracture, vug, and matrix), respectively. We derived this model's analytical and numerical solutions of wellbore pressure at a constant rate and found the numerical solution's computational speed is faster than the analytical solution, but the analytical solution is easier to consider wellbore storage and skin effects and also more convenient to conduct the rate decline analysis. On the transient-pressure log-log curves, because reserves may be dominated by vug system or matrix system, flow in this system can be divided into six or eight flow regimes comprehensively. Fracture linear flow is typical of fluid flow for acid fracturing wells. Meanwhile, three and two characteristic V-shaped segments can be observed on their pressure derivative curves, respectively. The first one corresponds to the transition flow between natural fractures and hydraulic fractures or wormholes, and may not be observed at a high interregional diffusivity ratio or a low interregional conductivity ratio. The last two correspond to the inter-porosity flows happened in the triple-porosity reservoirs. In the late time, for different interregional diffusivity ratio, interregional conductivity ratio and interporosity coefficient, except fracture storativity ratio and dimensionless reservoir radius, all the pressure and pressure derivative curves will normalize. From the transient- and cumulative-rate curves for the same model, volume fracturing mainly contributes to the early-time production and has little influence on the final cumulative rate after compared with the model without this stimulation. In the early time, as interregional diffusivity ratio increases or interregional conductivity ratio decreases, the transient rate at the same wellbore pressure increases. By introducing a new pseudo-steady constant, we further established new Blasingame type curves for the system to deal with the problem of both variable rate and variable wellbore pressure. They have more clear flow regimes and better normalizations than the traditional rate curves and are convenient for us to conduct well testing analysis.

References

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