High-Frequency Electromagnetic Heating: 3D Model for Petroleum Production Applications

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Abstract

Oil production industry is currently investigating new methods to improve oil and gas extraction from natural rocks. Since long enough time the dedicated simulation software has been used to better understand the behavior and predict the production from oil and gas reservoirs depending on the developed technologies. Modern reservoir simulators are capable to model main conventional and some unconventional methods and associated physical mechanisms of oil recovery. It is not the case, however, for high-frequency (HF) electromagnetic heating (EMH). New approach is required to extend the reservoir simulator capabilities. The main purpose of our work is to develop adequate numerical tools for evaluation of the promising technology based on the HF heating of petroleum deposits [1]. In particular, we will illustrate how the code coupling based on COMSOL Multiphysics® can be useful in doing what dedicated reservoir simulators are not able to do.

Technically speaking, the COMSOL Multiphysics® environment provides a complete Java interface which is useful to develop a code coupling software using the same programming language. The greatest benefit of such an approach is the ability to modify easily the COMSOL model depending on in-situ reservoir information received from the reservoir simulator. Note that sometimes the application programming interface (API) has to be extended with some additional features necessary for coupling or simply to improve the computational performance. It means that a developer may adapt their programs according to the specific problem they want to solve. For example, several functions have been developed for the coupling code to compute the heating power per cell of the reservoir model grid and to transmit this information to the reservoir simulator at each coupling time step.

Other benefits came from the intrinsic features of the finite-element based multi-physical simulator in the framework of so-called loose coupling (cf. [2]). Mention just few but most important of them, namely, the computational domain dimension and size, numerical grid, FEM order and shape, solver parameters etc. can be chosen according to assumptions of the EM field model without additional limitations associated to reservoir model.

After model validation using known analytical solutions for Maxwell equations and published data [3], the promising results for 2- and 3D reservoir-size models have been obtained within a reasonable computational time. Examples of numerical analysis giving valuable information addressing the computational performance, the recovery process applicability and efficiency

subject to well configuration and pattern, are provided. EMH advantages either related to more deep volume reservoir heating or local convective heating enhancement are discussed. COMSOL Multiphysics® based code coupling with a reservoir simulator is an important feature in modeling of the electromagnetic heating as a method of hydrocarbon recovery from natural rocks.

Reference

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