Numerical Simulation of Recovery of Light Oil By Medium Temperature Oxidation in Porous Media

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Abstract

Introduction: Recovery percentages from light oil reservoirs range from 5% for difficult oil to 50% for light oil in highly permeable sandstones reservoirs. Other reservoirs contain oil that is too difficult to produce with conventional means. One of the methods to recover oil from medium and low viscosity in complex reservoirs uses air injection leading to oil combustion. In this case the oxygen in the air burns the heavier components of the oil, generating a heat wave leading to vaporization of lighter components (Figure 1). In this work, we consider a model for air injection in light oil reservoir containing only one component in dry porous rock to improve understanding of the oxidation/evaporation/condensation mechanism. Use of COMSOL Multiphysics: Numerical modeling of the combustion process is difficult due to the disparity in time and space scales at which processes occur. Consequently high resolution is required in the regions where combustion takes place, whereas less resolution is required outside the combustion zone. As the combustion zone moves, adaptive mesh refinement is required for numerically solving the model equations. We study a simplified version of the one-dimensional model. In this case the temperature of the medium is bounded by the boiling point of the liquid and thus remains relatively low. The molar mass balance equations for liquid and gas components, the reaction and vaporization equations, Darcy velocities equations, heat balance equation, liquid-gas equilibrium equation, initial and boundary conditions are formulated in weak form and implemented in COMSOL. Results: The numerical result is shown in Figure 2. We show the oil saturation Sl, the reduced temperature (T-Ti)/ (Tb-Ti), the oxygen mole fraction Yo and the hydrocarbon gas mole fraction Yh. Here Ti is the initial temperature and Tb is the boiling temperature. The plot shows the initial stages of the combustion process. Long time simulations suffer from convergence problems that have not as yet been solved. We observe that the temperature rises steeply near the injection side (left) after which it gradually decreases towards the initial temperature. The surprising result, which is also confirmed by analytical solutions, is that the evaporation occurs upstream of the combustion process. Therefore the oil saturation near the injection side is very small, whereas the oxygen mole fraction decays slowly showing that the combustion process occurs over an extended region at the low temperatures. Conclusion: The model gives some essential insights in the nature of the combustion process. The main striking insight is that the vaporization occurs upstream of the combustion zone. This is also shown in an analytical study of the same problem. The initial results indicate that it is possible to study the combustion process in dependence of the combustion rate, vaporization rate and boiling point of the oil. For this, however, the problems with convergence of long time solution need to be resolved.

Reference

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Figures used in the abstract

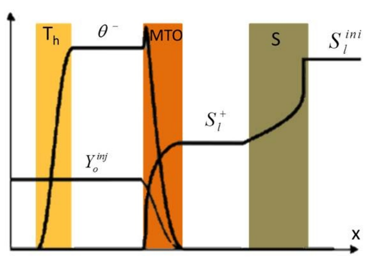

Figure 1: Wave sequence solutions with the thermal (T_h), MTO(medium temperature oxidation) and saturation (S) waves. Indicated are the distributions of the temperature θ, liquid saturation S_l and oxygen fraction Y_o. The value of S_l^{ini} determines the initial liquid saturation.

Figure 1: Wave sequence solutions with the thermal (Th), MTO(medium temperature oxidation) and saturation (S) waves. Indicated are the distributions of the temperature θ, liquid saturation Sl and oxygen fraction Yo. The value of determines the initial liquid saturation.

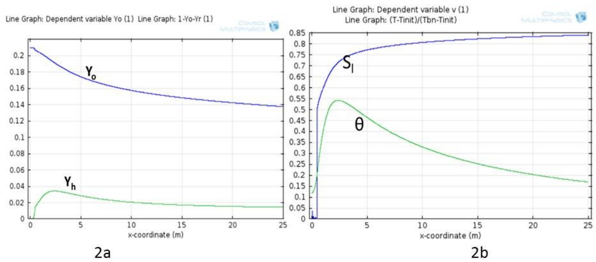

Figure 2) 2a: The dimensionless variables Y_o (oxygen mole fraction), Y_h (hydrocarbon mole fraction) 2b: θ (temperature), S_l (liquid saturation) profiles as function of x

Figure 2: 2a: The dimensionless variables Yo (oxygen mole fraction), Yh (hydrocarbon mole fraction) 2b: θ (temperature), Sl (liquid saturation) profiles as function of x.