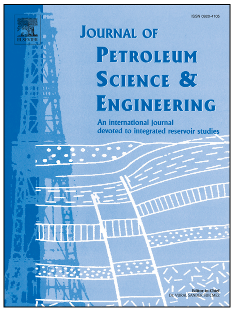
Accepted Manuscript



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PII: S0920-4105(18)30142-6

DOI: 10.1016/j.petrol.2018.02.035

Reference: PETROL 4705

To appear in: *Journal of Petroleum Science and Engineering*

Received Date: 30 April 2017

Revised Date: 5 February 2018

Accepted Date: 12 February 2018

Please cite this article as: Luo, H., Delshad, M., Pope, G.A., Mohanty, K.K., Scaling up the interplay of fingering and channeling for unstable water/polymer floods in viscous-oil reservoirs, *Journal of Petroleum Science and Engineering* (2018), doi: 10.1016/j.petrol.2018.02.035.

Scaling Up the Interplay of Fingering and Channeling for Unstable Water/Polymer Floods in Viscous-Oil Reservoirs

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Abstract

Unstable displacement and the resulting viscous fingers remain a challenge for reservoir simulation as practical gridblock sizes are usually much larger than the viscous finger wavelength. Traditional reservoir simulators do not consider sub-grid viscous fingering effects and tend to overestimate the oil recovery at the field scale. Several previous studies suggested that fingering can be ignored at the field scale because channeling (caused by heterogeneity) is dominant, but they missed the existence of viscous fingering at the small scale, which affects the displacement efficiency. In our work, we consider that fingering and channeling coexist in the field across different scales, based on the fact that the heterogeneity increases with the scale. At the small-scale (e.g., lab-scale) where heterogeneity is small, fingering is dominant and causes oil bypassing. An effective-fingering model was developed to scale up fingering effects. The model divides each gridblock into three dynamic regions: two-phase flow, oil single-phase flow, and bypassed-oil regions. Model parameters represent the maximum fraction of viscous fingering and the growth factors of different regions, and they are used to modify flow functions. Model parameters from history-matches of a set of laboratory experiments show clear power-law correlations with a dimensionless viscous finger number, a function of viscosity ratio, fluid velocity, permeability, interfacial tension, and core cross-sectional area. The correlation was achieved at the lab-scale by considering relatively homogeneous cores. We extended it further to the field scale by performing high-order spatially accurate numerical simulations at the intermediate scale using gridblock sizes that are roughly the same as that of the core. Geostatistical realizations of the permeability field were generated with various variances and correlation lengths. In a statistical way, we were able to quantify the viscous finger number for a gridblock at the field-scale affected by various heterogeneities. It is also observed that channelized permeability distributions increase the viscous finger number drastically, showing the important role of channeling in such cases. This new model was applied to a synthetic field case with high heterogeneity undergoing water/polymer floods. It is observed that the oil recovery was improved by the polymer slug because of the enhancement in both local displacement efficiency and sweep efficiency.

Keywords: fingering; channeling; viscous oil; water/polymer flood; field simulation