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A comprehensive simulation model for solvent-aided thermal recovery of heavy oil and bitumen— Analyzing the impact of diverse factors on productivity and product selectivity

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A new simulation model for solvent-aided thermal recovery of heavy oil and bitumen has been developed. The simulation model describes non-isothermal, multiphase, and multicomponent reservoir systems involving multiple kinetic reactions of heavy oil cracking. In the development of numerical simulator, we include 12 fluid-and-solid components in four phases of 1) aqueous, 2) liquid organic, 3) gaseous, and 4) solid phases. The 12 fluid-and solid components are 1) water, 2) heavy oil, 3) light oil, 4) asphaltene, 5) methane, 6) ethane, 7) propane, 8) hydrogen, 9) carbon monoxide, 10) carbon dioxide, 11) hydrogen sulfide, and 12) coke. It describes relevant physical and chemical phenomena during in-situ heating and production, such as dynamic changes of rock-and-fluid properties as a function of system conditions, phase transition thermodynamics, heat transfer by conduction and convection, pore clogging by coke generation from reactions, and porosity and permeability alteration.

The application cases of numerical simulation are categorized into four as follows.

Firstly, we conduct local sensitivity analysis of productivity and product selectivity to diverse uncertain parameters. They include reaction parameters, formation water saturation, and rock permeability. The effect of each parameter has been quantified, and the most influential parameters to the hydrocarbon productivity have been figured out. Product selectivity, especially for unwanted gases of carbon dioxide and hydrogen sulfide is analyzed, as being affected by uncertain parameters. The delivered most influential parameters are the most important data to be measured, to reduce the prediction uncertainty of unwanted acid gases of carbon dioxide and hydrogen sulfide.

Secondly, we analyze the diverse heating methods. The heating methods include 1) electrical heating, 2) heating by hot water drive, 3) heating by hot water drive containing condensate, 4) electrical heating with hot water drive, and 5) electrical heating with hot water drive containing condensate. In each case, both physical and chemical changes of system are considered and compared, such as viscosity, density, and composition of the fluid phases; and optimized heating method for maximizing productivity has been figured out.

Thirdly, we also quantify the effect of heating temperature to the productivity and product selectivity. High heating temperature activates the reactions of heavy oil cracking, but also accelerates the generation of solid product, coke. Here, the effect of pore clogging by coke generation to the permeability alteration and subsequently altering fluid flow and heat convection is analyzed. Through a case study, we find an optimal heating temperature for maximizing productivity.

Fourthly, we conduct the simulation runs using diverse ratios between condensate and water in the cases of hot water drive containing condensate. It is found that the optimal ratio between condensate and water is affected by the wettability of the porous media and initial water saturation.

From the plentiful simulation cases, the optimization of in-situ heating and production in heavy oil and bitumen reservoirs has been realized. The developed simulator provides the powerful tool to investigate the impacts of various unknown parameters and controlling factors, and hence enables us to increase the success-likelihood of hydrocarbon production from thermally-cracked heavy oil/bitumen reservoirs.

References

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