Characterization of CHOPS Processes by Use of a Pressure-Gradient-Based Wormhole Growth Model

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Abstract

Cold heavy oil production with sand (CHOPS) techniques have been successfully applied for developing unconsolidated reservoirs in Western Canada due to intentionally stimulated sand production. Sand production mechanisms have attracted numerous attentions for further understanding and improving the performance of the CHOPS techniques and also post-CHOPS enhanced oil recovery (EOR) techniques. A pressure-gradient-based (PGB) wormhole growth model has been proposed to quantitatively characterize the wormhole growth and its propagation during the CHOPS processes. To simplify the mechanical analysis at a pore-scale, a pseudo-interaction force between a failed throat and the rest was proposed to comprehensively and implicitly represent the contributions of cementation and geomechanical stresses to wormhole growth. As such, a PGB sand failure criterion was derived from mechanical balance analysis by considering the pseudo-interaction force, pressure gradient, and friction caused by the mobilization of sand particles. The PGB sand failure criterion has been incorporated with a reservoir simulator and a foamy oil model to develop the PGB wormhole growth model. Compared to the existing wormhole growth models, the PGB wormhole growth model reveals an explicit relationship between the pressure gradient and sand production rate. Subsequently, the PGB wormhole growth model was validated by history matching production profiles and wormhole propagation of a laboratory CHOPS experiment in the literature. Good agreements have been found between numerically simulated and experimentally measured data, confirming that the PGB wormhole growth model can accurately and visually reproduce the dynamic wormhole growth under the CHOPS conditions. The history-matched pressure profiles indicate that the wormhole growth greatly depends on the magnitude of breakdown pressure gradient. Moreover, sensitivity analysis of the breakdown pressure gradient demonstrates that, if the boundary effect is involved, the sand production only can stimulate the oil production until no more sand is produced, which is in accordance with the experimental results. It has also been found that using two sets of three-phase relative permeability efficiently captures the transition stage on the production profiles.

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